

FIG. 1.—Tom Sawyer solves a problem in applied psychology. To Tom life seemed hollow and existence a burden. Thirty yards of board fence six feet high to whitewash and nothing but trash with which to pay the boys to help. An inspiration! He took whitewashing out of the realm of work and made it a privilege. The boys paid him for permission to demonstrate their skill. Working in shifts, the boys paid him: an apple, a kite, a dead rat on a string, 12 marbles, part of a jew's harp, a piece of blue bottle glass to look through, a spool cannon, a key that wouldn't unlock anything, a glass stopper, a tin soldier, a couple of tadpoles, 6 firecrackers, a kitten with one eye, a brass doorknob, a dog collar, the handle of a knife, four pieces of orange peel, and an old window sash. He had a nice, good, idle time all the while—plenty of company—and, in the end, the fence had three coats of whitewash on it.

(Mark Twain, *The Adventures of Tom Sawyer*. New York: Harper & Brothers, 1917. Picture by courtesy of *Life*.)

Psychology

BY

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Preface

TO give the student the essential facts about psychology in such a way that he can reach an understanding of himself and others, and to teach him how to increase this knowledge when his formal study of psychology has ceased—these objectives have guided the writing of this book. They have imposed three criteria on the presentation of material: to build upon experimental evidence; to make an impartial selection of source materials; and to encourage the reader to think independently.

There are, of course, many gaps in the experimental evidence upon which psychology is based, and in indicating these I have tried to make clear the distinction between speculations which bridge those gaps and the basic facts. References to the source material will enable the student to trace the evidence for himself, although the names of the original investigators have been omitted from the body of the text for the sake of smoother reading.

In considering source materials I have uniformly weighed all the available evidence and have stated my interpretation as simply as I could. Obviously it has been possible to include only a small fraction of the original source material, but I have attempted to represent all vital areas adequately.

The scientific method is emphasized throughout these pages in terms of an intellectual honesty that demands controlled and rechecked observations and experiments, that examines facts without prejudice and values them above any man's interpretation. In short, the student is encouraged to make the scientific method basic to all of his thinking.

I have not attempted to favor any particular school of psychology. Although each instructor will vary his emphasis, the

fundamental material is basic to all the various methods of presenting psychology. The writer of a textbook in this subject must therefore keep a middle course, careful to present all the essential material, but in such a manner that the individual instructor can add to it his own vital contribution.

Without a precise vocabulary, accuracy in thought is impossible. Technical terms, therefore, in addition to being defined at the time of their first use, are placed in a general glossary at the end of the book for easy reference.

Crucial experiments are presented in such a way that the student can discern the exact manner in which the results were obtained, and also survey the experimental methods critically in order to devise ways of improving upon them. The student who performs some of the simpler experiments himself will find the methods of psychological research a revealing and absorbing experience.

As is true of all subjects, certain topics are more interesting than others, which may, in addition, be difficult for the beginning student. Wherever it has been possible to do so, difficult sections have been alternated with easier materials so that the student will have an opportunity to review the perplexing topics while studying the easier sections.

Practical applications of psychological truths are indicated throughout the book, but it is in the last chapters that they are most numerous. There the student explores the principles for clear perception, adroit problem solving, and satisfactory personal and social adjustments. It is appropriate that these "practical" aspects of psychology should be postponed until the student has had some training in the fundamentals of the subject, for without such a foundation no one can expect to understand, or apply, these rules for successful living.

Evanston, Illinois J. J. B. M.
April, 1941

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Psychology

Chapter I

THE SCIENTIFIC ATTITUDE

THE life of each human individual is a process of continuous adjustment from the time he is conceived until he dies. This fact makes the topic of individual adjustment an essential focus for all psychological study. Whether an individual proceeds through life in a haphazard manner or according to well-established and beneficial principles will depend upon the degree of psychological insight possessed by his parents, nurses, teachers, associates, and by himself. Since one must live, and since living is adjusting, most persons pick up some random knowledge about human nature. Such learning is likely to be fortuitous and to contain misinformation and erroneous generalizations. Mistakes are sure to follow, and disclose themselves only after it is too late for the individual to correct them. Psychology attempts to organize the principles of human adjustment into sound and systematic form.

It has been found, for example, that many of the characteristics which seem to be an integral part of adult individuals originated in early childhood. An attitude of suspicion which is characteristic of one person may be traced to the deceit practiced upon him by an unscrupulous nurse. A fixed impulse to help the unfortunate may have originated in a childhood experience in nursing a motherless pup. A malicious desire to inflict physical pain upon others may have had its beginning in jealousy because of favoritism on the part of the individual's parents. Certainly, an objective and scientific attitude is of vital importance if the student is to study personality characteristics without preconceived prejudices about them.

Problems of social adjustment are becoming more and more difficult with the growing complexity of modern civilization.

Social, political, and economic theories all have their foundation in some sort of speculation about human nature. It is becoming apparent that we must substitute sound psychological principles for outworn superstitions if we are going to live together in peace and comfort. Practically any crackpot can refer to some aspect of "human nature" to support his wild ideas. But, unless a person has some background of sound information about psychology, he is in a poor position to know what to accept and what to reject. He judges on the basis of his own emotions, which may lead him to select ideas which are just as erroneous as those of the advocate of racial hate, violence, or world revolution. Human behavior is extremely complex, and no act can be explained by reference to one simple causal factor.

Many persons who have not studied psychology are inclined to believe that there are some relatively simple rules which apply to all individuals. For example, everyone has heard such assertions as: You cannot change human nature. Everyone loves flattery. All persons are selfish. Don't trust a person who won't look you in the eye. The greatest element in success is hard work. Clothes make the man. An infant instinctively loves his mother. Fat people are good-natured. Such statements are misleading and, at best, are but partial truths. It is vain to attempt to explain human behavior by reference to any such simple rules. The first task that the student of psychology should undertake is to rid himself of this common and almost irresistible urge to hunt for some simple explanation of human conduct. Why try to oversimplify a subject which derives its interest and its challenge from that fact that it is intricate?

On the other hand, the admission that human behavior is bewilderingly complex should not deter one from attempting to ascertain why people act as they do. The student of psychology has a right to expect that he will learn something about human motives, why one individual is different from another, why some persons make good friends while others are always fighting, why some persons learn from experience and others do not, why some are happy and others sad, why some persons are trustworthy and others consistently unreliable, how time changes persons, how various circumstances affect people, and something about the degree to which human conduct can be predicted.

As a result of his study, the student should be able to work more efficiently, learn more quickly, reason clearly, contrive to use his emotions instead of being victimized by them, be more self-reliant, and be a better companion to those who have to live with him. In short, psychology offers boundless possibilities in the direction of personal advancement and in the improvement of social relationships.

WHY PEOPLE ACT AS THEY DO

Psychology is concerned with the study of how people act and why they act as they do. A casual glance over the topics which we shall study will show how each one contributes something toward providing an answer to these *how* and *why* questions.

An individual's behavior is partly determined by the kind of person he is. Man is not a billiard ball whose activities can be explained as a simple resultant of the physical forces acting upon him from the outside world. Psychology is most significantly concerned with individual differences and changes in the same individual as factors in influencing behavior. We shall find that a great many circumstances contribute toward making a man the kind of person he is. Some of these are listed herewith:

1. A man's physical structure is partly determined by biological inheritance.[1] Having had human parents, he has acquired a human body and, therefore, cannot perform as a dog, a cow, a monkey, or a fish. Biological factors determine that he shall breathe air, walk in an erect position, eat certain foods, reproduce his kind, and eventually die. The study of psychology involves some knowledge of heredity.

2. Developmental changes influence behavior in a variety of ways. A child cannot walk when he is born because the necessary equipment has not matured. A certain degree of maturation is a necessary prerequisite for speech. Nevertheless, it would be inaccurate to attribute such an act as speech to maturation alone. A child does not talk merely because his speech apparatus is full-grown, even though he cannot talk until it is mature. He

[1] The student is urged to use freely the glossary at the end of the book. All technical words are defined there. If the meaning of every word or phrase is clearly learned when first encountered, the student will find his study more interesting and enjoyable—as well as easier.

needs practice and instruction. Psychology must concern itself with maturation and with the effects of exercise upon the maturing organism.

3. Behavior is influenced by certain needs of the individual. These range all the way from needs for chemical substances and for foods to highly developed and acquired wants, such as the desire for prestige. Consequently, psychology must concern itself with the intricate problems of motivation.

4. Behavior is influenced by emotional tensions. Emotional conduct cannot be explained wholly in terms of the environmental stimulations or wholly in terms of the make-up of the individual. Certain conditions are exciting in and of themselves; but it is also clear that different persons show different emotions to similar situations, and that emotions change with the course of life. To understand human conduct, something must be known about human emotions.

5. Learning changes people. Learning takes a variety of forms and psychology must concern itself with all these forms: motor habits, memorizing, ways of thinking, social adjustments, perceptions, rules for living, and the like. In fact, learning permeates all phases of psychology, even though we shall consider the main problems of learning in three chapters: Motor Skills, Memorizing, and Conditioning.

6. Conduct is partly determined by the structure of the nervous system. The nervous system is the main instrument for co-ordinating activity. The student of psychology should have a clear picture of the general nature of the nervous system and its functions, even though the details of neural activity must be left to the physiologist.

7. The structure and functioning of the sense organs affect behavior significantly. How each sense organ acts and how it contributes to our knowledge of the outside world is an essential aspect of any adequate psychological understanding.

8. A clear picture of the way in which all these components are integrated into a unified personality is necessary in any study of psychology. The harmonious solution of personal problems is considered in the chapters on perceiving, intelligence, problem solving, and personality.

An individual's behavior is partly determined by the influence of external events and the presence and activities of other persons. No man lives in a vacuum. Each person is being constantly affected by external circumstances and, no matter how well we may understand his organization and his ways of acting, such influences are vital elements in his conduct. A deaf and blind person will not act in the same manner as one who can see and hear, even though the two might be equal in all other respects. A boy who sits on a tack will not behave in the same manner as one who sits on a soft cushion.

Nor does the same environmental circumstance affect all individuals in the same manner. This fact complicates the study of psychology and, at the same time, makes it more interesting. As an illustration, one experimenter was testing children to determine how easily they could solve a problem which involved the use of a stick. As a stick, she used a common yardstick. Whereas most of the children entered the game eagerly, one little boy cried and refused to try to solve the problem. This seemed strange until it was learned that his mother used a yardstick to whip him.

After we have studied all possible aspects of the human personality and have analyzed all the environmental influences surrounding him, can we give a specific answer as to why a man acts thus and so? Only in a crude, qualitative, and conditional manner. In spite of the fact that our subject is so complex and the present state of our knowledge so inadequate that we cannot hope to reduce the explanation of any single act to a mathematical formula including all significant factors, the search for the most significant elements in any bit of behavior is an extremely fascinating pursuit. The answer is always elusive, but the search is only made the more exciting because of our inability to arrive at a definite answer. If you add two to two, you get four; and that is the end of it. But if you confront a child with a problem that is extremely difficult for him, you do not get a simple definite response, nor will you get the same response on repeated trials. It is interesting to watch what he does, but it will only detract from the challenge of psychological problems if the student attempts to arrive at some fixed answer.

In the face of this complexity of subject matter, the student must have some means for enabling him to steer a straight course.

The methods evolved by scientists provide the best answer to this need. Consequently, we shall devote some time at the very beginning of our study to an examination of scientific thinking. The student not only should understand the essentials of scientific thinking, he should absorb them to such an extent that the scientific attitude becomes a part of himself and dominates his thinking throughout the course.

SCIENTIFIC THINKING IN PSYCHOLOGY

The elusiveness of psychological problems makes it particularly important that the student give attention to his thinking so that he will not go too far astray. Largely because of the complexity of human life, there are many superstitions, prejudices and misconceptions to mislead the student. He should begin his study by attempting to think clearly, to make his vocabulary more precise, and to maintain an objective attitude throughout. He should attempt to keep his thinking on a scientific plane even though the interest of the subject matter should tempt him to leave reality and to permit his imagination to run riot.

Sources of evidence. In his search for the truth, man has appealed to five sources of evidence: (1) customs and traditions; (2) authority; (3) syllogistic reasoning from self-evident propositions; (4) personal experiences; and (5) scientific inquiry. These sources are not of equal value.

1. *Customs and tradition.* Customs and tradition rule a great part of our ordinary living, our clothes, speech, food habits, and social behavior. We follow customs because we know no better guiding principles, because we have no desire for other methods, or because we have not time to search for better ones. Following traditions makes life easier, but the fact that a belief or condition has always been maintained provides a flimsy argument for its truth or falsity. Dependence upon tradition leads to intellectual inertia.

2. *The appeal to authority.* The appeal to authority is the device of the weakling in time of stress. Not knowing what to do, he appeals to some individual or source of power to give him aid. If we would arrive at the truth we must know more than that a well-known individual made a certain statement. We should base our credence not on the fact that he made the state-

ment but upon a critical evaluation of the evidence which he brings forward to substantiate his statement.

3. *Syllogistic reasoning.* The appeal to syllogistic reasoning[2] is an advance beyond dependence upon either tradition or authority. Its weakness lies primarily in the possible falsity of the premises which lie behind the logical arguments, and in the possible ambiguity of the terms used in the arguments. Historically, it has had great value in that it directed critical attention to man's reasoning processes. When man studied logic, he began to ask why we knew certain truths instead of accepting them blindly.

4. *Appeal to personal experiences.* The appeal to experiences has some fundamental weaknesses. The greatest source of error is that each experience is a unique event. To assume that a situation will repeat itself is certainly unwarranted. In addition, any interpretation of a personal experience is likely to be incorrect. When we come to study perceptions we shall learn that the old adage that "seeing is believing" is certainly unsound. Our sense organs are constantly deceiving us and we seldom know accurately the significance of what we do take in through the senses. Anecdotes of personal events make interesting stories but they are poor scientific material.

5. *Scientific inquiry.* Scientific methods have been developed in order to overcome the defects of other methods of inquiry. Science has been defined as the systematic investigation of some specific field, together with the organized knowledge resulting from such investigation. It alone is free from the defects of the preceding four methods of searching for the truth.

Since psychology is a field in which the student will find it easy to lose his way and to be unable to discern truth from fiction, it is important for him to know what is involved in scientific thinking. An intimate acquaintance with the rules that should govern scientific thinking is especially important in view of the fact that much which is called science is anything but that.

The rules of science. On the basis of the experience of many scientists through centuries, certain important rules have been formulated. [2][3]

[2] The structure and use of the syllogism are explained on page 517.

[3] The numbers in brackets throughout the book indicate the exact original sources or supplementary information listed at the end of each chapter.

It is essential that trust be placed only in those observations which are repeated under the same conditions or under conditions which are changed by known amounts. Repeated observations are absolutely essential, but these would be misleading were not extreme care taken to control the circumstances surrounding such observations. An illustration will make clear the importance of this rule.

At one time it was thought that dampness caused malaria because it had been observed repeatedly that malaria was more frequent in damp areas than in dry places. How could this proposition be checked scientifically? Select two groups of persons who were equal in all possible respects, have them live under similar conditions with the one exception—one group would live in a dry place and the other in a damp place. If an equal number of persons in each group contracted malaria, it could be concluded that dampness played no part. It was in this manner that this erroneous belief was overthrown. But other hypotheses were then advanced and each tested in the same manner. Finally, it was suggested that the mosquito carried malaria. Two groups were treated in identical ways except for the one factor to be tested. One group was protected from the mosquito and another group was exposed to and bitten by mosquitoes. Those who were protected did not develop malaria; those who were bitten did develop it.

It is just as important to consider facts which go against a proposition as evidence which favors it. It is possible to obtain proof for almost any hypothesis if a diligent search is made for supporting evidence, and if all contrary material is carefully avoided. The testimonial method for proving the value of a certain medicine is an instance in point. Suppose we have a vested interest in castor oil and would like to prove that it will cure malaria. If we give castor oil to individuals who have malaria, we will doubtless find that some of them recover. We might accumulate many testimonials saying that the patient took castor oil and subsequently recovered from the disease. Such testimonials are not only useless but actually misleading because we have ignored the negative instances, that is, those individuals who took the castor oil and did not recover.

How about indicating the percentage of patients who

recovered? If we can show that 60 per cent of all those treated with castor oil recovered, is not that evidence in favor of the treatment? No. This is a device commonly used and is extremely misleading. It may be that 60 per cent would have recovered without any treatment at all. How shall we ascertain whether our treatment was a vital factor or a useless gesture? By the use of a control group. If more individuals recover in the group treated with castor oil than in the untreated group, this may be taken as evidence in favor of the treatment. Even if 99 per cent should recover in the treated group, no faith could be placed in the efficacy of the treatment if 99 per cent should also recover in the untreated group.

It is important to avoid preconceived ideas and prejudices. Skill in making accurate observations involves getting away from emotional bias. A calm attitude may be easily obtained when one is studying chemicals, physical stresses, rocks, or plants; but it is peculiarly difficult to remain impassive when studying ourselves or human beings like ourselves. A motion picture of an ape playing with a child is much more likely to entertain a class of students than it is to stimulate an unemotional study, such as a cool analysis of the fact that the ape can outdo the child in many respects. It is easier to overestimate the intelligence of a person if he is handsome and agreeable than if he is ugly and mean.

Admonitions to be unemotional are not sufficient to overcome this universal tendency. The psychologist has, for this reason, been driven to evolve all sorts of techniques and devices to accomplish this end. The eternal question in psychology is: By what method were those facts obtained? The validity of any psychological item depends upon the prejudice-proof nature of the method used in securing it.

An artificial word has been devised to designate the substitution of emotional thinking for logical thinking. The word is "thobbing." It is made up of the initial sounds of the words thinking, opinion, and belief. It is defined as thinking misdirected by emotion, prejudice, the will to believe, or other nonrational factors. The scientific thinker is constantly on guard against the dangers of thobbing.

Inaccuracy of observation, inaccurate instruments of measurement, dependence upon subjective judgment, estimates, and

guesses may prejudice results. It is important to count cases or measure results accurately. Psychology has a hard time living up to this requirement. It is not easy to measure a fear or to count the number of times a child must be thwarted before he develops stubbornness. Great progress has been made in developing devices to measure precisely some of the more easily controlled types of behavior in human beings and animals in the laboratory and, for this reason, psychology has some definite conclusions to offer in relation to reaction times, to methods of learning, and to sensory discriminations. Ingenious methods have been devised for measuring some of the more complicated forms of behavior but much still needs to be done. These needs will be easily apparent to the alert student as he proceeds with his study.

The failure to distinguish between assumption and law should be avoided. The part that assumption plays in the different stages of scientific thinking should be clearly recognized.

Most scientific thinking, in its earliest stages, contains considerable speculation. Theories are propounded and generalizations are made which are only vaguely suggested by the available facts. Such speculations are valuable if they are not taken too seriously and if they lead to further search for evidence both for and against their verity.

If the insecure basis of speculation is recognized, a speculation becomes a hypothesis. A hypothesis is a preliminary and tentative presupposition, or principle, adopted for the explanation of observed facts.

With increasing accumulation of factual evidence to support a hypothesis, a general formula or principle may be propounded to express it; which formula or principle may be dignified by the name of theory.

Finally, when extensive research has demonstrated a fundamental uniformity in nature, this may be stated in the form of a law. In other words, there is a gradation depending upon the increasing adequacy of evidence (as demonstrated by rigidly controlled procedures) from speculation, through hypothesis and theory, to law. [8]

Laws are not unchangeable. They merely represent the best statements of facts accumulated to date. In every branch of research laws are being modified continually; old statements must

give way to new formulations. The younger the science the more rapid are such changes. Psychology is a relatively immature science. The student will learn some principles which are on a fairly secure foundation, but he will encounter also some relatively new and less stable hypotheses. It is, consequently, important that he should learn to weigh evidence, to adopt an intellectually critical attitude toward newer theories, and to avoid the idly complacent belief that the last word has been said.

THE METHODS USED BY PSYCHOLOGISTS

Each branch of science has to develop its own tools. The general purpose of such tools is to increase the accuracy of observation and to reduce vague qualitative values to quantitative form. The astronomer uses the telescope to bring the stars nearer. The biologist uses the microscope to enable him to see micro-organisms. The physicist uses scales and meters to measure and to count so that his observations may be made with greater accuracy. The tools that the psychologist uses have been borrowed largely from other sciences. He has, however, shown ingenuity in developing devices to control the presentation of stimuli to his subjects and to make accurate recordings of the reactions to such presentations. [5]

Regardless of the mechanical devices used, psychological information is gleaned by two general methods, which may be used separately or in combination: introspection and objective observation.

Introspection. The examination of one's own feelings, sensations, efforts, ideas, or imaginations is called introspection. In some instances it is the only way in which we can learn about psychological facts. For example, we can tell better than any other person whether we are happy or sad, whether a color appears brighter or duller than another, whether we are hungry or not, or whether we love or hate a certain individual. To be sure, it is possible for an individual to deceive himself or to report incorrectly what he does experience. Consequently, psychologists do not always take introspective reports at their face value. They have been ingenious in the development of devices to overcome the influences of self-deceit, purposeful distortion, or dishonesty on the part of observers in psychological experiments.

Objective observation. Much attention has been given to methods whereby the behavior of others may be interpreted. Certain fields of study lend themselves to such methods more readily than do others. For example, improvement in motor skill can be studied without any reference to introspective reports from the learner. To be sure, the learner may make a contribution by telling about any change in attitude or about some change in method which occurred during the learning process; but much can be determined by objective observation in the absence of any verbal report.

Although both introspection and objective observation have their individual advantages in different experiments, more attention has been given to the latter in actual psychological research in recent years. There is no essential antagonism between the two methods. Instead, they should supplement each other, and emphasis on one or the other depends upon the nature of the specific problem that is being studied.

SOME PSYCHOLOGICAL GENERALITIES

Some studies are built upon self-evident truths which the student accepts without question. Psychology has no such axioms upon which to erect a system. However, there are some facts which can be so generally observed that it might be well to accept them without much question. At least, taking them for granted will not lead us astray in our study, and giving them attention at this point may eliminate some needless confusion. [9]

1. The human individual is a unitary creature. It leads only to confusion to attempt to divide him into mind and body, into conscious and subconscious personalities, into the ego and the social self, or the like. A man is made of parts, but the parts have to be unified into a whole to make the man. He may do without some of his parts, but he must retain enough to remain a person.

2. No two individuals are alike. It is a mistake to attempt to interpret the acts of others by attributing to them the motives that we think we observe in ourselves.

3. Every person is continually changing. He can never be the same during two successive moments. Each experience leaves

its imprint upon him and he is different from what he was before that experience.

4. Actions which appear very much alike may result from a different combination of causes.

5. The same combination of causes may produce diverse actions in different individuals or in the same individual at different times.

6. A stimulus from the environment "sets off" a response. The stimulus acts as a release of energy which is already present in the individual.

DIVISIONS OF PSYCHOLOGY

The study of psychology may be divided into different specialized fields. While these fields overlap, a brief survey of them will give the beginning student some conception of the broad scope of the subject upon which he is entering.

General psychology is that branch of psychology which studies what is true of individuals in general rather than the way in which individuals differ from each other. It may deal with children, normal persons, or animals but, in any case, the emphasis is upon general factors found in the group studied. It is the opposite of individual psychology.

Differential psychology, or the *psychology of individual differences,* is the branch of psychology which investigates the differences in certain fundamental characters as manifested in different races, in social groups, or in individuals in the same group. It deals with sex, age, racial, occupational, social, and trait differences and with differences in the same individuals at different times.

Genetic psychology studies the origin and historic unfolding of the activity of the individual or of a group of organisms. It usually is divided into two divisions: (1) ontogenetic psychology, the study of the origin and growth of mental life and behavior in the individual; (2) phylogenetic psychology, the study of the origin and growth of mental life and behavior through various animal species.

Child psychology studies the mental life and behavior of children from birth, or earlier, to maturity. It is sometimes included as a part of genetic psychology.

Animal psychology is the study of animal behavior. Animal psychology may be studied because of an interest in animals themselves, or because of the light that such studies throw on human psychology.

Abnormal psychology studies those individuals who are widely divergent from the typical individual. This includes those individuals who may be subnormal, supernormal, or qualitatively deranged. It includes pathological psychology (that is, the study of those persons who are mentally sick) and such mental conditions as dreams, hypnosis, hallucinations, delusions, and the like.

Physiological psychology investigates the functions of the nervous system, the sense organs, the motor organs, glands, and other physiological organisms in their relation to mental life and behavior.

Social psychology is that branch of psychology which studies (a) the behavior of an individual in so far as his behavior stimulates others or is affected by others, (b) the behavior of individuals in group situations, (c) the study of personality as it develops in relation to the social environment, and (d) the interaction between groups.

Applied psychology is that branch of psychology which is devoted to practical rather than theoretical ends. It includes legal psychology, educational psychology, psychology of advertising, psychology of selling, industrial psychology, and clinical psychology.

PRACTICAL VALUES OF PSYCHOLOGY

A course in general psychology will not enable a student to solve all his own personal problems, nor will it enable him to organize any system which will bring order into a troubled world. Nevertheless, it should do some or all of the following things:

1. It should make him keenly aware of the significance of individual differences. He will know that some men are bright while others are unintelligent, some are efficient and others inefficient, some are emotionally unstable and others placid, some can be trusted and others cannot. He may have an ideal of a social system where all men are alike; but he will know that any peaceful community requires a police system for the protection

of law-abiding citizens from those who have not learned to respect the rights of others.

2. His study of sensations and perceptions should make him understand that the way in which we interpret our world depends upon a great number of factors. He should learn why he does not see and hear his universe in the same way as others around him.

3. He should gain some insight into the significance of the complexity of human motivation. He may learn that even an enemy may have laudable motives.

4. He should develop greater personal efficiency in many directions. He should find himself better able to organize a program of motor training. He should be able to study and to memorize more effectively. He should be able to make decisions more wisely and be able to substitute cool analysis for impulsive conduct.

5. He should be able to improve his reasoning processes and his problem-solving ability.

6. Finally, he should be able to develop into a better integrated, more wholesome, happier, and more congenial individual.

To be sure, his study may do none of these things. He may merely memorize certain facts, pass the course, and proceed to forget it all; but his work will be richer if he continually examines ways of applying what he learns as he goes along.

A word of caution! There can be unwise application of what one is learning. A tiny boy may attempt to apply his knowledge of how to use a saw by amputating the leg of his mother's grand piano. Nevertheless, such a possibility does not argue against the value of conceiving practical applications as one learns. The application of any kind or degree of learning presupposes a moderate degree of what is ordinarily known as common sense.

QUESTIONS FOR REVIEW

1. Why is it important to accept the fact that human behavior is complex?
2. What kinds of problems does psychology investigate?
3. Show that behavior is partly determined by the environmental situation.

4. Enumerate some of the factors which make a man the sort of person he is.
5. Describe and evaluate five different sources of evidence that a scientist might use.
6. Why does a scientist attempt to avoid emotional bias?
7. By what different means does a scientist increase the accuracy of his observations?
8. What is meant by a control group?
9. Describe how a control group is used in scientific research.
10. Distinguish between speculation, hypothesis, theory, and law.
11. Explain the importance of repeated observations in scientific procedure.
12. What is thobbing?
13. Describe the method of instrospection and describe its limitations.
14. Contrast objective observation with introspection.
15. State six widely accepted psychological generalities.
16. Enumerate and delineate nine divisions of psychology.
17. Discuss some of the values of the study of psychology.

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Chapter II

HEREDITY AND ENVIRONMENT

"Some men are born great.
Some achieve greatness.
Some have greatness thrust upon them."

IN SPITE of the implications contained in these lines that there are but three components involved in achievement, we all know that any man is the product of a great many factors which interact with each other in an intricate manner. We may try to classify all these into such groups as heredity, learning, and divine intervention; but such a classification does not solve any problems for us. What we plan to do in this chapter is to isolate some of these factors for examination and to try to understand why they function as they do. As a prelude to this task, let us review a few of the problems which will confront us.

PROBLEMS

We have all seen men who were able to overcome the most inimical environmental influences in a masterful manner. Our admiration for such a person is often expressed by some such statement as "Blood will tell." It seems, in such cases, that there is inside such a person some rare inherited quality which is more than a match for events which would crush a person with an inferior heritage.

On the other hand, we have all seen individuals, whose parents were certainly of inferior quality, who achieved greatness in spite of such an apparently poor hereditary background. Do we infer that such a person is an opportunist, that he had good teachers, or that his success is merely an accident?

There is a widespread belief that inherited qualities cannot

be changed. If this is true, much of our educational effort is wasted. Instead of trying to teach those of inferior ability, it would be more profitable to perfect methods for detecting and segregating them and to devote all our energies to the education of the superior stock. But *is* it true that inherited qualities cannot be modified? And how much can they be modified, if it is shown that they can be?

Can learned habits be transmitted to the next generation by the mechanism of inheritance? Is there any foundation for the hypothesis, or belief, that if intense training in some special field (such as music) is continued for a number of generations, the results of this training are manifested in an improved natural endowment in the descendants? If this belief is without foundation, by what means may the human stock be improved?

Are extremely unusual persons more likely to acquire their peculiarity through inheritance or from some environmental condition? Are criminals, geniuses, insane individuals, and idiots born or made?

Even a superficial analysis of most of the debates on the relative importance of heredity and environment reveals the presence of personal prejudices in these arguments. The individual who believes he has "blue blood" in his veins is likely to take comfort from this belief and to emphasize the importance of heredity. The one who is not so sure of his ancestors and who realizes that he must make the most of his opportunities is likely to stress the importance of environment. The one who knows he has inferior ancestors and who is placed in an extremely hostile environment is likely to hope that there is some force above, beyond, and superior to either; he hopes that some such miraculous force may intervene and enable him to rise above his apparently insurmountable difficulties.

It is natural that these personal considerations should creep into our beliefs about heredity, and they are pointed out not to criticize the individual who entertains one or the other prejudice. The recognition of their presence is merely a signal that care needs to be taken to survey the whole situation objectively. It is necessary to clarify the problems and to point up vague meanings. Problems of heredity will never be solved by emotional thinking and debate.

Essential components of the general problem. A clear conception of our problems involves three areas of clarification:

1. A rigid definition of inheritance should be adopted. Using inheritance in its broadest sense, we can inherit anything we get from our parents regardless of the means of transmission. Thus, we can inherit a name, a title, real estate, money, or prestige. Such inheritance has been called social inheritance. But to the biologist, the use of the term "inheritance" is restricted to the transmission of characteristics from parent to offspring by the process of reproduction. There is no objection to the social definition so long as it is not confused with the biological one. Nevertheless, it is better for the student to adhere to the narrow definition of the biologist. Certainly, we should not permit ourselves to shift from one to the other.

2. The notion that heredity and environment are opposed to each other should be eliminated. Misunderstanding often arises from an erroneous tendency to oppose hereditary factors to acquired characteristics as though they were mutually exclusive entities standing in opposition. Once this artificial antagonism is set up, confusion about their interaction arises. Thus, people often divide themselves into two opposed camps, the environmentalists and the hereditarians, and seem to have the conviction that the same person cannot be both. The antagonism is an unreal one, and a person should be neither one nor the other, but both. The germ cell does not develop in isolation, nor does the environment exert any magical influence.

Nor do we gain anything by attempting to decide which is more important. The hereditarian will argue that improvement of the soil is of little value if the seed is inferior. The environmentalist will argue that a good seed will produce an inferior organism if the soil is defective. Both contentions are true; so why should there be any argument?

3. The concept of interaction between the organism and its environment should be substituted for the concept of antagonism between them.

The problem should be stated as a question of adjustment. Given the seed for a human organism, is there any limit to the degree to which it can be changed by environmental influences? Certainly there are limits. No amount of external influence can

change a human embryo into a dog, a wolf, or an ape. But, within limits, the changes that may be wrought by environmental influences are striking. Any human being is the result of his original cell (the fertilized ovum) being nourished and helped, or being interfered with and modified, by surrounding influences—a process that is continuous from conception to death.

We shall be better prepared to understand this entire adjustment process when we examine the mechanisms by means of which biological inheritance takes place.

THE MECHANISMS OF INHERITANCE

By some process of reproduction each animal organism is generated and, in turn, may reproduce offspring of its own kind.

Nonsexual reproduction. The simplest type of reproduction of living tissue is accomplished by the division of a cell into two parts. These parts then grow to full size and, in turn, subdivide to form two more cells, each of these growing and subdividing into two more, and so on indefinitely. This process of simple cell division is called mitosis. The number of cells that can be produced by this process in a short time is enormous. For example, if mitosis should continue through twenty generations with no fatalities, one cell would produce 1,048,576 offspring.

Mitosis takes place in such a way that both offspring from a division are identical; and when they grow to full size, both are exactly like the original cell—barring, of course, any modification brought about by external or environmental circumstances. It is

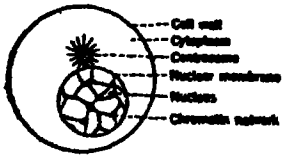


FIG. 2.—Diagram of a typical cell.

instructive to examine the process by means of which this similarity of parent and offspring is accomplished in simple cell division. To do this we must know something about the structure of the ordinary cell.

Each cell is composed of living substance, called protoplasm, and is usually bounded by a membrane which serves to separate

the cell from neighboring cells. In this protoplasm there may be nonliving substances in the form of salts, pigments, oil, and the like; but the most complex part of the cell, and the part that is essential for the continued life of the cell, is the nucleus. A typical cell is represented schematically in Fig. 2.

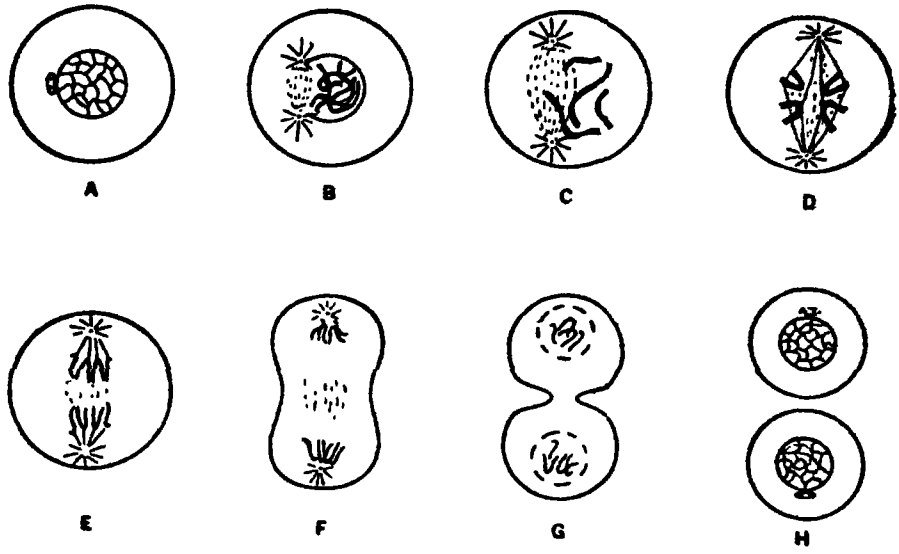


FIG. 3.—Diagram illustrating mitosis. Two pairs of chromosomes are shown. A, resting stage; B, C, prophase, showing the appearance of double coiled threads, each double thread representing a chromosome; D, metaphase, showing the arrangement of the chromosomes across the center of the cell; E, anaphase, showing the split chromosomes segregating to the poles of the spindle; F, G, telephase, showing the reorganization of the nucleus at each end of the cell; H, the two daughter cells, each with the same number of chromosomes as the original cell.

(From L. H. Snyder, *The Principles of Heredity*. By permission of D. C. Heath & Co.)

Within the nucleus of each cell are substances which take stains easily and for this reason are called chromatin materials. During certain phases of cell life the chromatin materials form into definite structures called chromosomes. The behavior of these chromosomes during the process of cell division is significant. The reason for this significance lies in the fact that they contain those elements, called genes, which determine the continuing characteristics of the species. They are the carriers of biologi-

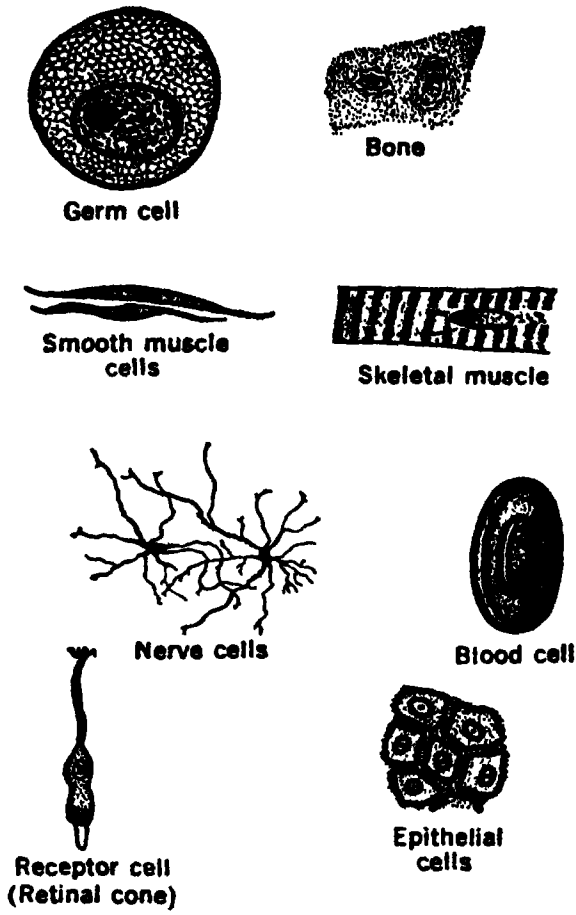


FIG. 4.—Types of cells. Cells become highly differentiated in accordance with the specialized function they perform in the organism. The nerve cell represents the most highly specialized cell. In it the cell body becomes extremely small in proportion to the rest of the cell and the power of reproduction is lost.

cal inheritance. In some way they must divide so that each of the two cells formed by a division has an equal share of the chromosomes of the parent cell. The process by means of which this equal division is accomplished is shown in Fig. 3.

It is easy to see why the offspring which result from mitosis are like the parent. They contain all the elements contained in the parent and in the same proportions. In organisms which are composed of many cells, the continuation of similar characteristics

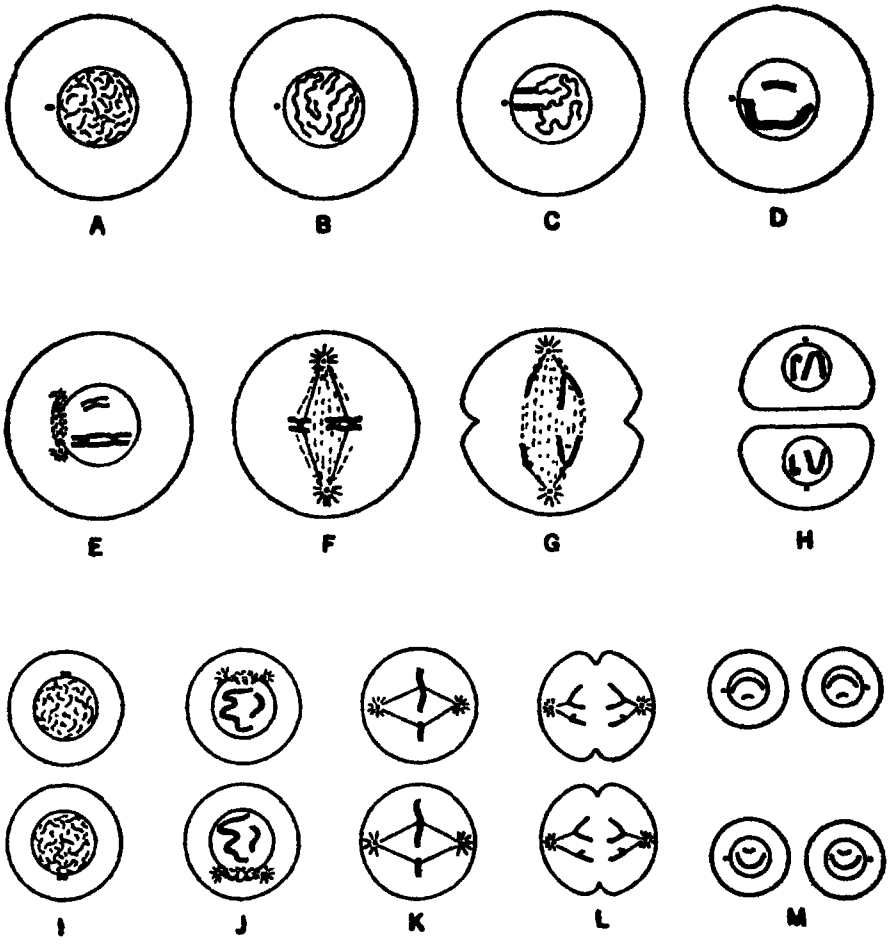


FIG. 5.—Diagram illustrating the maturation of the germ cell. The process looks quite similar to the mitosis shown in Fig. 3, except for the fact that the final germ cells at M have just one-half the number of chromosomes contained in the original cell at A.

from parent to child is not accomplished in any such simple fashion.

Sexual reproduction. Each higher organism is composed of a great number of cells, but these are not alike in form or in function. There are blood cells, bone cells, muscle cells, epithelial cells, nerve cells, germ cells, and many other types. Some of these are shown in Fig. 4. These cells form the body of the individual. They go through a complete life cycle; and the body eventually

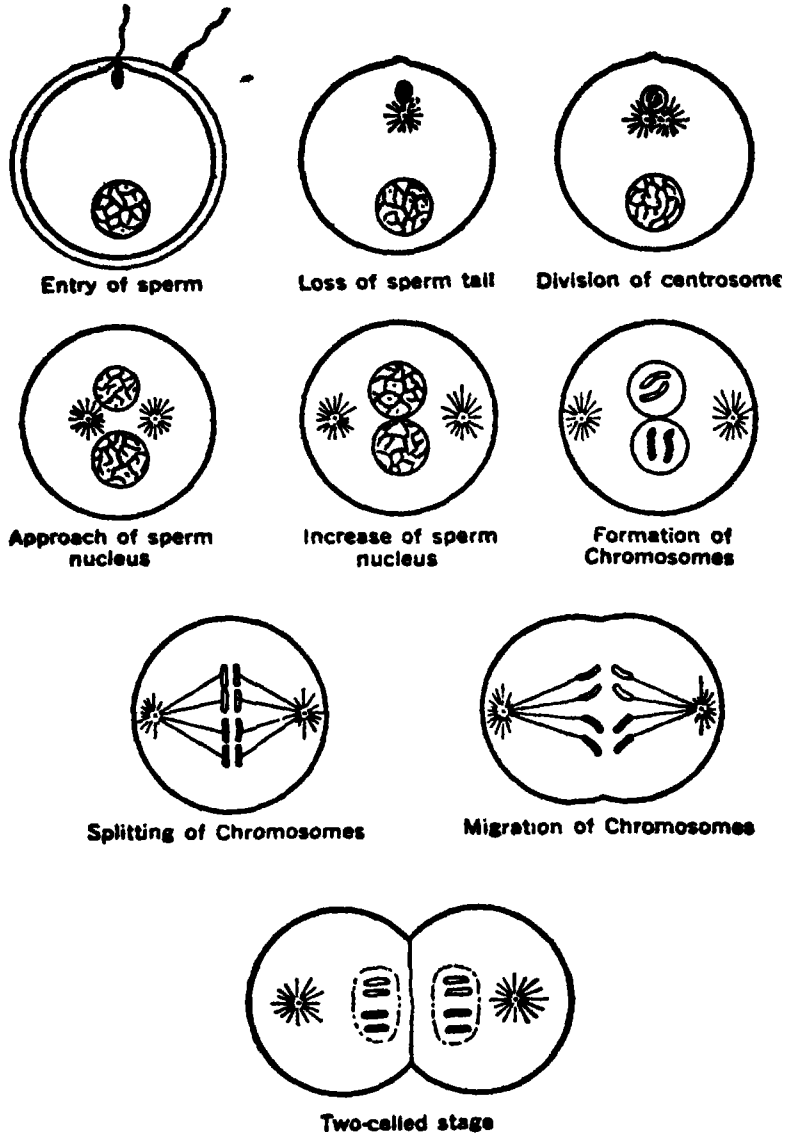


FIG. 6.—Diagram illustrating fertilization.

dies. The individual does not transmit directly his bone cells, his nerve cells, and the like, to his offspring. Instead, the function of reproduction is entrusted to the specialized germ cells. Hence, if the offspring of a complex organism are to inherit any similarity to their parents, the means for accomplishing this inheritance must be found in the germ cells.

An interesting problem is the manner in which each parent by sexual reproduction is enabled to contribute an equal share to the offspring. The human egg cell, called the ovum, is much larger than the male germ cell, called the spermatozoön; yet each contributes equally to the characteristics of the child resulting from their union. This equalization depends upon a preliminary process in the germ cells before mating takes place, which process has been called maturation or the reduction division. The reason for the name "reduction division" is that the number of chromosomes in each of the germ cells is reduced to one-half its characteristic number as a preparation for mating. The process is shown in Fig. 5. In the human germ cell there are 48 chromosomes, arranged in pairs. In the reduction division the number is reduced to 24, one of each pair being retained. Consequently, when a sperm with 24 chromosomes is united with an ovum with 24 chromosomes, the original number of 48 is restored by this union. The fertilized ovum, therefore, has 48 chromosomes; but 24 are from the father and 24 from the mother. [16] The process of fertilization is shown in Fig. 6.

Random combinations of factors in sexual reproduction. A significant question in biological inheritance is: What chance has a parent of producing a child exactly like himself? A number of conditions prevent exact similarity and the degree of similarity is determined by the random interplay of many factors.

In the first place, each individual has germ cells which vary in the combinations of genes which they possess. Of a great number of germ cells, all capable of reproducing, only a few ever do take part in the process of reproduction. Hence, what the offspring will be like depends, in part, upon which germ cell happens to enter into the process of fertilization. In the second place, there are two cells involved, one from each parent. The traits of the offspring depend upon a chance combination of mother and father genes.

This process of random selection of factors in man is so complicated that it cannot be easily understood. In order to make it clear, it may help to use a simple illustration from plant life. The understanding of such a simple pattern may enable us to imagine, at least, what happens in man, although we must avoid jumping to the conclusion that the process works with equal sim-

plicity in man. The illustration we shall give involves only one pair of determiners and it should be remembered that as the number of determiners is increased the chance elements increase in geometrical proportion.

A cross involving one pair of factors. [16] A good illustration of the process of random selection in its simplest form may be found in an experiment by Gregor Johann Mendel (1822-1884), an Augustinian monk who crossed a tall variety of peas with a dwarf variety. He found that all the resulting hybrid offspring were tall. When these hybrid tall peas were subsequently crossed with each other at random, he found, in this second generation, three tall plants to one dwarf.

On further breeding, he found that the dwarf plants of this second generation, when bred with each other, produced only dwarf peas. That is, they bred true. The tall peas of the second generation turned out to be of two varieties. One-third of them bred true and produced only tall plants. The other two-thirds produced offspring in the ratio of three tall plants to one dwarf plant.

The law derived by Mendel from his experiments is known as Mendel's law and can be stated as follows: When parents who are opposites in a particular genetic character are crossed, the progeny of the first generation will all be like one of the parents with respect to the character in question. The character which thus impresses itself upon the offspring in this manner is called a dominant character. The character which is suppressed is called a recessive character. When, however, the hybrid offspring of this first generation are, in turn, crossed with each other, they will produce a mixed progeny, 25 per cent of which will be like the dominant grandparent, 25 per cent of which will be like the other grandparent, and 50 per cent like the hybrid parents. The important element in this law is the fact that, while the hybrids of the first generation all look like the dominant progenitor, they contain both the dominant and the recessive factor in their germ cells. The recessive character will appear in the physical constitution of an offspring only when the dominant factor is absent.

The process involved is illustrated in Fig. 7. Furthermore, which mating does occur will depend upon random or chance conditions. The possible chances are illustrated in the diagram

in Fig. 8. Putting together the results as shown in this diagram, the offspring will occur in the proportions of one pure tall, two hybrid plants which will appear tall, and one pure dwarf which will appear dwarf. In appearance observable to the experimenter there will be three tall plants and one dwarf.

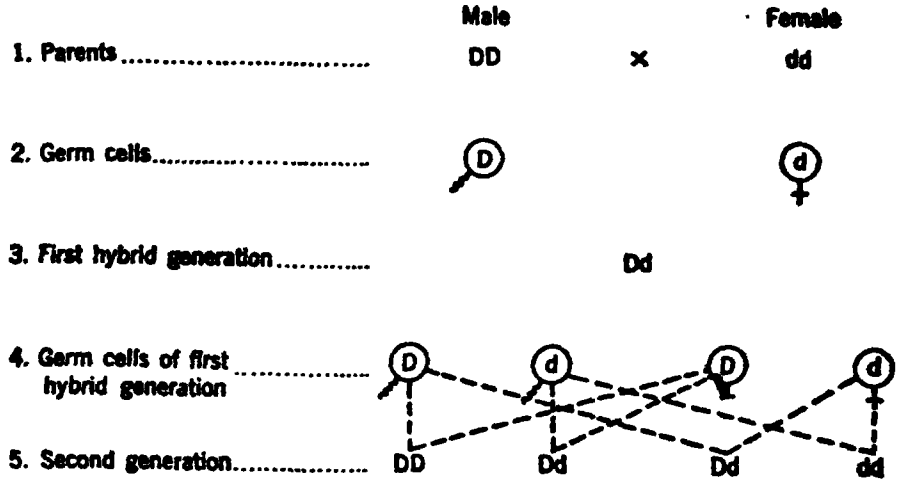


FIG. 7.—Diagram illustrating Mendel's law. The top row represents the parents, the male having only tall factors, represented by DD, and the female having only dwarf factors, represented by dd. The second row represents the germ cells after the reduction division. Each male germ cell has a D factor and each female germ cell a d factor. The third row represents the cell structure of the first hybrid generation. All have one D factor and one d factor, one tall and one dwarf. They all appear tall because tallness is dominant over dwarfness. Row 4 shows the germ cells of the first generation after reduction. A male germ cell may have either a tall (D) or a dwarf (d) factor. A female germ cell may have either a tall (D) or a dwarf (d) factor. Row 5 shows the possible combinations which could result from matings of the germ cells of the fourth row. Three of four possible combinations have a tall (D) factor and, since tallness is dominant, three of the four will appear tall.

Crosses involving a number of pairs of genes. It should not be forgotten that this simple situation exists only when there is one paired unit determiner, one pair of genes, behind the physical character in question. If individuals who show an opposite characteristic are mated, and the offspring of such a mating

are then interbred at random, and the progeny of these random matings show the trait (or the absence of it) in the ratio of 3 to 1, it may be assumed that only one pair of unit characters, or genes, were involved. On the other hand, when the number of genes involved is increased, the ratio changes strikingly. With two pairs of genes involved, there will be one in 16 who shows

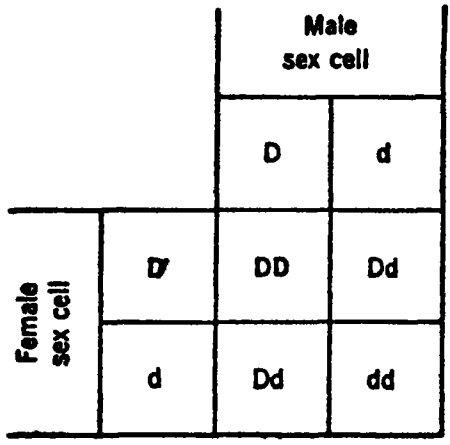


FIG. 8.—Crosshatch diagram to illustrate chance matings with one pair of unit determiners. The male sex cells at the top may contain either a tall (D) or a dwarf (d) factor. The female sex cells at the left may also contain either a tall (D) or a dwarf (d) factor. The four spaces show the combination of the factor at the top with that at the left. The resulting offspring will occur at the ratio of one pure tall (DD), two hybrids which will appear tall (Dd), to one pure dwarf (dd).

the characteristic of the recessive grandparent. If three pairs of genes are involved, the chances are one in 64 of getting an offspring like the recessive grandparent. The way in which the chances decrease with the number of genes is shown in Table I. [15]

Application of Mendel's law to human inheritance. If the inheritance of human traits depended upon some simple combination of genes, it might be possible to segregate these by some control of human marriages, and to effect matings which would perpetuate the desirable traits and eliminate the undesirable ones. No such situation exists. Even in dealing with animals which are much more simple in structure than human beings, it has been found that a character which is apparently simple is dependent upon large numbers of genes. For example, over fifty genes co-operate to produce the red eye color of a fruit fly.

TABLE I

THE DECREASE IN THE RELATIVE CHANCES THAT AN OFFSPRING HAS OF BEING EXACTLY LIKE HIS RECESSIVE GRANDPARENT WITH AN INCREASE IN THE NUMBER OF HEREDITARY FACTORS

Pairs of factors	Proportion of second generation exactly like recessive grandparent
1	1 in 4
2	1 in 16
3	1 in 64
4	1 in 256
5	1 in 1,024
6	1 in 4,096
7	1 in 16,384
8	1 in 65,536
9	1 in 262,144
10	1 in 1,048,576
20	1 in 1,099,511,627,776

Hundreds of genes co-operate to produce the straight wing on such a fly. [6, p. 17]

If, when only ten factors are involved, there is less than one chance in a million of securing an offspring exactly like his pure grandparent, the complexity of the combination of genes involved in producing a human trait makes the task of rational control of human matings a superhuman task. One is certainly not warranted in explaining how Mendel's law functions with a simple trait in a plant and then proceeding to the generalization that human traits are inherited in the same simple manner. The principles are probably the same, but the complexity of the problem grows in geometrical proportion to the number of factors involved.

THE TRANSMISSION OF ACQUIRED CHARACTERS

Geneticists customarily maintain that each individual grows from the germ plasm, that the individual carries the germ plasm in a condition which keeps it immune from bodily influence, and that the individual passes on the germ plasm intact and unchanged to the next generation. This theory runs counter to a common and popular belief to the effect that the germ plasm may be changed by the activities of the individual who is acting as a car-

rier. For example, the popular belief is that, if a man becomes a mathematical expert by incessant application, his germ plasm will show the influence of his endeavors, and any offspring he may have will be likely to show original skill in mathematics as a result of the biological transmission of the effects of this learning from father to son.

Popular belief unsound. This popular belief is probably based on wishful thinking. Many individuals have wished that acquired traits could be passed on. Breeders who are trying to improve the strain of the animals with which they are working would have an easier time if the effects of the careful nurture of their prize animals could register in the progeny of those so reared. Physicians have hoped that a patient who is protected from some disease by the process of immunization could pass on this immunity to his children. Those who bring about a moral improvement in a man may well wish that this moral improvement could be transmitted through the germ plasm to the next generation.

To console those who have a consuming ambition to contribute to the improvement of the next generation, it might be pointed out that such contributions need not be limited to biological heredity. A human being receives much more through social heritage than he does through biological heritage. For example, even if such a man as Pasteur could have affected his germ cells by his research and have passed on such changes, the effects of such biological improvement would have been infinitesimal compared with the contribution to human welfare which he passed on through the channel of social inheritance.

Evidence against transmission of acquired characteristics. Practically every controlled experiment which has attempted to test the transmission of skill in some performance through the germ plasm has given negative results. Occasionally an experimenter has reported positive results, but later checks have invariably shown that there was some error in technique or in interpretation.

Gross mutilations of the body certainly do not affect the germ cells and are not transmitted by inheritance from one generation to the next. A bobtailed cat gives birth to kittens with normal tails. Certain races have practiced mutilation through centuries with no effect upon their offspring. For example, Chi-

nese have bound the feet of their women; Jews have practiced circumcision; breeders have docked the tails or ears of dogs, dehorned cattle, and the like; but in none of these cases has the genetic structure been changed by such mutilations.

If the individual body could affect the germ cells, it would seem that an individual who manifested a dominant trait might influence the germ cell in such a way that the recessive trait which was present there could be changed toward the dominant. An experiment with the fruit fly shows that this influence will not operate. It has been possible to carry a recessive factor along through 350 generations in animals which showed the dominant trait in their bodily structure without those dominant characteristics modifying in the least the recessive factor. [15]

The conclusion seems to be that the germ plasm is immune to any sort of ordinary influence from the behavior of the individual who carries it. It has been possible, as we shall show in the following paragraphs, to produce genetic changes by subjecting the genes to violent treatment, but this is a different situation from that involved in the proposition of inheritance of acquired characters as ordinarily stated.

Effects of violent treatment of the germ cells. It has been shown that the germ cells may be changed in their structure by violent methods.

1. It has been found that the genetic system may be altered in many ways by subjecting the developing organism to powerful X rays. [12] The animals are injured; many are killed outright, many are reduced to sterility, and many which are still able to reproduce pass on abnormalities of various sorts to their offspring. The X rays have been shown to cause the chromosomes to break apart, to cause recombinations of the chromosomes, and to destroy some parts of the genetic structure.

2. An increase in the temperature in which a developing organism is placed has been found to cause decided mutations. [13] When the temperature is close to the lethal point many die; others survive with various abnormalities; and those who are still fertile may transmit changes to their offspring.

These experiments show that the germ cells may be modified by the environment in which they are placed. It is significant, however, that in order to produce observable changes, such violent

methods must be used. A man may lose a leg or an arm, or suffer mutilation; he may fail in his vocation, become a drug addict, or otherwise mess up his life; he may be racked with disease and lack physical stamina; and still, in spite of all this, he may be competent to be the father of a normal child. Whereas some individuals may wish that they could pass on their accomplishments to the next generation by biological means, most of us should congratulate ourselves that the mistakes of our ancestors stopped with their bodies and did not affect their germ cells, and that our mistakes will stop, in a biological sense, with us. When we make mistakes we hope that other people will forget. Occasionally they remember for a long time. Fortunately, the germ cells do not have to forget; they simply do not learn.

IMPROVEMENT OF THE HUMAN STOCK

In spite of the apparent difficulties confronting the advocate of human eugenics, it has been contended that, even if we do not know exactly how to arrange the best human matings, it would be well to make sure that only the best citizens be permitted to reproduce themselves. It seems logical to suppose that those who have proved that they are competent individuals would be more likely to have competent offspring than those who have demonstrated their defectiveness. The problem is not solved so easily, as we shall see when we examine the issue more critically.

We shall examine some of the methods used by breeders to improve the genetic strain of their animals, compare these methods with the method of widespread crossbreeding, and then measure these against the value of attempting to improve the individual by environmental influences.

Inbreeding. Inbreeding has been used by those who are trying to secure a pure genetic pattern in the offspring. By inbreeding is meant the mating of closely related individuals. There are different grades of inbreeding from the self-fertilization that may be found in many plants and in some animals, through brother-sister matings, to the mating of distant cousins.

Inbreeding functions by removing some of the chance elements in matings. When matings are truly random, the offspring contain genes in purely random patterns. When there is inbreeding, the range of variation is decreased and any trait is more

likely to appear in pure form than when there is wider mixing of strains or genetic patterns. If the traits thus produced are desirable, inbreeding may improve the stock; if they are undesirable, the stock will deteriorate. The latter situation is more likely to occur when the undesirable trait is a recessive one. If there is a wide mixture, the recessive quality appears in the individual more rarely than in a pure strain.

The rapidity with which a genetically pure strain is reached through inbreeding will depend upon the degree of inbreeding and the number of pairs of genes concerned. Self-fertilization, where

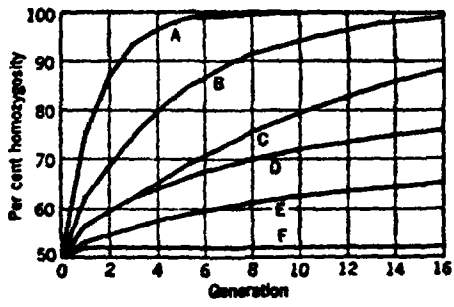


FIG. 9.—Graph showing the percentage of homozygosity (purity of strain) in successive generations resulting from various systems of inbreeding. A, percentage of homozygosity in successive generations from self-fertilization; B, from brother-sister matings; C, from matings of double first cousins; D, from matings of half brothers and half sisters; E, from matings of single first cousins; and F, from matings of second cousins.

both male and female cells originate in the same animal, will bring about purity most rapidly, eight or ten generations of self-fertilization being enough to bring about almost complete purity, even when there are a large number of genes involved. When inbreeding is as far removed as second cousins, the percentage of pure offspring does not increase materially as a result of such matings. [15] The various percentages with different degrees of inbreeding are shown graphically in Fig. 9.

Inbreeding may give rise to genetic stocks of unusual worth or it may give rise to striking defects. The results cannot be determined in advance. It is probably this factor which has made human beings look with disfavor upon inbreeding. While the

method has some value in animal work, it is literally out of the question with human beings. It would require complete control of all matings. It would mean the highhanded arrangement of marriages between brothers and sisters or parents and children in the same cold-blooded manner that the geneticist uses with fruit flies, pigs, or chickens. Even the most wild-eyed reformer would never advocate the use of this method with human beings.

Selection. Selection may be of two types: natural selection and artificial selection. In natural selection, the choice of the ones who will mate and carry on the race is left to the operation of natural laws. In artificial selection, the choice is made by man.

1. *Natural selection.* Many years ago, Darwin [1] evolved the theory of natural selection as a means for explaining evolutionary processes. His theory involves several definite factors: (a) *Overproduction.* The process of natural selection begins with the production of more individuals than can possibly survive in a given environment. The limitations of food and space make it necessary that some of the surplus be removed. (b) *Variation.* A second factor is provided in the fact that the members of a given species manifest variations. Some of the variations make it easier for the individual to exist in the strained circumstances in which he finds himself, whereas other variations may make survival more difficult. (c) *Competition.* A third factor is free competition between the members of the species to take advantage of what opportunities there are for obtaining food, space, and the other essentials for life. (d) *The survival of the fittest.* Given an oversupply of individuals who vary in their equipment for meeting the stresses of living, and given a situation of free competition between them, those who are more fit to meet the difficulties of the situation will survive those who are not competent. Those who survive will be the ones who produce their kind because the others will be killed off. Hence, the race gradually loses its weaklings; whereas the strongest members survive and reproduce their kind.

It should be noted that, when this natural selection operates, strength or weakness is measured in terms of ability or lack of ability to meet the immediate difficulties in the situation. It should be noted, likewise, that this theory of the survival of the fittest does not imply the transmission of acquired characters.

The offspring do not acquire strength from the struggles of the parents. They live merely because their parents were strong enough to outlive the weaker members of the species.

While natural selection may operate in wild animal life, it certainly does not function in civilized society. On the contrary, we do many things to prolong the life of the unfit and to destroy the fit. For example, medical science has contrived means for keeping alive many individuals who would have died under the conditions existing a few generations ago; whereas we have developed rigid selective methods for sorting out the best physical specimens for military service. We kill the best in war, and use our scientific knowledge to preserve the unfit. On the other hand, perhaps we do not want a race of beings whose essential virtue is physical fitness. Perhaps we want to develop brain workers with defective bodies instead of good physical specimens. Who knows? Let those who are too much upset by this issue take comfort in the previously cited fact that what the individual does leaves his germ cells intact. Perhaps the germ cells of the physical weaklings are as good as the germ cells of the stalwart heroes who die on the battlefield.

2. *Artificial selection.* Sometimes man has found it to his liking to favor those characteristics which are not necessarily connected with hardiness or virility. This has led to the search for artificial means for controlling and directing matings, as well as to a search for the kind of knowledge which would enable man to predict what will happen when he does exercise his directing influence. Such artificial selection methods may be classified into three types:

(a) *Selection on the basis of physical characteristics.* One of the oldest methods that man has used is that of choosing the best individuals of a group for breeding purposes. Those individuals who manifested most strikingly the desired trait were mated, while those who showed the least degree of the trait were not permitted to mate. This method will give results only when the individual bodily type corresponds with his genetic pattern, and this is often not the case. If the desired trait comes from a recessive character, then the method will give results. On the other hand, an individual may have a combination of dominant characters which will give him the appearance of approaching the

ideal which the breeder has in mind but, at the same time, he may have a combination of recessive characters which will make his offspring deviate from the breeder's ideal. The animals which take the prizes at a stock show may not be those who have the best pattern of genes for producing offspring like themselves.

(b) *Selection by the pedigree method.* Another method that has been widely used is the pedigree method. This method is better than the stock-show method and it works fairly well when it is combined with the latter. However, even when a long family tree is recorded, the individuals may have a genetic pattern that will produce inferior progeny.

(c) *Selection by traits shown in the progeny.* This is the best method for artificial selection. The only real test of the genetic value of a plant or animal is the offspring that the individual can produce. This fact is utilized in the progeny method of artificial selection. The method works in this manner: The same male is mated to a number of females and the quality of the offspring from each mating measured. The female which produces the best progeny is selected for further breeding. Conversely, the same female is mated with a number of males and the progeny judged. The male who has the best offspring is selected for further breeding.

When this method has been used through a number of generations, some remarkable results have been obtained. One illustration is an experiment on increasing the production of eggs. Eight years of breeding of prize chickens (the stock-show method) had failed to increase egg production. At the end of this period, males and females were selected for breeding based on the egg production of their daughters. After two years of this method of selection (the progeny method), egg production was nearly doubled. [15]

The progeny method is based on sound fact. The student who has followed the description of the mechanism of inheritance in the preceding pages will recognize this. The other methods of artificial selection are based on the fallacious notion that an individual is very likely to produce offspring closely like himself. This is not true. Instead, he is likely to produce offspring whose genetic structure is like his. Unless he knows his own

genetic structure as well as that of his mate, he must depend upon chance to reveal to him what kind of offspring he will get.

It is clear that this, the one successful, method of artificial selection cannot be used by human beings. It would involve the postponement of permanent matings until an examination was made of the offspring of a number of preliminary matings by the individuals involved.

These facts should give pause to the enthusiast who advocates the application of the methods derived from the study of animal breedings to the betterment of the human race. We do not know which human characteristics are most desirable and, even if we did, we would not be able to institute any genetic program to transmit them to our offspring.

Widespread crossbreeding. Certain students of eugenics, recognizing that neither inbreeding nor the different methods of selective breeding are practical in human life, have advocated extensive crossbreeding as a means for improving the human stock. In extensive crossbreeding all traits tend toward an average and the extremes are lost because, by mere chance, the genes mix indiscriminately. The extreme variants are hidden because they are outnumbered by those which are not so extreme. This phenomenon was observed by Galton, who gave it the name of filial regression. [4] His law may be stated as follows: Average parents tend to produce average children; but the children of extreme parents tend to inherit the parental peculiarities in a less marked degree than that found in the parents themselves.

If this method is used, as it is in many countries without any effort or supervision on the part of anybody, there will be a reduction of the chances for producing geniuses but, at the same time, a reduction of the chances for producing freaks. Perhaps we are better off without either.

Improvement of the individual. Regardless of any theories we may have for the improvement of the race by genetic methods, such methods are not being applied today; unless we accept the method of crossbreeding with its reduction in the number of freaks and geniuses as a genetic improvement. Therefore, why not devote our time and energy toward the improvement of those individuals who are born, instead of bemoaning the fact that they did not have better parents?

Improvement of an individual by environmental influences is based upon the thesis that an individual may be modified by his surroundings: by medical care, by proper nutrition, by social contacts, by educational procedures, by his experiences in overcoming difficulties, and the like. Is this viewpoint a valid one?

One reason why so much has been made of the importance of human heredity has been the widespread belief that inherited traits cannot be changed. We have seen that the germ plasm of an individual cannot be modified easily by what the individual does. We have found that the genes can be changed only by such drastic influences as X rays and extreme heat. Having been impressed by the stability of genes, unthinking individuals have assumed that the characters growing from the genes cannot be changed, that the physical characteristics of an individual cannot depart from the structure and pattern laid down by the genetic combination which obtained at the time of his conception. This false assumption is what has given rise to most of the misunderstanding and controversy on this subject.

What the environmentalists really object to is the contention of the hereditarian that what one inherits he has for "keeps." What the hereditarian objects to is the contention of the environmentalist that he can mold an individual into almost any form he wishes with no regard for the hereditary factors. The hereditarian is inclined to regard the inherited mechanism as the kernel of real value and to regard the environment as a dangerous threat to the integrity of this original seed. He considers that the task of the organism is to adjust *in* an environment. He reluctantly admits that the organism is influenced by his environment, but tends to think this is unfortunate and sees in the organism devices which enable it to resist too much influence. The environmentalist, on the other hand, is often inclined to think the stock is pretty bad; and his urge is to change it for the better. The true picture is better expressed by saying that an organism adjusts *to* his environment instead of *in* it.

Regardless of personal bias, it must be admitted that the geneticists have shown that the physical organism is determined in part by factors in the germ cells from which he originated. It may also be admitted that such an inherited structure predisposes an individual to act in a certain way. The inheritance of

four legs predisposes an individual to walk on all fours; whereas the inheritance of two legs predisposes him to walk on two legs. Nevertheless, it does not follow that an inherited structure cannot be used in different ways. A man may learn to walk on all fours, and a dog may learn to walk on two legs. The contention that what one inherits cannot be changed is a queer belief which continues to have adherents in spite of its obvious falsity.

Experiments with canaries. This issue is brought to a focus in some experiments with roller canaries. [14] These birds were raised in isolation from the time they were hatched, so that they had no opportunities to hear other birds sing. It was demonstrated by this means that it was not necessary for the male canary to hear the typical song of his species in order to produce it. He sang it without having heard it or without having been taught it in any manner. The song was a product of his organism.

Having demonstrated that the typical canary could sing without the environmental stimulation of other songs, the question was asked: Must this ability remain fixed throughout the life of the canary, or can it be changed?

In order to answer this question, certain of the birds who had been isolated were subjected to tones and to sequences which were different from their native songs. Their singing moved from their natural type toward the stimulating tones. That is to say, a bird inherited an organism which predisposed it to sing in a certain manner; but it could be taught to sing in a radically different manner. [9]

In another experiment, birds which had been isolated were put together in a cage where they could hear all the songs of the other birds. Such group influence tended to make the birds more alike. The birds which had sung faster than the average of the group tended now to sing more slowly. Those which had sung more slowly than the average now speeded up. That is, the unusual singer tended to give up his individualism and to drift toward the average as a result of the mutual stimulation of group life. [9]

The conclusions to be drawn from such a study as this may be expressed as follows: Each individual has factors or characteristics which are fairly stable and which resist change when

exposed to environmental influences. Some of these may appear without particular training or stimulation from the environment to bring them out. On the other hand, an individual may develop a pattern of behavior as a result of environmental influence; which pattern, in turn, may manifest different degrees of resistance to change. The degree to which a pattern manifests stability is, consequently, a poor index of its origin. If a pattern does show stability, there is no justification in jumping to the conclusion that it cannot be changed.

CONCLUSIONS

It is not wise to generalize too freely in the field of heredity and environment. Nevertheless, the following conclusions can be accepted without too many reservations:

1. A human individual is the product of a great many factors. Some of these exercise their influence but once, some operate at various times, and others function almost continuously from conception to death. These factors are practically innumerable, but some of the most obvious are: the genes which were present in the fertilized ovum from which he started his life, nutritional and other conditions which affected his development in his mother's uterus, the surroundings in which he matured as an infant, his education, his adjustment to the physical and social environment, and any chance or accidental circumstance which he may have encountered. Furthermore, the individual we now examine may have been a different individual in many respects at previous times, and he is almost sure to be different in another hour, in another day, year, or period of years. No conception of human life which makes a man a static creature can be correct. In the next chapter we shall examine the way in which some of these environmental factors influence the growing organism.

2. The combination of genes with which a man starts his life results from the chance mating of one of a great many ova from his mother with one of a great many sperms from his father. This chance combination plays an important part in determining his physical characteristics, and these physical characteristics may, in turn, make it easier for him to act in one way than in another. A canary finds it easier to sing like a canary than to bark like a dog.

3. The germ cells which an individual carries, and which determine the characteristics he will transmit to his offspring, are relatively free from influences derived from the activities of the individual who carries them. Consequently, the kind of children a person may have is determined by his germ cells and not by what he does. That is, acquired characteristics cannot be transmitted by biological means to the next generation. In human cultures social inheritance becomes of more vital significance than biological inheritance.

4. The species can be changed only by changes in the genetic structure. Many of the changes in genes are minor in character and affect the species but slowly. If changes are too radical, the cell may be damaged and unable to affect future generations. This immunity of the gene makes for racial stability.

5. The individual is more easily influenced by the environment than are his germ cells. Racial improvement is best achieved by measures which enable each individual to make the most of himself, instead of attempting to improve the genetic stock.

6. Practical considerations make it almost impossible to apply to the human race what has been learned about breeding. Improvement is furthered more by social heritage than by biological heritage. There is no ground for the popular belief that what an individual inherits cannot be changed.

QUESTIONS FOR REVIEW

1. What are some of the problems that arise in connection with the relation between heredity and environment?
2. Point out some emotional prejudices which are likely to influence a person's thinking on this subject.
3. What factors must be considered in a clear statement of the problems connected with the relationship between heredity and environment?
4. Criticize some of the superficial methods of evading the problem.
5. Show why the problem is more involved in sexual than in nonsexual reproduction.
6. Distinguish between body cells and germ cells.
7. Describe a typical cell.
8. What are chromosomes?
9. State some significant facts about chromosomes.
10. Describe the process of mitosis.

11. What are genes?
12. Describe the process of maturation.
13. Describe the process of fertilization.
14. Explain the processes on which Mendel based his law.
15. State Mendel's law.
16. Show how an increase in the number of genes affects the probability of a certain character appearing in the offspring.
17. Explain what is meant by a dominant character and a recessive character.
18. Give some reasons why people wish to believe in the inheritance of acquired characters.
19. Give evidence against the theory that acquired characters may be inherited.
20. What happens when the germ cells are treated by X rays or extreme heat.
21. What effect does inbreeding have on the purity of stock?
22. How does the degree of inbreeding affect the rapidity with which purity of stock may be secured?
23. Explain the process of natural selection.
24. Describe the three methods of artificial selection: (a) judgment of physical characteristics; (b) pedigree method; (c) progeny method.
25. Show why each of the methods of improving the stock by breeders is not applicable to human matings.
26. What results come from widespread crossbreeding?
27. Defend the theory that the best way to improve the human race is by means of social heritage and the improvement of the individual.
28. Point out how the experiments with canaries demonstrate that an inherited trait may be modified.

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Chapter III

PRENATAL AND INFANT DEVELOPMENT

THROUGHOUT our study of the hereditary background of the individual we were confronted with the fact that the inherited structures were influenced by the biochemical environment in which they matured. We concluded that an individual resulted from an interaction between the growing organism and its surroundings. Now we wish to examine more carefully the essential features of this interaction. Those who have worked intensively upon this aspect of the developmental process have kept a number of definite problems before them. A statement of these problems may be in order as we begin our survey.

THE RELATION BETWEEN MATURATION AND EXERCISE

The problem involved here might be stated in this way: To what extent is the maturation of an organ or of a complete individual influenced by exercise during the process of development? Several possible answers have been suggested, each of which seems to have something in its favor.

1. It has been suggested that maturation is a process determined wholly by the genes. We have already stated rather arbitrarily that this hypothesis is not a reasonable one, but we shall presently examine specific evidence on this point. A commonsense argument in its favor is that one cannot use such an organ as an arm before one has an arm; therefore, maturation must precede exercise and be independent of it. An argument that has been used on the other side is the well-known fact that if an organ is not used it atrophies. In rebuttal, it may be contended that, although exercise may be required to keep an organ alive and

in good health, this fact does not prove that exercise was a necessary prerequisite for its original development. The statement of these different arguments should make clear the complexity of the problem. Let us withhold final judgment until we examine the facts that bear on the question.

2. It has been suggested that maturation is wholly dependent upon environmental stimulation. Those who favor this hypothesis contend that the reason for the similarity shown by different individuals is that they grow in a restricted and similar environment. If a developing organism is placed in an environment different from its normal one, will its maturation show the effects of such changed surroundings? We shall examine some interesting experiments which have been performed in an attempt to answer this question.

3. Is there a definite time sequence between maturation and exercise? Is it possible that, as the organism develops, there is first maturation and then development through exercise? Does improvement through exercise require the cessation of development through maturation? Or, do the two operate simultaneously, but in different degrees at different stages of development? We shall review some interesting suggestions made in this connection as a result of experimental work with twins.

The problem of individuation versus integration. The two extreme viewpoints on this issue may be stated as follows:

1. *The theory of individuation.* The theory of individuation states that activity in an individual begins as undifferentiated mass activity (the individual acting as a whole) and that specific or local activities grow out of this mass behavior.

2. *The theory of integration.* The theory of integration states that activity begins in relatively isolated segments, and that development proceeds by means of the unification of these small units into larger and more complex patterns of behavior.

These issues are vital. When we know to what extent the developing organism is influenced by environmental factors, we will be able to surround it with favorable influences. If we remain in ignorance we are likely to time our efforts poorly and to apply them in incorrect amounts. If education during maturation is beneficial, it would be a grave mistake to postpone instruction until development is complete. Furthermore, our educational

procedures must certainly be different, depending upon whether the important problem is to enable the individual to integrate tiny bits of experience or to develop through the process of individuation.

In spite of their importance, these problems cannot be solved if we confine our study to human beings. Human maturation takes place in a situation that is relatively hidden from the prying eyes of the scientist. Since more liberty can be taken with animals, much of our information must be gleaned from a study of lower organisms.

TECHNIQUES USED FOR STUDYING PRENATAL LIFE

The degree of intricacy of the techniques that must be used to study prenatal life depends upon the conditions surrounding the embryo while it is developing. We shall begin with the simpler forms of life and proceed to those methods which have been used with the higher animals and with man.

Direct observation. In certain lower vertebrates, such as frogs and salamanders, it is relatively easy to study the first stages of development because the eggs have translucent coverings, and because the early stages of growth take place in water where the investigator may observe directly what is taking place. [9]

Making a window in the eggs of birds. A special technique is necessary to enable an experimenter to study the development of bird embryos. The shell of the blunt end of the egg is cut off as far as the inner membrane. Melted vaseline is applied to the inner membrane. This transforms the membrane into a clear transparent window and, at the same time, has no detrimental effect upon the egg. The incubator temperature keeps the vaseline at the proper consistency to maintain the transparency. [21]

Observation of fetal movements. In mammals, observation of the fetal movements may be made by placing the mother in a position favorable for direct observation. Mechanical devices have been used to record such movements in certain mammals. Human mothers have been asked to keep a record of the movements which they feel. However, such methods are usually crude, time consuming, and unsatisfactory.

Listening to fetal movements by means of a stethoscope. While only a little more satisfactory than the method of crude observation, listening to fetal movements, to heartbeats and the like, by means of a stethoscope can furnish some information about fetal development and behavior. This method can, obviously, give but sketchy information.

Premature removal of the fetus from the mother. This method requires the immediate death of the mother and the rapid death of the fetus following removal from the mother. [2] The fetus may be kept alive and studied for a short period of time after the operation but, since mother and offspring soon succumb, the knowledge gained from this method is likewise unsatisfactory. [9]

Operative techniques. Observations of the fetal behavior while the fetus is still alive and attached to the mother have been made possible by means of elaborate experimental procedures. [12] The mother is placed under a deep anesthetic and the spinal cord severed. A deep incision is made which will give access to the uterus by a slight subsequent operation. The mother is then permitted to recover from the anesthetic so that the fetus will not show any effects of ether when its behavior is studied. After this, the fetuses may be taken from the mother, kept alive in saline solution and studied at some length while still attached to the mother. These techniques have been used with guinea pigs, rats, and cats. Even with these elaborate methods, however, it has not been possible to study continuously the development of the same mammalian fetus over long periods of time.

Pathological conditions in human beings. Except for direct observations of movements, by listening with the stethoscope, and by reports from the mothers, our knowledge of the development and behavior of the human fetus must wait largely upon accidental circumstances. Such unusual conditions include abortions, death of the mother during the period of gestation, and surgical operations upon the mother. However, the accumulation of data from such infrequent situations, added to the knowledge gleaned from experimental studies of animals, has furnished us with some fairly accurate information as to the prenatal life of human beings.

BEGINNINGS OF ACTIVITY IN LOWER ANIMALS

The visitor to a fish hatchery is usually much interested in watching the newly hatched fish as they swim vigorously against a current of water. It appears as though the fish were born with a ready-made drive to swim upstream. Anyone who has seen a colt immediately after it was born will remember that, although it was wabbly, it quickly attempted to stand on all four legs. Does the fish swim because it has a tail? Does the colt stand because it has four legs? Certainly, the colt does not make the mistake of attempting to swim, nor does the fish attempt to stand on four legs. Does it not seem that the kind of movements that an animal makes is partly determined by the structure of its body? However, we shall soon see that much more is involved in the origin of activity.

A more fundamental question is: Why does the animal move at all? It has been noted by various observers that the growing embryo can be made to move by decreasing its supply of oxygen or by changing the surrounding temperature. That is, movement can be induced by environmental changes. It is probable, however, that, even if all environmental factors were excluded, the embryo would move because of chemical activities taking place within the organism itself. The question to be answered is how activities induced by such vague stimulating conditions as internal chemical changes, or external changes in oxygen supply or in temperature, can develop into useful acts such as swimming and standing. A partial answer may be found by tracing the early stages in the development of co-ordinated movements.

How the salamander learns to swim and to use its legs. The way in which internal chemical changes can result in significant activity has been brought to light by an analysis of how the salamander begins to swim. [11] This animal is well adapted to the study of elementary behavior because it can be observed in stages of development which are simple enough to be comparable with the embryonic development of higher animals.

The various phases in the development of its swimming activities are illustrated in Fig. 10 and may be outlined somewhat as follows: The first movements are initiated from processes within the organism. This is evidenced from the fact that they

begin at a stage of development when the animal is unresponsive to external stimulation. These movements consist of a simple bending movement, first to one side and then to the other, so that the animal alternately takes the form of a C and a Ↄ

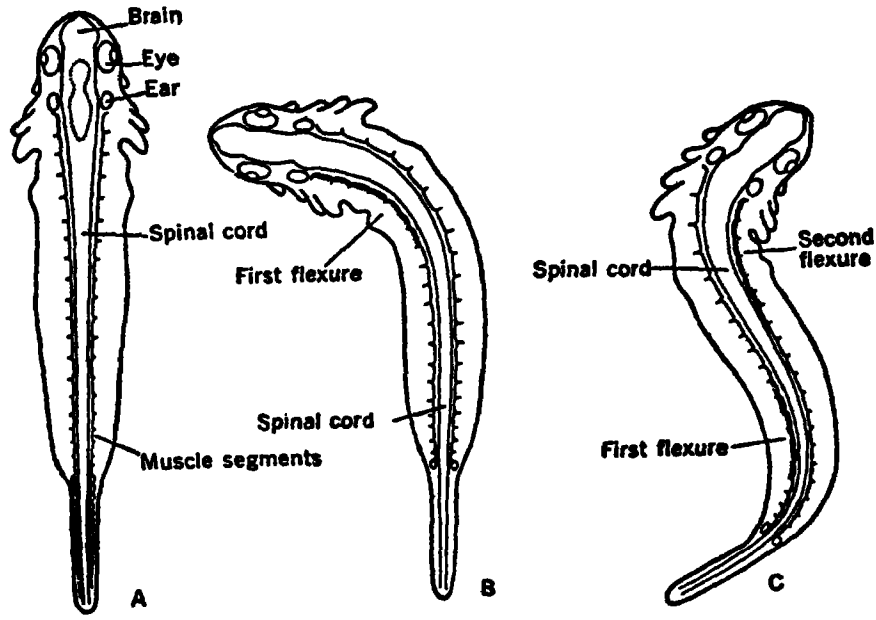


FIG. 10.—Development of swimming movements in the salamander (*Amblystoma*). A, resting position. B, flexure stage in which the animal makes a coil movement first to one side and then the other. C, the double flexure or swimming stage. This comes largely through an increase in speed of the alternations of flexure movements. Each flexure begins with the head and proceeds toward the tail. When a second flexure begins at the head before the preceding one in the opposite direction has reached the tail, an S-movement occurs which serves the function of causing the animal to move ahead.

(From J. E. Coghill, *Anatomy and the Problems of Behavior*. The Macmillan Company.)

(a reversed C). In these bending movements the tail tends to lag behind the head. Consequently, as the movements increase in speed, the head completes its movement to one side and starts to reverse to the other side before the tail has ended its first swing. This variation in timing between the two ends of the animal produces an S reaction, the head swinging to one side

while the tail swings to the other. Reciprocating S movements are literally swimming movements and the salamander is thereby propelled through the water. That is to say, the salamander learns to swim as a sort of accidental result of movements which had their origin in internal chemical processes.

How does the salamander learn to use its legs? At the time of the first swimming, the limbs of the salamander are not sufficiently developed to function independently. They merely hang as useless appendages to a body which swims by writhing movements. With further maturation of both the musculature and the nervous system, the forelimbs gain independence of movement, followed still later by movement of the hind limbs. Furthermore, each limb develops in a characteristic fashion. First the limb moves as a total mechanism, then elbow flexion gradually appears, then wrist movements, and finally independent movements of the digits.

The analysis of this succession of activities in the salamander lends support to several generalizations:

1. First, they seem to support the principle of individuation. Partial or localized activity patterns arise within a larger or total activity pattern and, by a process of learning, acquire varying degrees of specificity and independence.

2. The end of the organism which takes the lead in activity becomes the head end of the animal, whereas the part which is slower becomes the tail end. Whether the initial lead depends upon advanced maturation or whether an accidental lead in activity produces more rapid growth is a question still to be answered.

3. Development of an independent member begins as mass activity, the development proceeding from those parts nearest the main body and proceeding toward the remote parts of that member.

4. In a general sense, development must precede function. There must be the growth of a body before it can make any swimming movements. There must be a leg or an arm before it can function. Nevertheless, specific movements do not seem to spring forth fully developed. They begin with general mass activity and become specific with exercise.

Structure and function develop together in the chick. Prolonged studies of chick embryos [21] have corroborated the

conclusions that grew from the studies of the salamander. In the chick, it seems that practically every mechanism for activity is ready to function before it actually does function but that, in many instances, an organ which is still rudimentary in form will function in a crude fashion.

The studies of the chick embryos have brought out another significant point; namely, that development of behavior is gradual and continual. An organ does not develop to perfection and then begin at once to function in a highly integrated manner. The structural development of any organ is gradual and function usually goes along with structural maturation. Perfection in form and function come slowly, progressively, and in conjunction.

It seems safe to conclude that the early embryonic movements of the chick are elements out of which every later response of the adult chicken is developed. For example, many of the adult postures and attitudes of the chicken show a striking relationship to observed postures and attitudes of the chick before it is hatched from the egg. If we but had a complete and accurate record of every stage of embryonic development, it might be that we could discover all the intervening steps in development and that activities which seem to spring forth suddenly would appear as the growth from simpler patterns. The illusion of sudden appearance of fully developed activities would then disappear.

Is the embryo driven by a definite purpose? Much elementary behavior has beneficial results for the animal who manifests it. This has led thinkers to speculate upon the theory that the animal has some foreknowledge of the results of his activity and works to bring about favorable ends. There is much evidence against such a theory, a sample of which comes from a study of the newly born marsupials. The opossum and the kangaroo are good examples. A marsupium is an abdominal pouch formed by a fold of the skin and enclosing the mammary (milk producing) glands. The young of animals provided with a marsupium are born in a condition of considerable immaturity and are carried about and cared for in this pouch.

It has been reported that the newborn opossum travels from the opening of the mother's genital organ to the marsupium without the aid of the mother. Considering the immaturity of the newborn animal, and the length of the journey in comparison

to its size, this is a remarkable undertaking and has been used to support the theory of purposeful activity. A critical examination of this journey, on the other hand, reveals that the movements made are probably not purposeful at all. They are similar to an overhead swimming stroke in which the head sways as far as possible to the side opposite the hand which is taking the propelling stroke. With each turn of the head the snout is touched to the mother's body and if the teat is touched in one of these movements the embryo stops and takes hold. Once having obtained a grasp upon the nipple with its mouth, it stays attached in this manner for a period of weeks without ever once relinquishing its hold. [18]

The activity of the newborn kankagoo is somewhat similar to that of the opossum. It requires about thirty minutes for the newborn kangaroo to move from the genital opening to the pouch and, during the entire passage, the infant kangaroo receives no help from the mother. It moves very slowly, turning the head from side to side, the hands reaching about, opening and closing continually like a cat's paw.

Several points of similarity may be noted between these activities of the marsupials (in their journey from the birth orifice to the pouch and attachment to the mammary organ) and the beginning activities of the salamander. The head sways from side to side in a movement quite similar to the S movement by means of which the salamander develops his swimming skill. In both the salamander and the marsupial it is the head end which is most highly developed and the front paws are by far more highly developed than the hind paws. The front paws assume the brunt of the labor in the marsupials and the hind ones drag along in rather a useless fashion.

This, again, looks like the process of individuation, that is, the emergence of specific activity out of general mass activity. The marsupial is probably stimulated to a varying type of writhing movement because of the hunger resulting from ejection from the uterus. The form of these movements is determined by the stage of development already reached by the newborn animal. Once having become attached to the mammary gland, the movements cease; and when the animal finally releases its



FIG. 11.—A kangaroo carrying her young



FIG. 12.—The arm strength of the ape. In comparison with a child of comparable age, the ape far excels in physical strength and agility.

(From W. N. and L. A. Kellogg, *The Ape and the Child.* By permission of McGraw-Hill Book Company, New York.)

hold, after a period of weeks, it has developed so much more that its activity is then of quite a different sort.

That the newborn marsupial is not driven by some definite purpose has been demonstrated by a simple test. If, soon after the kangaroo becomes attached to the nipple, he is removed, he is unable to reattach himself. Were he driven by a definite purpose and were all his acts directed toward finding a specific object (the nipple), he certainly would be able to reattach himself when the nipple is merely pulled away from him. [9, p. 53]

The role of sensory stimulation in fetal development. Studies of the fetuses of white rats and cats have supported the findings from the studies of lower forms of life and, at the same time, have made a further contribution in that they indicate the part played by sensory stimulation. The best observations upon fetal rats and cats have been made by removing the fetuses from the body of the mother without breaking the placental connection, and observing the behavior of the fetuses while both mother and offspring were kept alive in a blood-warm solution.

The first movements observed in the fetal white rat were slight lateral bendings of the head. [9 and 31] Clamping the umbilical cord increased the products of metabolism (metabolites) in the fetal system and thereby initiated more violent activity and changes in behavior. The appendages of the very young fetus moved only with the trunk in much the same fashion as the legs of the salamander moved when the latter was developing swimming movements. In short, these early movements of the fetal rat remind one very much of the bending and S reactions that were found in the salamander and marsupials.

However, the students of the white rat have shown that the principle of individuation is not a complete explanation of growing behavior. The mass reactions are not merely broken up into specific patterns. Instead, some condition ordinarily arises which interferes with the primary mass behavior. This arrest of the primary or basic movement gives rise to secondary movements and specific patterns grow from these. In this progress the primary, basic, mass pattern of reaction is never quite lost, but the smaller, more specific activities develop relatively much more independence. These interferences with mass behavior arise from stimulation of the sense organs of the fetus. A study of

the fetal cat reveals the same general form and direction of development that has been suggested by the study of the more elementary forms of vertebrates. [12, 31] Here, again, the first fetal movements are found to be slight head flexions, followed by generalized trunk undulations, forelimb flexion, and rotation of the head and trunk. These primary movements are strikingly altered by sensory stimulation.

In other words, it would seem that the principle of individuation may account for the segregation of action patterns from internal and structural conditions alone, but that stimulation from the environment adds other elements by interfering with these patterns and thus producing still other forms of activity.

Experimental interference with the growing embryo. Evidence is multiplying that environmental influences will change in a striking manner the developing embryo. Although the salamander is normally an aquatic animal, it may be made into a land animal by being fed, in its very early developmental stages, with thyroid extract. So changed, it will live on land and go to the water only to lay its eggs. If a pregnant rat is fed with a diet deficient in Vitamin B_1, the offspring are defective in neural development. A young animal which would ordinarily become a female will develop into a male if a male sex gland is transplanted into it before sexual development has progressed far.

Probably the most striking experiments in this connection are the transplantation experiments performed upon animals in the embryonic stage of development. An illustration of such an experiment is the transplantation of an eye-bud. If an eye-bud, at just the right stage of development, is transplanted so as to lie under the skin of the abdomen, the skin and adjoining tissues are influenced in such a manner that a fairly complete eye is formed. That is, the eye-bud becomes a center of influence which acts upon tissue, which would ordinarily become abdomen tissue, and makes it into eye tissue. [29]

HUMAN FETAL DEVELOPMENT

The prenatal life of the human being is usually divided into three periods: the germinal period, embracing the first week and sometimes the first two weeks of prenatal life; the embryonic

period, extending from the third to the fifth or sixth week; and the fetal period, including the remainder of the prenatal period from the sixth week to birth. The normal term of pregnancy is usually given as 280 days, with variations in estimate between 270 and 284 days. An infant born at less than 180 days of age is not likely to survive.

Description of human fetal activity. During the germinal period there is little but a globular cluster of cells which are multiplying at a rapid rate. This cluster is free moving until the end of this period, when it becomes embedded in the tissues of the uterus of the mother. From this time until birth, the developing child exists parasitically in the mother. During the embryonic period the individual increases greatly in mass and attains considerable differentiation of structure. No spontaneous activity has been observed in this period.

The earliest movement of the human fetus is reported for a fetus slightly less than an inch in length and at the estimated age of six weeks. By two months the arms and legs move spontaneously. The early movements are likely to be slow, irregular, unco-ordinated, lacking in precision, and diffuse.

With increasing age, at approximately three months, the fetus may show more specific responses to definite stimuli. For example, the stimulation of one foot may lead to the movement of the arm on the opposite side of the body. Or, brushing the sole of the foot may lead to flexion of all the toes except the great toe. Later, it may be possible to elicit a movement of the leg by striking the patellar tendon (the tendon just below the kneecap), or a movement of the foot by striking the tendon of Achilles (the tendon just above the heel). Continuing up to full term, the fetus seems to make greater progress in his ability to react more specifically to local stimuli. These reactions have been called reflexes.

Conclusions from the study of fetal life. A significant result of the studies made of the human fetus has been a reformulation of the concept of reflex behavior in human life. It was formerly thought that reflexes constituted the elementary form of behavior. According to this old conception, a reflex was defined as a constant, congenital, relatively invariable, restricted, mechanical response which followed some specific stimu-

lus. A reflex presumably had its basis in some inherent mechanism the explanation for which was not clear.

The newer conception of human development embodies the conclusions from the studies of animal fetuses. It holds that human as well as animal behavior is at first crude, undifferentiated, and likely to involve the organism as a whole. As structural development progresses, behavior becomes more specific and localized. These individualized patterns then become more complex and elaborate, owing to the interference of environmental conditions, including both stimuli from the outside and interferences with movement imposed by outside obstructions. The reflex is, consequently, not the primitive form of activity, but an advanced form which develops with the growing independence of various parts of the organism. The appearance of reflex behavior in the full-term fetus is in striking contrast with the diffuse character of the behavior of the very young fetus.

It would seem, consequently, that the reflex is a more advanced form of behavior than is mass behavior, the reflex is not inflexible in its manifestations, it is not unlearned, and it may be broken down in times of stress and external interference and give place to more primitive reactions. In other words, a reflex represents a more precise, more efficient, and more localized way of dealing with a stimulus than can be accomplished by a mass reaction.

From this discussion, it would appear that growth is not to be considered as the mere unfolding of preformed materials, nor is it to be thought of as the imbuing with life (vital energy) of some prefabricated organ. It is rather the continual interplay of dynamic forces which form one system, only to be continuously superseded by newer systems as the result of changing relationships between the dynamic elements involved.

These dynamic processes that begin with the fertilized ovum continue through life. Development consists of alterations in both structure and function of the organism which is living in a continually changing environment. The aspects of this development are exceedingly complex; the forces that operate are numerous; and progress does not proceed in any one direction or toward any one end. Through the development one may perceive the continuation of primitive mass patterns, and he can also dis-

cern the emergence of new, localized, and specialized patterns which are partially independent of the mass reactions from which they grew.

ASSETS OF THE NEWBORN INFANT

Even after birth, the human infant retains many of the characteristics found in the immature fetus. His movements are still slow, asymmetrical, arrhythmical, and un-co-ordinated. His body is thrown about, curved, flexed, extended, and arched. His arms and legs merge with those of the trunk and are slashed and kicked, flexed and extended incessantly. The movements are not regular and there are no fine and precise gradations and little specificity in the reflex sense. All his activity is ineffective.

The significance of an infant's behavior cannot be determined by the degree of efficiency he manifests. Instead, his relative immaturity guarantees to him the possibility of developing in different directions, his reflex patterns are easily modified into different forms of behavior, and he requires only enough supervision from adults to safeguard him from errors which might bring death while permitted enough freedom to attain breadth of experience. As we review the assets of the child at birth, we should keep these aspects of the significance of infancy in mind.

Relative immaturity. Birth in itself does not represent any violent acceleration of the maturation process; it is merely the transfer of the developing organism from a restricted environment to a more complex and extended environment. The relative degree of maturity of the animal at the time that this transfer is made has some significance. While the marsupial is more immature than the human infant at birth, the marsupial remains in the mother's pouch, attached for a prolonged period to the mammary gland of the mother, and hence not being subjected to a wide environment in the same sense as the human infant. When the marsupial eventually becomes separated from the mother, it is more mature than is the human infant at birth.

Since the human infant is born in an immature state, he has few activity patterns already established. He must learn his forms of behavior while being subjected to stimulations and interferences from a complex environment and has, for this reason, the opportunity to develop more complex activity patterns

than would be possible if he completely matured in a restricted environment. It is an advantage for the human infant to be born in an immature condition. Much of his later intellectual progress may depend upon this characteristic of the human species.

Behavior of the neonate.[1] The neonate has few specific behavior patterns at birth. [5] Those which are present are likely to show a lack of uniformity at first, to manifest quick change, and easy modification when they have little value and are, consequently, not much exercised. An examination of some of the neonate's behavior will make this clearer.

1. *The sucking response.* The neonate has a vague tendency to orient the mouth toward the stimulation of areas near the mouth. The order from the highest to the lowest frequency of response is made to stimulation of: lips, above lips, below lips, and cheek. [26] With increasing age the cheek stimulation is the first to diminish in the frequency with which it will bring about the turning toward the source of stimulation. With the placing of the nipple in the neonate's mouth there is likely, at first, to be a disorganized attempt at sucking which quickly, however, becomes definitely organized.

The sucking response may be stimulated, after it has once begun and then tends to lag (as it is likely to do after the infant has taken some food and begins to relax), by a flash of light, pinching the toe, pulling the hair, making a loud sound, or any sudden or forceful stimulus. Mothers use these methods to keep the nursing child from going to sleep before he has received enough food. Sucking may also be augmented by giving the infant sweet or sour solutions, and it may be affected by giving solutions which vary from the normal temperature.

In other words, sucking is not the fixed machinelike reaction that it is sometimes described as being, nor is it as rigid in its operation as the sucking reflex in some lower animals.

2. *The grasping response.* The grasping response is the flexing of the fingers in response to contact stimulation of the palmar surface of the hand.

[1] The newborn infant is often called the neonate. This term "neonate" is used arbitrarily to designate the child during the period from birth until he is about one month of age. Some limit the use of the term to the first two weeks of life.

This reaction is very marked in such an animal as an ape. He will grasp an object and easily support his entire weight. [20] The grasping response is, on the other hand, variable in human neonates. It is stronger in periods of excitement or hunger, and disappears in sleep. It is weakened when the child relaxes after nursing. It disappears entirely after about six months. [17]

3. *The plantar response.* The plantar response consists of a flexion of the toes produced by stroking the sole of the foot. In neonates the response of the toes has been reported to be quite similar to the reaction of adults (known as the Babinski sign) who have a pathological condition of the spinal column; namely, the flexion of all the toes except the great toe which is extended or turned up.

This result has been asserted to be due to the immaturity of some of the fibers of the spinal cord. This reaction in neonates may be influenced by immaturity, but it is also dependent upon the strength of the stimulus used in eliciting it. [27] In other words, this foot response is quite variable and is partially dependent upon the nature and strength of the stimulus and not entirely upon the degree of maturity of the neonate.

4. *The pupillary responses.* In the human adult the pupillary response to light is one of the most regular that can be evoked. It consists of a change in the size of the pupil in response to a change in the intensity of the light stimulating the eye; a brighter light causes the pupil to become smaller, a reduction in the brightness of the light is followed by an enlargement of the pupil. This response, however, is by no means uniform in the neonate. Most investigators report that it is not present at birth, but that it develops during the first few days of life. [23, pp. 40–41]

5. *Other forms of infant behavior.* Other investigators have reported such responses as sneezing, hiccoughing, yawning, crying, smiling, the sudden spasmodic reaction in response to a quick change of position (called the Moro, or fear, reflex), and the raising of the head when placed in a prone position. [5]

The sense organs at birth. Since the reactions of the child provide the only means for interpreting the sensory acuity of infants, and since the reaction patterns are crude in their func-

tioning, it is difficult to gain any clear conception of the degree of accuracy with which the neonate is able to use his sense organs.

1. *Visual sensitivity.* The infant learns to respond quickly to brightness changes and to changes in hue and reacts to these stimuli in a variety of ways. The pupillary reflex is quickly learned by the neonate; the blinking reaction (palpebral reflex) appears about the end of the second month of life; the ability to direct vision upon an object appears at about the third month; eye and head pursuit movements in following a moving object have been observed at about two weeks of age; and a bright, intense flash of light may produce a general spasmodic reaction with clasping (Moro reflex) during the first three or four days of life. [25] This quick learning indicates that the visual apparatus is well developed at birth; but it is also apparent that the infant does not know how to utilize his vision without learning.

2. *Auditory sensitivity.* Great individual differences in auditory sensitivity are manifested during the first few days of life. Some observers insist that the infant is deaf at birth, others assert that the ear is stimulated effectively during prenatal life. In spite of this uncertainty, it is evident that the neonate soon becomes sensitive to sounds. He manifests his susceptibility to loud sounds by blinking (the palpebral reflex), respiratory changes, circulatory changes, spasmodic muscular contractions, and the clasping reaction (Moro reflex). This sensitivity is more marked to high-pitched tones, and to sounds of short duration and high intensity, than to low-pitched, prolonged, and mild tones. [23, p. 52]

3. *Smell (olfactory) sensitivity.* The neonate responds when stimulated with ammonia or acetic acid by throwing back his head, wrinkling or grimacing of the face, squirming of the body, respiratory changes, movements of the legs and arms, and by crying or sneezing. [26] Odorous substances which do not cause pain or discomfort in the adult do not produce a response in the neonate. It seems probable, consequently, that the neonate is responding to pain or discomfort rather than to the olfactory qualities of the stimuli.

4. *Taste (gustatory) sensitivity.* The most common taste stimuli that have been used to test infants are sugar, salt,

quinine, and citric acid solutions. The reactions used to indicate responsiveness to taste have been facial reactions, changes in the sucking reaction, circulatory and respiratory changes, or bodily movements. [25] It is quite likely that the neonate is sensitive to salt. There is disagreement among investigators as to the neonate's sensitiveness to the other three basic tastes; namely, sweet, sour, bitter.

5. *Thermal sensitivity.* To a general lowering of the environmental temperature the infant of only a few hours of age will respond by shivering and muscular activity. When a cold or hot stimulus, considerably below or above the normal body temperature, is applied to local areas of the body, vigorous movements of the stimulated part are produced. In addition, such local temperature stimuli cause more widespread responses, such as respiratory changes, circulatory changes, widespread movements, and, in some instances, crying. [25]

6. *Pressure or contact sensitivity.* Responsiveness to various kinds of pressure stimuli, touches, taps, and strokings have been observed in the fetal period and are probably fairly well developed at birth. For example, the sucking responses, blinking, plantar, and palmar reactions may all be produced by tactile stimulations. [26, p. 186]

7. *Pain sensitivity.* Premature infants are responsive to pain stimuli, but it is also true that sensitivity to pain increases with the age of the infant. It is greatest in the head areas and is less in the legs. The time for response is longer in the neonate than for the involuntary reaction found in adults. In addition, it is often necessary in the neonate to give repeated pain stimuli before a response is elicited. [26]

8. *Visceral sensitivity.* There is evidence that hunger contractions produce increased general activity in the neonate. When substances are introduced into the stomach there is a cessation of such contractions and general quiescence. This relaxation may be interfered with by gas pressure after eating, which in turn is customarily relieved by placing the infant in a position where he can easily belch, euphemistically called by mothers, "bubbling."

9. *Sensitivity to changes in position.* It is well known that swinging and rocking are effective in allaying crying in the

neonate. In the first two or three days of life a crying child will become quiet, and perhaps fall asleep, if he is taken up, rocked, or mildly jolted. All infants enjoy cradles and baby buggies. Experimental studies have been made of the effects of rotating an infant. After the rotation stops there is an oscillatory rotation of the head for about fifteen seconds in the direction opposite that in which the infant was rotated. This is known as nystagmus and is presumably dependent upon static sensitivity, or sensitivity to changes in position.

Dependence of the neonate. While the sense organs of the neonate are ready to function, the infant does not have the ability to react to complex stimuli by appropriate acts. It needs no experimental confirmation to establish the fact that the child must be fed, protected, and guided by adults or he would perish. The neonate has not the mechanical equipment required to enable him to move about in his objective universe; he has not the strength to move the body structure that he does possess; he has no well-developed reflex behavior patterns to enable him to react spontaneously and efficiently to various stimuli; instead, he must depend upon others to help him. He attempts to do various motor tasks, makes mistakes, tries other methods, makes more mistakes, and all the time is being given help from those around him. A colt or a lamb is much more efficient and independent at birth than is a human being.

Finally, when the child does achieve independence, he shows certain effects of this gradual learning under supervision. His movements are in the nature of intelligent adaptations to problem situations rather than automatic reflex actions to fixed stimuli. The advantage of this sort of early dependence, and its consequent effect of producing intelligent responses instead of blind automatic acts, can be seen by contrasting the behavior of a human being with an insect. On a summer's night the insect will fly toward a light even though it may be killed by the heat as a result of its action. It has a fixed pattern of behavior in response to a light and it cannot modify that behavior. The human being has a thousand and one reactions that he may make to a light. To be sure, the entire difference between an insect and a human being is not one of relative dependence in infancy;

but the differences would not be possible were not the latter immature and dependent.

The significant factor is that the child learns as he achieves independence just as he learns while he matures. A mechanical response to any situation incapable of being modified is a non-intelligent reaction. It might perchance be an efficient reaction for some specific situation, but an intelligent response is one that can be modified in response to a minor change and adapt itself to the needs of the moment.

THE COMPARISON OF AN APE WITH A CHILD

It is a significant fact that man's superiority over the lower animals is not dependent upon physical strength, motor skill, or sensory acuity, but upon his ability to put these qualities to efficient and intelligent use. A clever, unique, and enlightening experiment has made these distinctions clear. An ape and a child were given identical treatment for a prolonged period in order to observe differences between the two. [20] A female chimpanzee was taken from her mother at the age of 7½ months and "adopted" into the family of a psychologist who already had a son 10 months of age. These two "children" lived together as companions, playmates, and members of the same household for nine months. They were treated as nearly alike as was humanly possible. Each was given the same consideration, caressed in the same manner, engaged in the same games, ate with the same utensils, and slept in similar beds. During this time a continuous series of tests, comparisons, observations, and experiments was made upon the two.

In the ability to grasp small objects and to make fine finger co-ordinations, the child is more adept than the ape. This, however, is practically the only aspect of motor behavior in which the child excels. The ape makes up for ineptness with his fingers by greater skill with his lips. In co-ordinated arm movements, the ape was more proficient at the age of 9 months than the child at 18½ months. She learned to eat with a spoon more readily than did the child. In walking erect and in skipping, climbing, and running the ape was far superior to the child. In physical strength the child was far behind the ape (see Fig. 12).

The ape had greater sensory acuity in practically all sense

fields than did the child. The ape showed her sensitivity to light by turning her face from the source of a bright light, putting her hand, arm, or even her foot before her eyes to shade them. The child showed no corresponding sensitivity to light. The ape was much more sensitive to small objects, would stare and point at insects, or play with dust particles in the sunlight, and would notice immediately, and manifest curiosity toward, any new object in her environment. She showed interest in pictures and was much quicker in noticing her reflection in a mirror than the child. The ape, too, was much more alert to faint or weak sounds. She could detect sounds that were inaudible to adult human ears. In localizing sounds the ape was much superior to the child. In other spheres of sensation this same superiority was apparent. The ape seemed to have a better sense of equilibrium, learning to enjoy the dizzy sensation which comes from spinning, was more alert to smells, and seemed to be more alert to temperature changes.

It would be interesting to have such an experiment continued through a period of years in order to ascertain in what direction, and at what points, the ape and the child would diverge. We know that the child would have a marked superiority in his ability to utilize language, but it is possible that in some other directions the cleavage between the ape and the child would not be so great as we now are inclined to think.

At any rate, it would seem that the important factor behind human achievement is the manner in which man learns to use the equipment that maturation has given him, rather than in the strength, agility, and mechanical efficiency of his body, or the acuity or discriminating ability of his sense organs.

STUDIES OF TWINS

In the attempt to determine still further the degree to which inherited structure may lend itself to individual variation through educational and similar environmental agencies, the psychologist has resorted to a study of twins.

Some earlier studies failed to make a fundamental distinction between identical twins and nonidentical, or fraternal, twins. Identical twins have identical heredity, that is, they develop from a single fertilized ovum. Fraternal twins develop from two sepa-

rate fertilized ova and have no more similarity in heredity than do any other pair of siblings.[2]

It is not so easy as it might appear to be to identify identical twins. At one time it was assumed that when twins were identical, they would be enclosed in a single fetal membrane. All that would be necessary, according to this assumption, would be to examine the membrane at birth to determine whether both members of the pair were in a single membrane or in separate membranes. More recently, this assumption has been discarded. Identical twins have been found with each member of the pair in an independent membrane. Also, two membranes may fuse and appear as one so that some twins who have seemingly but one membrane may actually have two. The simple method of examining the birth membranes has been discarded. [24]

The determination of identical twins. A substitute method has been to judge them on the basis of similarity. The characteristics that should be similar in identical twins are as follows:

1. They must be of the same sex. While twins of different sex cannot be identical, twins of the same sex may be nonidentical, or fraternal. This criterion can, consequently, be used to exclude some twins who are surely not identical. On the contrary, after the twins of the same sex are sorted out, these will include both identical and nonidentical pairs.

2. They must be essentially the same in certain characteristics, such as: (a) hair color, hair texture, and hair form; (b) eye color and pigment pattern on the iris; (c) skin color, provided there has not been change by exposure to sun; (d) distribution of down on the body, especially on the face, neck, and hands; (e) facial features, such as nose, lips, chin, and ears; (f) type of teeth with same dental irregularities; (g) type and proportions of hands and fingers; and (h) friction ridges on fingers and palms.

The method of co-twin control. The most significant studies of twins are those using the method of co-twin control. In general, the procedure in these experiments is to give one twin special training as soon as he is mature enough to profit by it, to withhold similar training from his co-twin until some time later,

[2] Refer to glossary at back of book for definitions of unfamiliar words.

and then to train the co-twin along similar lines. In one such experiment, training was given to one member of a pair of twins in climbing and in the manipulation of cubes; in another training was given in digit memory, object memory, ringtoss, paper cutting, and walking boards of various widths; and in another the special training was in language. [19]

The most striking experiment using the method of co-twin control was that on the twins known as Johnny and Jimmy. [22] Johnny was given all sorts of special stimulation and training, while Jimmy was permitted to grow as an ordinary boy in a normal environment. At the close of the period of training in each activity the twins were compared. The experimenters classified the activities in which Johnny was given special instruction into two categories: (a) phylogenetic activities (those which are common to the human species), such as reflex reactions, locomotion, rolling over, reaching and grasping, and reactions to skin irritations; and (b) ontogenetic activities (those which are largely individual), such as climbing up and down inclines, climbing on and off stools, roller skating, swimming, finding hidden objects, jumping from a relatively high perch, and meeting difficult problem situations. At 19 months, Johnny could roller-skate, swim, drop from a five-foot perch, and persist in a problem situation for as much as forty minutes at a time. Jimmy could do none of these acts. In the phylogenetic activities there was little difference between the twins, the special training of Johnny in these produced little or no effect.

Eleven months after the end of Johnny's training, Jimmy was trained in the same acts. After the completion of Jimmy's training, the twins were approximately equal in securing objects with sticks; in manipulating ropes, pulleys, and strings to procure objects; in size discrimination; and in intelligence tests. One difference persisted, however, and that was that Johnny continued to be more persistent and deliberate than Jimmy in his approach to a problem.

The conclusion seems to follow that motor processes that are particularly dependent upon special training do not come to life by the mere process of maturation of hereditary factors. It also appears as though some of the more obscure traits of personality, such as persistence and deliberateness, may result from the type

of training a person has undergone. Since Johnny was stimulated to learn a task when in a much more immature stage of development than Jimmy, it probably was much more of a challenge to him. We may suppose that his rising to such challenging stimulation helped to develop persistence and deliberation. However, we know little specifically of the development of such traits, and it could be that just a little more stimulation might have had a quite different result, he might have become discouraged and have learned to shrink away from challenging situations, or to have become resistant and stubborn. In any case, it seems apparent that identical twins can be made permanently different in personality traits by subjecting them to radically different types of training.

Results of comparison of identical with fraternal twins. An elaborate statistical study was made in which fifty pairs of *identical twins were compared with fifty fraternal twins.* [24] The same investigators studied nineteen pairs of identical twins who had been separated from infancy and had been reared in different environments. Some general conclusions from their studies are as follows.

1. Fraternal twins are no more alike than siblings.

2. Identical twins resemble each other more than do fraternal twins or siblings.

3. The resemblance found in identical twins is much more striking in physical characteristics than in mental or personality traits. Identical twins are practically identical in such physical characteristics as finger ridges; they are similar in height, weight, and head length; and they are least alike in educational achievement, personality, and temperament.

4. Twins who have lived apart for a considerable time in widely different environments are less alike than those who have lived in similar environments. Social and educational changes in the environment are effective in producing variations in such traits as intelligence, school achievements, and temperament. Environmental differences do not greatly affect likenesses in physical characteristics.

5. Identical twins become neither more nor less alike as they grow older; whereas fraternal twins become less alike with

age in mental traits and in personality traits, but remain similar in physical traits.

6. The degree of similarity in twins varies with the trait involved as well as with the nature of the environment. No amount of education will bring about differences in the finger ridges in identical twins; nor is it probable that environment can be kept so similar for identical twins that they will have identical temperaments when they reach middle life.

CONCLUSIONS

1. Studies of the developing embryos of animals and of human beings indicate that activity is first initiated by chemical processes within the embryo.

2. The order of development seems to be:
   (a) From crude mass activity to more specific and localized behavior.
   (b) From weak, un-co-ordinated, and variable responses to those which are stronger, better, co-ordinated, and more regular.
   (c) Progress is from the head to the tail regions.
   (d) In each limb development progresses from the part nearest the body and proceeds toward the more distal parts.

3. Changes from mass activity to specific activity emerge from the interaction of two factors. The one is the maturation of more complex structures in the individual, including the development of the nervous system, the increase in acuity of sense organs, the enlargement of the bony framework, and the strengthening of the muscles. This maturation makes possible more complex forms of behavior. The second factor is the stimulating influence arising from difficulties in adjusting to the environment. Each stress provides the occasion for specialized and individualized reactions in place of the earlier crude mass actions, the response to a specific need by a more direct and localized response. In short, each demand for adjustment stimulates the development of activities which are less random and more intelligent.

4. The relation between maturation and exercise is not a fixed one. Maturation begins from forces present in the genes; but exercise begins before an organ is completely developed. Such

exercise may effect radical changes in the developmental processes. Hence, if the entire development of an organism takes place in a restricted environment, the organism will tend to develop according to a more rigid pattern than would be the case were it exposed to varying situations during development. When an animal is born while in a relatively immature state, he will have opportunities to vary his adjustment behavior patterns. This gives meaning to the fact that the human infant is born in a relatively immature state.

5. Reflex behavior seems to be a more mature form of activity than undifferentiated mass activity. The reflex patterns in a human infant are less rigidly established than are similar patterns in the lower animals. The behavior of the human being is therefore more flexible than that of the lower animals.

6. The comparison of an ape with a child seems to show that human superiority cannot be measured in terms of strength and efficiency. The ape is stronger and more efficient than the child. Instead, the human being, because of his variability of behavior, has a wider range of uses to which he can put his various capacities. It is flexibility rather than efficiency that is the true measure of man's superiority.

7. A study of twins gives indications that physical characteristics are more dependent upon hereditary factors than are personality traits. The elements in human life which count for most are those which man gains through his ability to modify hereditary patterns in accordance with his own individual experiences.

QUESTIONS FOR REVIEW

1. State three hypotheses that have been advanced to explain the relationship between maturation and exercise.
2. What is meant by individuation?
3. What is meant by integration?
4. Describe the seven techniques that have been used to study prenatal development: (a) direct observation; (b) looking into bird's eggs; (c) fetal movements; (d) the use of the stethoscope; (e) premature delivery of fetus; (f) operative methods; and (f) pathological conditions.
5. Describe the development of swimming movements in the salamander.

6. What conclusions may be drawn from an analysis of swimming?
7. What part do chemical processes play in early movements?
8. Indicate points of similarity between the swimming movements of the salamander and the early movements of marsupials.
9. What test has been used to show that the marsupial is not driven by some fixed purpose?
10. How do the sense impressions received by the fetus modify movements initiated by chemical processes in the fetus?
11. Summarize the lines of motor development which have grown from the studies of fetal development in animals.
12. Describe some results that may follow the experimental interference with the growing embryo.
13. Explain how the concept of reflex behavior has been changed by a study of prenatal development.
14. What is the significance of the fact that the human infant is born while in a state of relative immaturity?
15. Describe the following behavior patterns of the neonate: (a) sucking; (b) grasping; (c) plantar response; (d) pupillary response; and (e) the Moro reflex.
16. What is known about the ability of the neonate to receive impressions through the following sense channels: (a) vision; (b) hearing; (c) smell; (d) taste; (e) temperature; (f) contact; (g) pain; (h) viscera; and (i) position?
17. What significance has the dependency of the neonate upon his potentialities for intelligent behavior?
18. Outline the differences that have been found in the activities of an ape as compared with a human infant.
19. What significance have these comparisons between an ape and a child?
20. How may fraternal twins be distinguished from identical twins?
21. Describe various methods that may be used in studying the responsiveness of twins to environmental situations.
22. Why is the method of co-twin control superior to other techniques?
23. What results have been found by comparing identical with fraternal twins?
24. What significant conclusion grew from the experimental studies with Johnny and Jimmy?

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Chapter IV

INTELLIGENCE

INTELLIGENCE is correctly attributable to a person in so far as he manifests behavior which we ordinarily characterize by such terms as: judiciousness, penetration, perceptual alertness, good memory, acumen, discernment, judgment, rationality, prudence, adaptability, and sagacity. *Intelligence is purely a descriptive* term and its application to an individual carries with it no implication as to the factors which contribute to the behavior upon which the description is based; it says nothing about the sources from which it may have arisen; and it implies nothing about its stability. That a descriptive term does not involve any implication of cause, essential components, or stability can be made clear by the use of a simple adjective such as clean. When it is said that a person is clean, it does not mean that he has a trait of cleanliness, that he derived his cleanliness from any particular source, that he has always been clean, or that he always will be clean.

When we attribute intelligence to a man, we are not asserting that it is something he possesses or that it has a power to make him act in a certain way. We can, nevertheless, proceed to hunt for ways of determining to what extent any individual is intelligent, to what extent individuals are consistent in being intelligent, the practical value to the individual of intelligence, and some of the factors that may contribute to the retention of intelligence. [16]

TESTS OF INTELLIGENCE

Attempts to measure intelligence have been made difficult because of the inability on the part of psychologists to delimit

the term. It has been variously defined as: (1) persistence, that is, the tendency to take and to maintain a definite direction; (2) adaptability to new situations and to new requirements; (3) the ability to criticize one's own acts; (4) the ability to learn easily and quickly; (5) the ability to utilize facts and activities already acquired; and (6) curiosity, that is, interest in, and desire to know about things. [11, 16]

General approaches to the measurement of intelligence. Two general approaches have been used: the analytical and the empirical.

1. *The analytical approach.* Before attempting to measure such a vague concept as intelligence, it would appear reasonable to attempt to define it more accurately or to tease out the component factors by some logical or statistical device. Having ascertained the components, one could devise tests to measure each; and the combination of these component measures should give a measure of the original concept. This is the reasoning behind the analytical method, and the logic certainly appears sound. In spite of this apparent simplicity, attempts to carry out the procedures suggested by such a logical analysis have not proved to be very successful.

2. *The empirical method.* The empirical approach to the problem grew from a practical need. Alfred Binet was appointed by the French Minister of Public Instruction to membership on a committee which was assigned the task of finding some means for determining which of those children who failed did so from stupidity and which ones failed because of laziness, lack of interest, or some other factor. [3]

With this problem to be solved, Binet, in collaboration with Simon, a physician, began to work from the basic fact that children increase in mental ability as they grow older in years. He made no assumption as to whether this growth was due to heredity factors, to physiological maturation, to educational stimulation, or to the serial ripening of new elements. He merely set out to discover tests which would be indicative of this growth in mental ability which was so clearly apparent as children grew older.

He proceeded as follows: (a) He gathered a large number of tasks ranging in difficulty from very easy to very hard.

(b) He gave these tests to a large number of children of all ages. (c) On the basis of the performance of the children on these tests he selected those items which differentiated between children of different age levels, and discarded those which had no differential significance. That is to say, if a test was answered as well by children of all ages from three years up to eighteen, it was discarded. If a test could be answered correctly by a large proportion of six-year-old children and only by a minority of five-year-old children, that test was regarded as having discriminative or diagnostic value. It was on this basis, and this alone, that Binet made his selection of tests. (d) He arranged his tests in groups corresponding to the chronological age of the youngest group of children who passed them. A test that could be passed by from 60 to 90 per cent of a given age group was regarded as a suitable test for that age, provided it was failed by a large percentage of younger children.

These same principles have been used in constructing many other mental tests. The tests most widely used in this country are the Stanford revision [14] of the Binet-Simon scale and the Kuhlmann revision [9] of the Binet-Simon scale. It is important to keep in mind the empirical process involved in the construction of these tests and the implications which arise from this method of construction. With such a method the results are purely relative. All that is known is that, when one individual passes such a test with a higher score than another person, he is better than the other. The extent of his superiority is not known, nor can any deduction be drawn as to why the difference exists.

Furthermore, when an individual is given a score on such a test, the only information given is that his score is the equivalent of the average score of children of a certain age level. Binet gave his scores in terms of mental age, and the Stanford and Kuhlmann revisions have followed the same method. Consequently, if a person is given a test and secures a mental age of six years, for example, all that is meant is that this person has obtained a score which is the equivalent to the average score of the group of six-year-old children on whom the test was standardized.

Sample intelligence tests. In the Stanford-Binet scale there are six tests for each year-level, except for some of the

younger years where six tests are given for each six-month intervals. A few samples of the items from the various scales as used in this country, one from each age level, will give some idea of the nature of the material used:

3-month level: will carry hand to mouth by a definite rather than by merely a random movement.

6-month level: will pick up a small test cube from the table.

9 month level: will give definite attention to scribbling demonstration.

1-year level: will imitate such a simple action as shaking a rattle or ringing a bell.

2-year level: will identify by pointing such toy objects as the following when asked to do so: a cat, a button, a thimble, a cup, an engine, or a spoon.

3-year level: will copy a circle.

4-year level: will answer such questions as: "Why do we have houses?" or "Why do we have books?"

5-year level: will copy a square.

6-year level: after watching the examiner string a chain of 7 beads on a shoestring using alternately square and round beads, he will make a string just like it, taking not more than two minutes to do so.

7-year level: will be able to point out similarities in answer to at least two of the following questions: "In what way are wood and coal alike?" "In what way are an apple and a peach alike?" "In what way are a ship and an automobile alike?" "In what way are iron and silver alike?"

8-year level: will repeat verbatim a sentence of about fourteen words, as follows: "Fred asked his father to take him to see the clowns in the circus."

9-year level: will point out the absurdities in three out of four statements read to him, one example of which is: "Bill Jones's feet are so big that he has to pull his trousers on over his head."

10-year level: will name at least 28 separate disconnected words in one minute.

11-year level: will be able to tell the significance of such a problem as the following: "Donald went walking in the woods. He saw a pretty little animal that he tried to take home for a pet. It got away from him, but when he got home, his family immediately burned all his clothes. Why?"

12-year level: will be able to say backwards numbers of five digits after having them read to him, such as: 8–1–3–7–2.

13-year level: will be able to unscramble a disarranged sentence, such as: FOR THE STARTED AN WE COUNTRY EARLY AT HOUR.

14-year level: will be able to answer questions which concern orientation, such as: "Suppose you are going west, then turn to your right, then turn left; which direction are you going now?"

average adult level: will be able to indicate differences between such abstract words as: laziness and idleness.

superior adult level: will repeat correctly the thought of a passage read to him, such as the following: "Many opinions have been given on the value of life. Some call it good, others call it bad. It would be nearer correct to say that it is mediocre, for on the one hand our happiness is never as great as we should like, and on the other hand our misfortunes are never as great as our enemies would wish for us. It is this mediocrity of life which prevents it from being radically unjust."

Computing the mental age. In giving an age scale, such as the Binet-Simon test, the examinee is given tests to a year-level low enough that he passes all the tests in that year, and to a year-level high enough that he fails all the tests in that year. All the tests in the range between these two year-levels are given and the mental age computed by scoring the tests in this range. The final score is an average mental age, and is abbreviated MA. The process will be clearer from the following illustration. Suppose a child passes all the tests at year III, fails all the tests at year VI, and makes the credit shown below on the intermediate levels:

		Years	*Months*
Year III,	all passed. Basal year level....	3	
Year III,	and 6 months (written III–6), 5 tests passed, credit 1 month each		5
Year IV,	3 tests passed, credit 1 month each		3
Year IV–6,	3 tests passed, credit 1 month each		3
Year V,	1 test passed, credit 2 months		2
Year VI,	all tests failed, no credit.....		0
	Total credit.....	3	13

Mental age 4 years, 1 month, written 4–1.

The fact that the score obtained in this manner is expressed in terms of mental age should not be permitted to mislead us into assigning it some unusual significance. It is merely a score made on a test and is no different in nature than would be the case if expressed in terms of percentage, the letters *A, B, C,* or *D,* some arbitrary number, or the like. Let us repeat: What a mental age score tells us is that the individual being tested made a score equivalent to the average score of children of that age on whom the test was standardized. In the case of our illustration the child tested made a score equivalent to that of the average child of four years one month. A striking advantage of this method of scoring is that it makes clear at once the meaning of the score in a way that a score as 75 or B would not do. On the other hand, the use of a mental age method of scoring should not lead to any unwarranted assumptions that mental age has some peculiar, subtle, or symbolic significance. Mental age is a score on a test and it is nothing more than that.

The intelligence quotient. The brightness or dullness of an individual cannot be determined from the MA alone. An individual may have a MA of nine years, for example, and still be a genius, bright, dull, or feeble-minded. A four-year child with a MA of nine years would be an extremely bright individual; whereas an eighteen-year-old person with a MA of nine years would be very inferior. In order to give due weight to the chronological age (abbreviated CA) of the individual tested, it has been found convenient to use the ratio of the MA score divided by the CA. This ratio is called intelligence quotient and is abbreviated IQ. Taking the illustrations above: The individual with the MA of nine years and the CA of four years would have an IQ of 225. (The actual ratio would be 2.25. In order to eliminate decimals, the ratio is multiplied by 100 and the IQ expressed as a whole number.) With the same MA an individual with a CA of nine would have an IQ of 100. With a CA of 15, a person with a MA of nine would have an IQ of 60.

Performance tests. A casual survey of the sampling of items from the Binet test will reveal that it depends to a considerable degree upon language ability. Such a test imposes an undue handicap upon illiterate, foreign, blind, or deaf persons.

To provide tools for testing such individuals, psychologists have developed a number of tests which minimize the use of language, or which provide a means of testing persons with sensory handicaps. These tests have been given the general name of performance tests, although the degree to which language has been eliminated is not the same for all of them. [1, 5]

The apparatus used in a representative performance test (the Pintner-Paterson Scale of Performance Tests) is shown in

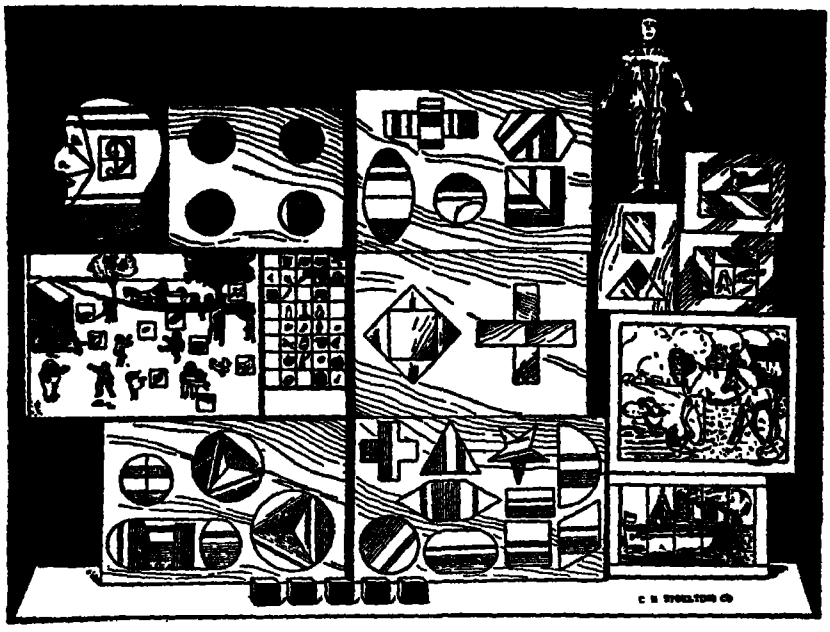


FIG. 13.—Apparatus used in the Pintner-Paterson Scale of Performance Tests.

Fig. 13. In the upper left corner is a feature profile test. The problem is to fit the face and ear pieces in place when they are set in mixed order before the child to be tested. In the upper right corner is a manikin test. The problem is to fit the pieces into the form of a manikin when the pieces have been presented in disarranged order. Eight of the tests are varieties of form boards. The problem in these is to fit the pieces into their proper grooves when the boards are presented with the blocks removed and disarranged. Three of the tests are picture completion tests.

In one the problem is to select from forty square blocks the ones containing the proper picture to fit into the openings on a picture of a schoolyard scene. The second is to select blocks of varying shape and form to fit into a picture of a mare and foal. The third is the picture of a ship cut into five rectangular pieces which must be fitted together properly. The five cubes at the bottom of Fig. 13 are used as follows: Four cubes are placed before the subject and are tapped by the examiner by means of the fifth cube in a given order. The subject's task is to observe and repeat the experimenter's movements. A fifteenth test in this particular performance scale is the digit-symbol test illustrated in Fig. 14.

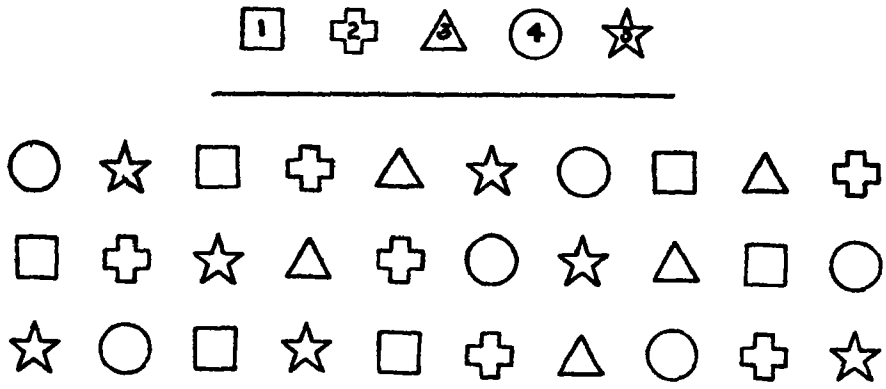


FIG. 14.—Section of the Woodworth-Wells digit-symbol test. The top five figures are the keys, and subject is required to place the correct digit in each symbol in the test. Score is in terms of number of correct answers recorded in a specified time.

This scale is merely representative. A number of other performance tests have been standardized and are in common use today. [6, 10]

Group tests. The development of group tests was stimulated by the need, during the World War, for a means of securing a quick rating of the ability of drafted men who were brought into the army. Since that time a number of such tests have been developed and widely used. [18]

The Army Alpha test. The Army Alpha test contained eight subjects, some samples of which are as follows:

Test 1

Directions: Cross out the letter after K, and also underline the second letter before E.

A B C D E F G H I J K L M N O P

Test 2

Directions: Get the answers to these questions as quickly as you can.

A rectangular bin holds 500 cubic feet of lime. If the bin is 10 feet long and 5 feet deep, how wide is it?

Test 3

Directions: This is a test of common sense. Three answers are given to each question. Make a cross in the square before the best answer to each question.

A train is harder to stop than an automobile because

- ☐ it is longer
- ☐ it is heavier
- ☐ the brakes are not so good

Test 4

Directions: If the two words of a pair mean the same or nearly the same, draw a line under **same**. If they mean the opposite or nearly the opposite, draw a line under **opposite**.

deride—ridicule .....same—opposite
depressed—elated .....same—opposite

Test 5

Directions: Below are mixed-up sentences. Think what each would say if the words were straightened out. Then, if what it would say is true, draw a line under the word **true**; if what it would say is false, draw a line under the word **false**.

made cloth wool cotton and is from.....true—false
never man the show the deeds.....true—false

Test 6

Directions: On the two dotted lines write the two numbers that should come next.

10	15	20	25	30	35	....	....
1	4	9	16	25	36	....	....

Test 7

Directions: The first two words are related to each other in some way. Underline the word in heavy type that is related to the third word in the same way that the second word is related to the first.

blow—anger : : caress—woman kiss child love

Test 8

Directions: Draw a line under the one of the four last words which makes the truest sentence.

The silo is used in **fishing farming hunting athletics**
Arson is a term used in **medicine law theology pedagogy**

From the nature of these tests, it is apparent that their solution depends in large part on language ability.

The Army Beta test. At first, in the army program, it was planned to give performance tests to all those who, because of language handicap, could not take the Army Alpha. The number of such individuals proved to be so great that the procedure was impossible, because the performance tests all are individual examinations and each person tested requires the full time of an examiner for a period of at least thirty minutes. Various compromises were tried, until a group test was developed which required a minimum of language. This test was called the Army Beta examination. Sample of this test are given in Fig. 15.

The directions for the Beta examination were given to a group by gestures and pantomime, using a large demonstration board with samples of the test and an assistant who performed the test before the group.

Adult mental age. Some of the tests used by psychologists have been scored in terms of MA and others have used various other means for indicating relative proficiency. The practice has grown of translating scores to MA regardless of the way in which the actual test is scored. This practice brings up an issue which should be clear to anyone using mental tests with adult individuals.

It will be remembered that Binet standardized his intelligence scale by selecting tests which differentiated between groups of

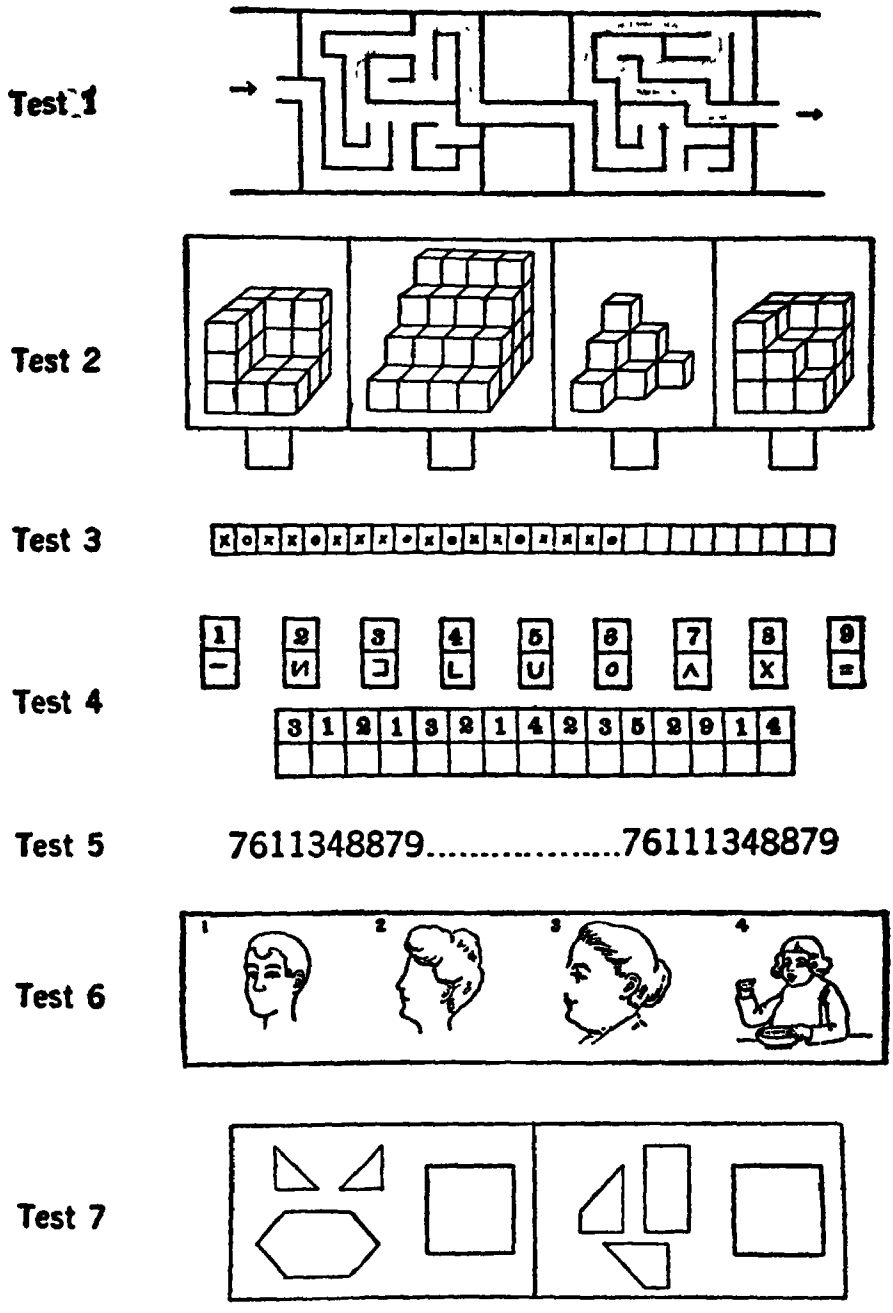


FIG. 15.—Samples of the seven tests included in the Army Beta test for foreigners and illiterates.

children of different chronological ages. As children reach maturity and grow on into adult life, the differences in intelligence between chronological ages becomes less clear-cut and less measurable. Some persons have thought that this fact indicates that intelligence ceases to grow after about middle-teen age. A better interpretation would be that as individuals reach and pass maturity they cease to develop mental ability in a uniform and measurable manner but, instead, spread out in such diverse directions that it is practically impossible to find any test which will correlate with this spread of abilities. In other words, no one has been able to differentiate in any understandable fashion between the intelligence of a twenty-year-old group and a thirty-year-old group, or between a twenty-five-year-old group and a fifty-year-old group. There is no consistent relationship between intelligence and chronological age after about fifteen years of age. This does not mean that intelligence ceases to grow, but it does mean that it ceases to grow in such a straight and consistent fashion that it can be measured by a simple battery of tests.

However, adults are frequently given mental tests and their scores recorded in terms of mental age. When this is done, it should be kept in mind that the statement that a person has a certain mental age means merely that he did a performance equivalent to the performance of an average child of that chronological age. For example, if a man of thirty has a mental age of ten years, it means that he did the same grade of work on the mental test that is done by the average ten-year-old child. Certainly, his mentality is not equivalent to that of the ten-year-old child, for the child is likely to continue to develop, whereas the thirty-year-old man is not so likely to make further progress in mental development.

Adult IQ's. Neither can a mental age score for an adult be translated into an IQ in the same manner that the conversion is made for a child. Nevertheless, there are cases of adult individuals whose ability to pass intelligence tests is poorer than that of a child of fifteen and it is often desirable to make comparisons of individual differences in adult ability which will be significant in relation to the abilities of children. To accomplish this a compromise has been effected for computing IQ's for adults. If an individual is older than fifteen, his IQ is found by dividing his

MA by fifteen. If the individual is between thirteen and fifteen, an adjustment is made in computing his IQ to allow for the approach to maturity. It is only when his CA is thirteen or less that his IQ is found by the simple process of dividing the MA by the CA.

FACTORS INVOLVED IN INTELLIGENCE TESTS

It was pointed out at the beginning of this chapter that when psychologists attempted to devise intelligence tests by a logical analysis of the factors involved in intelligence, they did not achieve any very striking success. They have been more fortunate in the use of empirical methods. On the other hand, after having standardized tests by the empirical method, they are still confronted with the problem of stating what is being measured with the tests. [2]

Kinds of material used in tests. If one makes an examination of the kinds of materials used in intelligence tests, it is clear that these are so varied that they cannot be reduced to any simple category. A casual inspection will show that the Stanford-Binet intelligence test requires the following kinds of reactions from the person tested: (a) language ability, (b) motor skill, (c) visual and auditory discrimination, (d) comprehension, (e) memory, (f) ability to make comparisons, (g) ability to abstract, (h) problem solving, (i) appreciation of absurdities, (k) ability to copy, (l) ability to define words, (m) orientation, (n) arithmetic ability, and (o) reasoning ability.

Statistical analysis of intelligence tests. Much work has been done in an effort to analyze by the statistical method of factor analysis the components of batteries of intelligence tests. The results are not in agreement. One group of investigators has contended that they have evidence for a common factor, which they call a g factor, and which is supposed to play a part in a great number of intelligence tests. In addition to this common, or g, factor, they find other specific factors (s factors) which work with the g factor in diverse ways. [11]

After analyzing a great number of tests by a different factor analysis method, another investigator concludes that the tests he studied contain at least nine group factors which he characterizes as follows: [17]

1. S—*A spatial factor.* The spatial factor is characterized by facility in processes involving a high degree of spatial and visual imagery.

2. P—*A perceptual factor.* The perceptual factor is characterized by facility in perceiving details which are embedded in irrelevant material.

3. N—*A number factor.* The number factor is characterized by facility in numerical calculation.

4. V—*A verbal relations factor.* The verbal relations factor is characterized by facility in the use of verbal ideas and verbal meanings.

5. W—*A word factor.* The word factor is characterized by facility in dealing with words, that is, with fluency.

6. M—*A memory factor.* The memory factor is characterized by facility in recognition and recall.

7. I—*An induction factor.* The induction factor is characterized by facility in finding a rule or principle.

8. R—*A resistance factor.* The resistance factor is characterized by the facility to complete successfully a task that involves some form of restriction or obstacle in the path of solution.

9. D—*A deduction factor.* The deduction factor is characterized by facility in finding a rule and then applying it to the given examples involved in the test.

The teasing out of these nine factors by the factor analysis method is not meant to imply that no other factors are involved in an intelligent response. It merely indicates that these factors are present in the tests constituting the battery used in making the analysis. Since the tests used were those which have demonstrated merit as measures of intelligence, the factors outlined above certainly are important, even though others may be discovered by subsequent research.

In the attempt to analyze intelligence tests into their basic components, it should be clearly recognized that it is the tests that are being analyzed and not any trait of intelligence in the individual. The tests were selected in the first place by the empirical method, that is, because they happened to work. The fact that they were found valuable does not mean that they comprise all the qualities involved in successful adjustment by an individual. It is quite possible that qualities or factors are involved in indi-

vidual adjustment which the tests do not touch. Hence, a factor analysis of a battery of tests cannot be considered to represent an adequate analysis of any personal trait. We still have unanswered the question of just what components are involved in adjusting to intellectual problems and what proportion of each is needed in any specific problem or test situation. Our intelligence tests give some fairly good clues as to what to expect from individuals who are confronted with problems, however, even if they do not tell us why a person fails or succeeds.

THE SIGNIFICANCE OF A CORRELATION

Many physical measurements are made by the direct application of a measuring instrument to the object to be measured. For example, the length of a board may be measured by placing a linear scale upon it and observing how many times a given unit, such as an inch, must be used to cover the length of the board. In psychology such direct measurements are impossible and it has been found valuable to utilize indirect method of measurement. The value of any indirect method depends upon the degree of correspondence between the scale which is used and the object or event which is measured. The degree of such a relationship is expressed as a coefficient of correlation. While the beginning student may find it advisable to postpone his attempt to compute such coefficients, he should understand their significance. [4]

Relationships expressed by coefficients of correlation. Although relationships may vary in complexity and in degree of intimacy, it may be well to confine our attention to so-called "linear" relationships. A linear correlation may be illustrated by the relationship between the diameter of a circle and its circumference. This relationship may be expressed by saying that the circumference always equals 3.14159 times its diameter. It may be indicated by saying that the correlation between the diameter of a circle and its circumference is perfect and positive, or that the coefficient of correlation between the two is 1.00.

A perfect negative correlation may be illustrated by the relationship existing between the weight of a board and the number of holes bored through it (assuming that the board is of uniform thickness and weight and that the holes are of the same size). If the board originally weighed one pound and each hole takes

out one ounce of material, the relationship at various stages of the boring would be as follows: 0 holes—16 ounces; 1 hole—15 ounces; 2 holes—14 ounces; 3 holes—13 ounces; 4 holes—12 ounces; and so on, until all the available space for holes becomes exhausted. Such a relationship may be expressed by saying the coefficient of correlation is —1.00.

An absence of relationship may be illustrated by correlating the order of drawing of numbers enclosed in uniform capsules from a bowl in which they had been thoroughly mixed. This absence of any relationship may be expressed by saying the coefficient of correlation is .00.

In other words, coefficients of correlation may range all the way from a perfect positive correlation (1.00), through no correlation (.00), to a perfect negative correlation (—1.00).

The interpretation of coefficients of correlation. A coefficient of correlation may be used to indicate the degree of relationship between a test and the characteristic to be measured. Our task is not complete, however, when we have expressed such a relationship in the form of an exact number. We must know how to use the information which the coefficient of correlation gives us.

We can illustrate the problem by referring again to the perfect relationship between the diameter of a circle and its circumference. If we say the coefficient of correlation between the circumference of a circle and its diameter is 1.00, we mean that we can tell exactly what the circumference will be by measuring its diameter. If a correlation is perfect, we can predict what one of the factors will be by measuring the other.

What would be the meaning of such a statement as: The coefficient of correlation between the thickness of a bundle of papers and the number of sheets in the bundle is .98? Or, what is the significance of such a statement as: The correlation between an intelligence test and success in high school is .60? These two statements, taken together, would certainly mean that we can predict the number of sheets in a package by measuring the thickness of the package with greater accuracy than we can predict success in high school by intelligence test scores. Nevertheless, the actual difference in the accuracy of prediction is not directly indicated by the difference in the correlation coefficients. The

relationship of the coefficient of correlation with prediction efficiency (called the coefficient of "forecasting efficiency" or the coefficient of dependability) is as follows:

When a correlation is	1.00;	prediction is 100	per cent perfect.
	.98;	80	
	.95;	69	
	.90;	56	
	.86;	50	
	.80;	40	
	.70;	29	
	.60;	20	
	.50;	13	
	.40;	8	
	.30;	5	
	.20;	2	
	.10;	0.5	
	.00;	0	

THE PREDICTIVE VALUE OF INTELLIGENCE TESTS

The purpose of giving an intelligence test is not so much to determine what a person will do on that test as it is to use the test performance as a means for predicting what the individual will do in other situations. Will he succeed in school, in a certain profession, in meeting an emergency, in solving a problem of management, or the like? This leads to the question as to the degree of accuracy with which we can predict intelligent behavior from scores on intelligence tests.

Time intervals. When a child is tested and retested after a very short interval of time, it is rather common for the two tests to vary by as much as 10 points in IQ; the majority of cases, however, do not deviate by more than 5 points. As the length of time between tests increases, the probability of variation between test and retest increases. There will be a tendency for those who tested high on the first test to decline on the second test after an appreciable interval of time, and a tendency for those who tested low to test higher on the final test than on the first.

When the retest is at intervals from 1 to 24 months, the correlation between the two tests is about .88. This means that the efficiency of the first test as a means of predicting what the

individual will do on the second test is about 53 per cent better than chance. When the retest interval is from 60 to 145 months, the correlation between the two drops to .60; that is, the predictive efficiency is only about 20 per cent better than chance.

The above facts hold when the surrounding conditions, which might influence test ratings, are uniform. In individual cases it has been found that IQ may change by as much as 50 points in test-retest situations. In order to reduce the degree of error, tests should be given only by those well trained in testing procedure. The tests have been standardized and the scoring methods based on the assumption that they will be given in a precise manner by one who knows how to evaluate replies. A slight change in the giving of instructions may seem trivial to a novice, but such a deviation may have an important effect upon the way the testee responds. The responses that may be made are quite varied and one must be skilled and have extensive experience to know exactly when to give credit for a reply and when to refuse credit.

Influences which may affect IQ. The probable truth is that the IQ is relatively constant just so long as the relation between the individual and his total environment remains relatively the same, but that the IQ undergoes change with marked shifts in the total situation. There have been attempts to determine which factors are most influential in producing such changes. What these factors are cannot be stated with any clearness, but some suggestive findings will be presented.

Age at which test is given. The predictive value of an intelligence test varies with the age of the individual tested. It is relatively impossible to give tests which have any significant value as instruments of long-time prediction to an infant who is less than four months of age. It is really not until the individual is about four years old that predictions can be made over a span of as long as a year with any hope of accuracy.

Effect of nutrition. While studies of general nutrition have not given striking results, it has been found that where a marked change in diet was instituted with undernourished children, some improvement was shown with improved nutrition. On the other hand, it is probable that specific elements in the diet are more important than general nutrition. It has been found, for example, that vitamin B_1 deficiency has a strikingly deleterious

effect on maze learning in rats. It has been suggested, although not demonstrated, that the nutrition of the fetus and young infant may have an influence on the manifestation of intelligence in later years.

Endocrine hormones. Several studies indicate that IQ may be influenced by the hormones from such endocrine glands as the pituitary and thyroid. In some cases of thyroid deficiency, for example, where thyroid extract has been administered, there has been found a striking improvement in IQ, as well as in bodily structure. These changes with hormone therapy seem to be most effective with very young children and to decrease with the age of the patient. The activities of these glands will be discussed in greater detail in the next chapter.

Degenerative changes. In certain diseased conditions there is actual destruction of brain tissue. With such degenerative changes there is certainly a lowering of IQ. A loss of intelligence may be found in cases of deterioration with old age.

Changes in social environment. A number of studies have been published in recent years which show that when individuals spend a period of years in a sordid and nonstimulating environment, their IQ becomes lower, whereas the IQ improves when they are reared in a stimulating environment. For example, five-year-old children in certain nonstimulating communities had an average IQ of around 90, whereas fourteen- and fifteen-year-old children in the same communities had an average IQ of around 60.

On the other hand, children who were placed in stimulating foster homes and in stimulating school environments when very young manifested an improving IQ with the passage of time.

Constancy of the IQ. There has been much animosity shown between those who advocate the constancy of the IQ and those who contend that it may be modified by certain conditions. Taking all the experimental, statistical, and clinical findings into account, the following conclusions seem to be warranted:

1. The IQ may be lowered by degenerative changes in the nervous system, by injury to the nervous system by mechanical means, by deprivation of essential food elements or essential hormones, by injury from poisons, and by deterioration with old age. No one will deny such changes in the IQ.

2. The removal of injurious agents may lead to improvement of the IQ. If the removal of a deleterious agent occurs after maturity, the assumption would be that there would be a stopping of degeneration. This has been experimentally demonstrated in clinical treatment of patients. In such cases, the IQ does not improve but it ceases to deteriorate.

If the removal of such a harmful agent occurs in infancy or early childhood, what would be the logical effect? The deteriorating process would stop and at the same time it would be reasonable to suppose that the individual would begin to profit more from environmental stimulation and educational opportunities. Hence, improvement of IQ by removal of obnoxious influences is more striking, the younger the child. This seems logical and seems to explain the improvement found in glandular therapy and nutritional studies.

3. If large changes in IQ can be produced by major influences, lesser influences may produce minor changes. To use an analogy, the finding that Niagara Falls is being subjected to the slow influences of erosion does not mean that the whole Falls is going to cave in shortly. The discovery that the IQ is affected by certain educational and social situations does not mean that in six months of exposure to such situations an idiot can be made into a genius, or a genius into an idiot. Conversely, because these changes are not violent is no reason for arguing that they do not exist.

In short, it seems perfectly clear that the IQ can be changed, and that the degree of change varies strikingly with the nature of the factors which bear upon it.

RESULTS OF TESTING INTELLIGENCE

Intelligence tests have been widely used in various ways. They have been used to study differences between various groups of individuals, to study individual differences for the purposes of educational or vocational guidance, for the selection of employees, and for the study of feeble-minded and superior individuals.

Distribution of IQ's in children. When the Stanford-Binet was given to a group of 2,904 children ranging in CA from 2 to 18 years, the IQ's distributed themselves in a close approximation to the normal distribution curve, as shown in Fig. 16.

The normal distribution curve, or the probability curve as it is sometimes called, is the curve secured when a group of individuals are measured in some trait or quality which is determined by a large number of factors operating in chance fashion. Many biological traits, such as height and weight, distribute themselves in a manner which has some resemblance to the probability curve. The shape of the curve in Fig. 16 suggests that intelligence, as measured by the Stanford-Binet test, is determined by a large

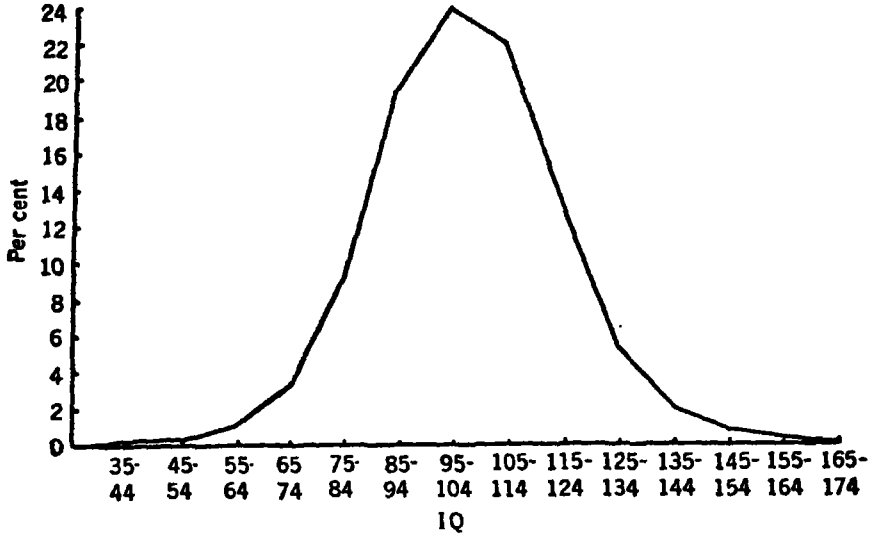


FIG. 16.—Distribution of IQ's of 2,904 children ranging from two to eighteen years of age.

(From Lewis M. Terman and Maud A. Merrill, *Measuring Intelligence*.. Boston: Houghton Mifflin Co., 1937.)

number of factors operating in chance fashion. The conclusion which follows from this may be stated as follows: Intelligence is not a unitary quality which one either possesses or fails to possess, but a complex quality which depends upon the operation of a large number of components. [14]

Intelligence tests as educational guides. Probably the greatest value of intelligence tests is in the accomplishment of the purpose which Binet had in mind when he began his experimentation on an intelligence test scale; namely, the determination of the causes why children failed to progress in their schoolwork. [7]

The relationship between IQ and ability to succeed in school is rather close during the primary and secondary grades, especially when each child is permitted to progress at his own rate and in his own way. The relationship between intelligence test scores and success in college is not so striking. A number of studies designed to discover the best means for predicting college success have shown that the best single indicator of later college grades is the first-semester or first-quarter college grades. The next best index is high school grades, and the third best is a content examination of one sort or another. In other words, intelligence tests indicate whether a person is likely to succeed in his earlier educational career, but as he gets to the college level, the best indicators are samples of the sort of thing he must do in college rather than intelligence tests.

The customary use to which tests are put in the study of individual cases is to give the intelligence test and to check the test scores with the actual progress that the student is making. If he is doing as well as the test scores indicate that he can do, little or nothing is done. On the other hand, if the test scores indicate that he could do better work than he is doing, an attempt is made to find influences other than intelligence which contribute to poor schoolwork.

In addition, it may be possible to analyze the results of test performance and to discover the particular factor that is contributing to the failure of a particular student. For example, if the tests in which the student made his lowest scores are primarily concerned with the verbal factor, this information may be used as a guide for further educational guidance. The student may either be given extra training in the factor in which he is deficient, or he may be guided into fields where that factor does not play such an important part.

Vocational guidance. Although vocational guidance specialists have found that the interests of the individual are of primary importance in indicating the probable success of an individual in a specific vocation, it is also true that the intelligence of a person has some vocational significance. [8] When men in different vocations have been given intelligence tests, it has been found that the averages of various vocational groups differ from each other.

Some typical differences are shown in Table II.

TABLE II

AVERAGE SCORES ON ARMY ALPHA TEST MADE BY MEN IN DIFFERENT VOCATIONAL GROUPS

Group	Low quartile	Average	High quartile
College Students	111	150	178
Civil Engineers	99	117	143
Bookkeepers	77	101	127
Telegraphers	61	85	110
Telephone Operators	52	70	100
Carpenters	40	60	84
Truck Drivers	37	58	88
Barbers	37	58	83
Farmers	30	48	73
Laborers	28	47	68

The high and low quartiles are given for each group. The table is read as follows: The average score for college students was 150 with 50% falling between the scores 111 and 178; the average score for civil engineers was 117 with 50% falling between the scores 99 and 143; etc. The highest possible score on the test is 212.

Other studies have shown that men with low intelligence, when employed on jobs which require a higher average intelligence than they possess, tend to leave those jobs. In other words, the job itself tends to eliminate the unfit just as school requirements tend to eliminate those incapable of doing scholastic work. To hire men indiscriminately, however, and to permit them to stay on jobs until they manifest their incompetence is an inefficient procedure—unsatisfactory for the employee and costly for the employer.

It has been found expedient to determine the minimum intelligence requirements for a given job, to give intelligence tests to all applicants, and then to employ only those who are able to demonstrate that they have more than the minimum. Such a procedure may help the employer to eliminate those who are unfit for the jobs he has to offer, and may save some men from the disappointment which would result from failure on the job; but it does not contribute much to the guidance of the individual who would like to know for what occupation he is best fitted. Taking

a broad view, it would seem that individual vocational guidance is not helped much by the use of intelligence tests. If an individual rates very high, he may be directed toward some professional work; if he makes a very low score, he may be directed toward unskilled occupations. The specific occupation, on the other hand, cannot be selected by general intelligence tests. Some progress has been made by the standardization and administration of special aptitude tests, but these are still in the experimental stage and are not sure criteria for vocational guidance. The conclusion seems to be that the employer can get more help in selecting employees by the use of tests than can the individual who seeks vocational guidance.

Feeble-mindedness. One of the most significant values that has resulted from intelligence tests has been a more skillful handling of the problem of feeble-mindedness. Long before psychologists had devised tests to measure intelligence, it was recognized that there were extreme variations of intelligence, ranging from the lowest degree of feeble-mindedness to the cleverest genius.

Before the development of tests the different grades of feeble-mindedness were defined in terms of the degree to which they could adjust to the social and economic order. They were classified and defined as follows:

1. Idiots were those persons who were mentally defective to such a degree that they were unable to guard themselves against common physical dangers.

2. Imbeciles were those persons who were mentally defective to such a degree that they were incapable of managing themselves or their affairs with ordinary prudence.

3. Feeble-minded persons (corresponding to the *moron* group as defined by later writers) were those persons who were mentally defective to such a degree that they needed care, supervision, and control for their own protection or for the protection of others.

The main reason why individuals had to be classified on the basis of the degree of success in social and economic adjustments which they manifested was that there was no way of measuring their ability. They were necessarily exposed to life and their intelligence judged by the way in which they adjusted. Now, we utilize tests to derive an index of their ability, and then direct

them so that they are able to adjust to society. In other words, if we can determine by means of a test that a person is an imbecile, he can be placed in a carefully supervised job and will adjust to it perfectly. He need not be thrown into a situation which proves too much for him in order to decide the level of his intelligence.

Consequently, the modern psychologist defines the various degrees of intelligence purely in terms of ability as manifested on a standard test. In terms of IQ the different grades of intelligence have been delimited as shown in Table III.

TABLE III

IQ RANGES OF DIFFERENT GRADES OF INTELLIGENCE

	IQ range
Idiot	0 to 25
Imbecile	25 to 50
Moron	50 to 70
Borderline	70 to 80
Normal dull	80 to 90
Normal	90 to 110
Superior	110 to 120
Very superior	120 to 140
Near genius	140 and above

Since there are all levels of occupations in life, the important consideration is to see to it that each individual is placed in some situation which is not too much out of line with his ability. When a feeble-minded person fails, we no longer blame him for not being able to measure up to the responsibilities placed upon him. The blame lies on those who were responsible for such misplacement. The remedy, of course, is to see to it that he is placed in a situation where he can adjust.

Superior intelligence. A very high IQ is no more a guarantee of success than a low IQ is a certain index of failure or delinquency. The high relationship between intelligence test scores and chronological age stops at about fifteen years. That is, there is no standard growth in a straight line after adolescence. Nevertheless, it is apparent that some men make striking progress through many years and up to old age. The puzzling part of this to psychologists is that they have not been able to measure those qualities which make for success in mature life. It would seem

that abilities spread out over a wide area and there are many types of wisdom as well as many types of folly. Now, it is true that many bright men have had high IQ's in childhood. It is also true that many other successful men have not had such high IQ's. It might be safe to say that a man who has a high degree of superiority in all the nine factors which have been shown to operate in intelligence tests has a better chance of succeeding than one who has an inferior rating in all of them. It is probably true also that the specialized work of adult life may call for high proficiency in some one type of activity which may not play too big a part in an individual's general test rating, but which he finds extremely important in later life.

The interest of psychologists is now becoming centered in those features of adaptability which play a role in adjustment which are not primarily reflected in general intelligence test scores. Some of these have been called personality traits or personality factors. We shall investigate some of these in the last chapter.

QUESTIONS FOR REVIEW

1. What are some of the traits which the ordinary conception of intelligence involves?
2. What limitations are inherent in a descriptive term?
3. State six different definitions of intelligence which have been proposed by psychologists.
4. What are two general approaches that have been used to the problem of measuring intelligence? Describe each.
5. Outline the four steps taken by Binet in devising and standardizing his intelligence scale.
6. What limitations should be placed upon any conclusions derived from testing with a scale which has been standardized by the empirical method?
7. Give a brief description of the general structure of the Binet scale.
8. What is meant by mental age?
9. How is the mental age computed?
10. What is the intelligence quotient?
11. Why were performance tests developed?
12. Give a general description of some performance tests.
13. Describe two group tests.
14. With what reservations should mental ages be applied to adults.

15. What is the difference in the formula for computing the IQ between a child and an adult?
16. What are some of the processes involved in the Stanford-Binet test?
17. Outline the nine factors discovered by the factor analysis method in intelligence tests.
18. What effect does time elapsed between tests have upon the predictive value of a test?
19. What can be said about the predictive value of a test given to a four-month-old infant?
20. State some factors which may affect IQ.
21. What general conclusions as to the constancy of the IQ can be drawn?
22. What evidence is there that IQ is determined by a large number of factors operating in chance fashion?
23. How effective are intelligence tests in predicting scholastic success in the grades?
24. Name in order the three best indices of college success.
25. What conclusion can be drawn as to the value of an intelligence test as a means for giving vocational guidance?
26. Give the socioeconomic definitions for: an idiot, an imbecile, and a moron.
27. Define the different grades of intelligence in terms of IQ.
28. Is a high IQ in childhood a guarantee of success in later life? Why?

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Chapter V

SPRINGS OF ACTION

WHY do people act as they do? Why is one man energetic while another is lazy? Why can one man be depended upon while another is completely untrustworthy? Why will a man spend years in an attempt to accumulate property? Why do some men kill their fellows? Why do some persons gamble? Why do some become addicted to the use of alcohol or morphine? Why are some aggressive and others submissive? The reasons for any act are always complex and are usually hidden from outside observers as well as from the one who is driven to act. We usually understand our own motives as vaguely as we understand the reasons for the behavior of others. Too often the reasons we assign for our own are incorrect or, at best, but partial explanations.

Elusive as human motives are, they provide the key to an understanding of conduct. Just as the solution of a mystery story depends upon a correct analysis of the motives of all persons concerned, so the interpretation of any simple act of human behavior depends upon the true evaluation of each factor influencing the individual in that act.

Classification of motives. Motives have been classified in various ways: (a) According to whether they are inborn or acquired; (b) according to the degree of dependability they manifest, that is, the degree to which they can be counted upon to function consistently; (c) according to whether they are immediate or delayed in their effect; (d) according to whether they stimulate a person to increased activity or tend to thwart activity already in progress (rewards and punishments); or (e) whether they have their origin without the individual or are due to some internal set or attitude.

Some persons emphasize the condition or state of an individual which makes him ready to respond in a certain manner, whereas others think of a motive as a sort of trigger that sets him off. It should be clear that the individual needs to be set to respond, but he also needs the spark or immediate incitement to set him off. Before a gun is fired, it must be loaded; but the trigger must be pulled before the powder can do its work. It would be better to think of our problem in terms of a group of factors working together rather than to attempt to isolate one element as *the* essential factor.

Definitions. Perhaps adherence to the following usage of these terms would help us to avoid confusion: Let "motive" be a general term to indicate any dynamic element in the whole setting. Let "drive" refer to the readiness of the individual to perform. Let "incentive" refer to the stimulus which sets off the energy already stored in the individual. Let "goal" refer to the thing or external situation which, when reached or secured, is followed by a reduction or complete cessation of goal-seeking activity. For example, if a man were running a foot race, the physiological processes which enable him to run would be drives; incentives could be such factors as competitors and the supporters who watch the race; the tape at the end of the race, the cup to be awarded to the winner, or the good will of some friend could be the goal toward which the runner was aiming.

Two other words need to be defined because of their almost universal use. The term "want" (or its synonyms: wish, desire, appetite, liking, craving, longing, etc.) indicates the tendency in a person to secure goals which may or may not be good for him. "Need" (or its synonyms: requirement, lack, shortcoming, insufficiency, etc.) indicates a judgment passed, whether by a person himself or by others, as to what would be good or beneficial for him. A person may or may not desire what he needs. He may or may not need what he desires. If a want or a need has a driving force that impels an individual to act in a certain manner, what the psychologist wants to know is why and how that force acts. It is an insufficient explanation merely to say that he acted thus and so because he needed something or because he wanted something.

A DYNAMIC VIEW OF MOTIVATION

Motives are active agents exerting an influence upon an organism which is already in active operation. The resultant must always be considered as due to the interaction of a number of dynamic components. An almost universal misconception needs to be corrected before we can even begin to understand the motivating factors in human life. Whether stated or not, most of us act as though we believed that man is naturally an inert mass who needs to be prodded, pushed, or stimulated in some manner to get him going. We lose sight of the fact that, before a man is stimulated, he is already living; and living is activity.

The most powerful of all drives is the drive to live. It takes precedence over any motivating factor that can be applied from the outside. Living is not a simple process. It comprises a group of processes within the organism (such as the processes of metabolism, growth, reproduction, food storage, and excretion) which, by their co-ordinated operation, serve to maintain internal harmony in the individual. Break down the intricate balance between these processes and the individual dies. Hence, vital functions take precedence over everything else and nothing must be permitted to stop them or to change them too radically. This being so, the effect of a stimulus will depend upon what is going on within the individual at the moment, as well as upon the character of the stimulus. Food to a half-starved man is different from the same food given to a satiated one.

Relation between simple drives and complex motives. Simple action patterns are important driving forces which are often ignored as factors in human behavior. These may be patterns which were established before birth or at any stage during the life of the individual. However, these simple patterns never operate in isolation and it would be a mistake to attempt to explain a complicated act by reference to them alone.

As we found in the Chapter III, careful observation of a newborn infant will reveal certain reactions which are fairly consistent, such as: the contraction of the pupil to light, the movement of the toes when the sole of the foot is stroked, withdrawal movements in response to a pinprick or other painful stimulus, muscular twitchings when a tendon is struck, a closing of the

hand when the palm is stimulated, a startle reaction when dropped or stimulated by a loud sound, sneezes, coughs, yawns, cries, struggles in response to restraint, restlessness in response to hunger or thirst.

In spite of the fact that such simple patterns are easily elicited in later life, and although some complex adult behavior may be traced to origins in these simpler forms, any attempt to explain mature behavior in terms of these simple patterns is misleading and of little value.

A simple illustration will make the issue stand out more sharply. Suppose we observe a man eating with his knife, and ask: "Why does he eat with his knife?" If we adhere to the method of explaining conduct by some primitive pattern or urge, we may attribute his conduct to the hunger impulse. Nevertheless, the cogent reason for this man's unconventional method of eating does not lie in the fact that he is gratifying his primitive hunger. He probably is eating because it is mealtime and not because he is particularly in need of nourishment; and he is eating with his knife because he learned to eat with his knife instead of with his fork. The essential explanatory factor in this situation is a simple process of learning and not a possible dynamic factor which led to that learning. He probably would never have eaten if he had not at some time been hungry; but he eats now and in a certain manner largely because of habit.

The essential factor in motivation is the arousal of some sort of irritation or maladjustment. A condition of maladjustment leads to some sort of response by the individual. If he has some simple patterns of response readily available, he may make use of one or more of them. If such acts remove the irritation, he will probably relax again into relative quiescence. If his response does not deal adequately with the irritation, other acts will be tried. [21]

In other words, a motive is an irritation which the individual tries to remove. Most of the irritations of later life are complex and are not met by such simple things as putting food in the stomach, by contracting the pupil, by pulling back the arm, or the like. The flight of a bug into a street lamp on a summer's night may be explained by reference to a fixed and relatively simple action pattern; but the persistent study of a student through four

years of college cannot be explained in any such simple manner. Elementary drives are not absent in complex behavior; but they become less significant in the explanation of intricate acts. The student should know what these elementary patterns are, and how they function, but he should not let their simplicity tempt him to rely upon them as complete solutions to the problems of motivation.

The fact of the matter is that modern civilization has become so complicated that these elemental drives have been pushed into the background. In spite of the logical case that can be made for their importance, man is more extensively occupied with sensory comforts, social approvals, aesthetic satisfactions, strivings for security, and the like than with the satisfaction of primitive urges. We want food, of course, but we want it served in a particular manner; we want it to conform to certain tastes, and we want to eat in the company of approved friends. We want not only protection from the weather and from wild animals, but we want to have certain types of homes with arrangements for physical comfort. We are motivated more by the standards of decency which we have set up than we are by primitive appetites

THE NEED FOR MAINTAINING BALANCE

There are certain processes that are called vital processes which must carry on in proper fashion or an organism dies. We shall find, as we examine some of these, that they function without conscious control, and usually with remarkable precision. It is only when something gets out of adjustment that vital mechanisms come to the attention of an individual and cause him to modify his conduct.

As a tentative hypothesis we may say that ordinarily a person is not driven by an urge to live, to keep his vital processes in operation, or to maintain a balance between vital functions; instead, any marked deviation from a wholesome balance may become a driving force in behavior until a condition of relative safety is again reached. Neither does one ordinarily stay pivoted; rather, he sways backward and forward around an optimal center between limits of danger, beyond which he dare not pass.

This balance in change has been given various names: unstable equilibrium, adaptive stabilization, comfortable constancy,

and homeostasis. [4] All these terms imply two essential elements; the ability to change or adapt, and the ability to avoid dangerous excesses. Whatever it is called, this "balance in change" is present in all forms of life. It is relatively simple in the lower forms and becomes more intricate as one progresses from plant life, through the lower animal state, up to human life.

Age seems to affect the strength of the urge to maintain balance. The ideal of older persons seems to be to make life secure and immobile. Youth, on the other hand, is impatient with security. The sane life should be a compromise between mature caution and youthful rashness. Precipitate change is necessary in emergencies and is customary in youth; while prudence is customary in old age and gains the upper hand as life wanes. Rashness and indiscretion may carry with them the seeds of self-destruction because of the excessive changes which they imply; but, on the other hand, excessive caution may end in stagnation. The end in either case is death. Death may come quickly to the foolhardy, slowly to the cautious; but it comes inevitably, in time, to both.

In spite of the certainty of eventual death, the living organism is constituted with safeguards to enable him to ward off threats of destruction. Some of our fundamental drives to activity are protective devices. On the other hand, much of our behavior is not so narrowly restricted in its value; we do many acts whose purpose is to make living pleasurable. Most of us not only want to live; in addition, we want to live pleasantly.

A brief survey of some of the body's automatic adjustment devices may lend support to the hypothesis that maladjustment or imbalance is a stimulus to activity. We shall see that such maladjustments have the effect of making the individual do something. Whether he does the right thing is another matter.

The need for a proper amount of water. It can be shown that conscious thirst is a poor index of the actual need of the body for water. In the case of an accident, where there is a severe loss of blood, thirst comes only as a secondary reaction. Before thirst has time to function, or before the person is aware of his need, the process of coagulation begins to stop up the wound, there is a constriction of the blood vessels near the wound which decreases the supply of blood for bleeding, and water is taken from

storage in various parts of the body and put into active service to replenish the loss. Thus, the vital functions of the body are supplied with water in spite of the loss occasioned by bleeding. If such adjustments depended upon conscious control, most of us would be dead before now.

Thirst functions in a more leisurely manner to motivate the individual to replenish his depleted stores. Nevertheless, one may need water without being thirsty and he may be thirsty without needing water. For example, thirst can be produced by causing the mouth to become dry even though there may be no diminution of the general amount of water in the body. Other experiments have shown that a diminution of water in the body does not cause thirst if the mouth can retain its moisture. Nevertheless, under ordinary circumstances, a dry mouth does provide a signal of water need.

With lower animals, thirst can become a powerful drive to make the animal engage in violent activity, to overcome barriers, and to take punishment in order to alleviate his thirst. The thirsty human being, on the contrary, is likely to be exacting in his choice of liquids. He wants them to be the right temperature, mixed to suit his taste, and served in the conventional manner. A man would have to be parched with thirst before he would drink filthy water from the gutter. In ordinary civilized life, the only type of thirst that motivates individuals is the highly sophisticated thirst for artificial drinks.

The need for a normal supply of salt. Human beings are seldom aware of the need for a balanced supply of salt in the body. This arises from the fact that foods ordinarily contain enough salt to supply all bodily needs and the body stores salt so that the proper amount can be doled out as it is needed. It is only when some unusual circumstance arises that salt imbalance becomes a driving force. It is seen as such a force in animals. If an animal takes too much salt, it develops salt fever. If it is deprived of salt to an extreme degree, it will develop salt hunger. Animals will travel long distances to reach salt licks in order to supply this need and gratify their hunger for salt.

Maintaining a balanced supply of oxygen. Experimental work with animals has demonstrated clearly that the breathing of the newborn animal is caused by oxygen need. In one experi-

ment, sheep embryos were kept alive in saline solution while still attached to the mother by the umbilical cord. While the period of gestation of sheep is 147 days, the movements of the diaphragm that occur with breathing could be induced as early as the 39th day by pinching the umbilical cord and thus cutting off the supply of oxygen. After the animal had begun to breathe by this means, it stopped breathing when oxygen was supplied by an injection of blood from the mother. This experiment indicates that breathing is the direct consequence of oxygen lack. [1]

Throughout life the adequacy of supply of oxygen is achieved by adjusting the speed and depth of breathing to the needs of the body. However, a complication arises from the fact that the breathing of man is not flexible enough to meet the widely changing demands made upon him. The oxygen requirement of a man of average size, while at rest, is about a quarter to a third of a liter a minute. When he exerts himself violently, he may need 15 liters a minute. The most he can take in is four liters a minute. In other words, although he takes in 12 to 16 times as much oxygen during exercise as during rest, he may still be getting only a fourth as much as he needs. There is no storage of oxygen in the body to meet such an emergency requirement; so the adjustment is made in another way. The work that the oxygen needs to do is permitted to accumulate, to be done at a later time. The body takes on an "oxygen debt." This debt is in the form of an accumulation of lactic acid in the muscles which the oxygen taken in later will be required to burn to carbon dioxide. If the debt becomes too large, that is, if too much lactic acid accumulates, fatigue sets in, the muscular contractions become slower and less efficient and finally stop altogether. [4]

It is clear that the regulation of oxygen supply is almost entirely out of conscious control. It is too vital a need to be trusted to human guidance.

One hates to contemplate what would happen if all the vital adjustments of the body depended upon conscious control and direction. Man brags that he is master of his fate, but this survey of a few adjustment devices should convince the reader that he does not control those adjustments which are essential to survival. The only aspects of life that man is permitted to control are those

which are less essential and which will permit a wider range of error without serious consequences.

HORMONES AS DEVICES FOR MAINTAINING BALANCE

A hormone is a specific organic substance formed by the cells of one organ and passed from that organ through the blood or lymph to other organs, upon which it produces characteristic effects. Most of the hormones are produced in glands which have no ducts, but which discharge them directly into the blood.. These ductless glands are called endocrine glands and the secretions which they produce are sometimes called endocrine secretions. These secretions play a large part in physical and mental growth, in bodily form, in mental alertness, and in the production of personality characteristics. [8, 11]

With a proper balance of hormones functioning in an individual, he has a good chance of developing into a normal person; but if some of the hormones are absent, or lacking in balance with others, the most grotesque results may occur. Persons with endocrine imbalances formerly provided most of the freaks for the amusement of royalty and circusgoers; whereas now they are being studied and many of them are being made into normal individuals by means of hormonic therapy. Even where the hormonic lack is not so striking as to cause bodily malformations and extreme mental aberrations, it is becoming more and more evident that the endocrine glands provide much of the driving force that makes an individual into the kind of person that he is. The psychologist is most concerned with the pituitary, the thyroid, the adrenals, and the sex glands.

The pituitary. The pituitary gland is located at the base of the brain. It secretes a number of hormones with different functions. One of these hormones affects bony growth, one influences sex development, one affects sex activity, one modifies the production of fat, and others play a part in controlling the general tension of the body.

The thyroid. The thyroid gland consists of two lobes situated one on each side of the larynx and upper windpipe. It produces a secretion, containing iodine in chemical combination with other elements, called thyroxin.

Excessive thyroxin will lead to increased heart rate, a rise

in the metabolic rate, an increase of sugar in the blood, a loss of fat, increased oxygen consumption, an increase of water in the body, an increase in bodily heat, and the stimulation of sexual maturation. It is generally agreed that the thyroid is the most important regulator of the basal metabolic rate of an individual, and consequently of his level of general activity. [18]

The adrenal glands. The adrenal glands are paired glands located adjacent to the upper part of the kidneys. Each gland consists of two distinct parts: (1) an internal medulla, which yields adrenalin and (2) an external layer, or cortex, which yields a hormone necessary for life, called cortin.

Adrenalin circulates in the blood stream in a quantity just sufficient to maintain normal blood pressure and to reinforce the blood supply in times of need. It plays an important part in emotional activity and is essentially the emergency hormone.

Cortin, the hormone from the outer layer of the adrenals, plays an important part in regulating body tensions. When the adrenal cortex of an animal is removed, a definite train of symptoms follows: These are easy fatigue, loss of appetite, loss of interest, irritability, twitching, convulsions, and death. When animals from which the adrenal cortex has been removed are treated with cortin, these symptoms (except death) disappear in reverse order. [9]

When rats were experimentally subjected to excessive physical exercise, an overdevelopment of the adrenal cortex resulted. Also, the administration of cortin enhances the work capacity of an animal. When the adrenal cortex was removed from hibernating ground hogs, they lived through the period of hibernation in apparent good health. In early spring, when they renewed their customary activity, death occurred with the typical symptoms of adrenal cortex insufficiency. [2]

Another worker found that exposure of animals to cold, subjecting them to excessive muscular exercise, or giving them doses of poisonous drugs led to an overdevelopment of the adrenal cortex, suggesting an overstimulation of this organ in the attempt by the animal to meet these damaging stimuli. Furthermore, he found that animals who had been thus trained to adapt to these harmful situations would continue to adapt fairly well after the adrenal cortex was removed by operation; whereas other animals

who had not been trained, and whose adrenal cortexes had not been overdeveloped, died as a result of equal exposure to cold, excessive exercise, or to poisoning. [9]

These experiments suggest that the adrenal gland functions as an instrument, which enables the organism to meet extraordinary difficulties; that it performs this function by working harder itself; and that it thereby causes extra resistance by the organism to these damaging stimuli so that it can carry on after the adrenals have been removed and can no longer help. [20] The adrenals apparently are more active in emergency situations than in regulating activity in normal conditions. When we come to study emotions (Chapter VII) we shall see that both the thyroid gland and the adrenals play important roles.

The sex glands. A number of hormones are involved in the complicated activities of sexual development and reproduction. The pituitary gland secretes hormones which are essential for the process of maturation. The hormones from the thyroid play an important part in stimulating sexual maturation and activity. The cortex of the adrenal glands produces hormones which are essential in the development of secondary sexual characteristics, such as the distribution of hair, voice changes, and the like. On the other hand, the gonads produce sex cells which carry on the process of reproduction. Hormones from all these glands interact to produce a balancing of these intricate functions.

Maldevelopments of the gonads may lead to significant changes in physical development and in psychological behavior. If there is an overdevelopment of the primary sex glands, there may be precocious maturation and an exaggerated sex urge. If there is an excessive development of the adrenal cortex, there may be premature pubescence, and the presence of secondary male characteristics in girls. On the other side, lack of gonad development in the immature person leads to underdevelopment of the musculature, striking alterations of primary and secondary sex characteristics at adolescence, slender build, and overdevelopment of the long bones. If the failure of gonad function begins in later life (principally after thirty), it produces adipose tissue.

Hence, the sex drive depends upon the proper development and functioning of the pituitary, thyroid, adrenals, and sex glands. In the animal world, where sex behavior is not complicated by

conventional patterns, these structures and their secretions play the dominant, and almost exclusive role in the sexual drive. On the contrary, in the human species, sexual activities are by no means so simply explained. The child's sexual behavior is determined not so much by the glands of internal secretion as by the teaching of his elders. He is made conscious of his sex from the first by the emphasis given to it. He must act differently, must dress differently, and his behavior toward the other sex is made so complex by these insistent teachings that, when he comes to the age of adolescence, most of his sexual behavior patterns are established and the physical aspects play a relatively unimportant part.

MEASUREMENTS OF THE RELATIVE STRENGTH OF DRIVES

Psychologists have devoted much time and have exercised great ingenuity in their attempts to measure the relative strength of animal drives.

Description of methods. We shall describe briefly five of the most common methods that they have used.

1. *The obstruction method.* The obstruction method is based upon the logical assumption that the stronger drives will be able to overcome more resistance, or opposition, than the weaker drives. Stimulate a drive, oppose its operation by means of a measurable obstacle, and the strength of the drive can be expressed in terms of the size of the resistance that the animal will overcome in giving play to the drive. So the argument runs.

The customary experimental setting evolved from this reasoning is as follows: The animal is placed in a compartment and stimulated to move to another compartment in order to get to some desired object, such as food, an animal of the other sex, water, offspring, or freedom. The usual barrier between the animal and the goal is a metal grid, which is connected with a source of electrical current and may be charged with a current of varying strength. As soon as the animal touches this grid, he will experience an electric shock which can be varied by changing the strength of the current. The strength of the urge to get to the desired goal may then be measured either by the amount of punishment he will take, or by counting the number of times he will attempt to cross the grid. The general plan for one such obstruction apparatus is shown in Fig. 17. [24]

2. *The free choice method.* If an animal is confronted with the possibility of selecting with equal ease any one of a number of alternate objects or goals, it may be inferred that he will select the one that is most satisfying to him.

This method has been used by placing the animal in a starting box and permitting him to choose between various kinds of food, between food and a mate, between food and free exploration, between a mate and freedom, and the like. This same method has been adapted for use in studying various preferences of children and adult human beings as well as animals. Interests, attitudes,

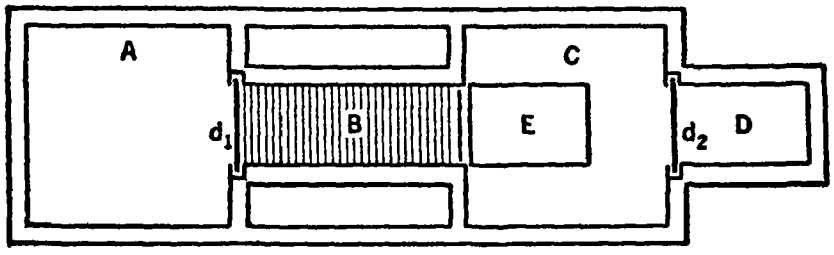


FIG. 17.—Obstruction apparatus used in measuring the strength of drives. A, entrance compartment; B, wires which can be charged with electrical current and punish animal which steps upon them; d_1, manually operated door between entrance compartment and punishment grid; E, plate which automatically makes an electrical connection when animal steps on it and thus opens door d_2; C and D, incentive compartments.

(From T. N. Jenkins, L. H. Warner, and C. J. Warden, "Standard Apparatus for the study of animal motivation," *J. comp. Psychol.*, 1926, 6, 366.)

food preferences, moral opinions, religious preferences, vocational interests, advertising displays, racial prejudices and numerous motivating factors can be evaluated by means of the free choice method.

A practical everyday application of this method is seen in the buying and selling activities of human beings. If a man wants an object more than he does the money it will take to buy the object (providing he has the money or the credit), he will buy. If he values his money more highly than the product, he will not buy. Much trading activity and advertising is based on an attempt to change the urges of the other person. A man's evaluation of any element in life can be determined by the price he will pay for

it, in terms of money, sacrifice, other commodities, prestige, or the like.

3. *Comparison of the effects of different incentives on behavior.* In this method the tasks assigned to an individual are equated as nearly as possible and the effect of each different incentive upon the efficiency of performance is measured.

A task may be assigned to an animal (such as getting out of a maze) and he may be stimulated at one time by the offer of food, at another time by the offer of a drink, at another time by a mate, or at another with freedom. If all other factors are kept

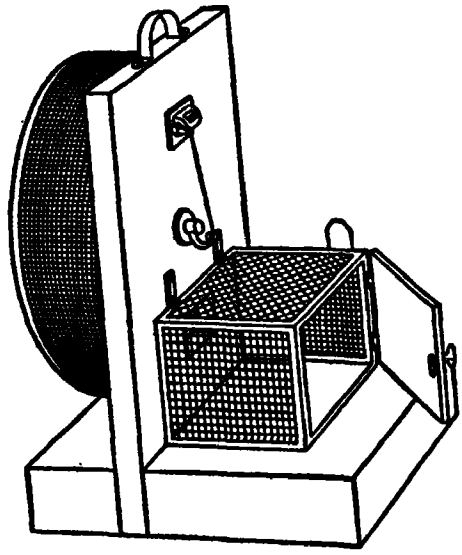


FIG. 18—The revolving activity cage. When inactive, the animal rests, eats, sleeps in the rectangular cage at the right. When he enters the wheel-shaped cage at the left his running movements cause the wheel to turn. Each revolution in either direction is registered by means of a cyclometer.

constant, and he learns to run a maze better and more quickly with one incentive than with another, it is assumed that it is a more effective goal than the one which affects learning less favorably.

4. *Shifting motivating factors during activity.* Valuable information concerning the force of a drive may be gathered by changing the motivating influence during the course of a work period, or during a learning experiment. If the introduction of a different motive retards or accelerates activity or learning, such a change may denote a significant difference in the force of the different drives involved.

5. *The measurement of changes in the level of general activity.* Several methods for measuring the level of general activity have been used.

(a) *The revolving drum cage, or cyclostat.* The animal whose activity is to be measured may be placed in a cage that is cylindrical in shape and so mounted that it will turn about a cen-

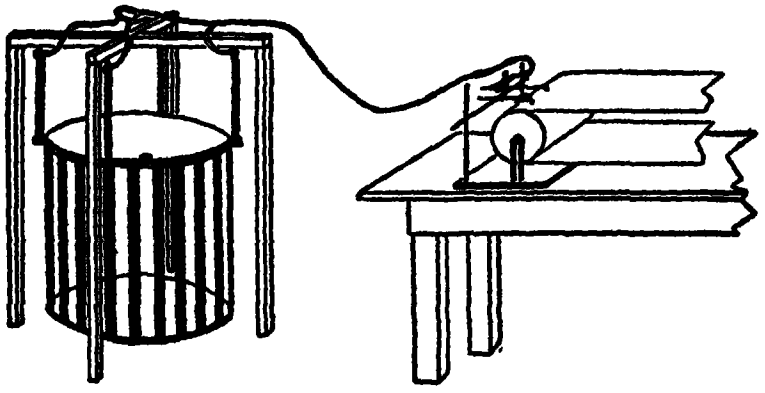


FIG. 19.—Diagram of stabilimeter for recording the movements of animals. The cage is supported on flexible hollow tubes which are connected into one system. Any movement of the animal will change the air volume and actuate the writing arm and make a tracing on the moving paper to the right.

(From Karl U. Smith, "An improved stabilimeter method for recording activity in laboratory animals." *J. exper. Psychol.*, 1940, 27, 89–93.)

tral axis with any movement which the confined animal makes in a direction at right angles to (or not parallel to) the axis. This apparatus is merely a squirrel cage put to experimental use.

In one type of such cyclostat (Fig. 18) every complete turn of the cage operates a counter and the activity is measured in terms of the revolutions of the cage. A more accurate cyclostat has a cumulative recording system whereby any minor movement in either direction is included in the record whether a complete turn of the cage is made or not.

(b) *The activity cage for animals.* The activity cage, shown in Fig. 19, is supported on hollow flexible tubes. These are connected so as to form a single pneumatic system. The pipe from the supporting tubes connects with a marker which leaves it tracing on a rotating smoked drum. If the animal in the com-

partment is motionless, the record on the drum is a straight line; if the animal moves, all such movements are recorded on the drum as a series of marks made by the recording lever.

(c) *Bed movements recorder for human beings.* Various devices have been attached to beds or chairs so as to enable an experimenter to keep a continuous record of the movement of the occupant. These usually operate through a lever system arranged in such a manner that any movement of the bed or chair is transmitted to a writing lever which records on a moving drum. This device has been used extensively in the study of movements of individuals during sleep. [12]

Results from measuring the relative strength of drives. The most clear-cut results from comparing the relative strength of drives has been done by means of the obstruction method with white rats. [16, 24]

The strength of the maternal drive was measured by taking a mother rat from her litter and making it necessary for her to cross a punishment grid in order to reach her young. The number of times she would cross the grid and take the punishment was used as a measure of the strength of the drive. The drive to obtain food was measured by counting the number of times the rat would take the punishment to obtain food after a fast of from two to four days. The sex drive was determined by placing a mate beyond the punishment grid. In similar fashion the other drives were measured. The results are given in Table IV.

TABLE IV

RELATIVE STRENGTH OF DRIVES

Drive tested	Average number of crossings of punishment grid to obtain the goal in the reward chamber
Maternal	22.4
Thirst	20.4
Hunger	18.2
Mate	13.8
Exploratory	6.0
No incentive	3.5

These results represent the findings under optimal conditions for each drive. Circumstances may modify them considerably.

For example, when a rat is placed in new surroundings, he will forgo either food or sex until he has first thoroughly explored the place. When an animal is intensely interested in his mate, he has little interest in food; and when he is hungry, and in the presence of food, he is little concerned with his mate. Making due allowance for incidental factors, it is revealing to know that the drives come out in the order given in the table.

Even when an animal is not stimulated from the outside by any particular situation, and is not impelled by the presence of any specific incentive, he manifests a tendency to engage in a certain amount of motor activity. A rat in an activity cage will spend a good share of his time running in the wheel rather than sitting quietly in the stationary compartment. Such activity cannot be explained on the basis of any one factor. It may de-

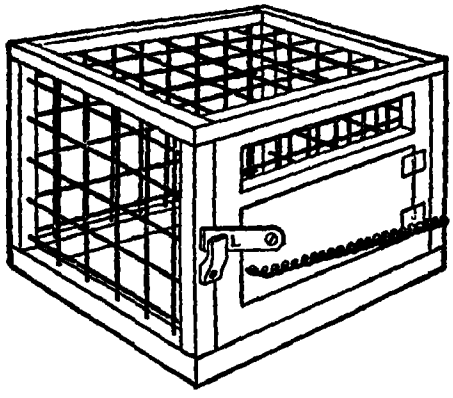


FIG. 20.—Puzzle box. This is a typical puzzle box used in experiments with cats. The animal can release himself only when he reaches through the bars and raises the latch. The spring then opens the door.

pend partly upon ordinary chemical processes, such as those which motivate the salamander embryo to engage in the coiling movements which finally result in swimming (see page 50). Part of it may be habit. Part may be hunger, thirst, or the driving force of various glandular secretions. As we have pointed out before, living is essentially activity, and so it is reasonable that the living animal should manifest an urge to be active.

It also has been found that thwarting will intensify an elementary drive. In fact, thwarting is effective in practically all levels of animal and human adjustments. If an animal is placed in a puzzle box, such as the one shown in Fig. 20, he needs no incentive to activity except a realization of the fact that he is

unable to get out freely. Should he be slipped into the box when he is asleep, or is unaware that he is locked in, he will manifest no struggle. Let him attempt to get out and fail to do so, and his efforts will be stimulated by the thwarting. Hold a cat's tail in such a manner that he interprets it as mere petting, and he will offer no resistance; but let him feel a little tug on it, and he will fight to get loose. A newborn child will fight if his free movements are hampered. The most prized possessions of an adult are the things for which he had to strive, which did not come too easily.

ANALYSIS OF SOME TYPICAL DRIVES

It is instructive to examine some of the components in drives which seem to be relatively simple, and to analyze some complex types of activity in which they play a dominant role.

The maternal drive. The maternal drive, as measured by the obstruction test, may be regarded as the urge to take care of the young. It should not be confused with a desire to have children. There is no evidence for the latter desire in lower animals. The widespread desire for children by human beings is regarded by most writers as the result of cultural factors and not of any inherent drive in women. [10]

Various theories have been advanced to explain the desire to care for children. One is that the mother desires the young because of the discomfort she experiences when the mammary glands become congested. Such a theory probably explains the frequent instances in which an animal will take care of and suckle an infant of another species. Having once cared for an infant, the mother usually shows the same solicitude for the adopted child that she would for her own. [25] This theory would not hold for nonmammals, such as birds.

Another theory explains maternal behavior on the basis of internal secretions. An interesting experiment gives support to this point of view. A hormone extracted from the pituitary gland, known as prolactin, when injected into an animal will bring about behavior in that animal which is ordinarily described as maternal behavior. For example, such an injection will cause a virgin rat to manifest interest in young, it will cause broodiness in hens, and will make a male rat take interest in making nests for

young rats, in caring for them, and in licking them in a motherly way. [14, 19]

In human society, any such elementary drives are certainly modified, reinforced, or counteracted by many other considerations. It is, for example, conceivable that the encouragement which a little girl receives to play with dolls may affect her maternal behavior in later life.

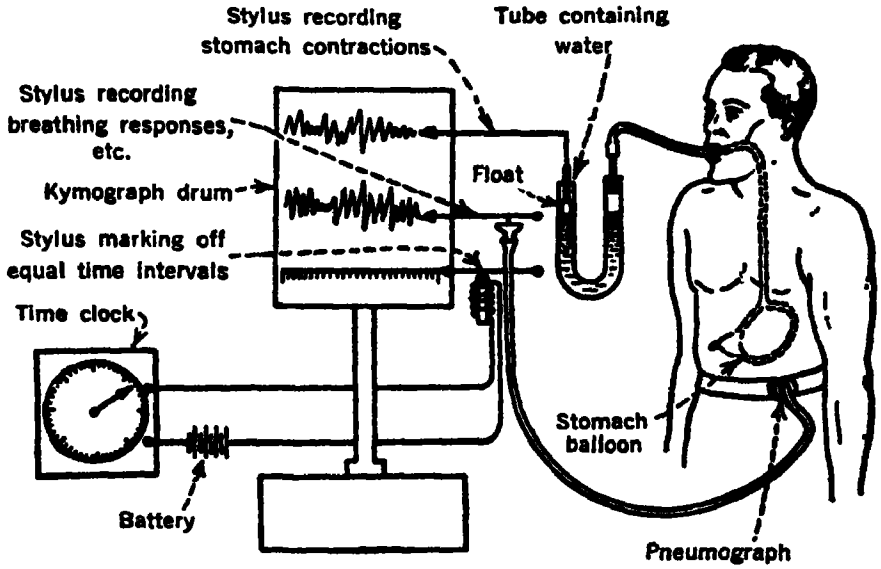


FIG. 21.—Schematic representation of apparatus used for recording changes in tonus of stomach muscles.

(Reprinted by permission from L. W. Crafts *et al.*, *Recent Experiments in Psychology*. New York: McGraw-Hill Book Co., 1938.)

The hunger drive. Experiments have shown that hunger pangs are associated with the periodic contractions of the stomach walls. [3] These experiments were performed as follows: The subject swallowed a balloon made of very thin rubber and attached to a small rubber tube. The other end of this tube was connected with a recording device and the whole system inflated so that the balloon in the stomach would respond accurately to any movement of the walls of the stomach. A graphic record was thus made of the stomach contractions (see Fig. 21).

Are these stomach contractions dependent upon the need for food? There is evidence for both a positive and a negative answer to this question. When a small quantity of blood was taken

from a starving dog and injected into the body of a dog which had just finished a meal, the latter jumped up and started eating again. This seems to indicate that some condition in the blood is what causes the contractions. On the other hand, the contractions may be stopped by chewing and temporarily by swallowing. They may be slowed or stopped by strong emotions, by tobacco, by alcoholic beverages, by vigorous muscular exercise, and by strong tightening of an abdominal belt. The effectiveness of these conditions cannot be explained by reference to a change in the need of the body for blood sugar. However, such negative evidence does not disprove the theory that blood sugar deficiency is a major cause of hunger contractions of the stomach. These circumstances may be merely interferences which prevent the stomach from responding to blood sugar need. [5]

Furthermore, it is clear that physiological hunger is not related in any simple manner to conscious hunger or appetite. The amount of punishment that an animal will take in order to obtain food is not directly correlated with the degree of need of the tissues for nutriment. Animals were deprived of food for increasingly long periods until death from starvation resulted. From the beginning of the period up to about four or five days the animals would take more and more punishment from an electric grid interposed between them and the food. From that point on to the period of death, there was a decline in the amount of punishment they would take to get to the food. It is probable that with increasing need there was also increased physical weakness, more fear of the grid, and less ability to tolerate unpleasant shocks. Initial hunger may be stimulating, prolonged hunger is likely to be debilitating.

We may still have an appetite after our hunger has been satisfied. If this were not so the phenomenon of overeating would not be so common. Experimental work with animals has confirmed this statement. It has been found that the amount of grain which a hen will eat is increased by enlarging the size of the pile from which she eats. When a hen has been permitted to eat all the grain that she can apparently consume from a large pile of grain, and another hungry hen is then placed with her and begins to eat, the first, or apparently satisfied, hen will jump up and renew her eating. When, however, several hens have eaten

to satiety and a hungry hen is then placed with them, the fed hens will not renew their eating. It would seem that it is the majority influence which counts with these animals and not the mere suggestion given by one eating animal. [13, p. 152]

Relation between hunger and appetite. Man is equipped with no devices which impel him to eat the foods he needs; nor does he have any natural appetite which will ensure that he selects a balanced diet. Nevertheless, he does have a crude sort of hunger which makes him restless and this agitation incites him to perform acts which may eventually satisfy his needs and develop in him a serviceable set of appetites.

In some cases, individuals have been known to develop a keen appetite for substances which do supply a need of the organism. Rats whose parathyroid glands had been removed, thus causing a calcium deficiency, showed a definite increase in their appetite for calcium. Rats whose diet was markedly deficient in vitamin B_1 selected, by both taste and smell, solutions in which there was a large amount of this vitamin and drank large quantities of it. [17] Diabetic patients, whose sugar metabolism is out of joint, will develop an intense craving for sweets, in spite of the fact that the eating of sugar is harmful for them.

How can a person develop such appetites? We have no definite experimental evidence on this point, but we may imagine a hypothetical situation in which such appetites could conceivably develop. For example, let us suppose that an individual, who is too lacking in training to have developed a salt hunger, has a genuine need for salt. His need may make him uncomfortable even though he does not know why he is unable to remain calm. He may be stimulated, because of this discomfort, to get up, move around, to make noises, wave his arms, drink, eat, tease someone, or to do any of a number of acts. Suppose that, in the course of these activities, he eats something containing salt. As a result he will feel better, and his agitation will decrease. When he next feels a similar need he may go through a similar series of random activities before he again becomes satisfied; but in time he may learn that eating is usually followed by relief from his discomfort and, further, that eating foods with a certain taste (saltiness) will bring about this relief quicker than foods which do not taste salty. This method of learning is called random learning or trial-

and-error learning. We shall encounter it again in different connections.

Suppose, on the other hand, that as a result of the restlessness caused by salt hunger our subject was stimulated to eat some ipecac (an emetic drug) and became nauseated as a result. It would not take him long to learn to avoid ipecac. In other words, the agitation brought about by a common cause—salt hunger in this case—might teach an individual to seek salt or it might teach him to avoid ipecac. It is evident, however, that the hunger was not the sole cause, or even the most important factor, in learning either the appetite for salt or the aversion for ipecac. The essential factor in each case was the experiences that the individual went through during the process of learning. Without the hunger drive he probably would not have learned, but with the drive and no experience he would not have learned either.

An experiment in infant feeding demonstrates clearly the workings of this type of learning. [6] Newly weaned children were presented with an array of foods and were permitted to eat any or all the foods with perfect freedom. It was found that they ate heartily and selected foods which nourished them properly. It was often evident that they did not know at first which foods to eat for they often temporarily had an unbalanced diet. At times they showed a tendency to eat excessively of one food or another, but they soon evened off to a temperate amount of that food. These periodic spells of taking an excess of one food the experimenters called food jags—egg jags, meat jags, cereal jags, etc.

Similar experiments have been conducted with pigs, cows, chickens, rats, and mice. [15] Give a child or an animal a wide selection of foods and he will tend to learn to eat those which nourish him properly. After such learning, appetites and aversions may become reliable guides in the selection of diets. Nevertheless, we must not lose sight of the fact that many appetites and aversions have no relation to bodily needs and, for this reason, blind faith in appetites and aversions is not warranted. [7]

In the development of appetites, more is to be considered than the mere satisfaction of an organic need. The child soon encounters all sorts of social traditions, prejudices on the part of elders and other children, and fears of an unbalanced diet on the part

of doctors and mothers, with consequent pressures and restraints. Eating becomes mixed with all sorts of restrictions as to the time of eating, table manners, scoldings, teasings, reprimands because of accidents with dishes, and the like. A child may hate a certain food merely because his father scolded him for spilling some of it on his new suit. The persistent and violent food aversions for certain foods which may be found in most adults are probably based on childhood experiences which parents regarded as trivial at the time. Not only may a child's enjoyment of mushroom soup be spoiled by a scolding for breaking the window next door, but the grown-up child's enjoyment of a meal served years later may be marred because the meal is begun with mushroom soup. In short, social and aesthetic factors greatly modify the hunger impulse in human beings. It makes a difference who is present, how the food is served, and what conversation goes with the eating.

The driving force of routine and habit. Each organism, after a certain amount of familiarization with any type of activity, tends to settle into a pace which it characteristically uses for that activity. A great many elements may be thought of as contributing originally to the establishment of this pace; but it tends to be maintained, regardless of its origin, in spite of circumstances that might be expected to change it. For example, a person will tend to walk at the same rate uphill and down although different amounts of energy are required in accordance with the terrain over which he is walking.

This principle can easily be tested by setting a person at a totally new activity. He will work at different speeds until he gets his bearings and then will settle into a pace which seems to please him, after which he will tend to maintain it. The longer he uses that pace on a specific task the greater will be his tendency to resist any influence designed to change it. The tendency to maintain such a customary pace may become a powerful motivating factor.

Specific habits are even more effective as determiners of behavior. An illustration may be seen in the morphine habit. Continued use of this drug causes an individual to develop a need for it that is extremely powerful. Once having developed the morphine habit, a deprivation gives rise to hunger pangs which cause the victim extreme agony and even death. The effects of mor-

phine hunger upon various aspects of the individual's life are far-reaching and tremendously powerful; he will lie, steal, and even commit murder to get morphine.

To be sure, most habits have no such dominant influence upon a person but, to a lesser degree, they do provide an important directive influence which cannot be ignored. A child, who has acquired the habit of going to sleep with a doll or a Teddybear in his arms, will have difficulty in relaxing if these companions are missing when he goes to bed. The mere fact that we are doing something makes us resent any interference with that activity. Our zeal for repeating customary procedures may not make sense; but we will still fight to continue such routines.

The striving for rewards and the avoiding of punishments are largely habitual. It has been the custom for certain persons to attempt to attribute the dynamic force of rewards to efforts on the part of an individual to supply the needs for food, shelter, warmth, and the like; and the restraining force of punishments to the attempt to avoid starvation, cold, disease, and the like. Such factors may operate in a primitive civilization, but certainly in modern life a man's wages are spent for things he has learned to crave rather than for basic needs. He spends his money to buy food prepared and served in the approved way, to wear the clothes that others wear rather than to keep his body warm, to buy a car, to live in a fine house. We do not work to keep the wolf from the door so much as to keep the door open to people whose criticism we must avoid.

QUESTIONS FOR REVIEW

1. In what different ways may motives be classified?
2. Distinguish between the following: motive, drive, incentive, goal, want, and need.
3. To what extent can simple action patterns be used to explain human conduct?
4. Define homeostasis.
5. Explain the connection between thirst and the need for water.
6. Why is salt hunger not an important drive in human behavior?
7. Explain how the body adapts to changes in the need for oxygen.
8. Describe how hormones operate.
9. Explain the general effect of hormones from the pituitary, from the thyroid, from the adrenals, and from the sex glands.

10. Outline and explain the different methods that have been used to measure the relative strength of drives.
11. What are some of the results obtained from experiments on the relative strength of drives?
12. What effects may thwarting have on the strength of a drive?
13. What factors may be involved in the maternal drive?
14. How has it been proved that hunger depends upon stomach contractions?
15. What evidence is there that hunger and stomach contractions may not be related in a simple manner?
16. Describe how an appetite may be developed.
17. How may a child learn to eat what is good for him?
18. Explain queer appetites.
19. How may routine be a motivating influence?
20. Show how habit may become a dominant force in human life.

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Chapter VI

SOCIAL MOTIVES

OTHER persons may influence our behavior in a number of ways. (a) We act differently when other persons are present. (b) There are emotional interactions between individuals which modify the actions of all concerned. (c) Working together affects members of a group enterprise through such factors as competition and co-operation. (d) Direct pressure may be brought by one individual upon others through personal domination, leadership, suggestion, and competition. (e) Finally, each person is influenced in a striking manner by the customs and culture of the society into which he is thrown.

THE EFFECTS OF BEING OBSERVED

When we are alone we do not act in the same manner as we do when we are being observed. We have curtains on our windows to shut out the curious eyes of others in order that we may feel free to do as we please. The effect of being observed increases when we believe that the observers are critical or hostile. Even though our behavior may be circumspect, such observation makes us uncomfortable and, if we have some difficult task to perform, we may lose all self-control and be forced to stop our activities altogether. Stage fright is an illustration of the effect of such discomfiture.

Experiments have shown that an individual, when he is being observed, will work more rapidly than he will when working alone, but his work is likely to be of an inferior quality. [1, p. 269] Other experiments indicate that group situations make individuals work toward the group average. Persons who are better than the average when alone, do poorer work in a group situation; whereas those who do poor work when alone, improve

in the group. [7, p. 336] However, even though individuals tend to conform to a group average when they work together, the group is nevertheless a stimulus; for the group average is higher than the average of the performances of the individuals who make up the group when these same persons work alone. [7, p. 339] None of these experiments were conducted under situations where competition or group pressure of any sort was present.

It would seem that individuals try to make a good showing when others are around. What happens when they become convinced that they are not making a favorable impression on those who observe them? Razzing is used in a baseball game to impair the skill of a pitcher. Does it affect other types of performance? One experiment attempted to answer this question by having subjects "razzed" as they worked. It indicated that razzing causes an improvement in tasks involving speed, whereas the steadiness or skill of a performance may be injured by razzing. [8]

The conclusion seems to be that others make us self-conscious. This self-consciousness does not slow us down in motor acts. Instead, we are inclined to speed up. For example, we talk faster when we are confused than when we are calm. On the other hand, self-consciousness tends to interfere with motor control and deliberate thought. We become unstable, jittery, and jump to a conclusion which calm thought would tell us was unsound.

MOTIVATING FORCE OF LOVES AND HATES

The most powerful social motives known to man are probably the loves and hates of human beings. The strange part of this situation is that psychology has little to say about these forces; romantic literature has much more to contribute than does psychology. The probable reason for this situation lies in the fact that these emotions are not easily subject to scientific experimentation. In the realm of clinical psychology, it has been found that many pathological conditions are centered in these emotions. These studies are all anecdotal in nature and are more akin to literature than to scientific experiment. These case histories have aroused much speculation and many hypotheses have been advanced which may, sooner or later, be subjected to the rigorous

tests of science. Until that time arrives, all we can do is to give a brief account of the probable manner in which these emotions act as motives in human life.

Love is a feeling of well-being which comes about as the result of pleasing interaction with another person. Hate is an unpleasant feeling which results from real or fancied mistreatment by another. Neither of these emotions is inborn. They depend upon learning. We can be sure of this even though we may not be able to demonstrate such learning in the psychological laboratory.

The first love of a child is usually for the person who feeds him. His hunger makes him uncomfortable and he becomes restless as a result of this discomfort. If a certain person is the customary attendant when this discomfort is removed, he comes to respond favorably to this person as a result of this learning. The principle is the same as the one which operates when one feeds a stray cat. When the cat gets hungry again, he will return for more food. The child cannot return, but he can make positive reactions toward the one who fed him. The onlooker calls the behavior, of either the child or the cat, love.

This is not meant to imply that feeding is the only way to produce a love reaction in a tiny child. It is merely an illustration of the way in which any alleviation of discomfort may produce such behavior on the part of the child. One psychologist [13, p. 72] has contended that the only stimulus which will bring out a love response in a child at birth is touching or stroking the skin of the infant. The important factor is not what stimulus will cause such positive responses, but that they are always the result of stimuli which produce satisfaction in the child. The multiplication of a variety of situations in which the child is made comfortable by the same person produces a fixed habit of loving that person.

Hates are developed in a similar manner; the essential difference is that the hated object is the repeated means for making the child uncomfortable and unhappy.

Although a love or a hate is a specific reaction developed in connection with certain individuals, it may easily transfer to others. We love on sight a person whom we class in the same category as one we already love. Sometimes the classification is based

on some trivial factor, such as the color of the hair, the tone of the voice, the nationality, some chance word spoken, or the like. Furthermore, the individual often does not know why he reacts as he does and is inclined to explain it upon some apparent reason that is not the significant one. For example, it was found that a little boy hated his teacher, explaining that he did so because she was unfair to another boy. Investigation showed that his hatred was based on the fact that she looked very much like a maid whom he hated because of her mistreatment of him.

As we proceed with our study of the ways in which social motives operate, we should keep in mind that the forces of love and hate form a background of many of our social interactions even though they are covered by habit, convention, and a conscious attempt to disguise them. We do not know enough about them to evaluate them in any specific situation, but we all have enough common knowledge of human life to be aware of their presence.

COMPETITION

A prominent aspect of our civilization is the competition for prestige which may be defined as the aggressive enhancement of one's own ego at the expense of that of another. From very early life a great deal of pressure toward achievement is put upon all individuals. The child who fails to respond to this pressure by the development of ambition is regarded unfavorably by his teachers, parents, and comrades.

If efforts toward attainment are thwarted only by objective difficulties, the energies of the child are directed toward overcoming them; but seldom is there any striking feeling of resentment or hate toward such barriers. What does often result is a profound regard for work as a means for acquiring fame or success. The teacher and parent seem intent on getting more and more work from the child, he learns to discipline himself and looks upon his tireless exertion as a step in the right direction. Should he discover that his efforts are too slow or ineffective, he may learn the trick of exploiting others, getting them to work for him in such manner that, while they get some reward, he gets the lion's share. Teachers often encourage such exploitation as a manifestation of executive ability.

Means for inciting personal competition. In order to induce a child to compete, it must be made clear that the gaining of the reward is dependent not on how well he performs, but on whether he performs better than another. He may do his best and even do better than he ever did before but, if another does better than he does, he loses. The winner thereby becomes the one who deprives him of his objective. Were it not for the better man, he would win. There is little doubt that efficiency of performance is enhanced by such means, but some unfortunate social consequences also arise. The winner comes to gloat over the failure of his competitor. He may be encouraged to be generous with the loser, but his generosity becomes a sort of specious condescension, which aggravates the discomfiture of the loser. The loser is told to be a good sport, but most often he comes to hate his rival. We talk idly about being good losers, but the objective is to win.

If too much is done to mitigate the sting of failure, the stimulating influence of competition is lost. For example, one young man was heard to remark that he ruined his golf game one summer because he had devoted all his efforts toward pretending to do his best while seeing to it that his boss won.

Jealousy and hate. The social attitude which grows from a competitive situation is jealousy of, and hate for, one's successful rival. This is merely another way of saying that jealousy springs from a background of personal comparisons. In an open contest the comparison is overt and easily recognized. In other situations the comparisons are more subtle. When a mother praises one child, for example, she may not think she is making a comparison of the praised child with the other, but such a comparison is implied.

Jealousy by children manifests itself in various ways. The jealous child may make bodily attacks upon the hated rival. He may ignore the presence of the other, or even deny his existence. Or, he may show no outward manifestation of jealousy or antagonism but develop a change in personality. For example, he may become a pouter, become delinquent in his behavior, become irritable, fail in his studies, and so on. The jealous child is likely to show, in addition to jealousy, one or more of the following characteristics: pugnacity, selfishness, overactivity, destructiveness,

troubled sleep, persistent bed-wetting, independence, and a craving for attention. The common factor that is behind all other manifestations, however, is hate for the rival who is presumed to be detracting from his prestige.

There are a number of factors that have been found to affect jealousy in young children. When siblings are from 18 to 42 months apart in age there is more likely to be jealousy than when the age difference is greater or less. As the number of children in a family increases, the proportion of jealous children decreases markedly with each increase in number. Jealousy decreases as the family income increases. Oversolicitous parents are more likely to have jealous children than are others who are more easygoing. Jealousy increases with marital discord. All these factors have the common factor of making personal comparisons easier and personal rivalry more acute. [11]

So long as a person feels that there is a possibility of outdoing a rival he may be stimulated by personal comparisons to work harder, even though he may hate his rival in the meantime. When prestige is lowered to an unusual degree even the incentive to compete may be lost. For example, it has been found that public reprimands, sarcasm, and ridicule cause the performance of children to deteriorate. There is little doubt that jealousies instigated by personal comparisons serve to arouse an individual to a high pitch of emotional tension and spur him on to his maximum effort; but the individual, class, and national hatreds which probably grow out of, or at least are accentuated by, personal hatreds cost exceedingly more than the increased efficiency produced by personal competition. [3, p. 83]

Co-operation. Although much has been said about co-operation, we know relatively little about it from observation, statistical studies, or experiment. Time samples of the behavior of children from 25 to 60 months of age during free play reveals that there are frequent quarrels lasting on the average for about 23 seconds. Within this age range there are fewer quarrels as the children become older but those that do occur last longer. The majority of these quarrels begin as a struggle for possession of some article.

As children grow older they make more contacts with children of their own age and fewer with older persons. There does

seem to be some increase in sympathetic reactions between children as they grow older. These are accentuated if the child is permitted to have an animal for a pet. At an early age children tend to warm up to those children who are compliant in their behavior, who seem to attempt to act in ways that the others approve, and who have respect for property rights; they withdraw from those who fight, who refuse to fight if they are attacked, who dawdle, or who prefer to remain aloof and play alone.

It has been found that when a prize is offered to a group for good work, this motivation will induce them to work together to improve their score. The same improvement may be seen when one group is pitted in competition against another group. Those who have reported these experiments have been more concerned with efficiency than with the attitudes of friendship or co-operation engendered by such mass competition. The child who refuses to join in such activity is regarded as an enemy of the group and he is forced to join or suffer loss of prestige. [3, p. 82]

AGGRESSION

The term "aggression" has been given different meanings, and investigations of aggressive behavior have taken different directions depending upon the definition adopted by the investigator.

Definitions of aggression. Aggression has been used to designate the characteristic behavior of a person who tends to take the initiative as contrasted with the individual who habitually lacks initiative. In this sense, aggressiveness is usually regarded as wholesome and teachers and parents are likely to encourage it. It is merely the expression of animal vigor and denotes health and vitality. On the other hand, aggression may be the expression of acts of retaliation by a weak individual for a real or fancied wrong. It is a kickback against thwarting. This latter type of aggression has the greatest social significance. [3]

Analysis of aggression. The important factor to consider in studying aggression is the attitude or motivating element in the individual who manifests the aggressive activity. Up to a certain point the overt activities may be quite similar and the motive behind the acts are the only distinguishing elements. In extreme

form the two types (the wholesome expression of animal vigor and the compensation of the weakling against thwarting) part company and can be more easily differentiated. Because this distinction between the motives behind aggression is not given due credit by those who instruct young children a great deal of confusion surrounds their instruction in competition in sports and other activities.

Some contend that competition is bad and point out the fact that in some sheltered situations it does not exist. For example, a study of Hopi children showed that it was normal and universal for them to show self-depreciatory attitudes. The ambition to distinguish oneself or to get ahead was absent. The children refused to engage in competitive enterprises and tended to praise the work of others rather than to look for approval for their own. [7, p. 106]

Others place so much emphasis upon winning that a child is made to feel intense humiliation if he does not win. To be sure, the advocates of intense competition do not stress the need for humiliating the loser. In fact, they call attention to the need for teaching a child to accept defeat and talk much about the nobility of the boy who is a "good loser." At the same time the urgings to win, the setting of high rewards for the winner, the turmoil made about who will win is so intense that the child must win or feel deep chagrin. If all frustrations which a person encounters were due to nonhuman interferences, aggression would never lead to conflicts between individuals. It happens, on the contrary, that most of the difficulties of living arise because others get in our way. It is more often a person than an inanimate object that stands between us and our goals.

To add to the confusion there is an extreme amount of inconsistency in training children in their social relations. The unaggressive child is an easy mark and children are taught to have little regard for the one who cannot defend himself. On the other hand, the child who is too aggressive is frowned upon. A child is thwarted by adults, and yet he is punished when he attempts to thwart other children in the same manner in which his parents thwarted him. A child must be humble and not show off, and yet he is encouraged to search for popularity and to be a

leader. He must submit to parental authority and be obedient, and yet must not let another impose upon him.

It must be admitted that psychologists have not solved this problem. However, a realistic view of the facts leads to the following conclusion: We are in a competitive society and the child had better be taught that all individuals are not going to sit back and encourage him to take his turn. Even if such universal unselfishness might be enjoyable, common sense tells us that it does not exist in modern society.

Clinical studies of children have made it clear that it is a wholesome exercise for a child to meet and overcome obstacles. He can be challenged by difficulties in a wholesome manner and be stimulated to do better work because of obstacles than he would manifest were tasks too easy. We know this is true even if we do not know just how to achieve a balance between easy and difficult tasks. Case studies indicate a possible solution of the problem of aggression. The child can be taught the pleasures that may be derived from meeting and overcoming obstacles with less emphasis upon the specific objective attained and still less upon a comparison of his success with that of others. The type of aggression that distorts the personality of the one who develops it, and becomes a disruptive social force, is the kind that is the expression of the self-conscious weakling who has his attention centered upon the humiliation or defeat of another in order that he may thereby rise to greater power and thus increase his own self-satisfaction.

Forms of aggression. Because aggression has become a pronounced social force, it affects the lives of great numbers of individuals. It is of vital significance for the student of psychology to be able to recognize it in all its forms.

1. The aggression may be directed at the frustrating agent. For example, the jealous child who feels that his brother has come between him and his mother may manifest his irritation by direct violence to his brother.

2. The aggression may be directed against a substitute for the frustrating agent. Instead of hitting his enemy, a thwarted person may institute a lawsuit against him or start a scandal by talking about him. Furthermore, if any action against the frustrating agent is prevented, the aggressor may take it out on any

innocent bystander or on some inanimate object. One may kick a chair instead of his enemy.

An experiment was performed which illustrates how aggression may fall upon an innocent bystander. Rats were trained to strike each other under certain circumstances. If one rat was placed with another rat, each tended to hit the other. If, on the other hand, one trained rat was placed in the test apparatus with a doll, he struck the doll instead of another rat. [3, p. 42] Innocent individuals, groups, and nations are continually being subjected to indignities because they happen to be the substitute recipients of aggressive activities logically intended for others. There is a tendency on the part of farmers to vote political incumbents out of office following years with poor rainfall. It is well known that the public tends to vote against the party in power after an economic depression. These are illustrations of displacements of aggression from the real frustrating agent to innocent bystanders.

3. Aggressions may be directed against oneself. It is not uncommon to hear a person say he hates himself for something he has done. Self-condemnation may lead to emotional depressions and even to suicide. Such aggression against oneself appears only after overt aggressions have been checked. For example, a frustrated child may respond by biting, pinching, and kicking the adult who began the frustration. If such acts are checked, he may hit other children or his pet or even his doll. If these indirect expressions are likewise checked, he may bump his head against the wall, pull his own hair, or make faces at himself in the mirror. Martyrdom probably has an element of aggression against the self in it.

INFLUENCING OTHER INDIVIDUALS

Whenever individuals meet, there is a resulting mutual influence of some sort. Whether the influence acts in the way in which one plans, whether it depends upon the giver more than the recipient, and whether it can be controlled, are factors which make the question of individual influence a complex one. Courses of selling which teach the salesman a set method of approach and make him memorize a set speech take for granted that persons are similar in their responsiveness. Such an assumption is contrary to the

facts. On the other hand, those who contend that the only prerequisite for becoming influential is to develop a striking and dominant personality are certainly in the wrong. All social behavior is reciprocal and personal influence is no exception.

Individual differences in responsiveness to others. If we could measure the degree of readiness with which individuals respond to others, we would doubtless find that they range all the way from those who are extremely resistive to any personal influence to those who are extremely responsive. It is also probable that most individuals would fall somewhere between these two extremes and that a curve drawn to represent a group of individuals on such a scale would be somewhat like the ordinary probability curve, such as we get when we plot the distribution of individuals in height, weight, intelligence (page 95) and the like. Those who tend toward the responsive end of such a distribution have been called suggestible. Those who tend toward the resistive end are called negativistic. Most persons are partly negativistic and partly suggestible. The one who wishes to be influential in his dealings with another must first know the degree of general responsiveness of the other person, the kinds of things that will increase his responsiveness, and certain techniques for making his influence effective.

The habit of suggestibility or negativism. The degree to which one tends to be responsive or resistive to the suggestions of others is a learned habit. If a child is brought up in surroundings where people are trustworthy and kindly disposed toward him, he will learn to depend upon them. As he widens his contacts, he will tend to act toward his new acquaintances in a similar manner. Should these, in turn, prove to be trustworthy, his habit of responsiveness will be strengthened. Thus, other things being equal, a person's degree of suggestibility is in direct proportion to the degree to which his social contacts have tended to encourage him to trust others. If one could imagine a person who had attained maturity and had never experienced a single situation in which others had proved untrustworthy, it would be easy to understand how such a person would trust others to the extent that he would be an easy prey to any malevolent impostor. On the contrary, one whose early and later contacts had been with untrustworthy individuals would most likely develop an

attitude of suspicion, and would tend to resist any attempt on the part of others to influence him.

However, such a habit is in the form of a generalized attitude which takes specific form only in individual situations and, because each situation is different, will not be a habit that displays itself with the same degree of uniformity as would a motor habit. In

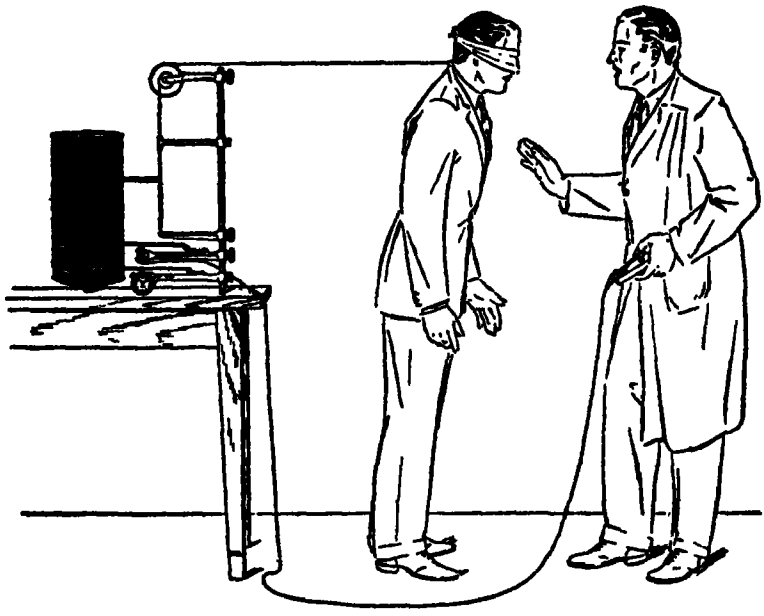


FIG. 22.—Diagram of the sway test for suggestibility. A blindfolded subject is told that he is swaying forward. Without his knowledge, the swaying movements are recorded on the kymograph.

(From C. L. Hull, *Hypnosis and Suggestibility*. New York: D. Appleton-Century Co., 1933.)

other words, while a person might tend to be negativistic more often than suggestible, he would probably adjust his responsiveness to the particular situation in which it occurred. He might be negativistic to most persons but relatively responsive to some one individual. In short, if it is desired to influence a person, it is not enough to decide whether he is preponderantly suggestible or negativistic; one must go further and try to determine under what circumstances, or to what persons, he is more likely to be responsive.

Attempts to measure suggestibility. Attempts to measure suggestibility have not met with striking success. One of the most promising methods has been the sway test. This method is illustrated in Fig. 22. The subject is blindfolded and, without his knowledge, a light string is fastened to his body and connected to a device which will record any swaying movements on a kymograph. The experimenter then suggests to the subject that he is moving forward or moving backward. It has been found that suggestible individuals tend to move in the direction indicated by the examiner, although they are not aware that they are doing so. It has also been found that negativistic individuals become rigid when told to sway and refuse to respond. Some individuals, who have been called negatively suggestible will respond by doing the opposite of what is commanded. When told to sway forward, they will sway backward. [5]

Kinds of suggestion. The factors which may play a part in eliciting a response from an individual are so diversified that they cannot be placed into logical and mutually exclusive categories. Until someone devises some measure of suggestibility and dissects the component factors by factor analysis, or by some other method, the following four factors may be distinguished:

1. *The factor of directness.* Suggestions may be given in a straightforward manner, so that the recipient knows exactly what is intended. Or, they may be presented by indirect means, so that the intention of the person giving the suggestion can only be guessed by the recipient. Where two individuals enjoy an association of mutual trust there is no reason why suggestions should not be direct and undisguised.

2. *The factor of awareness.* Some suggestions operate even though the recipient is not aware that he received them, whereas others may be consciously discerned. Many acts of everyday life are probably determined in part by stimuli of which we are not aware.

3. *The factor of prestige.* Prestige suggestions are those which result directly from the influence of one person upon another; nonprestige suggestions are those whose effect is not dependent upon any personal factor. When we obey a person because we like him we are displaying prestige suggestibility. When we refuse to respond to a person because we hate him

we are manifesting prestige negativism. Illustrations of non-prestige responses are the response to monotonous situations by becoming drowsy, by the watering of one's mouth at the sight of appetizing food, or by the desire for a new car at the sight of a handsome new model.

4. *The verbal factor.* Suggestions may be verbal or non-verbal. A nonverbal suggestion is illustrated by an individual's gazing intently at a certain object and thus influencing others to look at the same object. A verbal suggestion is illustrated by the statement: "Look at that spot on your tie."

Generalizations. From the above discussion we may make the following generalizations:

1. The ease with which any person can be influenced by others depends upon his habit of trusting others. To be balanced, this confidence should be determined in large part by an understanding of the motives of the person who is attempting to exert his influence. Hence, the readiness to trust others should be determined separately in each specific instance. It is more important to know something about the personal integrity of a salesman than it is to hunt for indications that his wares are as represented.

2. If one is to exert personal influence successfully, he should understand others. Understanding is more important than the knowledge of devices for influencing others. To be sure, devices applied mechanically will work at times, but when a critical situation arises, genuine understanding must supersede any routine method of influence.

LEADERSHIP

Leadership relates fundamentally to a social situation in which one person stands in a dominant relationship to others.

Background of leadership. What is it that makes people follow another's lead? Essentially it is a real or imagined need for help. In times of crisis, it is essential for each person to do what he can for the common good. At such times, the person with intelligence, energy, self-confidence, who is quick to decide and energetic enough to carry out his decisions, easily takes the lead. Others, feeling keenly the value of such services, accept his leadership willingly and even eagerly. Since these traits are not too rare, the best leader in any situation is the one who, in

addition to these traits, has enough insight into the immediate emergency to contribute materially. In each need there should logically be a different leader.

However, things seldom work that way. Observations of children have shown that, once a child takes the initiative, that very fact changes his relationship to the others. He develops a feeling of superiority which he enjoys. The followers look up to him and, in the next crisis, turn automatically to him to lead; and he readily takes the initiative again. There is, in other words, a sort of halo built up around one who takes the initiative. [11]

In adults the same factors operate, only in a more powerful manner. In political, economic, or social crises, the mass of individuals become demoralized through fear and grope blindly for someone to guide them. The greater the emergency, the less discriminating the needy ones become and the greater the likelihood that an individual who is motivated more by his desire for domination, than one who desires to contribute, will be able to gain control. So long as the emergency lasts, his excess activity will be interpreted as efficiency and he will be able to maintain his position. Since emergencies do not last, it has been the age-long custom for autocratic leaders to fortify their position by other means than their own ability. Robes, parades, insignia of office, inaccessibility, speaking only from a lofty position under circumstances calculated to intensify the submissiveness of auditors, and many other devices are designed to intimidate anyone who doubts the supremacy of the officeholder. In some situations, the ruler is so revered that any attempt to dethrone him is regarded as treason, punishable by death.

Another curious feature of this situation is that the initiative in attempting to displace a person in office is usually taken by those who themselves have a mighty zeal to rule. In short, the most striking characteristic both of the one who clings to his office and of the one who tries most zealously to displace him is a desire to dominate.

Ascendance-submission patterns of behavior. These facts about leadership lead to the conclusion that whether one leads or whether one follows is determined largely by certain habit patterns which he develops. The leader is one who has

developed habits of ascendance and the follower is one who has developed habits of submission. To be sure, persons become placed in social situations where they are not adjusted to these habit patterns; but when this happens, there is usually an attempt to get into a more congenial situation. The person who has the ambition to be ascendant and who is in a subservient position takes the first opportunity to dominate others; whereas the submissive person who has authority thrust on him seeks the first opportunity to retire in favor of another.

It therefore becomes an interesting problem to study how a child learns to be ascendant or submissive. A study of ascendant and nonascendant children showed characteristic differences between the two groups. The nonascendant children showed fear of facial demonstrations of displeasure by their companions; they made frequent appeals to adults for help and attention; they followed adults or held on to them; they interfered with the activities of others with no apparent reason; they hesitated after starting to do something and, at times, failed to do the act after it was begun; they showed reasonless laughter or enthusiasm; they reacted strongly to criticism, ridicule, or threats by blushing, apologizing, or retreating. [11, p. 398]

This description will be recognized as fitting a child who lacks self-confidence. Two kinds of home background may foster feelings of insecurity: The first is the home in which the child gets too much attention. He never learns to do anything for himself, feels more and more dependent as he gets older, and when finally he is thrown in contact with outsiders, he mistrusts his ability to get along with them. Too often his lack of confidence is intensified by his actual failure in social affairs. The second situation which will produce anxiety and feelings of insecurity is that in which the child is given no attention and is thrust into hostile surroundings before he is capable of working out a plan for taking care of himself. Children who are so lacking have been changed by special training designed to build self-confidence. Most effective was training in some simple skilled act. As proficiency increased the child gained poise and was able to prosecute his work in the presence of others with a corresponding loss of the symptoms enumerated above. To generalize, the nonascendant child is one who is hyperconscious of himself; he

is afraid of the criticism of others of a nearly-equal status; and he is dependent upon those upon whom he has learned to lean for support. Interest and skill in pursuing an objective task is the best cure for such a condition. Instead of wondering how others regard him, the competent person knows he is doing a good job.

Suppose that instead of being supervised by some understanding person who taught him to be efficient and poised, such a nonascendant child fell into the hands of a dominating person whose main objective in life was to convince others that he was boss. The result would be either an increasing submissiveness and subservience or, if the pressure became too excessive, a violent revolt. Such a revolt, instead of leading to poise, would result in an excessive desire to dominate others and probably end in another social situation where a new person, or group of persons, would fall prey to his compulsion to rule. The groundwork is laid for tyranny.

Many of these problems are adjusted satisfactorily by children themselves if the children are not thwarted by supervisors. A tyrant is recognized and the group "gangs up" on him. Likewise, the abused child is protected by those who see his plight.

MOTIVATING FORCE OF CUSTOMS AND CONVENTION

Types of uniform social behavior. Various types of uniformity in human behavior have been distinguished. [6]

Chance uniformities. Chance uniformities are characterized by activities which are uniform but which arise from some factor in the environment that is not closely related to the thinking or attitudes of the persons involved. An illustration is the fact that men turn up their collars in a blizzard.

Folkways. Folkways are better known as conventions. They represent the traditional pattern of a group—the "proper" way of doing things. Usually they are not rationally thought out, but often arise from trial-and-error methods of persons in their attempts to meet their needs. They are uniform, invariable, and imperative. Folkways are not improved by laws which make the individuals in the group conform; but the one who makes the conventional error is laughed at as ridiculous, he may be shunned, or he may even be excluded from the group. Illustra-

tions of such conventions are: wearing shoes, shaking hands, kissing, eating with a fork, or using a handkerchief.

Mores. Mores are customs which the social group regards as the only right ones, as vital to the welfare of the group, and which must be maintained at any cost. The negative ban against transgression of the mores is spoken of as a taboo. They are usually explicitly expressed and are thought of as codes for the direction of individual conduct. For example, monogamy is considered essential to the welfare of our society and polygamy is not tolerated.

Institutional uniformities. In institutional uniformities there is more regimentation, more rational justification for the uniformities, and less emotional horror at a violation. Still, the group regards as important the submission of the individual to certain institutional patterns, while realizing that such conformity is a matter of expediency rather than of vital moral significance. The concept of institution applies to such cases of uniform behavior as those arising from membership in political parties, business corporations, schools, or churches. A person has a relative amount of freedom in joining but, having joined, he is expected to adjust his behavior to the requirements of the institution.

Fads and fashions. A fad implies a more unstable pattern of behavior than does a fashion. Nevertheless, both are changeable and appear and disappear with little reason and with no apparent contribution to human welfare. While at the crest of their influence, fads and fashions do exert a powerful influence, different members of the society vying with each other to keep up with the changing tide. Common activities strikingly affected by fad and fashion are: dress, slang phrases, popular music, hobbies, recreation, tastes in food, parlor games, radio programs, dance steps, and literally hundreds of others.

Conforming behavior. An outstanding feature of this outline of uniformities in behavior is the fact that most of them are self-imposed. We attempt to find out what is being done and to do it. We find the group having the strongest influence and then join that group. Not being able to attain membership with the in-group, we may accept a position in the out-group. However, having done so, we tend to exert our efforts toward increas-

ing the relative strength of the organization we have joined and to supplant the in-group.

Even after an individual has joined a group, has adopted a fashion, or accepted a conventional mode of behavior, there is still some variation in the degree of adherence to the uniformity imposed by such allegiance. He may submit because of expediency but, often, his own individual wishes cause certain reservations. Various kinds of pressure are brought to bear to restrain individualistic impulses, and the resultant behavior is usually some sort of compromise between the need for conformity and the tendency to be individualistic. A person may manifest some freedom in selecting the institutions which he joins; he may transfer from one country or state to another when he does not subscribe to the political system of the first; he may change his religion when he finds himself affiliated with one which does not suit him; he may change clubs, economic associations, join the Foreign Legion, or become a monk. Some of these affiliations permit a continuation of more individualism than do others, but no sane man imagines that he can live in association with others and still be a complete individualist. Life is a combination of freedom and the voluntary or forced restraint of freedom. What seems to bother many persons is whether their restrictions are self-imposed or are imposed from without. Such individuals prefer to join institutions which keep up the appearance of allowing their members freedom. Any restraint must be rationalized as expressing the will of the majority of the group, or the will of representatives of the majority.

Other groups of individuals have been brought up through childhood in institutions where they have been taught to believe the individual has no rights. They take for granted that some greater power has ordained the state of affairs and their only obligations are to learn what necessary restrictions exist and to adhere rigidly to these.

In most situations there is neither strict regimentation nor strict individualism. Instead, there are certain aspects of life which permit great freedom and certain others which permit little or none. In such cases, it is interesting to study those segments of behavior which are restricted and to compare them with the nonrestricted areas. It is also interesting to ascertain

how the self-imposed regulation compares with the restriction which is arbitrarily imposed from the outside.

The measurement of conforming behavior. If conforming behavior is measured and is plotted in the form of a distribution curve, it has been found that the general shape of such a curve differs strikingly from the distribution curve constructed from measurements of such biological functions as height, weight, or intelligence (*Fig. 16, page 95*). The form of the curve obtained from measuring a function which depends upon the chance operation of a large number of factors is the bell-shaped

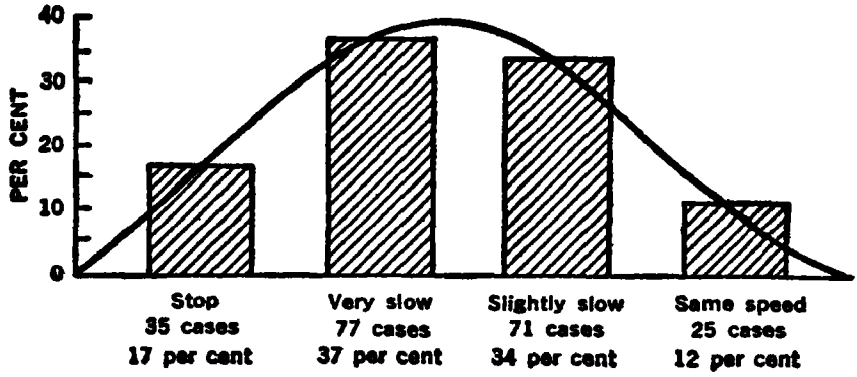


FIG. 23.—How motorists stop at intersections where there are no traffic signals. The curve resembles closely the normal distribution, indicating that a great many factors, operating in chance fashion, are operative.

normal distribution curve. Such a curve is shown in Fig. 23. When certain factors become more pronounced in their operation, the resultant curve departs from this bell-shaped form and becomes "skewed." In the skewed curve, the highest part of the curve tends to move toward one end of the distribution instead of being in the middle. Or, in some curves, there may be more than one peak. [2]

In conforming behavior, there is not a chance distribution of factors controlling behavior. Instead, one or a few factors predominate and one would expect to have a curve differing in form from the normal distribution curve. These expectations have been verified by measuring and plotting such behavior as:

stopping at stop signs, getting to work on time, length of time cars were left parked in areas where there was a time restriction, religious attitudes, and the like.

Figure 24 shows how men behaved when the intersection was guarded by stop signs. This curve, which results when conduct is largely determined by the desirability of acting in a specific manner, has been called a J-curve.

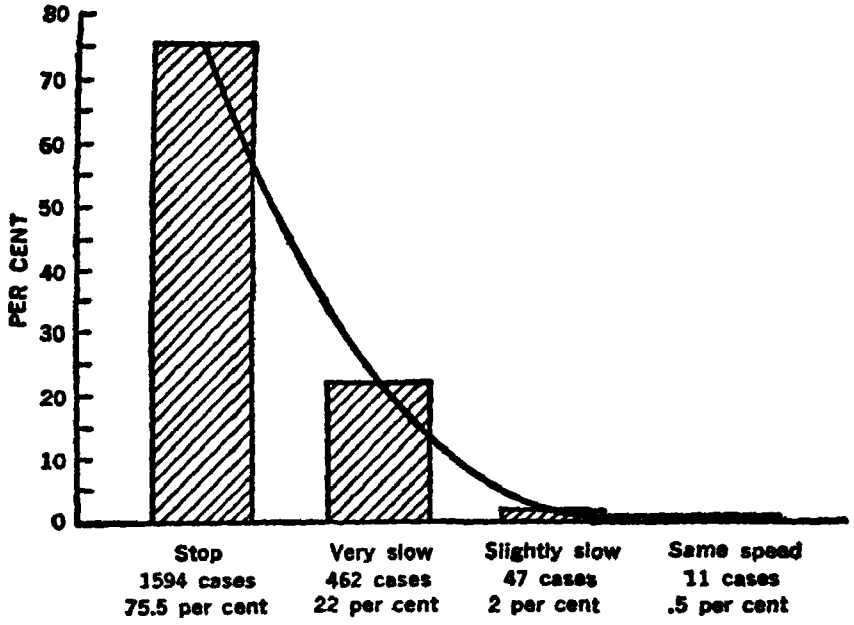


FIG. 24.—A typical J-curve. Distribution of responses of 2,114 motorists at an intersection protected by traffic signs. The departure from the normal distribution form and the approach to the J-curve form indicates the degree of responsiveness to factors which demand conformity of behavior.

(After Allport, Dickens, and Schanck.) [2]

In other situations, where the compulsion exerted upon the group is not so severe, the piling of the individuals toward one end of the distribution will not be so striking. If enough pressure could be brought to bear, presumably every individual could be made to respond in a uniform manner. If, for example, it was made clear that all those who did not stop at a stop sign would be put to death, not many would fail to stop. The shape of a curve, then, becomes a fairly good index of the degree to which

a group accepts the pressures exerted to make their conduct uniform.

It should be clearly recognized, on the other hand, that such outward compliance tells nothing about the degree of inner compliance which the individuals in the group may have. While all persons involved might presumably do an act rather than die, there probably are all degrees of willingness to comply. Some attempts to measure attitudes show that these internal factors also may show the effect of conformity. It is quite likely that when an attitude is closely related to the mores of the group the tendency would be toward conformity because of the moral pressure. The curve recording the belief in monogamy, for example, would likely be a J-curve.

In brief, when the need for conforming is at a minimum, social activities are determined by thousands of factors inherent in the personality characteristics of the persons involved. When social pressure of any kind is brought to bear, such freedom is restricted and freedom in certain directions is hampered. The curve of distribution of an act may be taken as an index of the effectiveness of the pressure exerted in any particular situation.

MOTIVATING IDEOLOGIES

A commonly accepted belief is that a man's conduct is merely the reflection of his system of attitudes, his character tendencies, his philosophy of life, his conscience, or his religion, all of which may be included under his ideology. If this is a sound belief, the complete knowledge of a man's ideology would enable us to predict what he would do in a given situation. For example, if a crime has been committed and we know the ideologies of the different individuals who might have participated in the crime, we should be able to pick out the culprit. It is this procedure that makes detective stories so fascinating. The clues give a possible motive for the crime, the individuals are studied to find one who might have been driven by such a motive, and—Q.E.D.—we have the criminal.

Ideologies as disguises of real motives. In practice, the problem is by no means so simple. Any detective knows that real attitudes and genuine determining drives in an individual are seldom revealed in his expressed attitudes. The degree of dis-

guise may range all the way from that of the professional man who takes up religion to increase his clientele to the international spy who wins the love of her victim in order to gain military information for her country.

An even greater obstacle than intentional deceit in the way of true discernment of real attitudes lies in the fact that practically all of us engage in self-deceit, are sure that we entertain one set of attitudes when we actually are nursing others, and are so genuine in our convictions that the disguise becomes impenetrable.

This statement, which may appear quite dogmatic, has been amply verified by clinical studies. A generalization, which it is probably safe to accept tentatively although it cannot be proved by statistics or by controlled experiment, is that the smoother the ideological system which a person presents, and the more zeal he manifests in defending it, the more one should suspect that his expressed views are disguises for attitudes which, if exposed, would not appear so praiseworthy. The reformer, the fanatic, and the opinionated individual are not likely to be actuated by a logical interpretation of the relevant factors in a situation, but by very personal and probably narrow emotional attitudes.

The man who appears to be extremely interested in saving your money, in saving your soul, in tipping you off to a good investment, in warning you against your enemies, or in giving you a better government, is probably more interested in himself than in you, although he himself may be unaware of the real motives behind his apparent altruism. This should not be taken as an excuse for going through life with morbid suspicions as to the sinister motives in all our friends. It merely is a simple statement to the effect that personal emotional bias lies behind much of the conduct of all of us, and we should take this for granted as an essential part of social life. The honest man admits that he has personal interests in his attitudes; the dishonest man contends that he has no interest except in others. He has personal interests just the same, but they must be discovered beneath his disguise of pretended disinterest in himself.

The driving force of defense mechanisms. Defense mechanisms may be defined as forms of conduct which tend to guard some aspect of an individual's personality from scrutiny by others, or by himself, by calling into play disguised acts. They

are forms of deceit. To the psychologist, however, the important consideration should not be that they are lies, but that they are probably the most potent motivating forces in human life. In line with these driving values, these defense mechanisms have been renamed dynamisms—a term that is probably more pertinent. [14, p. 150] To know what dynamisms actuate an individual, it is necessary to know the sort of person he is. Hence, we shall postpone a more extended discussion of these personality qualities until the last chapter.

INTERACTION OF MOTIVES

It should be perfectly apparent, from the foregoing survey of the various motivating forces in human life, that any act is the resultant of a vast number of factors. Behavior cannot be explained by selecting one factor and ignoring the others. Neither can it be explained by enumerating all the elements in a given situation. The theoretical explanation of any act would require the knowledge of each influence, the direction in which it was exerted, the force of each, and the time relations between all of them.

Psychological valences. An analogy used recently in this connection was borrowed from chemistry. It is the concept of valences. As used by psychologists, a valence may be defined as the attracting or the repelling value of an object. [10] The possible combinations of valences may be outlined as follows:

A simple positive valence. This is a situation where a simple stimulus elicits an approaching reaction. For example, when a girl is offered a doll, she will make a positive or approaching response.

A simple negative valence. An illustration of this is the negative value of touching a hot stove.

Poise between two positive valences. A child may be offered a dime to drop his play and go to bed. He may want to continue to play and may want the dime. Consequently, he may hesitate which one to choose. If the two were of exactly equal weight and persisted through a period of time, nothing would happen. Usually there is no more than a momentary balance; one or the other will win.

Poise between two negative valences. A child may be told that if he does not do some unpleasant task he will be punished. He may take the punishment rather than do the task; he may do the task to avoid the punishment; or he may try to evade both the task and the punishment.

In an actual situation, a great number of forces combine and the behavior is the resultant of all these forces. One objection to this analogy of valences is the tendency it breeds to ignore the factors within the individual. Not only should the student make an analysis of objective forces, but he should also consider the personality make-up of the individual upon whom these play. For example, the opportunity to get a dime may be a strong force for one child and not for another. It may have a powerful force at one time when the child needs money, but be powerless at another when the child is surfeited with wealth.

Individual interpretation. The conclusion that stands out is that each situation must be analyzed as an individual situation if we are to understand the motives behind any bit of conduct. Analogies or attempts to simplify only mislead us. An immediate act is dependent upon the genes from which the person originated, the biochemical processes in his body, prenatal influences, maturation, care during infancy, the food that was eaten, the hormones secreted by his ductless glands, the attitudes he has developed, and the influences of other individuals.

Is there any method by means of which the dominant trends in an individual may be discerned? An excellent opportunity to observe individual differences in adjustment tendencies comes when a number of persons are exposed to the same objective crisis. The behavior of each will, in a measure, reflect his essential dominating trends. Most persons can dissemble well enough under ordinary circumstances; but a crisis will usually break through any ordinary disguises. For example, a train wreck will bring out the worst and the best in those involved. To understand a person, observe the way in which he reacts to unusual or difficult circumstances.

QUESTIONS FOR REVIEW

1. Cite some effects of being observed and describe the experiments upon which these conclusions are based.

2. Show how loves and hates are developed.
3. How is a child induced to compete with his fellows?
4. *Explain how jealousy may arise through competition.*
5. *What evidence is there that co-operation must be learned?*
6. Define aggression.
7. What distorting effects may aggression have on the personality of an individual?
8. Describe the three major forms of aggressive behavior.
9. Explain how suggestibility and negativism may be learned.
10. Describe an attempt that has been made to measure suggestibility.
11. Describe four factors that may occur in suggestions.
12. Explain how leadership may develop.
13. What part may attitudes of ascendance-submission have on an individual's reactions to leadership?
14. Outline five types of uniform social behavior.
15. Cite some problems which arise concerning conforming and individualistic behavior.
16. What is meant by a J-curve?
17. What is an ideology? A defense mechanism? A dynamism?
18. Describe the theory of valences as explanations of human behavior.
19. Explain the different valence situations that may arise.
20. Why is it important to study how an individual behaves when he is in a critical situation?

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Chapter VII

EMOTIONAL BEHAVIOR

EMOTIONAL behavior describes those forms of response which are relatively intense, random, unusual, disorganized, and indiscriminate. A person is emotional when he is in a stirred-up condition.

Subjective and objective aspects of emotion. Emotional behavior has two different aspects.

1. Subjectively, the individual is disturbed. He is aware of feeling of excitement; he is aware of increased tension in his muscles; and he is aware that his customary acts are disrupted and disorganized.

2. Objectively, the emotionally aroused individual may be observed to do acts which are different from his ordinary manner of behaving. He shows his disturbance by his facial expression, by his postures, by loss of motor co-ordination, as well as by other actions. He may shiver, laugh, cry, run, whisper, or yell. Even when he tries to hide the obvious manifestations of an emotional experience, inadvertent acts may disclose his agitation to the critical observer.

Emergency aspect of emotional activities. Behind these two aspects of emotion, the subjective and the objective, there is a deeper significance which arises from the reasons for emotional activities. When we view emotional behavior in its most primitive aspects, we may say that a person is emotionally aroused when he is faced by an emergency. If an individual has an adequate response for his present situation, his behavior is likely to be precise, mechanical, and orderly, that is, not emotional. In proportion to the extent to which elements are introduced for which he is unprepared, which are unfamiliar to him, for which he has no ready response, or which are a threat to his safety, he

must digress from mechanical, habitual, and orderly reactions. He does something different but, at the same time, he manifests considerable uncertainty as to just what he should do, or how intensely he should act.

All the terms that we have used to define emotional behavior are relative. There is no point that separates clearly the mechanical act from the haphazard act, the habitual from the nonhabitual, the orderly from the disorderly, the precise from the inaccurate act. There is no sharp distinction between tension and relaxation, between order and disruption, or between mild and excessive feeling tone; hence, it is futile to attempt to determine whether any specific activity is emotional or nonemotional. It would be safer to assume that there is some emotional aspect to all conduct and devote our efforts to determinations of the degree of emotionality in any particular situation. For a person to be entirely free from the emotional aspects of conduct would imply that he is perfectly adjusted. Since no living being is perfectly adjusted (life is a process of continual adjustment), the act with no emotional aspect becomes an absurdity.

Emotional patterns. Emotions may be classified (a) in terms of the situation which produced the activity; (b) in terms of the subjective experiences of the individual; or (c) in terms of the outcome of his behavior. Most of the terms we find commonly used imply a mixture of these three factors. For example, fear might be thought to indicate a certain subjective experience—the individual feels afraid. Nevertheless, to state that a person is afraid implies that he has experienced contact with some threatening situation (either real or imagined), and furthermore that he has not successfully met that threat. Anger implies a subjective experience; but it implies also that there is a frustration which the individual is actively resisting in some manner.

As soon as we attempt to give an emotion a name or to classify it, we encounter insurmountable difficulties. The main reason for this situation is that emotional behavior is dynamic and classifications are static. The only escape from this dilemma is to forgo all attempts to evolve a rigid classification and to be contented with a description of the dynamic aspects of emotional behavior.

For example, the use of motion-picture analysis has made possible the description of a *startle pattern* which might well be substituted for such an abstract concept as fear. When infants are stimulated by the sound of a pistol shot, they have been observed to show a pattern of behavior which includes various combinations of the following: shutting of the eyes; distortion of the features; a forward movement of the head; a raising and drawing forward of the shoulders; abduction, forward elevation, and inner rotation of the upper arms; a bending of the elbows; a pronation of the forearms; clasping of the hands; contraction of the abdomen; a forward movement of the trunk; bending of the legs at the hips and knees; and random foot movements. All this is merely another way of saying that when the infant is confronted with a sudden stimulus for which he has no ready or adequate response, he reacts with many of the movements of which he is capable. Apes and monkeys as well as experienced adults show a similar combination of bodily movements to the firing of a pistol shot. [24]

If we proceed on the basis of such descriptive studies, we are almost forced to the conclusion that there is but one basic emotional pattern, which rests on the interaction of two opposing mechanisms. There is excitement, which leads to some variation of the startle pattern when one is confronted with a sudden, violent, or novel stimulus; and a tendency to relax when events move in a routine, mild, and familiar manner. Differentiation is possible only in terms of changes in the significance of the stimulating situation, in terms of some habitual way of responding to such stimuli, and in certain attitudes toward the outcome of the whole situation.

Emotions may, then, be differentiated on the basis of degree of disruption involved. In ordinary activity, for example, there is a minimum departure from habitual rhythms, orderliness, precision, and relaxation. Such calm behavior might be classed as nonemergency, or normal, behavior. At the other extreme of this continuum we have the activity resulting from major shocks, such as the exploding of a shell in a trench next to a person. Such major shocks may lead to extreme motor activity, a marked loss of co-ordination, or even physical collapse. Between these two extremes are all degrees of disruption. There may be medium

shocks, which could be precipitated by the slamming of a door or by some other sudden stimulus which is recognized almost immediately as harmless. Or, approaching the major shock area, there may be the sudden appearance of a real danger, such as the skidding of one's car.

This distinction between mild emotions and shock behavior will gain more significance when we come to discuss the mechanisms by means of which emotional behavior is accomplished. There is a system of organs which brings about an arousal of activity and another opposed system which brings about relaxation. It is probably best to permit the concept of emotional behavior to include both these sets of behavior rather than to call the operation of one set emotional and the other nonemotional. We may conclude that there are two sets of emotional activities which are continually balancing each other; namely, the exciting and the relaxing activities. [43]

PHYSIOLOGICAL PROCESSES INVOLVED IN EMOTIONAL BEHAVIOR

Emotional reactions involve the activities of numerous and diverse physiological mechanisms. Without some conception of the way in which each of these operates and how the different ones interact, an understanding of emotions is almost impossible.

Skeletal motor activity in emotional behavior. Any part of the muscular apparatus of the body may be involved in an excited reaction. A person may run, may fight, may tremble, and in diverse ways use his skeletal muscular apparatus to respond to an emotion-producing stimulation. This is obvious, but it is often overlooked in our interest in the more subtle and evasive internal tensions and subjective feelings that go with many emotional situations. Instead of overlooking these skeletal activities, we should keep in mind that the ultimate emotional response is an overt act designed to deal with the emotional stimulus. A great many processes may be set off by some threatening situation, but these may all be regarded as contributing to the main response, which is a skeletal reaction to the objective situation. Excited behavior is essentially one aspect of a complicated adjustment process, and the fact of greatest significance is to get a complete perspective of this process and not limit our view to the subjective experience. It may be important to know that a person is afraid,

but it is also important to know what the person is doing about the situation causing the fear. It is a mistake to ignore the overt behavior of a person in any study of his emotional experiences.

Visceral emotional reactions. When there is an absence of emotional excitement, that is, when there are no emergencies to be confronted, the internal viscera maintain regular rhythmic movements in their essential function of carrying on the metabolic processes of the body. These organs are composed essentially of smooth muscles whose period of contraction is much slower than that of skeletal muscles. These smooth muscles are very much involved in emotional situations. However, the sensations arising from visceral activities are so vague that they cannot be localized with accuracy.

Glandular reactions in emotion. A number of duct glands are influenced by emotional situations. The salivary glands secrete lavishly during emotional calm and diminish in their activity (so that the mouth becomes dry) during excitement. The tear glands may be stimulated during certain emotions, and may be inhibited in others.

The most significant glandular reactions during excitement are the reactions of the endocrine glands. These glands secrete hormones which are discharged directly into the blood stream and, in turn, produce striking physiological effects upon various organs in widely different parts of the body. For example, thyroxin has a marked effect upon the basal metabolic rate of the body.

The autonomic nervous system. The way in which these different mechanisms combine in emotional behavior is most interesting and explains many of the apparently queer reactions that the emotionally aroused person performs. This co-ordination of activity is controlled by the autonomic nervous system [11]

The entire nervous system is usually regarded as being composed of two general parts—the skeletal system and the autonomic system. The skeletal system (also called the cerebrospinal system) has its centers located in the skull and in the spinal column. It receives fibers from the sense organs and sends fibers out to those muscles which move the bony framework of the body. It will be studied in some detail in a later chapter.

The autonomic nervous system has its centers, or ganglia,

outside the skull and spinal cavities. Nerve fibers come from the cerebrospinal system to these autonomic ganglia and carry messages in one direction only, that is, from the cerebrospinal centers to the autonomic ganglia; all messages to the autonomic system must come by way

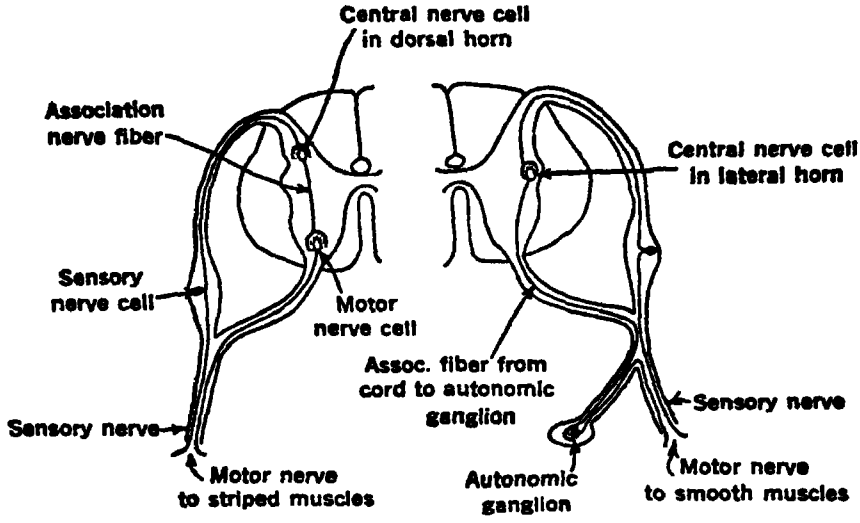


FIG. 25.—Schematic illustration to show the comparison of the ordinary skeletal reflex (left) with the autonomic reflex (right). In the ordinary skeletal reflex the impulse comes through the sensory fiber to the center in the dorsal (rear) part of the cord, is transmitted by means of an association fiber to a motor cell, and is carried out along a motor nerve to some muscle. In the autonomic reflex, the sensory impulse comes in through the dorsal part of the cord to the lateral horn of the gray matter in the spinal cord. From here an association fiber carries the impulse to the sympathetic ganglion, outside the spinal cord, where it makes connection with the smooth muscles.

of the cerebrospinal system. The fibers from the autonomic ganglia go direct to the internal organs of the body, such as the stomach, intestines, heart, various glands, and the muscles around the hairs in the skin; that is, to all smooth muscles. In brief, the skeletal system controls those muscles which operate the bony framework of the body, whereas the autonomic system controls those muscles which operate the internal organs. The skeletal

centers receive messages from the sense organs; the autonomic system receives messages only from the skeletal centers.

The way in which these two systems function is illustrated in Fig. 25. In the left part of the diagram is shown an ordinary skeletal reflex mechanism. A sensory nerve conducts the nerve impulse from a sense organ into the neural center in the spinal cord. Here there is an association fiber which conducts this incoming sensory impulse to a motor nerve cell, and the motor fiber then conducts the impulse out to some striped muscle. Such a simple mechanism is called a reflex mechanism. (In actual life simple processes of this kind never occur in isolation, but it is convenient to abstract such a simple elementary process to clarify our thinking.) On the right side of the diagram is illustrated what happens when an autonomic ganglion is involved. The association fiber carries the nervous impulse to an autonomic ganglion outside the spinal cord and from this ganglion the nerve impulse proceeds to the smooth muscles and glands.

The general arrangement of the autonomic system is illustrated in Fig. 26. It is conventionally divided into three segments: (1) the cranial segment, which embraces those ganglia in the head region; (2) the thoracic segment, also called the sympathetic segment (as well as the thoracicolumbar), which embraces those ganglia in the central region; and (3) the sacral segment, which includes those ganglia in or near the pelvic region.

Some writers, probably the majority, combine the cranial and sacral into one group and consider the whole system as having two separate parts: (a) the sympathetic system, which corresponds to the thoracic or central region, and (b) the parasympathetic, or cranial and sacral regions. This latter grouping has in its favor the fact that evidence seems to point to balanced interaction between the sympathetic and parasympathetic.

The functioning of the autonomic system in emotional activities. There is reason to believe that the sympathetic segment (that is, the thoracic, or central, segment) is concerned with emergency functions of the organism, and that the parasympathetic segment (comprising the cranial and sacral segments) is concerned with routine physiological activities. A review of the behavior of these two segments will pave the way for a clearer

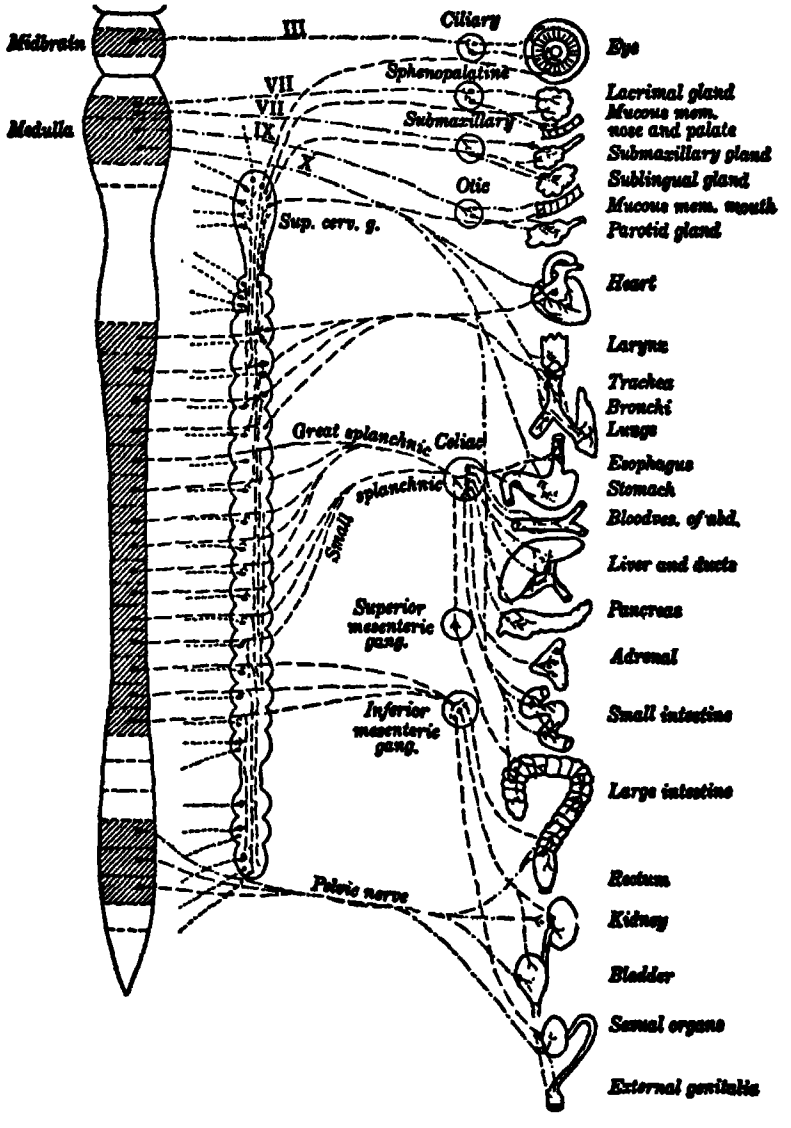


FIG. 26.—General plan of the autonomic nervous system. The part to the left represents the spinal cord extending up to the midbrain. The area immediately to the right of the cord represents the main sympathetic ganglia. The organs depicted to the right are the essential organs influenced by the autonomic nervous system.

understanding of the way an individual behaves in various emotional activities.

In emotional excitement it is important that widely scattered parts of the body act in collaboration. The fact that fibers run directly from the sympathetic ganglia to widely scattered parts of the viscera makes for immediate and widespread control. This wide distribution makes possible the following effects on organs served directly by fibers from unified centers: constriction of the small blood vessels of the abdominal organs, skin, and other parts of the body; acceleration of the activity of the heart; increase in the secretion of the sweat glands; the inhibition of the activity of the smooth muscles of the gastrointestinal tract; the liberation of blood sugar from the liver; the acceleration of breathing; the dilation of the pupils; the retraction of the eyelid and a projection of the eye forward, causing the wide-open bulging eye so characteristic of strong emotion; the stimulation of the smooth muscles around the hairs (making the hair to stand up or forming goose pimples); an inhibition of salivary and gastric secretions; and the stimulation of the secretion of adrenalin by the medullary (central) portion of the adrenal glands.

All these activities have the common characteristic of being emergency functions. The effects are to mobilize energy and to provide methods for its ready utilization. Stimulation of the sympathetic segment leads to an increase in the available supply of blood sugar in the blood. It slows up or stops unnecessary activity in the digestive system. Circulation is modified so as to supply extra food and oxygen to the parts needed to carry away the waste products of metabolism more effectively. This is accomplished by acceleration of the heart action, constriction of the blood vessels not needed in the emergency (the digestive system), more active breathing and sweating. The sympathetic segment of the autonomic nervous system acts as a unit, and thus mobilizes all these forces, in such emergency situations, as: pain, asphyxiation, emotional excitement, vigorous muscular exercise, exposure to cold, and states of lowered blood sugar (hypoglycemia). The fact that emotional excitement and damaging circumstances produce the same physiological results is strong evidence in favor of regarding those emotions which affect the

sympathetic segment of the autonomic nervous system as emergency activities. [10]

This emergency function of the sympathetic segment differentiates it most strikingly from the parasympathetic system. The parasympathetic is able to exert its effects upon single organs without, at the same time, affecting other organs, whereas the sympathetic calls a great many organs into violent activity in a relatively unselective manner. The parasympathetic system is parsimonious, whereas the sympathetic is extravagant.

It has been experimentally demonstrated that the sympathetic segment is necessary in emergency conditions but that an animal can get along very well without it if he is shielded from emotional stimulation. [12] The surgical removal of the entire sympathetic system causes no striking alterations of the body. A number of animals have lived in good health for over a year after such an operation and, so long as they are kept under quiet laboratory conditions, they show no deficiencies in behavior. On the other hand, when such animals are confronted with some stressful situation they are at a decided disadvantage. In cold weather, they lose heat rapidly, and have a low body temperature. When threatened with some danger, their blood sugar does not rise, their hair is not erected, there is no rise in blood pressure, no great acceleration of the heat rate, no increase of secretion of adrenalin to hasten blood coagulation and to abolish the effects of fatigue. Although they show typical signs of aggression when confronted with an enemy, that is, they make the customary skeletal responses, they cannot summon the visceral support, which is under sympathetic control. Similarly, a cat which has been deprived by surgical operation of the sympathetic segment will be unable to erect its hair when confronted by a dog.

DESCRIPTION OF EMOTIONAL ACTIVITIES

Now that we know something of the physiological processes involved in emotional behavior, we may be able to sketch typical emotional patterns.

Nonemergency behavior. The greater portion of any individual's time is spent in conditions of relative calm, without any need for emergency behavior. Subjectively a person experiences a passive type of happiness which may be in marked con-

trast with some preceding condition of violent emotional tension.

Objectively such a person appears relaxed, his movements are usually co-ordinated, free from tension, and relatively slow. His voice is relatively low in pitch and his flow of words suggests poise. His autonomic nervous system and the viscera and glands which it innervates are functioning in an efficient manner. There is a steady output of nervous energy which keeps the body in a state of even tonus. There is a sustained contraction of the blood vessels, the pulse is regular, the pupil becomes smaller than during periods of excitement and the eyeball tends to recede in its socket, the digestive processes proceed efficiently with strong peristaltic action of the stomach and intestines and free flow of digestive secretions, the smooth muscles of the skin relax and the skin texture becomes soft.

In short, the individual is in a condition of vegetative happiness. This state is a relief if the person has just been through some violent experience. Ordinarily, it is sooner or later interrupted by some environmental stress or some internal conflict. The average person, however, does not attempt to maintain such a vegetative calm for too prolonged a period. He has learned to enjoy emotional turmoil just as keenly as he enjoys intervening periods of emotional calm.

Various aspects of emergency behavior. Emergency behavior is never simple. Even in its early appearance in an untrained child it is complicated. It becomes still more complicated with experience.

An emergency implies exposure to a situation that is unexpected, violent, or contains some factors to which the individual has no means of quick or easy adjustment.

1. There is a change in the overt skeletal reaction. This is the sort of behavior we have already described as trial-and-error behavior. The individual departs from organized and habitual reactions and makes random movements, usually increasing the violence and speed of his reactions.

2. There is a stimulation of the sympathetic segment of the autonomic nervous system. This stimulation leads to the combination of visceral and glandular effects which we have already outlined.

There have been some interesting speculations as to how

and why a violent stimulation affects the sympathetic segment so strikingly. One older theory maintains that stimulation of the sympathetic segment in intense emotional situations is due to an overflow of neural energy when such energy cannot find an adequate outlet in normal skeletal reactions. In response to a mild stimulus a few reactions are usually made by a combination of skeletal structures which unite in a co-ordinated act. With more stimulation, such a response cannot take care of all the energy and so it spreads to other larger muscles and those not usually involved. When even a widespread skeletal reaction is incompetent to take care of all the energy generated by the exciting situation there may be a further overflow which brings about involvement of the autonomic system.

A more recent theory is that of chronaxie. According to this theory, the pathway that a neural stimulation takes is determined by the relative chronaxie of the possible pathways. [45] Chronaxie is the index of excitability of a tissue. It is found in this manner: The minimal current needed to excite the nerve is determined. Then a current twice this strength is applied to the same nerve and the time needed for the nerve to respond to this current (which is twice the threshold strength) is found. The length of time that this current must be applied to get a reaction is called the chronaxie of that nerve.

It has been found that the nerves of the cerebrospinal system (those going to the muscles which move the bones) are much more sensitive than the nerves which lead to the sympathetic ganglia (those affecting the smooth muscles of the viscera). With stimuli of minor intensity the easiest pathway will be to the skeletal musculature, a relatively small portion going to the sympathetic segment of the autonomic system. With an increase in intensity the more resistant sympathetic pathways may be made to function. [45, p. 13]

3. The activity of the sympathetic mechanisms reinforce skeletal activity. The various emergency functions of the sympathetic segment supply energy for violent activity by the whole body. Vegetative processes are slowed down or stopped and the bodily forces are mobilized for intense activity. These adjustments require much more time than do skeletal acts. Hence, while the first skeletal responses to an emergency are soon made, the

surging up of reserves takes considerable time. Smooth muscle reacts much more slowly than skeletal muscle, and it takes still longer for the ductless glands to become active and to affect the organism through the influence of the hormones secreted. It is this difference in time that gives emotions some of their most striking characteristics. After the initial stimulus has come and gone, perhaps, the individual stimulated becomes aware of the surging up of tension, and of changes in a great many physiological processes.

To summarize the situation briefly: An individual is confronted with some situation and responds with the mechanism

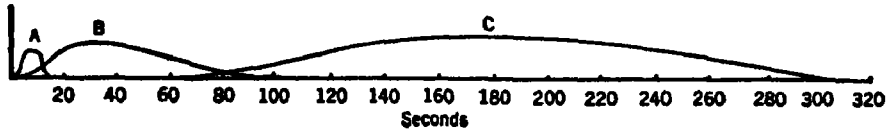


FIG. 27.—Curves showing time relationships between (A) skeletal, (B) visceral, and (C) glandular components of emotional reactions. All three are initiated by a stimulus acting at the extreme left. The skeletal movement is completed while the visceral movement is getting started and long before the glandular reaction becomes manifest. The height of the curve represents degree of excitement.

that is capable of the quickest and easiest reaction. This is the cerebrospinal skeletal system. If such a reaction is completely adequate, the situation is no longer an exciting stimulus for the individual. If such a simple skeletal action is inadequate, those centers which offer a higher resistance to stimulation also respond; namely, the sympathetic centers. As shown in Fig. 27, the smooth muscle and glandular reactions require much more time to manifest their influence; hence, emotional behavior based upon their activity appears with relative slowness. In fact, these may be reaching their peak of activity long after the original emergency has passed. Hence, we have the anachronism of getting ready to deal with an emergency long after the crisis has passed. These considerations have been checked by the experimental observation of animals in the laboratory. Emotional tensions in animals have been observed to persist for as long as twenty minutes after they received the emotional stimulation.

These time relations have led to some erroneous interpretations. Because overt behavior comes quicker than visceral reactions, it has been thought that the skeletal activity caused the visceral response. The preceding discussion should make clear the fallacy involved in such reasoning. The emotional stimulus sets off the entire emotional pattern, including the skeletal reaction, the smooth muscle response, and the reactions of the endocrine glands. The internal responses are just as much a response to the original stimulus as are the skeletal reactions. The reason they come later is because they require more time to function. The older theories were based on the old fallacy which assumed that, if one event preceded a second event, it was a cause of the second event.

4. There is a subjective aspect to emotional experiences. The subjective experience of emotion is probably dependent upon a number of elements of the total emotional pattern. An individual is certainly aware of the overt activity in which he engages. The first overt response he interprets as a reaction to some specific exciting situation. The change in visceral activity and the other aspects of autonomic function he can discern in the form of visceral tensions, changes in general tonus, and in changes in metabolic processes. While there has been a tendency in the past to identify these subjective experiences with emotion, and to exclude the skeletal adjustments, such a limited conception is not warranted. To hit an enemy is certainly as integral a part of an emotional adjustment as the feeling of tension in the pit of one's stomach.

VARIOUS ASPECTS OF EMOTIONAL LEARNING

While an adult's emotional reactions should be different from those of an infant, some adults are relatively immature emotionally. Just as one may find adults who are incompetent to use language, to read, to operate a typewriter, to hit a target, or to perform a problem in algebra because of a lack of adequate training, so one may find adults who fly into a useless rage at the slightest thwarting, who scream with terror at the sight of a harmless insect, who tremble at a peal of thunder, who hide from people, or who literally collapse at the slightest discomfort because of a lack of emotional education. Furthermore, much adult

conduct called emotional is far removed from anything that might be described as emergency behavior. Starting with a common origin, various lines of development may be traced which eventuate in various kinds of behavior having little to relate them, except a common origin.

Learning better methods for meeting emergencies. Since the usual cause of primary emotional behavior is some threat, some thwarting, or some emergency, the most logical improvement in emotional behavior would be the development of better means for meeting emergencies. That is to say, the most rational type of emotional learning is learning to make more efficient overt reactions to the objective situation which made emotional behavior necessary. We do not improve our fears; instead, we learn better ways of dealing with those situations which make us afraid. We do not improve our angers; rather, we learn to deal intelligently with the situations that made us angry. The presence of an emotional pattern is evidence that the best overt adjustment has not been made. We should learn to substitute skilled, intelligent reactions for the disorganized behavior which characterizes emotional behavior.

However, the substitution of a completely mechanical, unemotional, or habitual reaction for previous emotional activities should not be construed as evidence that the individual has made the best social, moral, or economic adjustment. It is easy to find a person who is completely complacent in the performance of an inefficient or immoral act. The elimination of emotion by overt adjustment means adjustment from the individual point of view. To increase the efficiency of a person who has got into a rut, it is often necessary to upset his complacency, to get him maladjusted, that is, to make him emotional, so that he may be incited to do something different from his routine performance, and possibly do a better performance. Motivation, as we have seen, is often a disruption of the complacency of an individual.

Observation of rats in an experimental situation has verified the fact that there is an inverse relationship between emotionality and stereotyping of behavior. Emotional rats manifested greater variability than relatively nonemotional animals running in the same maze. If, through definite direction, the animal can be made to avoid emotional stimuli, he will develop stereotyped be-

havior; if an emotional stimulus cannot be avoided, the animal will manifest more variability of behavior. [23]

Learning to disguise emotional behavior. Because of conventions, social pressures, and because frank emotional behavior places us at the mercy of our enemies, or because of self-deceit, we soon learn that it pays to refrain from undisguised emotional expression. For example, the girl who guilelessly makes evident her love for a boy places herself at a social disadvantage. We must learn to mask our emotions if we do not wish to be ridiculed and victimized.

The forms that such disguises take are exceedingly numerous. (a) A person may react to an indifferent situation in order to conceal the fact that he is really being influenced by another. (b) One may attempt to refrain from all emotional expression, giving himself away only by inadvertent movements which he cannot control. (c) Another may manifest one type of emotional behavior in order to cover a tendency to react in another manner. For example, hateful behavior may really be a cover for love. [42]

The display of emotions to influence other persons. A child does not progress far in his life before he learns that other persons respond more readily to him when he manifests some emotion than when he remains unemotional in his behavior. Others respond to him when he cries, laughs, pouts, throws a temper tantrum, becomes angry, fights, becomes afraid, loves, hates, and the like. He soon learns to cultivate emotional behavior, not so much because he is biologically or physiologically maladjusted or faced with some emergency situation as because of the way others respond to his expression of emotions. It makes little difference whether the emotion is genuine or not; the important element is whether others act as though it were.

The development of emotions of a child under such circumstances evolves from the close observation of others in order to discover how they respond to his emotional expressions. When the child is closely associated with a person who is sensitive to one type of emotion in others (love, fear, anger, or the like), he tends to develop the behavior which goes with that emotion, because he finds that such behavior influences the other person. The way in which children modify their crying in order to gain their way with other persons illustrates this principle. In the early stages of an

infant's life, crying is one element in the mass activity which follows a maladjustment of any sort. [7] Before the child is much more than three or four months of age, he modifies his crying to the sort of cry that will appeal to those around him. [5]

This use of emotional expression is carried through all aspects of life. The impassioned orator can move his audience more than the collected speaker who deals in abstractions. Zeal is a part of good salesmanship. Tears will gain arguments better than logic. Smiles will often result more quickly in raises in salary than will efficiency. We gain help quicker by manifesting distress than by attempting to do the best we can in an emergency. Since most of us decry the unmitigated shamming of an emotion, most persons try to effect a compromise with themselves by attempting to support expression with a genuine emotion. As long as the emotion is real, it seems to be quite acceptable to utilize an emotion to gain our ends with others.

Expression of emotions for the dramatic effect. The function of dramatic art is to convey a message to the observer. If this end is accomplished, it makes no difference whether the actor actually experiences the emotion he is enacting or not. To be sure, with the inexperienced actor, the presence of a genuine emotion is more likely to lead to effective dramatization than the absence of subjective feeling with entire emphasis upon technique. For example, when children act emotional scenes for motion pictures they are often given a real reason for crying or laughing which may have no relation to the plot. Experienced actors, on the other hand, may become so skilled in their art that they do not need to experience the genuine emotion each time they act a part. In fact, the actor accomplishes more by knowing the conventional way of expressing an emotion than he does by being genuinely emotional.

The cultivation of visceral tensions. In ingrown forms of emotional learning, visceral tensions become an end in themselves; the individual places himself in situations, and acts in such ways, that the visceral tensions become pronounced and lead to no relevant overt behavior. The cultivation of visceral tensions represents a secondary displacement of the original function of emotional behavior, namely, the adjustment to an emergency. Some of the reasons for such displacement are as follows:

1. Some ingrown emotions are cultivated because they are enjoyable. The beginnings of such learning can be observed in a child. He may inadvertently drop a tin plate. The noise frightens him but, after he discovers that no real damage has been done, a smile spreads over his face—he really enjoyed being frightened. Then he proceeds to drop the plate deliberately, showing signs of fright before it hits the floor, and laughing with glee at the sport of experiencing fright.

Adults achieve the same end by means of some of the devices found at amusement parks—being dropped in a parachute, being twirled around, having the floor suddenly drop, and the like. Daredevil, reckless stunts achieve the same end. Of course, these may be done for the benefit of the onlookers, but in many instances they are executed because the actor wants a thrill for himself. If he did not enjoy it more than the audience does, he would not be likely to continue for long.

The same process is found in more sophisticated form in such activities as reading novels, going to plays, visiting art exhibits, listening to fine music, and the like. These are all socially approved forms of ingrown emotional behavior.

In most spheres the cultivation of internal tensions does no particular harm. In certain social situations, on the other hand, this emphasis often precludes a successful adjustment. For example, the adolescent may sit around studying his tensions, wondering "if this is love." When someone comes along who succeeds in making him feel good he believes he has found love. He fails to find the real social adjustment which comes from making overt adjustments to others. He loves himself, while believing that he loves another, because that other person makes him feel good.

2. Some ingrown emotions are cultivated as an escape from the need for making an overt adjustment. Failure to deal adequately with an emergency situation accentuates the emotional tensions but, at the same time, the individual is aware that he is acting incompetently and is in a mood to welcome some means of avoiding further active attempts to adjust to the difficulty. Attention to the emotion itself provides a ready excuse for failure to make any further attempts. This is especially easy for one who has been taught that emotions are undesirable and should be con-

trolled. By devoting his attention to his own visceral tensions, such a person attempts to forget the actual emergency which confronts him. Furthermore, this substitution may be effective also as a means of diverting the attention of others from his real difficulty, when it is something he would rather not have known. He talks glibly about his fears, about his worries, about how he must try to control his temper, in order to hide the cause for his fears, worries, or his anger.

Such a device appears foolish when the nature of the emergency is extremely obvious. For example, if a person were confronted with a vicious animal, it would be ridiculous for him to devote his energies to overcoming his fears of the animal. What he needs to do is to deal adequately with the animal.

As long as we maintain the tradition that certain emotions should not be permitted to function there will be a need for such disguises. In some cases they do no particular harm but in others they lead to chronic distortions of behavior and even to pathological mental conditions. The attempt to disguise or to distort overt expression leads to an accentuation of the internal tension even though adults may fail to recognize this relationship in complex situations. It is illustrated by the comment made by a little boy who was badly frightened by a dog and whose father, at the same time, was telling him that he should not be afraid. Finally, he said, "No, daddy, I am not afraid now, but my stomach still is."

3. The fear of emotions often leads to the cultivation of ingrown emotions. Certain individuals become unpleasantly preoccupied with autonomic tensions. For various reasons they feel obliged to eliminate them. They may attempt to accomplish this end by avoiding emotion-provoking situations or by refraining from overt activity which might indicate the presence of the tensions. Attempts to evade in this manner are often unsuccessful. The attempt to avoid emotionally toned situations often ends in giving emotional significance to incidents which ordinarily would be commonplace. The attempt to refrain from overt expression while the aggravating situation remains unchanged often leads to an accentuation of the internal tensions.

Whether the individual cultivates his autonomic tensions because of their pleasurable aspects or attempts to shun them because he regards them as unpleasant, he has distorted the function

of emotional behavior. He becomes preoccupied with his emotions instead of utilizing them as instruments to make better adjustments.

The effect of learning on the total emotional pattern. Whereas emotional behavior has its inception in the need on the part of an organism to adjust to some emergency or to some vital biological need, it may become so transformed as to make such needs appear insignificant. The individual may learn to deal successfully with the objective threats; he may become engrossed in disguising his behavior so that others will not know the struggles through which he is passing; he may learn to cultivate the expression of emotions for the purpose of influencing other persons for personal reasons; he may cultivate expression for dramatic purposes; or he may cultivate his own emotions for the enjoyment they give him, to escape from the dangers of overt adjustments to difficulties, or because of some learned moral inhibition against the emotions themselves. The changes effected by such learning processes may be so great that the resultant behavior bears little resemblance to the original emergency behavior of the infant. We all become adept at emotional distortion, and it becomes difficult to discern when a person is emotional and when he is not.

These facts complicate tremendously our study of the emotional reactions of any one individual. When we find a person who has the habit of showing fear, for example, we cannot assume that he has been exposed to emergency situations which brought out fear reactions in him so repeatedly that fear became a habit. Instead, it could be that he has associated with a fearful individual and through this association learned to imitate the fear behavior. Or, it could be that he learned to enjoy the visceral tensions that go with fear and developed fear behavior for the enjoyment he derived from it.

Certainly, any attempts to change the emotional patterns of an individual should be varied according to which factor predominated in the original learning. For example, suppose a person is attempting to escape from persistent fears. If he developed the fears because he has been exposed to many emergencies, he could be taught other ways of dealing with emergencies. If he developed the fears because he enjoyed the visceral tensions which go with fear, he could be taught other ways of enjoying himself. If

he learned to fear because his mother was responsive to his fear behavior, he could be taught other ways to influence his mother, or he could be made to associate with others who were not responsive to fear behavior.

It follows that it is not possible to judge the significance of an emotional act by a study of the act alone. For example, the fact that a person is crying tells one little about the significance of the crying. He may be crying because his eyes have been irritated by a bit of dust; he may be crying because he has suffered a bitter disappointment; he may be crying because he is extremely happy; he may be crying because he has been thwarted by some person; he may be crying because he is in love or because he has been disappointed in love; or he may be suffering physical pain. Every emotional action is a unique action and its significance cannot be determined arbitrarily

THE EXPRESSION OF THE EMOTIONS

Who has not been deceived in his attempts to interpret the significance of emotional behavior in others? We discover a person hates us after his behavior had led us to believe that he was kindly disposed toward us. An inner turmoil may be hidden beneath a smooth exterior. Joyful behavior may be a mask to cover sorrow. Has psychology any methods or devices which make it possible to look beneath these conventional masks and to interpret emotional behavior in others?

In judging an emotional activity it is almost impossible to separate the different aspects of the subject's behavior. (a) Some of it is essentially the subject's attempt to make an adaptive adjustment to the difficulty. (b) Some results from the autonomic activity and shows itself in such behavior as changes in breathing, pallor, flushing, and the like. (c) Some shows itself in what may be called by-products of the situation; namely, in-co-ordination, tremors, and apparently inane activities. [13]

Interpretation of overt emotional behavior of infants. The interpretation of the emotional reactions of infants and young children should be relatively simple owing to the fact that they have not learned how to disguise the real meaning of their acts. Experiments have shown that the problem is not so easy as it appears at first glance. The scientific advantage of the simplicity

of the behavior of infants has been destroyed, at times, by interpreting the child's behavior as one might that of an adult. For example, if a child acts in a manner similar to that of an adult who is angry, we have no warrant for assuming that the child is angry. If the child acts toward his mother in a manner similar to that of an adult who is in love, we may be entirely in the wrong if we assume that the child is loving his mother.

1. *The attempts to interpret emotions by tracing them to unlearned emotional patterns have not been fruitful.* Some earlier psychologists thought that a neonate (a newborn child) could manifest emotions, such as the following, without any learning on his part: fear, anger, disgust, tender emotion, distress, lust, curiosity, feelings of subjection, feelings of elation, feelings of loneliness, appetite or craving, feelings of ownership or possession, feelings of creativeness, and amusement. [6] The best reason for rejecting the view that the child is born with such emotional patterns is that they cannot be found. Close observation of infants by one group of observers seemed to give evidence that three emotions were manifested: rage, fear, and love. Fear seemed to be elicited by loud noises or by loss of support; rage seemed to be evoked by restraint of movement; love seemed to result from stroking and fondling. The other eleven emotional patterns in the list just cited were strikingly absent. While these observations led to a radical departure from what had been more or less widely accepted, more careful experiments have thrown doubt on the presence of even these three original emotional patterns.

2. *Interpretation demands knowledge of stimulus as well as infant's reactions.* The emotion of an infant cannot be identified correctly by the kind of behavior he manifests. One experimenter took motion pictures of infants after they had been stimulated by four different kinds of situations; (1) hunger resulting from deferred feeding; (2) sudden dropping through space calculated to arouse fear reactions; (3) the pricking with a pin to arouse pain; and (4) active restraint of movement of the head, designed to produce anger. These pictures (eliminating any part that would suggest the nature of the stimulating situation) were exhibited to college students. These observers were informed that the stimuli were limited to the four enumerated, and were

asked to judge whether the behavior shown in the pictures was the behavior pattern of hunger, pain, anger, or fear. Half the observers called hunger pain, a quarter of them called hunger rage. Less than a third of the observers named the behavior after restraint of the infant's head as anger, and almost as many called it pain. In short, the observers could have guessed at random and have replied almost as accurately as they did by inspection of the pictures. When they were permitted to see the situations which gave rise to the behavior they judged more correctly. That is, when the observers had knowledge of what caused the behavior, they named the emotion in accordance with what they thought it should be under the circumstances. [43]

This inability to judge correctly the significance of emotional behavior in infants may be interpreted in two ways: It may be argued that the results depend largely upon defective judging ability on the part of the observers. The second possibility seems to be the more correct one; namely, that infants vary so much in their emotional reactions that consistent interpretation is impossible. Emotional behavior is judged more by the situation to which the individual is reacting than by the particular form of behavior that he adopts in meeting that situation. We call angry behavior anything that a person does when he is thwarted. We say he is afraid when he is confronted with a difficulty so overwhelming that he can make no adequate response.

3. *The emotional activities of infants have meaning if they are regarded as varied and changing attempts to adjust to emergency situations.* An infant's responses to emotional situations are likely to be random and nonspecific, varying in intensity somewhat in proportion to the challenge inherent in the situation. His responses are likely to be either aggressive or docile. Docility may be the consequence of situations which seem to offer no challenge, such as mild tones, soft touches, rocking movements, and the like. Aggressiveness is likely to be the reaction to violent situations. A retreating response which may superficially resemble docility is likely to occur when the child has made an attempt to meet a challenge by aggression and has failed. Such a response may come initially when the infant is confronted with a situation so sudden or so violent that any aggression is overpowered at the first instant. Instead of naming these three forms of behavior

rage, fear, and love (which involves reading adult feelings into them), it would be well to consider them as crude classifications of reaction to situations with varying amounts of challenge. In a soothing situation, an infant tends to relax and go to sleep; in a challenging situation, the infant tends to increase his motor responses in an unpredictable manner; in a situation that is overwhelming, the infant manifests violent motor activity interspersed with a cessation of behavior but with an increase of tension which shows itself in indirect signs of inner tension and in later overt activity of a still more violent sort.

To summarize: When the observer discerns the situation to which the infant is reacting, he designates an emotion which fits in with that situation. When he sees only the behavior of the infant without any knowledge as to the antecedent circumstances, his judgment of the emotion constitutes a guess as to what the situation was. His guesses are not accurate because the behavior of the infant is so indefinite and variable.

The facial expression of emotions. It is common knowledge that emotions are shown in the face, but the degree to which the observer can correctly interpret facial expression has been vastly overrated. The facial expressions of athletes during strenuous competition and after partial collapse from such competition show extreme tensions in the facial muscles during strain and lowered muscle tonus during extreme fatigue and partial collapse. [36] Are there general laws of facial expression?

Variability of facial expressions. Extensive studies have shown that there is a great deal of variation in the kind of facial expression that may be made to similar emotional situations. There is really no facial expression typical of any situation. Furthermore, when the subjects who have been utilized in an experiment with real emotional situations are recalled and are asked to repeat the emotional expression that they had shown when stimulated before, their expressions are not the same. It would seem that the actual expression and the traditional expression are vastly different. It also has been found that most subjects have but two or three facial patterns which they tend to use in all situations whether these situations are designed essentially to call forth pain, surprise, anger, exasperation, crying, disgust, sex responses, or revulsion.

In spite of these variations, no matter how much the expression of an emotion may be inhibited, modified, or intentionally assumed in the social relationships of adult life, there is a language of expression which seems to remain behind these disguises.

Methods used for studying facial expression. This being the case, psychologists have concerned themselves with attempts to determine the way in which facial expressions of emotions are produced, the accuracy with which their meaning can be understood by others, and the way in which skill in such understanding is acquired. The general procedure that has been used has been to give subjects different kinds of emotional stimulations and then to attempt to obtain records of the combinations of expression which they manifest. This reduction of a dynamic process to a static record, or cross section, of that process involves a loss of one of the most significant elements of emotional behavior; namely, the perspective which comes from viewing the entire emotional sequence.

We usually judge an emotion by the features in motion, by the play of expression, and not by any static pose. A motion picture is likely to be more significant than a still picture; a motion picture with sound gives more emotional expression than one without sound; the observation of the whole person in activity is more revealing than a momentary cross section of isolated parts.

Even though admitting this need for complete perspective, investigators have felt that it is necessary to break down the total performance and to study the parts separately.

1. *Drawings.* Various methods have been used to obtain a static representation of emotional expression. The Rudolph sketches represent a pioneer attempt in this field. [41] This collection contains 68 drawings made by a painter who retouched and somewhat idealized them to fit his conceptions of anatomy and emotional expression. He believed that all facial expressions were based on a few primitive types which could be classified as reactions of approach or of withdrawal. Fourteen of these pictures have more recently been selected and incorporated into a test of ability to read the significance of facial expressions. [32]

2. *Facial models.* The way in which the different com-

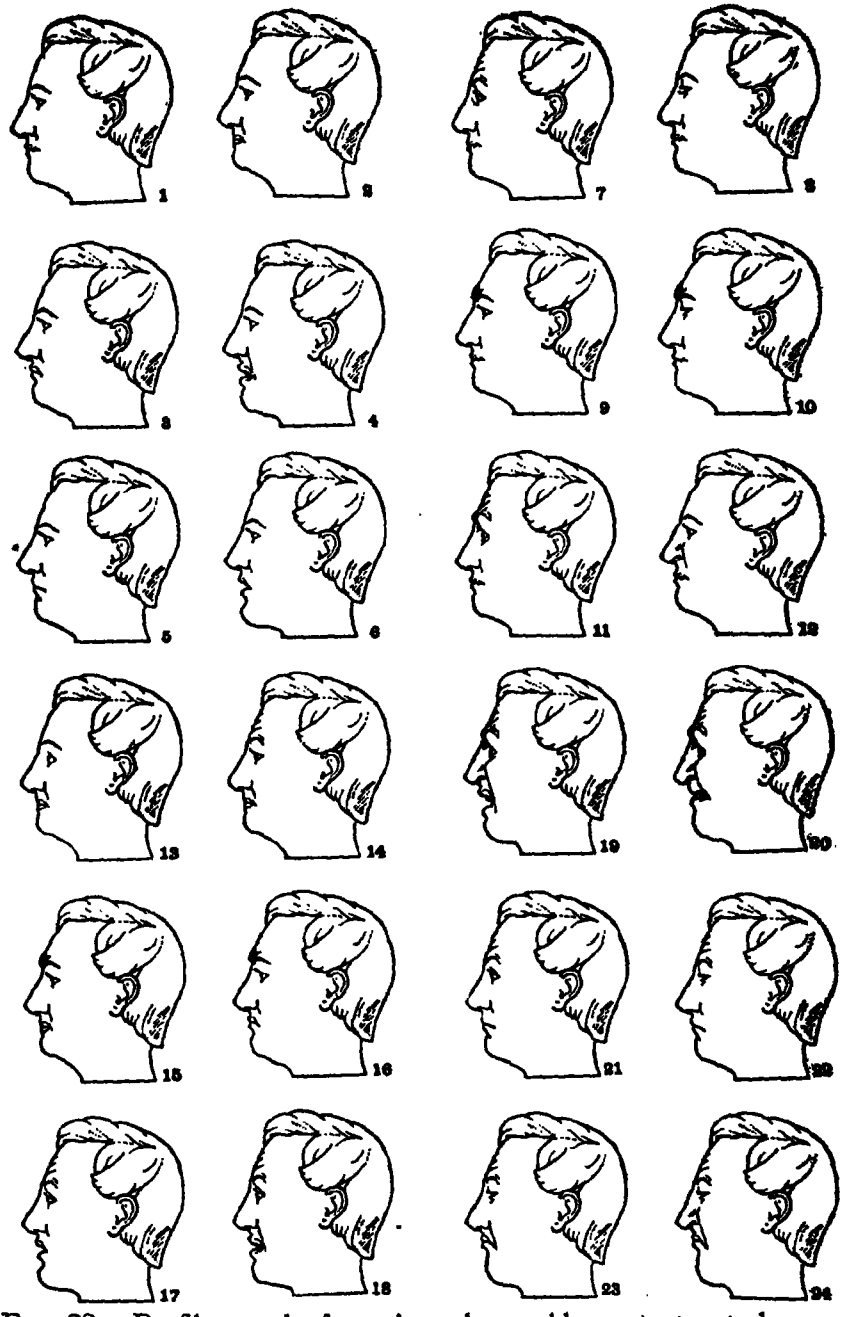


FIG. 28.—Profiles made from interchangeable parts to study emotional expression.

(By permission of E. G. Boring.)

ponents of the face combine to make a total emotional pattern may be demonstrated by means of a model in which the parts may be interchanged. An early form of such a model shows the face in profile and divides it into four parts: the mouth, the eyes, the brows, and the nose. [4] Figure 28 shows twenty-four different emotional expressions produced by an interchange of these component parts.

Profiles constructed from these parts are not recognized by observers as expressing the emotion they are supposed to represent. A profile supposed to represent anger was judged correctly by only 14 persons out of 716, that is, by about 2 per cent of the subjects. A profile designed to express dismay was judged correctly by about 6 per cent. Some of the other profiles fared a little better: one designed to express horror was judged correctly by 57 per cent of the subjects; disgust was judged correctly by 48 per cent; disdain by 34 per cent; and bewilderment by 32 per cent. [9]

Another experimenter showed that the ability to judge the intended expression of these profiles was strikingly improved when the experimenter gave the subject definite suggestions. It would seem that when one is given the meaning of an emotional expression, he reads into the face what he thinks it should mean. [25]

More recently, a facial model has been constructed using front-view parts. [22] The parts used in this model are shown in Fig. 29. By this means the number of variations may be increased and the expressive lines of the face can be made much more pronounced. Even with this improvement, it would seem that the use of such a model should be limited to demonstrating how facial expressions may vary with different combinations of component features, and that it should not be used to test the ability of individuals to discern the significance of emotional expression. [21]

3. *Photographs.* A number of psychologists have prepared sets of photographs taken while subjects were being emotionally stimulated. By this means, attempts have been made to analyze the parts of the face used to express different emotions. [18] Others have taken photographs of persons who consciously posed in an attempt to express certain emotions.

Posed photographs designed to represent different emo-



FIG. 29.—Articulated full-face models of emotional expression

(Courtesy of J. P. Guilford. Manufactured by C. H. Stoelting Co.)

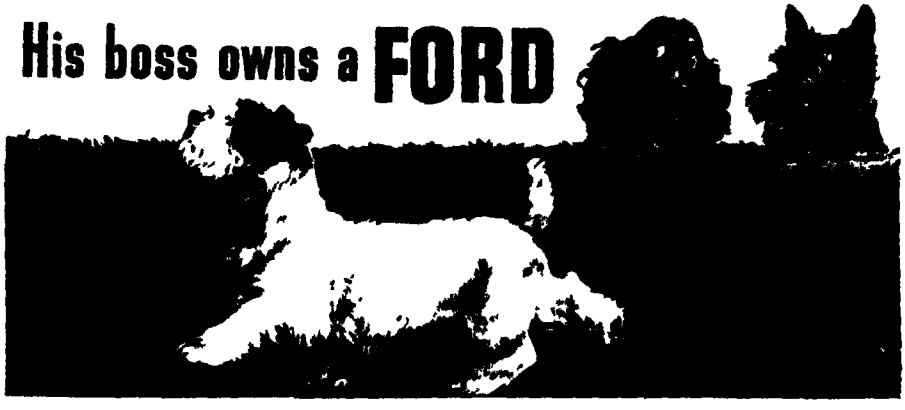


FIG. 30.—Can you mistake the emotions expressed by each of the dogs?

(Courtesy of the Ford Motor Co.)

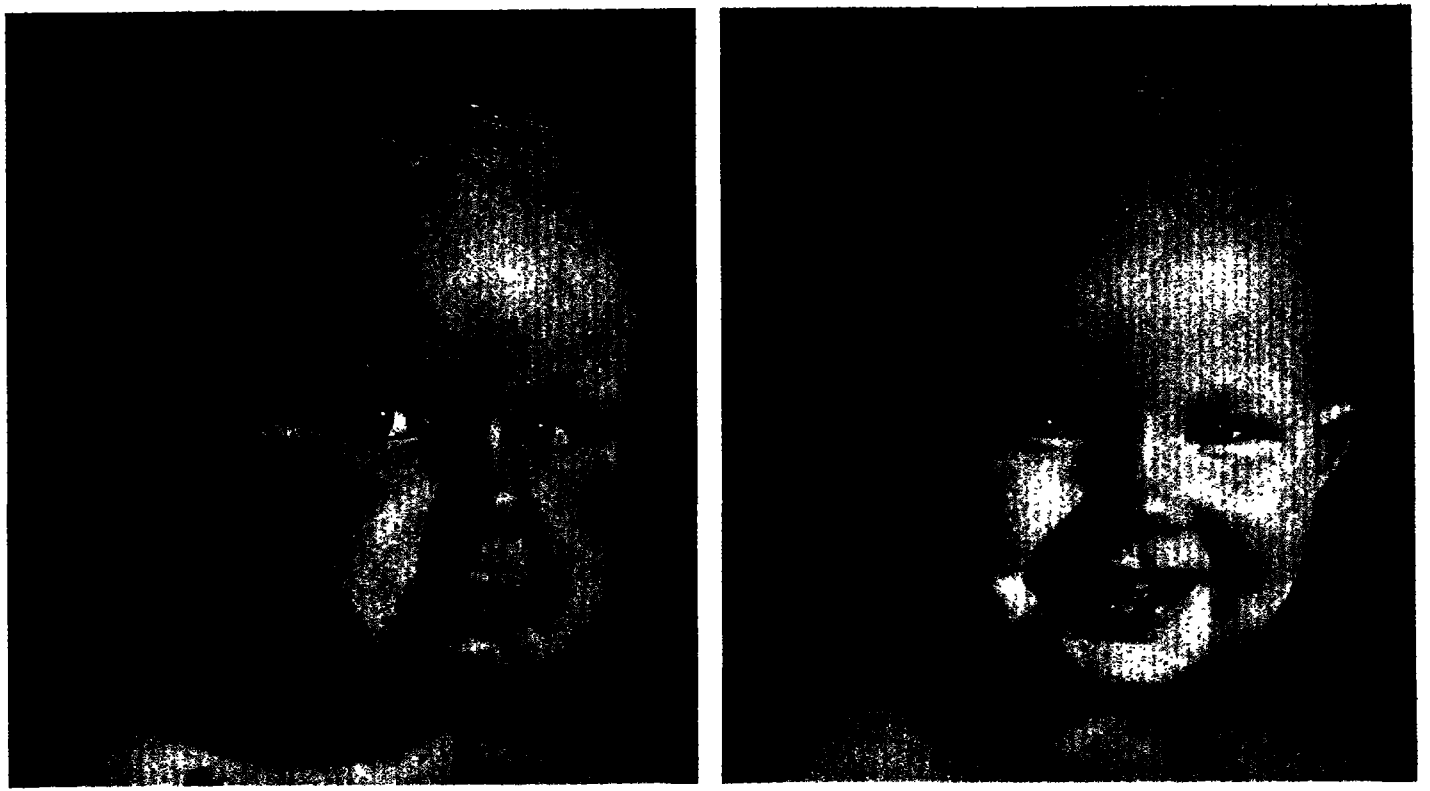


FIG. 31.—Facial expression of emotions. The facial expression in the photograph to the left is the child's reaction to being told that he could not have a certain article. His customary expression is shown in the picture to the right. The meaning of each expression is unmistakable.

(Copyrighted by R. H. Ross.)

tions are judged more accurately than models of drawings. [17] The judge may not get the exact emotion that the photograph is designed to portray, but he is likely to guess correctly within a general area. For example, a photograph designed to express love was judged as love by only 10 per cent of the observers making judgments, but it was judged happiness by 68 per cent of the observers. A photograph designed to express mirth was judged happiness by 51 per cent and mirth by 49 per cent. In other words, observers differ in the fine shades of meaning given to photographs designed to express different emotions, but they agree fairly well in the general type of emotional pattern. [46, p. 251] We may conclude, therefore, that a posed emotion can be fairly well recognized from a still photograph of the actor's face. [27]

There is evidence that the person expressing his emotions through his face learns to conform to conventional forms of expression, and that the individual who attempts to understand the significance of such facial expressions acquires interpretative skill through learning. All individuals tend to use certain muscles, muscle groups, or expressions in the majority of their expressive reactions, to the exclusion of other muscle groups. Most persons are poor actors because they have learned but a few forms of facial expression. There is a language of the face which the good actor must learn. Most of us could say more to our associates by means of facial expression if we studied patterns of facial expression and learned how to use them more appropriately. [29]

Children improve with age in their ability to judge the significance of posed photographs. [20] In one experiment, six posed photographs from a standardized collection were presented to children ranging in age from three to fourteen years of age. It was found that laughter is the easiest pose to recognize and contempt the hardest. Laughter was recognized at three years, pain at five years, anger at seven years, fear-horror at nine years, surprise at eleven years, and contempt at fourteen years. [39, pp. 258-259]

Adults improve with practice in their ability to interpret the significance of posed facial expression. Training on alternate days through a period of ten days increased accuracy by 51 per cent in one experiment. Those who were poorest at the beginning of the training made greater improvement than those who were

good at first, showing that practice tends to produce uniformity of judgments. It also was found that those who make snap judgments based upon the total impression judge much better than those who take an analytical attitude. [21]

Summary of studies of facial expression of emotions. The findings in connection with facial expression of emotions may be summarized as follows: (a) While a posed emotion can be fairly well recognized from the still photograph of an actor's face, the face reveals the significance of emotions best when it is in action, by the play of expression rather than by a static pose. (b) Judgment is more accurate when the entire facial pattern is considered than when an attempt is made to analyze the significance of the various components. (c) While there are great individual differences in the way the face is used to express emotions, there are conventional patterns which the individual learns to use and which observers learn to interpret. There is a vocabulary of the face. It would seem that one could learn to make his face more expressive through training. (d) The conventional facial expressions are quite different from the original patterns upon which they are based. That is to say, facial expressions are used by adult civilized humans more for the purpose of transmitting messages to others than to express their own emotions.

Vocal expression of the emotions. It is a commonly accepted fact that a person reveals his emotions definitely through his voice. Is the voice a primary factor in such expression or is it merely an adjunct to other forms of expression? If the voice is important in and of itself, what qualities of the voice contribute most to its effectiveness?

1. The infant's cry is of ambiguous significance. One experiment with infants shows clearly that listeners cannot tell, from the sound that the infant makes, the significance of his cry. When the cry alone was heard, about one-fifth of the listeners ascribed the infant's crying to colic; whereas, when they saw what had happened to the child to make him cry, none of them mentioned colic, although the sounds were identical in both tests. It seems that the infant does not know how to make himself understood by his crying alone. [43]

2. Meanings of vocal expressions are learned. Another experimenter has shown that school children improve in their ability

to interpret the significance of vocal expression. These children were given the task of interpreting the emotional significance of letters pronounced by individuals attempting to express such emotions as happiness, unhappiness, anger, fear, and surprise. There was an increase in accuracy of judgment with age, school experience, and intelligence. [20]

The analytical study of the voices of singers and orators supports the theory that vocal expression of the emotions is a learned and highly sophisticated art. The impassioned speeches of actors and orators show an unusual mobility and range of pitch in vocal expression; whereas an increase in the emotional fervor of an unsophisticated individual is more likely to result merely in raised pitch or an increase in intensity. [37]

3. The vibrato is a learned technique of emotional expression. Trained musicians manifest a peculiar ringing quality, which is accepted as a form of emotional expression, and which has been called the vibrato. It is a periodic rise and fall in pitch, or a periodic waxing and waning of loudness, or both. The listener often cannot distinguish whether the effect is achieved by pitch or intensity pulsations. The rate of these pulsations is from 5 to 10 per second (usually 6 to 8); and the pitch variations may be from 0.1 to 1.35 full tones (usually between .25 and .85 full tones). The vibrato, so widely accepted as a conventional form of emotional expression, is not a natural reaction resulting from emotion; instead, it must be carefully cultivated and can be perfected only by intensive training. [38]

In short, the use of the voice for emotional expression by adults, and especially by singers and orators, is a highly artificial and specialized performance. Nevertheless, these sophisticated sounds are better understood by the listener than the more primitive forms of vocal expression because civilized man has been trained to interpret them.

THE UNMASKING OF EMOTIONAL BEHAVIOR

Overt emotional behavior is much more easily controlled or disguised than are some of the internal visceral and glandular reactions. While a person may be insulted by a friend and may have the impulse to hit the offender, he may learn to refrain from such overt assault, although he may still have the visceral tensions

and glandular reactions which naturally result from such an insult. It may appear to an observer that the insult is being taken with a good grace, whereas the underlying resentment may be acute. Psychologists have, therefore, been much concerned with devices for detecting the internal emotional responses of an individual when these do not harmonize with observed conduct. Some of the devices that have resulted from these endeavors have not had any practical value, being too cumbersome and intricate for anything but laboratory use. Other devices which seemed impractical at first have turned out to be easily adapted for common usage. We shall describe some of the most common of these devices.

The psychogalvanic reflex. The psychogalvanic reflex (abbreviated P.G.R.) is the change in electrical skin resistance which follows sensory stimulation or accompanies thinking proc-

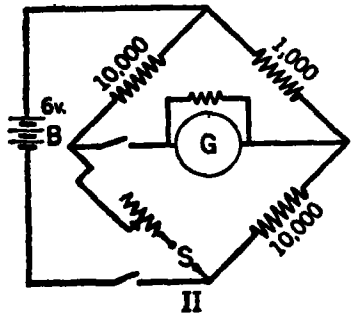


FIG. 32.—Diagram of Wheatstone bridge. The subject is connected in the circuit at S and a balance obtained by changing the variable resistance. After being set in balance, any emotional reaction by the subject will change the balance and the galvanometer needle (G) will move.

esses. Other names which have been given to this phenomenon are: the galvanic skin response (abbreviated G.S.R.), the electrodermal response (abbreviated E.D.R.), the galvanic reaction, the orectic (appetitive) reflex, the general autonomic reflex, and the sympathetic reflex. This diversity of names is indicative of the widespread differences of opinion as to the nature and significance of changes in the electrical potentials of the skin occurring with certain types of nervous activity.

Methods for obtaining the psychogalvanic reflex. By one method this reaction is obtained by attaching electrodes to any two parts of the skin and connecting these through a galvanometer, without any other source of electrical potential introduced into the circuit. With a sensitive galvanometer, it will be found that there is a change in potential, as designated by a movement of the galvanometer needle, with sensory stimulation or with shifts

in mental activity. A second method consists of measuring the resistance of the body by the Wheatstone bridge method. This method is illustrated in Fig. 32.

There is no disagreement as to the fundamental fact that changes in electrical potential do occur under either method. The disagreements that are found have resulted primarily from the fact that investigators have made unwarranted statements about the significance of the reflex.

Psychogalvanic reflex depends upon changes in sweat secretions. The majority of the evidence points to the fact that the electrical changes are the result of changes in amount of secretion by the sweat glands. [46, p. 281] When the sweat gland activity is inhibited by use of atropin, the galvanic skin reactions are abolished or strikingly reduced. Motion pictures taken by means of a microscope show that there is an emergence of droplets from the sweat pores during the psychogalvanic reflex responses. [16] Finally, there is a latent time between the presentation of the stimulus and the galvanic reaction, which would suggest that it is dependent upon some such slow reaction as the secretion of sweat. It is known that the sweat glands are innervated by the sympathetic division of the autonomic nervous system. It would seem, then, that the psychogalvanic reflex is dependent upon stimulation of the sympathetic segment. This has been verified by cutting the sympathetic chain of an animal in such a manner that all sympathetic fibers to a forelimb are severed. Such an operation abolishes the psychogalvanic reflex in the limb.

Stimulation of the sympathetic segment of the autonomic nervous system has other effects than an increase in secretion of the sweat glands. For example, such innervation causes: acceleration of the heart, constriction of the blood vessels, rise of blood pressure, inhibition of digestion, contraction of the sphincters of the bladder and anus, dilation of the bronchi, the liberation of adrenin from the adrenal glands, the liberation of sugar from the liver, the liberation of red corpuscles from the spleen, the erection of hair or the formation of goose pimples, the dilation of the pupils. This combination of reactions occurs in emergency situations. If the psychogalvanic reflex is an indicator of sweat secretions, which is a part of the complex emergency pattern of behavior, it would appear that it might be an ideal index of the

innervation of the sympathetic segment of the autonomic nervous system and thus indicate the operation of emergency behavior, that is, of emotional behavior.

An experimental check showed that there is not absolute uniformity in changes in the constriction of the blood vessels, changes in blood pressure, and the psychogalvanic reflex. [15] It would seem, therefore, that, while stimulation of the sympathetic segment causes a broad combination of responses, these do not occur in exactly the same time sequence or in the same degree. The use of the psychogalvanic reflex as an index of emotional behavior is, consequently, not infallible. In other words, sweat secretion is not the only factor affecting the galvanic skin responses, and emotions are not the only factors affecting the sweat secretions. With these qualifications it may be concluded that it is, nevertheless, a fairly good indicator of innervation of the sympathetic segment of the autonomic nervous system, and consequently of those emergency reactions which we call emotional. [46, p. 284] It has not been found possible to use this reaction to indicate the kind of emotion that a person is experiencing or to give an accurate quantitative indication of the degree of emotional tension. It would seem safe to use the psychogalvanic response as an index that the individual may be experiencing a change in his degree of emotional tensions; but it would also seem to be chasing a phantom to attempt to reduce this response to such definite determinations as when the person had 10 units of fear, 20 units of love, 5 units of anger, or the like.

Respiration as an emotional index. While part of the respiratory apparatus is controlled by the cerebrospinal nervous system and is under conscious control, an essential part of it is controlled by the autonomic nervous system and, consequently, involved in emotional behavior. The smooth muscles control the bore of the bronchial tubes. These tubes open wide in emergency situations, thus reducing the resistance offered to the passage of air to the lungs and supplying the additional oxygen which the body needs when reacting to unusual situations. The diaphragm, intercostal muscles, and abdominal muscles, which are the main respiratory muscles, are controlled by the skeletal system. This arrangement accounts for a very frequent occurrence, namely the autonomic response of the breathing in emergencies with the con-

scious attempt on the part of the individual to control the breathing so that breathing changes will not be apparent to an observer. This dual control of respiration makes it appear probable that respiration would be a good indicator of any conflict between the natural emotional reaction of an individual and his efforts to suppress all evidence of such emotional behavior.

Respiration affects emotional expression in another manner: through vocalization. We all are familiar with the emotional rising of the pitch of the voice in emotion, the choking, the catch in the voice, and the emotional stuttering and shakiness of the voice.

Psychologists have studied the changes of respiration during emotion with this in mind. The study of respiration, along with blood pressure, has been one of cardinal features of the so-called lie detector.

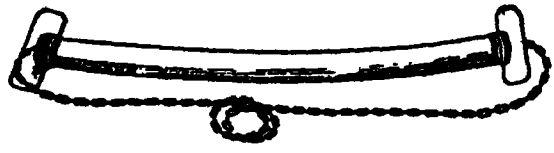


FIG. 33.—The pneumograph. The rubber tube, dilated by an inner spring, is fastened around the body by means of the chain. Breathing movements change the air volume in the rubber cylinder and these changes are carried to a kymograph by means of a tube.

Apparatus used to measure breathing. Various devices have been used to obtain a graphic record of breathing.

1. The girth-recording pneumograph. This pneumograph is essentially a hollow rubber tube that is kept distended by a coiled spring which it surrounds. It is shown in Fig. 33. One end is sealed and the other end connects with a smaller tube leading to a recording tambour. The pneumograph is strapped around the body, around either the chest or the abdomen; or one may be used at each position to record both chest and abdominal movements. When the body expands in breathing, the volume of air in the tube is increased; when it contracts, with expiration of air from the lungs, the volume is diminished. It is this change in air volume which moves the recording arm on the tambour up and down and

thus produces a graphic record (see Fig. 34). This is the type of pneumograph in most common use in psychological laboratories.

2. The breath-current recorder. The subject wears a breathing mask, inhaling fresh air through one tube and exhaling through another. A one-way valve in each tube makes it possible for the air to enter only through one tube and to be exhaled only through the other. A side tube activates a tambour so that the slightest flutter of the valve in the breathing tube is graphically recorded.

3. The body plethysmograph. A plethysmograph is an instrument for recording variations in the size of some part of the body. When such a device is used to record breathing, the subject

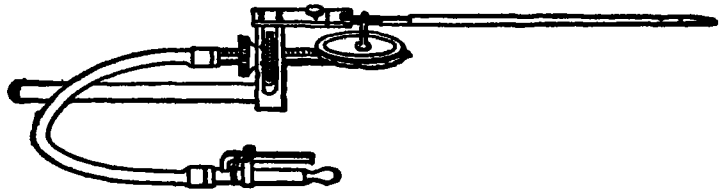


FIG. 34.—The Marey tambour. A device for transmitting changes in air volume to a kymograph by means of a writing lever. The incoming air is carried to the rubber-capped cup. Resting on this cap is a lever connected with the writing arm. Any change in pressure moves the arm up or down.

is seated inside a box with his head protruding from the top and the lid sealed around his neck. The air inside the box changes with the subject's breathing and all these changes are registered by means of a tambour connected with the box by a tube.

Variations in breathing. Breathing may vary in three ways: in rate, in depth, and in form.

1. and 2. Changes in rate and depth. Physical exercise and emotional excitement affect breathing in the same manner, they make respiration faster and deeper. However, the first shock of an emotional stimulus may produce a sudden and temporary stopping of the breathing. There is a catching of the breath. Then there is a speeding up. If the excitement continues for a long period of time there is likely to be a gradual slowing of the rate and a gradual lessening of the depth, which tends to bring it back to the normal rate and depth. Excitement does not persist

at maximum for long periods and this return of the breathing to normal with persistent excitement is merely a bit of objective evidence of that fact.

3. Changes in form. Changes in the form of breathing may well be observed by a study of the inspiration-expiration ratio, or by the inspiration fraction (see Fig. 35). In either case the time consumed in inhaling and the time consumed in exhaling are measured separately. In the inspiration-expiration ratio the

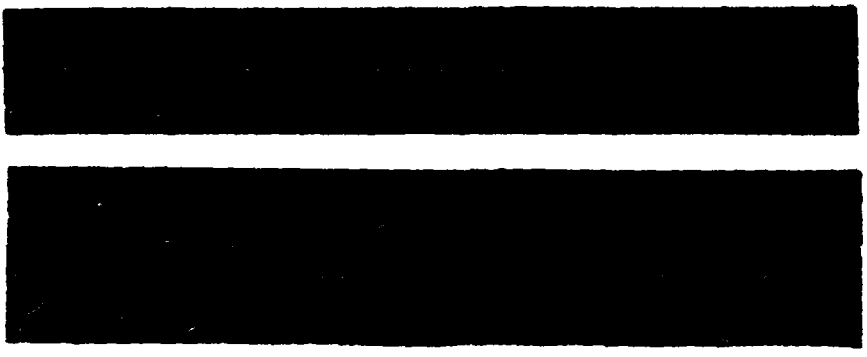


FIG. 35.—Breathing records as affected by tension. The upper curve is a normal breathing curve taken when the subject was relaxed. The lower curve is a record of the same subject when under tension. The downward movement shows quick inspiration; the rising curve, slower expiration.

time taken for inspiration is divided by the time taken for expiration. In the inspiration fraction the time taken for inspiration is divided by the time of the complete cycle. [46, p. 262]

The portion of the whole breathing cycle that is devoted to taking in of air (the inspiration fraction) is very small in singing, while in sudden fright it is very large. The inspiration fraction in certain conditions has been found by different observers to be about as follows: [46, p. 264]

in speech	.16
in laughter	.23
in attentive mental work	.30
in resting conditions	.43
in excitement	.60
in sudden fright	.75

The inspiration fraction has been used in attempts to detect lying. It has been found that the inspiration fraction just before a response is the same whether a person tells a lie or tells the truth. If he tells a lie, the inspiration fraction increases. Since the general conditions which cause such an increase are excitement or fright, it has been concluded that the liar is likely to be excited by his lie and thus manifest the incriminating respiratory change. [8, 31]

Circulatory changes as emotional indices. Whenever special demands are made upon the body, the blood becomes an important agent in supplying those needs. Such function may be accomplished both by changes in composition of the blood and by the quantity of blood flowing through the vascular system. Since chemical analyses of blood involve intricate techniques and consume considerable time, they have not been satisfactory as indicators of quick emotional changes.

Measures of changes in circulation have been more satisfactory. The flow of blood depends upon two factors: the force of the heartbeat and the resistance encountered in the blood vessels through which the blood moves. Therefore, both measures of the rate of heartbeat and measures of blood pressure have been used as indices of the circulatory changes and have proved to have some value in studies of emotional expression.

The heart works automatically but its rate is regulated by two sets of nerves. The innervation from the sympathetic segment of the autonomic nervous system tends to accelerate the heartbeat, whereas innervation from the cranial segment, through the mediation of the vagus nerve, tends to retard or inhibit the heartbeat. Various hormones, likewise, influence the heart action. The most notable of these are adrenin and thyroxin. Through nervous connections in the brain, the heart is responsive also to external sensory stimuli and to certain stimuli from within the organism, such as high blood pressure.

The fact that the heart action is influenced by such diverse factors and through so many media should serve as a warning against any temptation to give a simple interpretation to changes in heart action. In spite of the great amount of work that has been done in an attempt to use indices of heart action as emotional indicators, two of which we shall review, the multiple control of

heart action should provide a wholesome damper against over-optimism.

Effect of emotional stimulation upon heart action. Because the heart is so delicately responsive to many influences, it is not reasonable to expect any close relation between specific emotional situations and some particular heart pattern. Experiments have definitely shown, nevertheless, that the heart is sensitive to any increase in general excitement. Startle causes a prompt acceleration of the heart action. After this first response there is a quick recovery, which is followed by a secondary increase that is smaller in amount but more prolonged.

This was demonstrated by an experiment in which the subject was actually frightened. A trick chair was used to tilt an unsuspecting, blindfolded subject suddenly backward, as though the chair back had given way entirely. The pulse shot up from an average of 84 to 104 beats, receded promptly to about 87 and then rose again to about 97, and then remained in this area. When the subject returned the next day and was placed in the same chair, he showed a high pulse rate in anticipation of the fall of the chair. The heart will beat faster and blood pressure will rise as a result of excitement or anticipated excitement. [3]

Changes in blood pressure to detect deception. A number of experiments have shown that a witness who tells the truth is likely to have a small rise in blood pressure, whereas one who tells a lie will have a rather significant rise. Critical studies point to the fact that such changes in blood pressure are probably due to the excitement involved in deception and hence may be used in the same manner as the inspiration fraction in attempts to discover deception. [14, 33]

The most modern method for detecting liars is to take a combination of respiration, blood pressure, and heart-rate curves on a polygraph (which has been called a lie detector) and to attempt to determine from a study of the whole pattern whether a person is emotional or not when he replies to a significant question. If he shows emotional behavior, he may then be led to confess. Two individuals who have made extensive use of this device in police work claim that they have failed to discover the liar in less than 10 cases in 10,000 suspects. [28]

The detection of emotions though involuntary movements. When a person attempts to restrain an overt skeletal reaction that would naturally arise in an emotional situation, he usually discloses the presence of emotional tension by the inadvertent movement of some other portion of his body, even though he may be pretty clever in withholding a direct response. The checking of some vocal retort may give rise to tremors of the lips, movements of the throat, and the like. A tendency to strike with the fist may be suppressed, but reveal itself by biting the lip or by twisting the foot. The poker player may repress any expression in his face, but reveal pleasure or disappointment with his cards

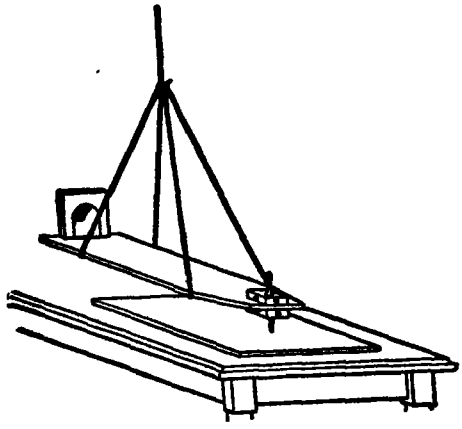


FIG. 36.—The automatograph. The arm rests on the board which swings freely, supported from above. Any movement of the arm is recorded graphically by the writing point on the writing pad on the table.

by involuntary movements which may be understood by one who has studied him closely.

Various devices have been utilized to attempt to interpret these involuntary movements. One form has been variously called an automatograph, a planchette, or an autoscope. It is essentially a device by means of which small, involuntary movements of a part of the body, usually the hand, can be made visible or recorded in some manner (see Fig. 36). Superstitious individuals have thought that some variations of these autoscopes, especially the divining rod, dousing rod, and ouija board, were possessed of mysterious power to reveal secrets; but all they can do is to make evident what the person whose arm operates the mechanism is feeling or thinking. These automatic movements probably are merely symptoms that the person has failed in making a satis-

factory adjustment to the situation at hand and has reverted to the more diffuse reactions that characterize infantile or primitive reactions to emotions. While attempting to restrain one part of his body, the crisis of the present brings about involuntary movements of others.

In a typical experiment designed to test this hypothesis, an individual was given the task of responding to a given word with

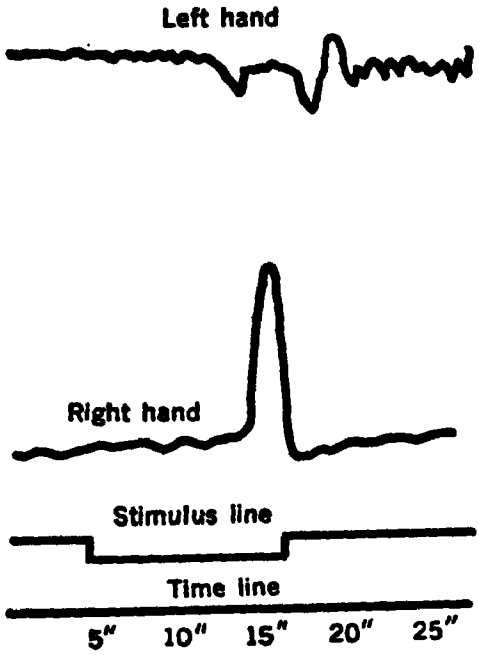


FIG. 37.—Involuntary movements as emotional indicators. The right hand holds a bulb which makes a definite response to the signal indicated by the downward movement of the stimulus line. The left hand holds a bulb which shows involuntary movements. These movements are accentuated when the stimulus has some emotional effect upon the subject. [33]

the first word that came to him. This is the typical free association test which often reveals the presence of an emotion by the type of response word or by the way in which the subject responds. In this experiment, however, the subject was given the additional task of pressing a pneumatic bulb at the same instant that he gave his response. Furthermore, all through the experiment he was made to hold with his left hand another bulb which recorded the slightest tremor of this hand, although he did not know that such a record was being made. The involuntary movements of the left hand were studied in various situations to indicate emotions which the subject was trying to conceal. [34] A typical record from this experiment is shown in Fig. 37.

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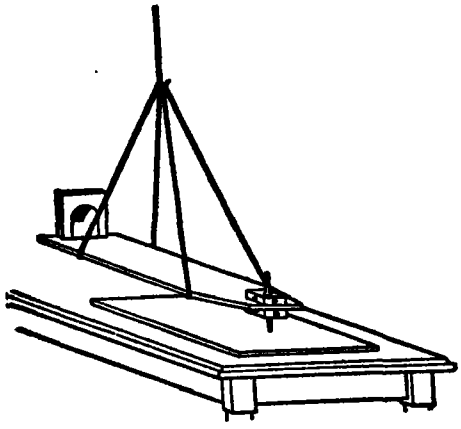


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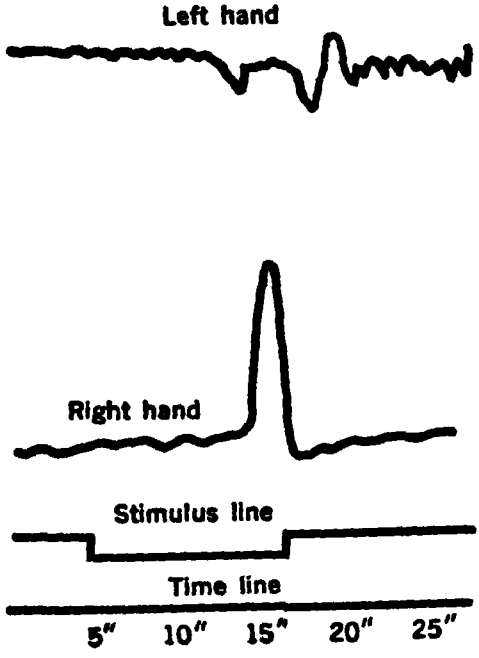


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Such a device may indicate the presence of a conflict or some emotional tension but it tells nothing about the nature of factors producing the emotion.

Free association methods for detecting emotions. Free association methods for the purpose of detecting emotions have received their widest use in clinical work. They have the advantage of being less artificial than methods requiring the use of apparatus fastened to the subject. They have the disadvantage of being more qualitative than the methods which use recording devices. This drawback may be more apparent than real, however. An instrument which makes a precise record may create an atmosphere of accuracy that is spurious. For example, it is possible to obtain accurate records of the action of the heart and an experimenter may thus feel that he has an instrument of precision for studying emotional behavior. He has an instrument of precision, to be sure, but the records must be interpreted qualitatively and the relation between his records and emotional patterns may be remote and unreliable. This is merely another way of saying that the clinician uses qualitative methods and must guess as to their significance, but that his guesses may enable him to get a better perspective than the laboratory man who attempts to read a precise graphic record which is influenced by a great many unknown factors.

Continuous method. The continuous method requires that the subject, beginning with a word selected at random or because it may appear to be related to some emotional situation, continue to give response words in an endless sequence as rapidly as he can. Whereas this requirement may seem to be simple, it is almost impossible for any one long to continue such a series without hesitation. These points of hesitation, or complete cessation of response, are regarded as the significant points. They presumably indicate the presence of some emotional factor in the subject which impedes his free output. For example: A person may be told to begin with book and continue his associative responses. Suppose he replies: book, table, newspaper, movie actress, show, dark—and then hesitates or stops. The implication is that dark suggested another word or situation having some personal reference or emotional significance. To be sure, the examiner has no notion what this means in any specific sense; all he

knows is that the individual probably has some emotional reaction. The real danger is that the clinician may think he knows more than he does.

Discrete stimulus method. In using the discrete stimulus method, the examiner gives stimulus words, one at a time, and the subject responds to each word with the first word occurring to him. The presence of an emotional background to any such response is indicated in a number of ways: by the response word itself, by the time taken to give the response, by some indirect sign of emotion while responding (such as blushing, squirming, stuttering), by repeating the stimulus word as though stalling for time, by giving a number of responses as though trying to correct the impression created by his first reaction, by giving a response so far removed from the stimulus as to appear to be an attempt to hide a natural response word, or by a failure to respond at all.

In using free association methods, the clinician does not arrive at any conclusions on the basis of a few responses. Instead, he relies on the accumulation of clues from a great number of responses. When he finds that some common element is present in numerous associations, he takes that as a clue and makes a guess as to the general area of emotional conflict. Using this guess as a hypothesis, he continues to test the subject, centering his attack around his hypothesis, in order to determine whether it is true or false. A clinician, in using these methods, usually makes guesses upon little evidence; but neither does he take any such guess seriously until he is able to corroborate it by a great number of different tests.

QUESTIONS FOR REVIEW

1. Differentiate between the subjective and objective aspects of emotional behavior.
2. What characteristics of emotional behavior suggest that it is emergency behavior?
3. How may emotional patterns be classified?
4. Why is it impossible to classify emotions?
5. Outline the part played in emotional activity by: (a) the skeletal system; (b) the viscera; (c) and the endocrine glands.
6. Give a general statement of the functions of the three segments of the autonomic nervous system.

7. Outline the evidence for the point of view that the activity of the sympathetic segment of the autonomic nervous system is essentially emergency activity.
8. Give a description of typically nonemergency emotional behavior.
9. What are the various reactions which result from stimulation of the sympathetic segment of the autonomic nervous system?
10. What is chronaxie?
11. Explain why a person may feel internal tensions after he has made an overt adjustment to an emergency situation.
12. Explain why overt responses represent the best form of emotional adjustment.
13. What is the significance of the fact that there is an inverse relationship between emotionality and stereotyped behavior?
14. What effect does the need for concealing emotional factors have upon emotional learning?
15. Show how a child may learn to utilize his emotional behavior to influence other persons.
16. What part does learning play in dramatic expression?
17. Give the various reasons why ingrown emotions are cultivated.
18. What bad effects may come from cultivating the internal aspects of emotional behavior?
19. Show how emotional learning may account for the great diversity of emotional expression in adults.
20. What errors may result from attempting to judge the emotions of children from similarity to adult emotional reactions?
21. Why is it advisable to discard the notion that infants are born with full-grown emotional patterns?
22. Give evidence that an infant's emotion cannot be judged by the behavior he manifests.
23. What is the significance of the fact that facial expressions of emotions are very variable?
24. What methods have been used for studying facial expressions?
25. What conclusions can be derived from experimental studies of facial expression?
26. How accurately may the significance of an infant's cry be judged?
27. Give evidence that the significance of vocal emotional expression must be learned.
28. What is the vibrato and what is its significance?
29. Of what importance is activity in the expression of emotions?

30. What are the general methods that have been used to discover the underlying significance of emotional behavior?
31. Describe the way in which the galvanic skin responses are obtained.
32. What is the best interpretation of the significance of the galvanic skin responses?
33. Describe the pneumograph.
34. What significance may be attached to changes in the rate and depth of breathing?
35. What is meant by the inspiration-expiration ratio?
36. What is the significance of the inspiration fraction?
37. What different factors may influence the action of the heart?
38. What is known about the effect of startle on the heart action?
39. How have changes in blood pressure been used to detect deception?
40. How does the "lie detector" operate?
41. Of what significance are involuntary movements in the study of emotional expression?
42. Describe the clinical use of free association methods for detecting emotions.

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Chapter VIII

THE ACQUISITION OF MOTOR SKILLS

THE perfect execution of an intricate motor performance arouses the admiration and envy of any spectator. Highly skilled acts are applauded because they result from arduous practice by one who could never have reached his present perfection without years of relentless effort and intelligent direction. At the same time that we recognize that motor skill depends upon hard work we also know that persistent effort alone is not enough to ensure mastery. Many persons practice with unusual zeal only to end as second-rate performers. An analysis of the processes involved in motor learning may indicate whether failure depends more upon original lack of equipment, improper procedures, lack of intelligent direction, or lack of persistence. Even if the reader has no intention of becoming an expert in any form of motor performance, he can utilize the principles of motor learning in his everyday life. He can learn to walk with more grace, to play some game or musical instrument better, to carve a turkey more skillfully, to eat a salad more neatly, to speak more fluently, or to drive a car more easily and safely; in fact, any motor act can be improved by an intelligent application of the principles which psychological research has brought to light.

BODY MECHANICS

Those activities which are easily observable are due primarily to the function of the skeletal musculature. Before we can understand the ways in which practice and learning will change the effectiveness of motor behavior we must know something of the manner in which skeletal muscles operate.

The arrangement of striped muscles. The bony skeleton furnishes a framework which functions much like a crane or a derrick, from which a system of movable arms or levers extends.

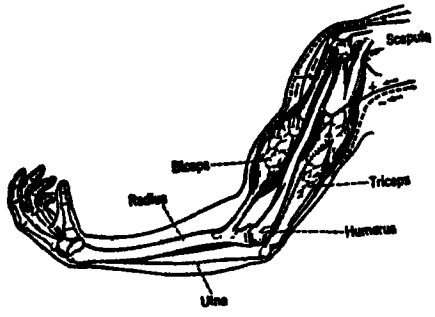


FIG. 38.—Diagram showing the action of antagonistic muscles. Explanation in text.

(From S. W. Fernberger, *Elementary General Psychology*. By permission of The Williams & Wilkins Company, Baltimore, Md.)

Movements of this framework and lever extension are produced by shortenings and extensions of the various muscles.

In most cases the muscles are arranged so that they work in opposition to one another. This is illustrated, as shown in Fig. 38,

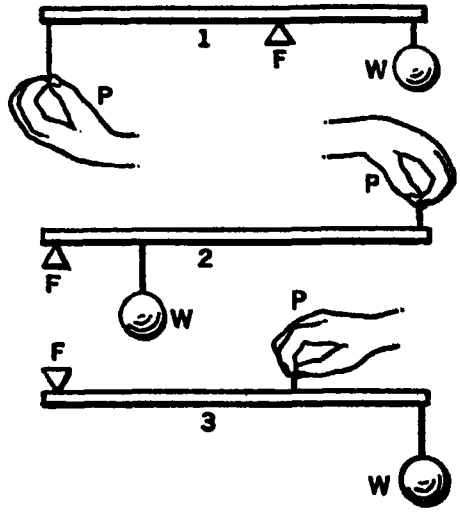


FIG. 39.—The three classes of levers. F—fulcrum; P—power; W—weight. In class one the fulcrum is between the power and the weight. In class two the weight is between the fulcrum and the power. In class three the power is between the fulcrum and the weight.

by the arrangement of muscles which control the movements of the forearm. The radius bone illustrates a lever of class three where the power from the biceps muscle is applied between the weight or resistance (the hand) and the fulcrum (the humerus). The ulna represents a lever of class one type where the fulcrum is between the weight, or resistance (the hand), and the power, or triceps muscle (see Fig. 39). From the diagram it is apparent

that movement of the forearm is not the function of the biceps alone or of the triceps alone but of the combined action of the two. If, taking into consideration the leverage advantages, the biceps and triceps exerted equal force upon the resistance, or weight of the hand, there would be no movement, regardless of how much force was being applied by them. The arm could be at rest with both muscles flaccid or with both muscles at a high degree of tension. In other words, in order to raise the hand the biceps must contract, or shorten, at the same time that the triceps relaxes, or lengthens. Vice versa, as the triceps shortens the biceps must lengthen. This antagonistic action of muscles should not be considered as a sort of conflict between the opposed muscles. A muscle ordinarily does not have to fight another muscle in order to contract, because the nervous impulse which brings about the contraction of one muscle is synchronized with another neural impulse which causes the stretching or relaxation of the antagonistic muscle.

The fundamental forms of movement. In any movement made by the intact organism there is co-operation between various muscles. The untrained person may have so little control of the components of a complex movement that there is little co-ordination, with resultant awkwardness, whereas the trained person may be able to execute his acts with great skill and precision. A classification of the types of skeletal movement may make the techniques for the development of skill more comprehensible. [11, 24]

Fixation. In fixation the member is held still by the contraction with equal force of opposing muscles. This balance of antagonistic muscles causes a rigidity which may be intense if the force exerted by the muscles is great or mild if the muscles are relatively relaxed. However, the antagonistic muscles never remain in absolute balance for any long interval. A record made of the hand holding a stylus or of a finger tipped with a writing point, while the individual is attempting to hold the member motionless, will reveal that the hand is only approximately at rest. It describes a to-and-fro movement around a center in an irregular manner, a tremor which may reach a frequency as high as 15 per second. Such movements may be demonstrated by means of the

automatograph, shown in Fig. 36, which holds the forearm suspended in a swing and permits tremors to be recorded.

The slow, or controlled, movement. This has also been called a moving fixation. It occurs when the opposing group of muscles are contracted, but with unequal tension, so that a change in the position of the member results. This type of movement may be considered as an extension of the tremor movements which take place in fixation, except that these tend in one direction and are therefore cumulative in their effect. Since the slow controlled movement is composed of a series of jerks, it is possible to stop or change the direction at any point along its course. Illustrations of controlled movements are seen in the hesitant applying the foot to the brake of a car or the uncertain handling of a fork, key, or spoon.

Fast movement under tension. This is a movement in which there is a tension in all the opposing groups throughout the movement. It is merely a speeding up of the controlled slow movement and results in a jerky, uneven movement. The greater the tension in the opposing muscles, and the more rapid the movement, the greater will be the irregularities in the total movement. It is the sort of movement made by the unskilled person who is trying to speed up in spite of the fact that he is not sure of himself.

The ballistic movement. The ballistic movement is a rapid, thrown movement. Its course is marked by an unquavering line. Control is exercised with the initial impulse and when once under way its course cannot be changed. In a ballistic movement the stimulus comes from the positive group of muscles without opposition from the antagonistic muscles. Furthermore, the positive muscle group relaxes long before the end of the movement, leaving the moving member free from muscular tension during the middle of its course so that it is carried only by its own momentum.

Relative value of different types of movement. In an intact organism movements of various types operate in conjunction. For example, while the arms are executing a ballistic movement, the body may be held rigid and other portions of the body may be engaged in executing movements of other types. No

movement requiring fine co-ordination is possible without relative fixation of the larger supporting muscles. Rapid walking, for example, consists of ballistic extensions and flexions of the legs, at the same time that an upright posture is being maintained by the trunk. Fixation movements are just as essential for skilled activity as are ballistic movements.

Nevertheless, in many instances efficiency is lowered and the acquisition of skill retarded because the correct combination of movements is not used. When there is a choice between the ballistic movement and the controlled movement, the ballistic type of movement has great advantages.

Ballistic movements cause least fatigue. It has been found that a long, sweeping, cursive movement is much less fatiguing than a short, tense movement. Several factors contribute to this advantage. In a ballistic movement, the muscular contraction continues only during the initial phase of the movement. During the major extent the muscles are relaxed and there is no pulling of antagonistic muscles against each other. For example, ordinary walking is much less exhausting than walking on ice. Ballistic movements do not produce such products of chronic fatigue as writer's cramp, telegrapher's wrist, pitcher's glass arm, or pianist's shoulder.

Ballistic movements are more graceful. Ballistic movements are characterized by greater smoothness and proficiency in such acts as piano playing, handwriting, the use of keyboard machines, dancing, and the like.

Ballistic movements are usually more powerful. Ballistic movements are the most powerful because they utilize momentum and the force of body weight. When a member of the body is swung through a complete arc, especially if there is a tool on the end of the member, the force of the movement is much enhanced. This is illustrated in such movements as swinging a hammer, following through on a golf stroke, and throwing a ball, javelin, or discus.

More speed can be developed through ballistic movements. The ballistic movement is quicker because it is not impeded by antagonistic tensions, by jerking changes in direction, or by tentative stops along the way.

FACTORS CONTRIBUTING TO MOTOR SKILLS

The most important factors in any skilled act are strength, speed, and precision. These factors are not of equal importance in all acts, nor can they be isolated in actual skilled acts. Nevertheless, the analysis of the act to be learned into its essential components may make it easier to learn that act and may lead to greater ultimate skill.

The development of strength. Frequently repeated exercise extended over months and years leads to an increase in the

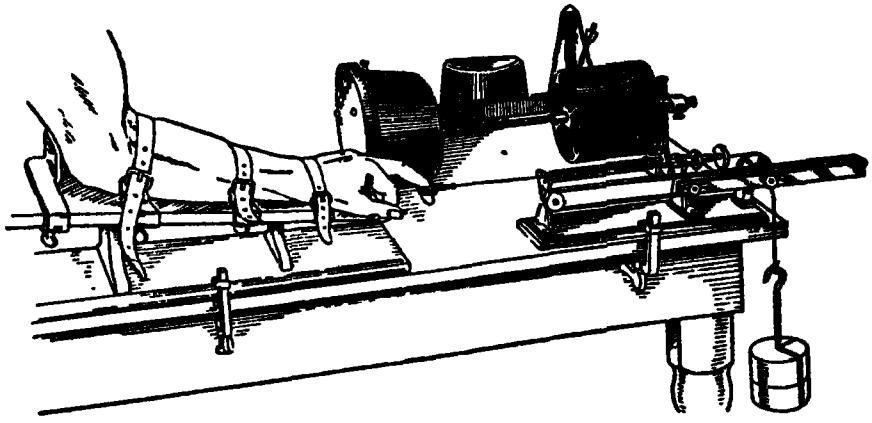


FIG. 40.—Mosso's ergograph. The middle finger raises and lowers the weight at regular intervals, each movement being recorded on the smoked drum of the kymograph.

(By permission of C. H. Stoelting Co., Chicago.)

size, strength, and tone of the muscle. This is accomplished through the thickening and toughening of the muscle fiber and by means of an increase in the amount of connective tissue within the muscle. The meat of heavily worked animals is tougher and coarser than that of animals subjected to less violent exercise. Any increase in size probably results from this enlargement of the separate fibers rather than from an increase in the number of fibers.

The gain in power of a muscle is far in excess of what might be expected by its increase in size. In one experiment the subjects were required to manipulate an ergograph by the repeated flexion of one finger at the rate of one contraction each two sec-

onds until they were forced to stop from exhaustion. This exercise was repeated to the point of exhaustion each day for thirty-two days. The subjects in this experiment were able to increase their efficiency practically threefold. They could work three times longer and do three times as much work. [13] The apparatus used in this experiment is shown in Fig. 40, and a sample fatigue curve is shown in Fig. 41.

The effective strength resulting from exercise is still more pronounced than that which results from the increased strength of the individual muscles involved in a movement. There is a

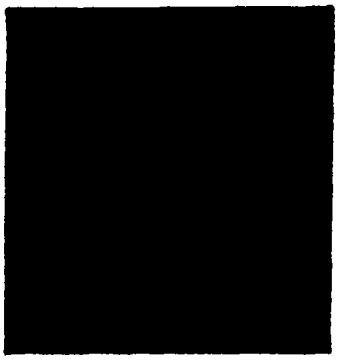


FIG. 41.—Typical fatigue curve. Curve made by the apparatus shown in Fig. 40. The weight is 3 kilograms and each peak represents a contraction of the middle finger at intervals of two seconds.

development of the heart and lungs and improved circulation which makes for more efficient supply of nourishment and the removal of the waste products of exercise, with less consequent fatigue. There is some evidence that there is an improvement in the mechanism for transmitting the nerve impulse to the muscle, a development of the capillaries which supply the muscle with blood, and a more complete use of all the fibers in the muscle.

Various instruments are used to measure the strength of muscular contraction. The general name for such an instrument is dynamometer. A dynamometer (see Fig. 42) in which the amount of strength exerted by the subject is indicated by a pointer on a visible scale is called a dynamoscope. Where the energy exerted is recorded on a moving record the instrument is called a dynamograph.

Improvement in the speed of performance. The speed with which an act can be performed is widely used as an index

of skill in that act. Increased speed may be accomplished by various means.

Repetition. Repetition will increase the speed of a simple reaction. In a later section we shall see that simple reaction time may be shortened by practice until a physiological limit is reached. In more complex acts the decrease in time is even more striking.

Elimination of useless movements. In the early stages of practice of a motor act, an individual usually includes many acts

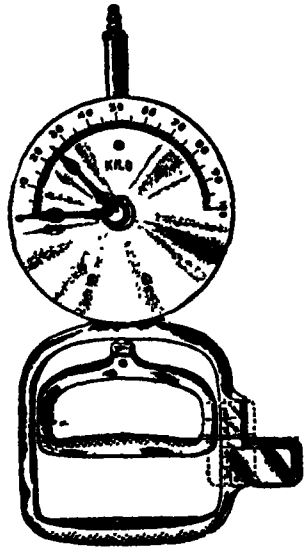


FIG. 42.—A hand dynamometer.

which contribute nothing to the total performance. When an infant tries to do such a simple act as the grasping of a rattle, he squirms, kicks, waves his arms, and grunts: whereas, after he has learned to use his hands efficiently, he no longer makes all those useless movements. The curve in Fig. 43 shows that, when an infant first tried to grasp a rattle, he did a great deal of useless kicking. As his skill in grasping with his hands improved, the useless kicking with his legs became less and less pronounced. On the first attempt to grasp the rattle, the child gave 70 kicks; after thirteen trials he gave but one kick.

In somewhat similar fashion, when a novice begins to play a piano, he will squirm, move his feet about, make grimaces, twist his body, and perform many similar acts which are extraneous to piano playing. The expert, on the other hand, uses only those

muscles which contribute to the total performance. In the process of learning he has gradually eliminated more and more of the unnecessary acts. The use of slow-motion pictures has enabled teachers of athletics, and supervisors of mechanical activities, to analyze the movements made in the performance of skilled acts and to direct players and workmen to eliminate the useless ones.

Decrease in tension. Since any movement involves the relaxation of antagonistic muscles, many acts are hampered by

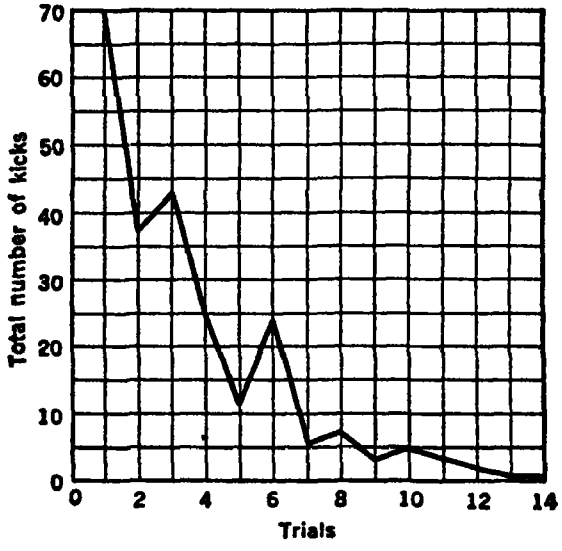


FIG. 43.—Graph to illustrate the elimination of useless movements when learning a motor skill. The curve shows the number of times an infant kicked his legs during successive attempts to grasp a rattle. (From M. W. Curti, *Child Psychology*. By permission of Longmans, Green & Co., New York.)

the partial contraction of muscles which should be relaxed. Hence, the expert learns to move with as little antagonistic tension from opposing muscles as is consistent with good control. More of the acts of the expert are ballistic and fewer are the slow, controlled type. It is this fact which makes the movements of an expert seem so easy. His acts are smooth because they move with no unnecessary restraints.

Improved speed of decision. Skilled acts are not performed in an identical manner each time they are performed.

Instead, the expert has learned innumerable ways of traversing the pathway from the beginning to the objective of that performance. There is a sequence of acts each one of which must be performed in a manner dictated by what has just preceded, as well as by concomitant circumstances. This procedure can be clearly recognized in such an act as batting a ball, but it is present in practically all skilled acts. The unskilled man has but few ways of doing an act and has a hard time choosing between them. The expert has numerous methods at his command and can pick and choose with no hesitation whatsoever. In the realm of motor skills, "he who hesitates is lost." When a good driver of an automobile gets into a predicament he cannot take time to decide whether to step on the gas or on the brake. He does not wait, and yet he does the right thing.

Better co-ordination. No movement is performed by means of a single muscle. Teamwork between muscles is essential and improvement in this aspect of movement is extremely essential in making progress in motor skills. It is this aspect of learning which probably is most dependent upon practice and which contributes most to final perfection. The athlete must develop his large muscles so as to give him power but he also must be able to direct the contributions that these large muscles make to the total performance. He cannot let himself get "muscle-bound," which merely means that some muscles have learned to "steal the show" and perform when, or to a degree which, they are not supposed to do.

Working with larger units. When a person begins to learn typing he cannot write words or sentences as wholes. Instead, he first learns to write each letter as a separate unit. Later he learns to write by syllable or word units. At this stage each key is not responded to separately as one spells the word. Instead, the word brings forth the complete pattern of reactions that make the total word. This lengthening of the unit continues until the expert stage when a sentence or a group of closely associated words can be dealt with as a whole. [3]

When the final co-ordinated act involves different parts of the body it may be that the most efficient way of learning is to begin with the use of the different parts simultaneously even though this appears to be the utilization of a larger unit at the

very beginning. For example, it has been found that the "hands-together" method is more efficient that the "hands-separate" method in learning to play the piano. When each hand learned its part separately there was conflict between the two motor patterns when the attempt was made to combine them.

Improved attitudes. The approach by a novice to his task is in striking contrast to the attitude with which the expert enters into and executes his performance. The expert is confident without manifesting the exaggerated bravado of the incompetent; he is stimulated by the challenge of his task without the fear which drives the novice; he is motivated by the task itself without the need for the prodding effect of some extraneous reward; and he never becomes bored with his task although he may become fatigued.

The development of precision. Precision cannot be isolated from strength or speed. In certain tasks one factor may be stressed to the disadvantage of the others but in an ideal learning situation the three should progress together. Without the proper foundation one may stress speed and make numerous mistakes as a result. For example, in beginning to learn music it is no doubt better to emphasize precision rather than speed. The beginner at golf who puts all his emphasis on the strength of his drive is likely to improve more slowly than the one who gives adequate attention to co-ordination and precision.

Various attempts have been made to discover some constant relationship between speed and accuracy but they have not proved successful. It is quite likely that such a relationship is dependent largely on the nature of the task and other extraneous factors rather than in the two factors themselves. Consequently, in most experiments in learning, a separate record is kept of both speed and accuracy.

Precision is a restriction placed upon an act by some extraneous circumstance which we may call an aim or a goal. A precise act cannot be described in terms of itself, it must be in the degree to which it approximated some arbitrary standard. Obviously, when a person first attempts a precise act he must have some aim and that aim must remain consistent throughout a series of acts. In other words, an act is judged in terms of its approach to the fixed standard. After making note of the degree of error in one

act, the learner must repeat his general reaction but with some variation. The variation is the attempt to modify the reaction in such a manner that the goal will be more nearly reached. Again and again the act is repeated with attempted modification each time. The accurate marksman may make a thousand different movements in hitting the bull's-eye; but nevertheless he hits it. It has been shown that in most skilled acts no fixed order of action holds and in some acts such as tennis, fencing, football, and baseball no fixed procedure is possible. No two games are alike. Skill consists in being able to use different methods for reaching the same goal, hitting the same target, or fulfilling the same aim.

THE SPEED OF REACTION

It requires less time to make a simple reaction than it does to execute an involved and complicated act. If the complicated act

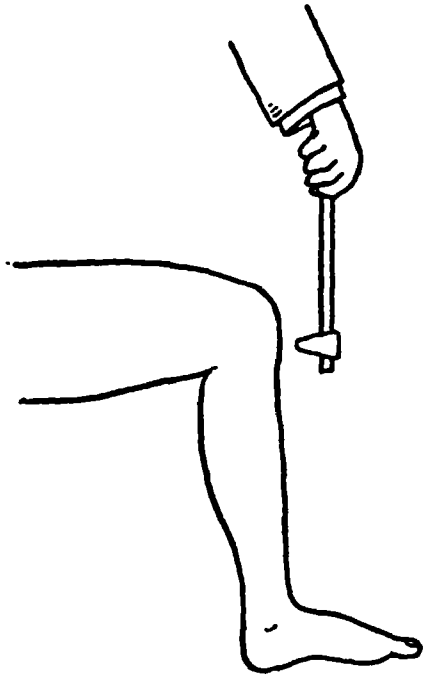


FIG. 44.—Diagram showing stimulus for knee jerk. The striking of the patellar tendon, just below the kneecap, causes the foot to kick out.

were merely due to an addition of simple acts placed end to end, the time of the complicated act could be determined by taking the sum of the time required for each component. Such is not the case. The speed of reaction is affected by other factors than the

mere number of steps involved in a process. It is important to have some knowledge of the speed required for various types of response in order to supply a background for a knowledge of how other factors affect the performance of skilled acts.

Reflex time. The simplest motor act that has been subjected to precise measurement in the intact organism is reflex time. The different reflexes are not equal in their time or in the precision of their operation, but the findings in connection with the knee jerk may be taken to illustrate some of the work in this field. [7]

The usual procedure for measuring the knee jerk is as follows: the tendon, just below the kneecap, is struck with a reflex hammer (see Fig. 44). This hammer may be attached to a device which either makes a graphic record or operates an electric switch which starts a chronoscope (illustrated in Fig. 45). The leg is connected with a device which makes a graphic record or operates an electric switch to stop the chronoscope. Usually there is also an arrangement to measure the extent of the excursion of the foot or the degree of contraction of the quadriceps femoris muscle.

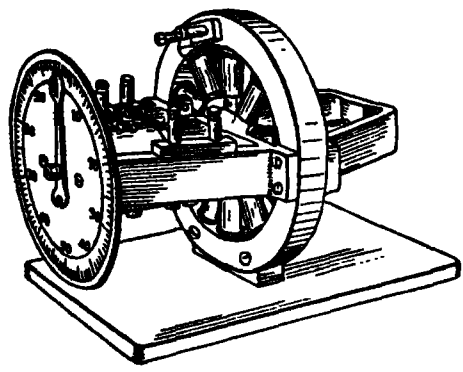


FIG. 45.—A chronoscope. The chronoscope is extensively used in psychological laboratories to obtain accurate time measurements. This model is driven by a synchronous motor. The hand starts to whirl at the beginning of the interval to be measured and stops at the end of the interval. It is accurate to one millisecond.

Measurements of this reflex under different circumstances have shown definitely that the reflex is a reaction which manifests considerable variability.

1. There are wide individual differences in knee-jerk time. In human subjects the knee-jerk time, as reported by different investigators, varies from 10 msec. (a millisecond, abbreviated msec., is $\frac{1}{1000}$ of a second) to 90 msec.

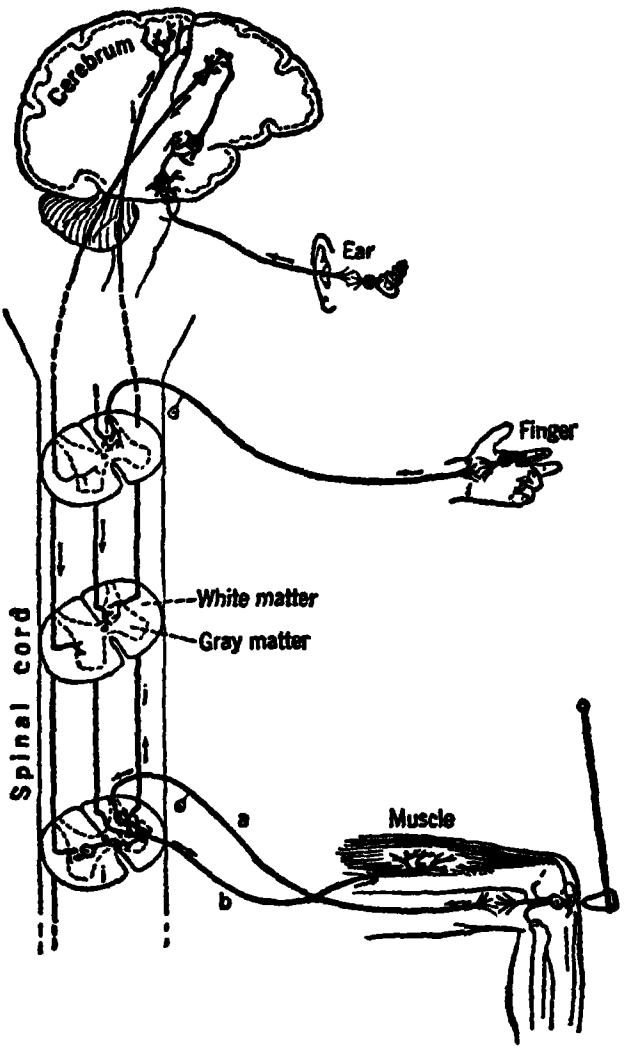


FIG. 46.—Diagram to show that the knee jerk is influenced by neural connections with the rest of the body. When the hammer strikes the patellar tendon a nerve current passes over *a* to the nerve center in the spinal cord and back over *b* to stimulate the muscle. The nerve center in the cord is connected with other parts of the body as shown. This diagram is extremely oversimplified.

(From J. F. Dashiell, *Fundamentals of General Psychology* By permission of the author.)

2. There are wide variations in the extent of the knee jerk. With conditions kept as nearly constant as possible, the same individual will show variations in the extent of excursion of the foot, and there will be wide variations between individuals. Different investigators have varied in their reports of the number of individuals who fail to manifest the knee jerk at all; these reports vary from less than 1 per cent to nearly 5 per cent.

3. Extraneous factors may influence the knee jerk. The extent and time are influenced by a number of factors, such as: general tonus, movements of other parts of the body, tactile irritations, simultaneous visual or auditory stimulation, fatigue, hunger, sleep, mental activity, emotional excitement, temperature, and influences of alcohol and other drugs.

4. The knee jerk is modified by isolation from the rest of the body. In a spinal cat (that is, an experimental cat in which the spinal cord has been severed so that the brain is not permitted to affect the spinal cord) the knee jerk is 6 msec., the shortest time reported for this reflex. The significance of this fact is that the reflex time is shortest when it is not hampered by neural connections from other parts of the body. The way in which other neural pathways may be connected with the reflex is illustrated in Fig. 46.

These facts indicate that the definition of a reflex should be broad enough to include factors of variability and of individual differences. A reflex may then be defined as a relatively simple form of response which involves a sense receptor, a central nervous connection, and a motor organ.

Apparatus for measuring reaction times. The essential parts of an experimental arrangement to measure reaction times are: (a) a chronoscope or a chronograph which will measure time intervals with accuracy and which can be started and stopped by means of mechanical or electrical attachments; (b) a stimulus which is connected with a device for beginning the time measuring apparatus as soon as it is given; and (c) a device which the subject operates as soon as possible after he receives the stimulus. A typical arrangement is shown in Fig. 47. The subject is told to depress his key and to hold it down until he receives the signal, whereupon he is to release the key as quickly as he can. The experimenter presents the stimulus and closes his key with the

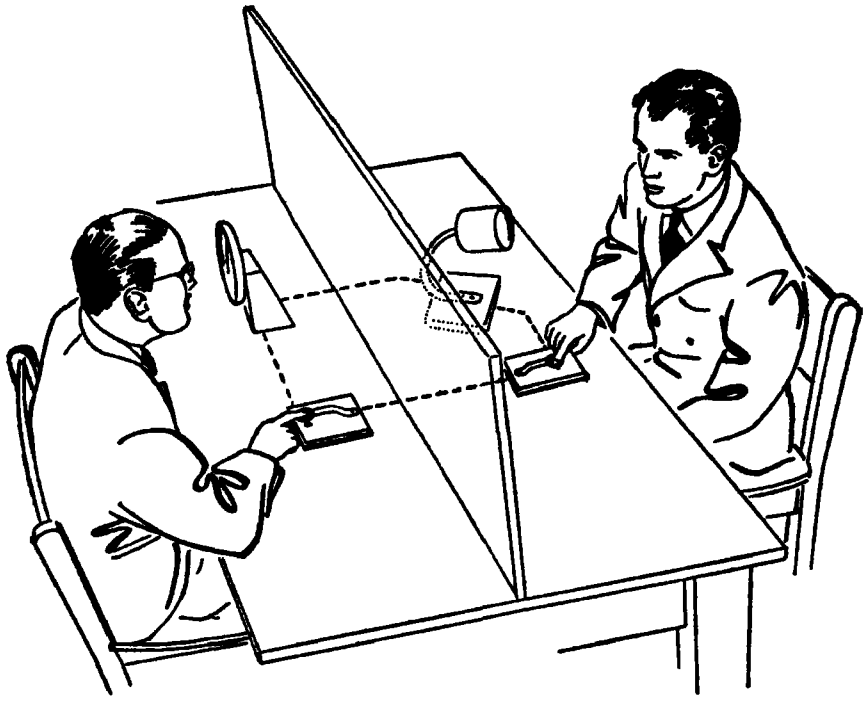


FIG. 47.—Diagram to show how reaction time is measured. When the experimenter, who is seated to the left in the drawing, gives the warning signal, "Ready," the subject presses down his key and holds it until he sees the flash of the light before him. This light flashes as soon as the experimenter closes his key. The subject tries to release his key as quickly as he can after he sees the light. The chronoscope begins to operate as soon as the experimenter closes his key and continues to record time until the subject releases his key. The chronoscope thus records the time which elapses between the flashing of the light and the release of the key by the subject.

same movement. The experimenter's key completes the electric circuit through the chronoscope, thus starting it, and it continues to operate until the circuit is broken by the subject's release of his key. The amount of time that has elapsed between the completion of the circuit by the experimenter and the breaking of the circuit by the subject may be read from the dial of the chronoscope.

Simple reaction times. The simple reaction is a single response to a simple, unequivocal stimulus. The subject is warned

in advance exactly what the stimulus will be (whether a flash of light, a sound, a touch on the skin, or the like) and is told exactly what response he is to make. In addition, he is given a preparatory signal to enable him to get in readiness to react.

In the early days of experimental psychology, reaction times were studied extensively because it was believed that the analysis of such a simple performance would disclose some single factor (such as a "personal equation") which might then be used to explain more complex behavior. This expectation was not realized. Instead, it has been found that reaction times are quite variable and depend upon the following factors: [31]

Reaction time varies with the sense stimulated. In Table V the approximate ranges of reaction time to various types of stimulation are given.

TABLE V

APPROXIMATE REACTION TIMES IN MILLISECONDS TO VARIOUS KINDS OF STIMULATION

Stimulus	Range of reaction time
Tactual	110 msec. to 190 msec.
Auditory	120 msec. to 185 msec.
Visual	150 msec. to 225 msec.
Temperature:	
Cold	150 msec. to 230 msec.
Warm	180 msec. to 240 msec.
Olfactory	200 msec. to 800 msec.
Gustatory	300 msec. to 1080 msec.
Salt	about 300
Sweet	about 446
Sour	about 536
Bitter	about 1080
Pain	400 msec. to 1000 msec.

Reaction time varies with the part of the sense organ stimulated. In the field of vision it makes a difference whether the eye is stimulated at the point of clear vision, that is, whether the stimulus is directly in front of the eye or to one side. The reaction time to a lateral stimulus is as much as 24 msec. longer than to one which enters the eye from directly in front. In the field of taste the reaction time to bitter is prompter when the

back of the tongue is stimulated than when the stimulus is applied to the tip of the tongue.

Reaction time varies with the intensity of the stimulus. As the intensity of a stimulus increases the reaction time tends to decrease. With light stimuli the reaction time decreases when the intensity of the light increases, when a larger area of the eye is stimulated, or when the duration of the stimulus is increased. Reaction time to sound also decreases as the intensity of the sound stimulus is increased. [21]

Reaction time varies with age. In the early years reaction time decreases with age. In one experiment it was found that reaction to sound decreased from about 177 msec. for 9-year-old children to about 144 msec. for 15-year-old children; the reaction to light decreased from about 194 for 9-year-old children to 158 for 15-year-old children. Old age is accompanied by a slowing of reaction times. In a group of 100 persons ranging from 26 to 87 years, the twelve oldest persons (whose average age was 79 years) had reaction times from 20 to 30 per cent slower than the average of the whole group.

Reaction time depends upon the direction of attention of the subject. Reaction time is shorter if the subject, after he has been given the warning signal and prior to the presentation of the stimulus, fixes his attention upon the coming reaction rather than upon the coming stimulus. In one experiment it was found that the average reaction to a sound was 123 msec. when the subject attended to the reaction he was to make, while to the same sound the reaction time was 227 msec. when the subject attended to the stimulus.

Choice or discrimination reaction time. In the choice reaction time the subject is told in advance there will be two (or more) stimuli and is instructed to react differently to each. He may be asked to react to one and to refrain from reacting to the other, to react to one with the right hand and to the other with the left, or even to react selectively to ten stimuli by using one finger for each of the ten to be given.

As might be expected, the reaction time will increase with each added degree of complexity. In one experiment, where ten degrees of complexity were used, the times ranged from 188 msec. for the simple reaction to 588 for the reaction when the subject

was obliged to make a selective response to one of ten stimuli. The increase in time as more stimuli are used is illustrated in Fig. 48.

Association reaction time. In the association reaction the variety of stimuli is greatly increased and, in addition, the reactions are correspondingly more numerous and complicated.

Association tests may be divided into two groups. The first is the controlled association, where the response of the subject is limited by definite instructions, such as: the verb-object, where the subject must give an object for the verb given; the noun-

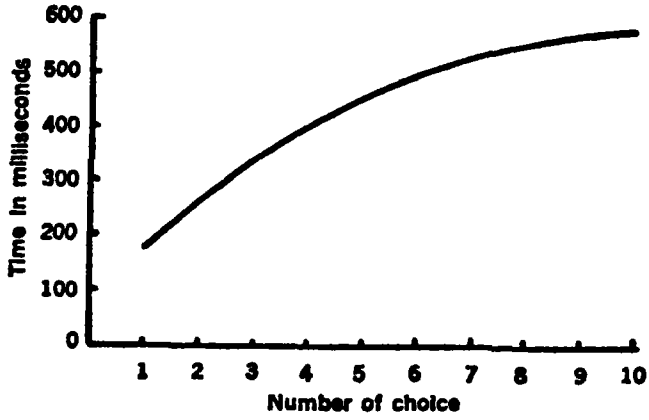


FIG. 48.—Increase in reaction time with increase in number of choices.

adjective, where the subject responds with an adjective to characterize the noun presented; the opposites, where the subject gives the opposite of the word given; and the like.

The second type is the free association method, where the subject is instructed to give any word that comes to him in response to the stimulus word. The free association method has been further differentiated by giving the subject not only word stimuli, but pictures, ink blots, or vague, ambiguous questions.

As the complexity of the choice reaction is increased, the time for response is correspondingly increased and the variability is also increased. The association reaction is, for this reason, better adapted than the simple reaction for studying individual differences.

THE LEARNING CURVE

Types of learning curves. The learning curve (also called the practice curve) is a graphic representation of the changes in performance during successive periods of practice, in terms of equal intervals of time or of equal accomplishment units. The units selected for recording the progress of learning will depend largely upon the nature of the task involved and the kinds of measures that can be used. It is well to have in mind the various combinations that are possible so that the best selection can be made for each learning record.

Methods for recording practice intervals. There are two ways in which intervals of practice may be recorded: (1) The whole practice program may be subdivided into equal units of work done or the number of formal practice acts. For example, a separate record may be kept for each ten shots at a target, for each attempt at walking the tightrope, for each race run, for each solution of a puzzle, and the like. The task is kept constant and the time for accomplishing the fixed amount of work is the variable to be plotted against it. These are called *amount intervals.* (2) The whole practice program may be subdivided into equal time units. For example, the learner may be given the opportunity to practice one hour each day on the learning task. These divisions of learning are called *time intervals.*

Methods for recording proficiency, degree of skill, or accomplishment. There are three ways in which the effects of practice (proficiency, skill, or accomplishment) may be recorded: (1) Increased skill may be manifested in terms of increased speed. For example, improvement may be shown by changes in time taken to run a specified distance, in the time taken to write a certain number of words on a typewriter, in the time taken to sort a specified number of cards, and so on. These are called *speed units.* (2) Accomplishment may be indicated by an improvement in the quality of the work done. For example, one may be able to come closer to a target in shooting or he may be able to walk a longer tightrope. These are called *quality units.* (3) Improvement may show itself in the reduction of errors made. For example, a rat running in a maze may make fewer false move-

ments, or one may make fewer misses in a ball-tossing experiment. These are called *error units.*

Since there are two ways for recording practice intervals and three ways for recording improvement, we can derive six types of learning curve that may be used for portraying changes that occur with practice. These are shown in Table VI.

TABLE VI

TYPES OF LEARNING CURVES

Improvement indicated by:	Practice in terms of: Amount intervals	Practice in terms of: Time intervals
Speed Units	Speed Amount-of-practice	Speed Practice-time
Quality Units	Quality Amount-of-practice	Quality Practice-time
Error Units	Errors Amount-of-practice	Errors Practice-time

Illustrations of typical curves. The six different types of learning curve may be more clearly understood from illustrations of each. [25]

1. *The speed against amount-of-practice curve.* The intervals of practice are in terms of units of work done and are plotted along the horizontal line. The horizontal axis is also called the axis of abscissas or the X-axis. We shall refer to it as the X-axis. The accomplishment values are in terms of increasing speed and are plotted along the vertical line. The vertical axis is also called the axis of ordinates or the Y-axis. We shall refer to it as the Y-axis. Such a curve is illustrated in Fig. 49. This shows the improvement in time required by animals to escape from a problem box in which they had been confined. Whereas the first trial took nearly 400 seconds, the animal learned to escape in a few seconds.

2. *The speed against practice-time curve.* The time devoted to practice is plotted along the X-axis and the number of successful acts per unit of time is plotted along the Y-axis. Progress made in learning telegraphy can be well represented

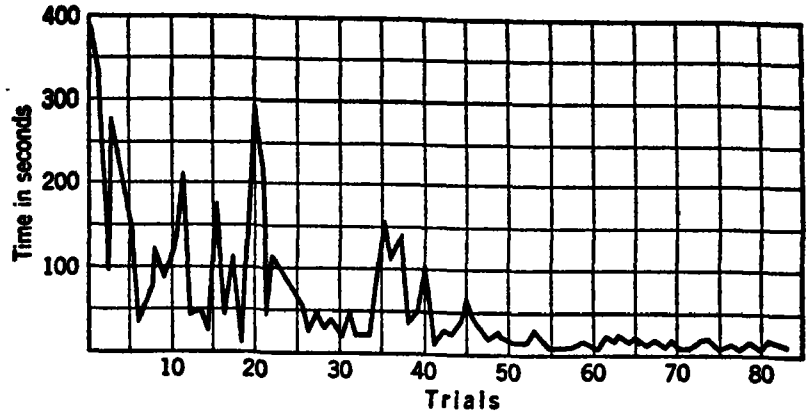


FIG. 49.—A curve in which speed is plotted against amount of practice. The height of the curve represents the time taken by an animal to escape from a problem box. The amount of practice is measured by the number of trials made by the animal. Note the great amount of irregularity in the early portion of the curve. With a high degree of skill the performance time is fairly uniform.

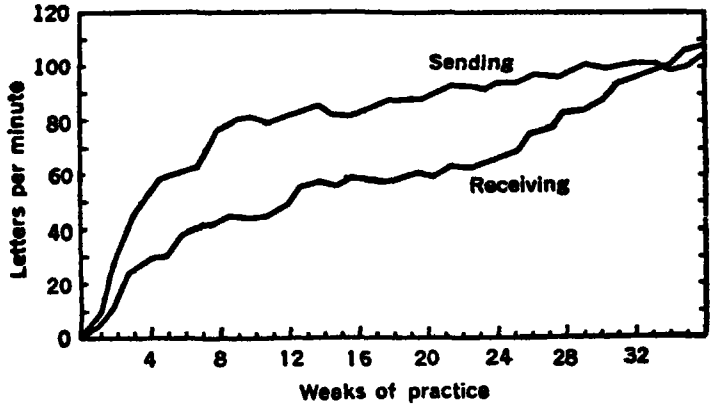


FIG. 50.—A curve in which speed is plotted against practice time. This curve represents the learning of telegraphy. Proficiency is measured by the letters sent or received per minute. The base line is divided according to time periods and each point on the curve represents the average performance of the individual for the particular practice period represented by the base line. The averaging of a number of performances makes this curve smoother than the one in Fig. 49.

by this type of curve, as is shown in Fig. 50. It will be noticed that improvement is represented by a rising curve (an increase in the number of acts per unit of time), whereas in learning to solve the problem box (Fig. 49) improvement is represented by a falling curve (the length of time required to escape).

3. *The quality against amount-of-practice curve.* The curve for improvement in dart throwing, shown in Fig. 51, illustrates the improvement in quality plotted against the amount of

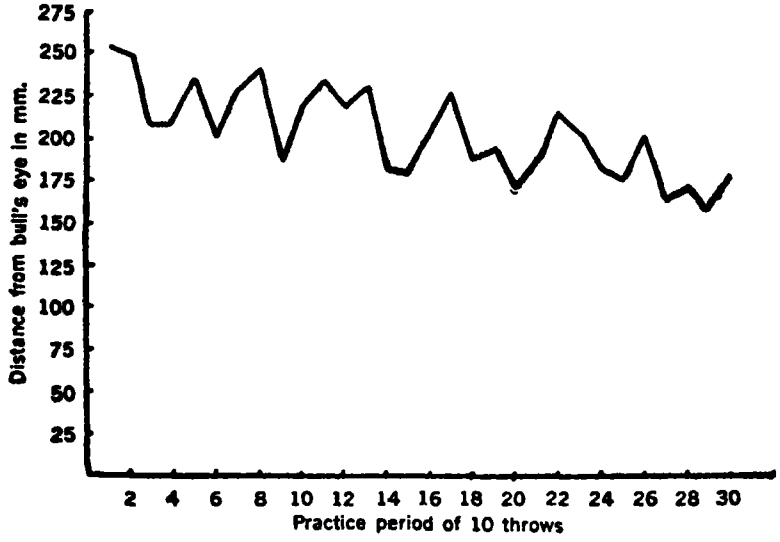


FIG. 51.—A curve in which quality is plotted against amount of practice. This curve portrays the learning of ten boys in dart throwing. Each practice period consisted of ten throws for each boy. Quality of performance is measured by the average distance of the throws from the bull's-eye in mm. Note the general straight-line tendency of the curve.

practice in terms of number of throws. The quality is measured by the average distance that the dart came from the bull's-eye. Improvement in this curve is represented by a falling line. Practice periods of ten throws each are represented along the X-axis, and average distance from the bull's-eye along the Y-axis.

4. *The quality against practice-time curve.* Figure 52 represents improvement in ability to keep two balls in the air when practiced for a certain time each day. Increased skill is

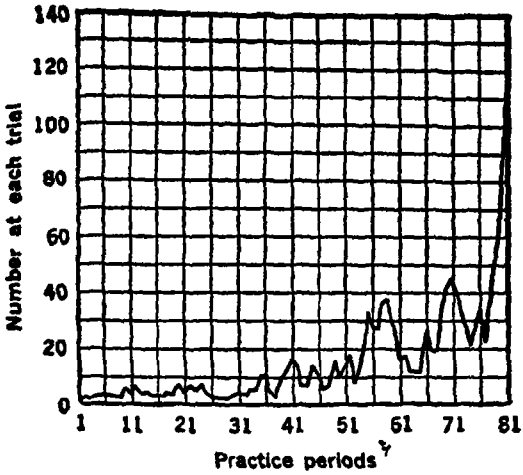


FIG. 52.—A curve in which quality is plotted against practice time. This curve portrays improvement in ability to keep two balls in the air. The base represents successive practice periods. The height represents the average number of catches without dropping a ball. Note that improvement is slow at first and rapid toward the end of the curve.

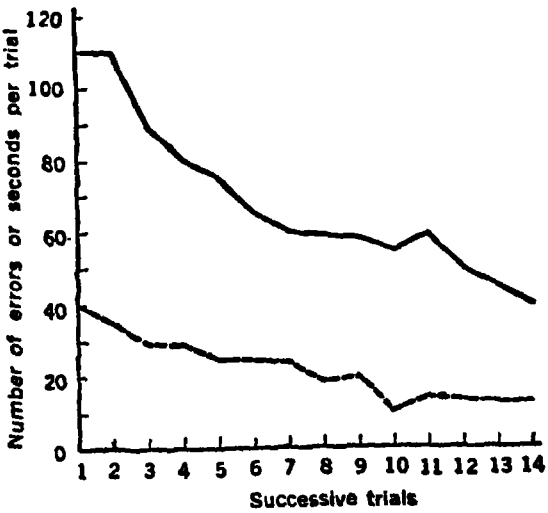


FIG. 53.—Curve showing improvement in tracing a star outline when seen through a mirror. The continuous line represents the reduction in seconds in successive trials, while the dotted line represents reduction in the number of errors. The relation between time and error scores changes with the task involved.

measured by the number of tosses that a person could make without dropping a ball and is plotted on the Y-axis; the successive practice periods are plotted along the X-axis.

5. *The error against amount-of-practice curve.* A good illustration of the decrease in errors, plotted against the number of times the act was tried, is the mirror drawing curve. The task is to trace a star when seen through a mirror. The subject is required to keep between two parallel lines, it being an error when he touches either line. Figure 53 shows the successive trials

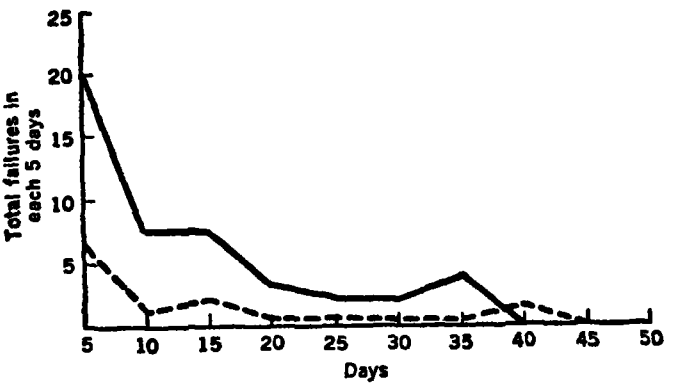


FIG. 54.—A curve in which errors are plotted against time periods. This curve shows the improvement of both a child and an ape in bladder control. Failure consists of inability to make a voiding reaction within the arbitrary limit of 10 minutes. Solid line is the ape. Dotted line is the child. The child shows superiority over the ape.

(From: W. N. and L. A. Kellogg, *The Ape and the Child.* By permission of McGraw-Hill Book Co., New York.)

plotted along the X-axis and the number of errors plotted along the Y-axis. This figure also shows the improvement in speed plotted against trials.

6. *The error against practice-time curve.* The errors are plotted along the Y-axis and the time intervals along the X-axis. Such a curve is illustrated in Fig. 54. A child and an ape were both given fifty days of training in bladder control. An error was counted when the individual failed to make a voiding reaction within an arbitrary 10-minute trial.

Characteristics of the learning curve. Every learning curve is the plotting of the variable of attainment against the

variable of practice. If equal amounts of practice gave equal increments of attainment, the learning curve would be a simple straight line. Experimental studies have demonstrated that such a simple relationship is the exception and the problem confronting the psychologist is to discover and evaluate the various influences which modify the form of the curve.

Most learning curves exhibit fluctuations. Most learning curves exhibit irregularities which often obscure the general trend of the curve unless they are ironed out in some manner. Figure 49 exhibits marked fluctuations. These fluctuations are especially marked when the curve for one individual is plotted and when the units of practice are rather small. They are probably due to an interplay of a great many extraneous and irrelevant factors, such as changes in physiological functions, distractions of attention, changes in motivation, or random sensory stimuli operating at the moment. Since these operate in haphazard fashion, some tending to cause improvement and others tending to interfere with efficiency, their influence may be excluded and the general trend of learning be ascertained by smoothing out the learning curve.

Fluctuations may be interpreted to mean that the learner can greatly improve his score. The peaks in an irregular curve indicate spots where he did unusually well. If he can do well at one time, he should be able, through practice, to equal his best score regularly. Fluctuations, therefore, mean that the learner is still doing unnecessary acts, that he is being influenced by extraneous factors, or that he has failed to learn the best combination of movements. The aim of practice should be to eliminate fluctuations not by bringing the whole performance to an average level, but by attaining the best method for accomplishing a task so that, when the fluctuations do disappear, the resultant regularity may be at a high level of efficiency.

Some learning curves manifest a general straight line trend. A straight line learning curve indicates equal returns from practice throughout the learning program represented by the curve. Such a curve may result from drill in some motor habit, and is illustrated in Fig. 51 which portrays progress in learning dart throwing. [20, p. 478]

The subjects were sixth-grade boys who practiced hitting a target with standard darts seven inches long. They were given

no instructions except to attempt to hit the bull's-eye. Practice consisted of ten throws each day for four days a week. While a line cutting midway the general area covered by the curve would be nearly straight, it is inconceivable that such a line could be projected indefinitely in either or both directions and still represent the facts of learning. For example, the average improvement in dart throwing, for the duration of this experiment, was about 2 mm. per practice period. Should we extrapolate the curve to the left indefinitely, we should have an absurdly large average error. On the other hand, should we extend the straight line to the right it would require only ninety more practice periods for the straight line to pass below the base line and indicate more than perfection.

A straight-line learning curve denotes that the learners did not begin with complete inability nor did they reach the point of complete perfection when the curve stopped.

In many learning curves the greatest rate of improvement comes at the beginning of the learning period. Illustrations are Figs. 49, 50, and 54. Various explanations have been advanced for this rapid initial learning. (a) One theory assumes that the performance of the task at hand depends upon a few operations which, at first, are hidden in a mass of irrelevant factors. The discovery of the correct ones is accompanied by the rapid rejection of great numbers of incorrect ones. As learning progresses, the number of rejections per practice period becomes fewer and so the progress is less rapid. (b) Another explanation is based on the supposition that such a curve begins at a stage in learning that is already well advanced. The curve for learning typewriting, for example, cannot be considered as the learning of a completely new function. It depends upon previous training in learning to use the arms, fingers, to co-ordinate the eye muscles, and to read. Typewriting capitalizes on all this past training and thus is able to show rapid improvement from the very beginning. As practice proceeds, the relative value of previous training becomes less and the learning curve shows a declining rate of improvement. (c) A third explanation would account for the quick improvement by the dropping away of initial fears, indecisions, feelings of newness, and other emotional factors.

It is quite likely that all three theories have some validity.

If so, the true explanation of the rapid improvement at the beginning of some learning situations must be an individual interpretation for each separate learning situation.

Some learning curves show little improvement in the early stages. For example, Fig. 52, showing the learning of ball tossing, rises very slowly at first and then more rapidly toward the end of the curve. If such a curve were continued it would necessarily rise at a slower rate and eventually level off when the individual reached the limit of his ability.

A complete learning curve would probably be S-shaped. It is reasonable to suppose that, if a person begins to learn a task that is totally new in its major aspects, his progress will at first be slow. As practice continues his rate of improvement will

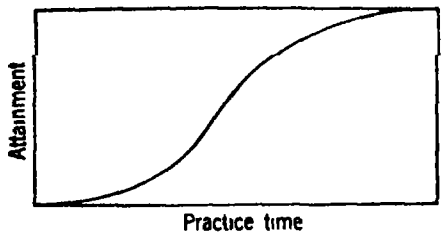


FIG. 55.—A hypothetical complete learning curve. Explanation in text.

increase and the learning curve will show a steeper slope. When the learner begins to approach the limits of his capabilities the rate of progress will fall off and the curve will be less steep. The complete learning curve would, consequently, be S-shaped. [26] Such an S-curve is shown in Fig. 55. A learning curve like this could be obtained only when there was a complete record from almost complete ineptitude to almost complete perfection. Most of the learning curves obtained in experimental situations are segments. The actual form of the learning curve is dependent upon the portion of the hypothetically complete curve from which the segment is taken. If it is taken from the beginning, the segment will show slow initial progress. If taken from the middle portion, it will show straight-line progression. If it is taken from the last portion, it will show quick initial progress and an ultimate lack of improvement as the limit of capacity is reached. The reason why so many of the experimentally derived learning curves show the typical quick initial improvement with negative accelera-

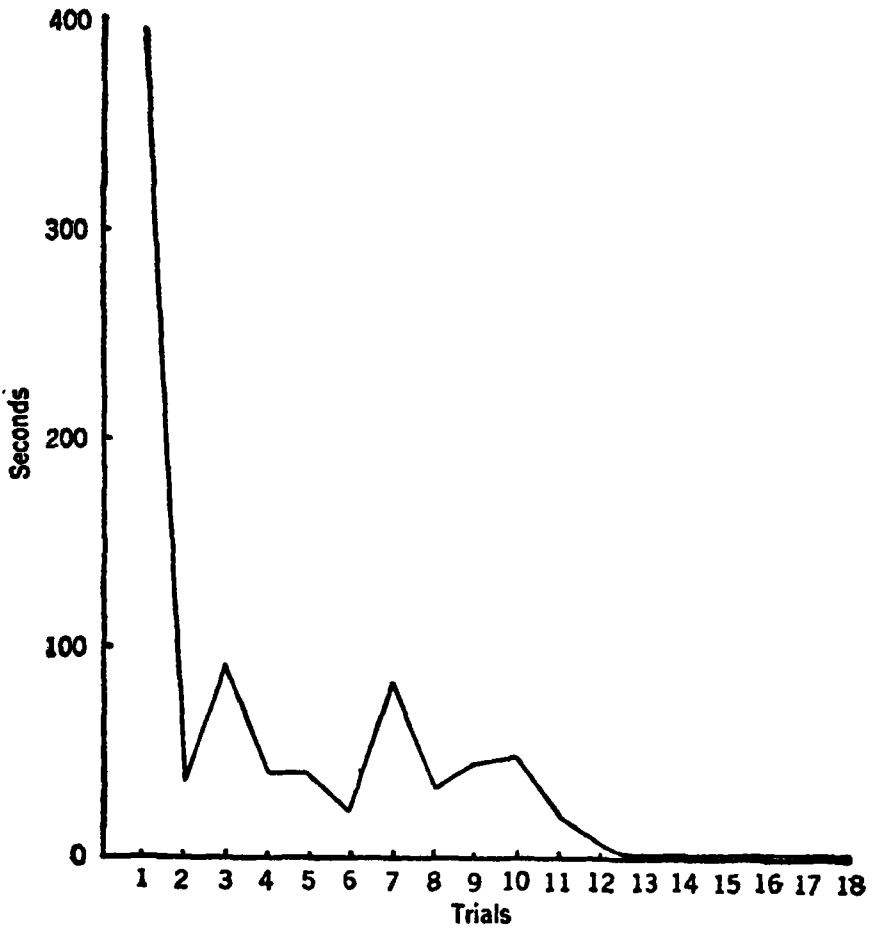


FIG. 56.—The learning curve for solving a bent nail puzzle. The first successes came by accident. The rapid improvement came from observing the general position in which the nails were held to get them apart. During trials 11 and 12, the subject learned the basic rule involved and performances after that point were fast and uniform.

tion is that most of the functions studied are made up of acts that are not new and are carried to a point where little further improvement is possible. For example, Fig. 52 can be regarded as a segment taken from the first part of the S-shaped curve, Fig. 51 as taken from the central range, and Fig. 50 as taken from the final part. Of course, these three curves do not fit together in

a way that would make one complete curve because they are plotted differently and represent totally different functions. Nevertheless, a comparison of the three does illustrate the principle.

Some learning curves show periods of extremely rapid improvement. Such rapid improvement may come at the beginning of the learning period or during the progress of learning. The learning of puzzles illustrates sudden learning. [22] Figure 56 shows the learning curve for an individual in solving a bent nail puzzle, shown in Fig. 57, with his eyes closed. The

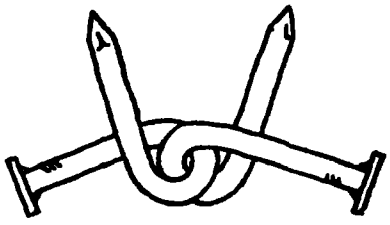


FIG. 57.—The bent nail puzzle.

first trial required between six and seven minutes because the subject had no idea of how to solve the puzzle and could only toy with it. After the nails first came apart he gained considerable knowledge as to the manner of solving the puzzle and his second trial required only thirty-eight seconds. Even with this rapid improvement, he was still using random methods through the tenth trial, and his curve is, consequently, highly irregular. During the eleventh and twelfth trials he worked out the exact principle and his record after that indicates very fast performance —less than two seconds.

A precipitous change in the learning curve *during* the process of learning is illustrated in an experiment devised to discover the way in which children learn such a concept as "opposite." The subjects were asked, "Do you know what opposite means? What is the opposite of good?" If the child failed, he was given the correct answer: "bad." This same procedure was repeated with the word "big." After these two initial demonstrations twenty-five words were given in turn, the child in each case being asked to give the opposite of the word. None of the subjects used in this experiment exhibited gradual learning of the relation of opposition. They went abruptly from 100 per

cent failures to 100 per cent successes. This precipitous learning is not an explanation of the learning process; it merely indicates that under some circumstances either (a) learning takes place quickly or (b) our methods of measuring improvement are so crude that we are unable to record the intermediate stages between failure and success. [16]

Sudden learning, and a precipitous drop in the learning time or a sudden spurt in learning quality, may appear in three

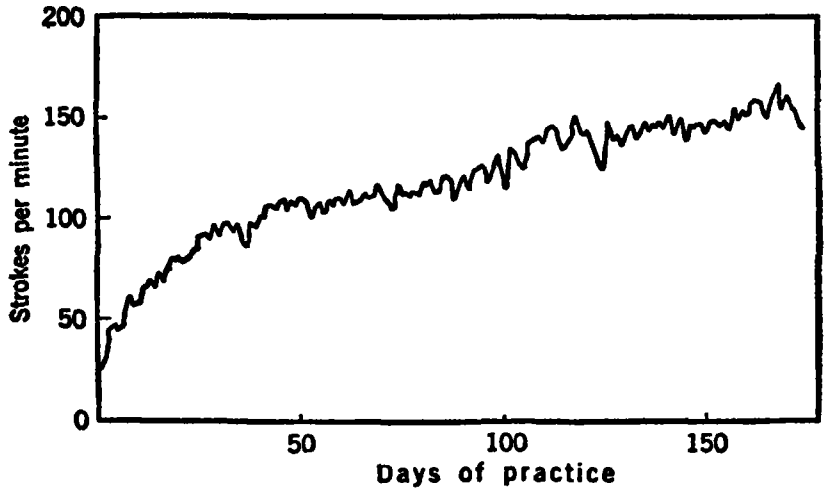


FIG. 58.—A curve of one subject learning to typewrite. Each point on the curve shows a day's record in number of strokes per minute. Note the plateau after the 50th day, followed by another period of fairly rapid improvement.

situations: (1) when the problem is a rational one and the individual thinks out the principles involved; (2) when the problem is a simple motor act which the individual stumbles upon by sheer accident; or (3) when the person receives a hint or instruction from another person who knows the answer.

Many learning curves exhibit plateaus. A plateau is a temporary halt in the progress of learning, indicated by inability to increase speed, to improve quality, or to decrease the number of errors. Various reasons have been advanced to explain plateaus:

1. A plateau is the natural result when a learning task involves several factors of unequal difficulty. Presumably the

easier component is learned more quickly and may come near to perfection when other components are in the beginning stages of learning.

This is the probable explanation of the plateau seen in the learning curve for typewriting in Fig. 58. The learner was compelled first to learn his keyboard and to know with which finger to strike each separate letter. These letter habits (and other patterns that go with them) were learned probably during the first fifty days of practice. For the next fifty days of practice the curve flattens out, but with some improvement as the learner increases his skill with letter habits. With the learning of word habits, or the combinations of the elementary word habits into larger units, efficiency takes another sharp rise with a subsequent flattening out. The plateau in this instance may, therefore, be interpreted as the result of the combination of two learning curves, the one the curve for learning letter habits which can be acquired more quickly, and the second the more time-consuming learning of word habits. [2] It is conceivable that the learning of some still more efficient method might transform what appears to be the approaching physiological limit into another plateau.

2. Plateaus may be due in part to a lack of enthusiasm or effort on the part of the learner. This factor may be demonstrated by comparing the progress of a person when he is permitted to work at his own rate with the progress he makes when he is more highly motivated. For example, after the learning curve of a typist has leveled off, he may be offered more pay provided he improves. Such added incentives have been found to cause a spurt and to raise the learning curve to a new high level.

3. Plateaus may result from difficulties in co-ordinating the different components of a task. The subject may become too engrossed in some specific aspect of the task and thus impede the development of other aspects of the problem. [1] He may vacillate between one aspect and another. He may give his attention to the way he is performing the act rather than to the end to be gained from the total act. [29] Having learned some valuable movement he may attempt to utilize it where it is irrelevant and thus impede his progress.

Arrests of progress are, therefore, more likely to occur as the task becomes more complex. In such tasks, whenever the

learner directs his attention toward the separate factors in the task there is likely to be a plateau or plateaus in the learning curve. [1] If the complex task is of such a nature that no such analysis or isolation of parts is possible, there is less likelihood that a plateau will appear. [14]

4. Plateaus may result from habit interference. [28] A plateau may occur because the learner shifts from one set of movements to the other without selecting the best and becoming proficient in it. This is demonstrated in an experiment in dealing cards. The subject was permitted over a period of time to deal the cards in any manner he chose, and to use several different ways of holding the pack, and of shoving out the top card with his thumb so that it could be caught with the other hand. After eight practice periods during which there was no improvement, a single method was adhered to exclusively for twelve practice periods. The learning curve rose rapidly above the plateau with which the curve started. (The subject had previously had much training in dealing cards.) After the twentieth period there was an intermission with no practice and the curve after the resumption of practice manifested another plateau. Theoretically, this level might have also been broken by the introduction of some new procedure.

5. Plateaus may result when the scores of various individuals of greatly different ability are averaged together. In the typical learning experiment the subjects are far from unpracticed at the moment the conditions of a formal learning experiment are imposed upon them. Some have had considerable opportunity to practice at least some acts that have a bearing upon their skill in the acts required by the experiment. In addition, there are differences in native capacity. To put a number of such individuals at the same task and to average the scores for each time unit, or for each task unit, throughout the experimental period may give a gross distortion of the actual facts. This may be illustrated by taking two hypothetical individuals of vastly different ability and averaging their learning scores. Suppose that subject A learns the required task to a given standard of perfection in eight practice periods and subject B requires sixteen practice periods to reach the same standard of perfection. Figure 59 shows the composite curve that would result were we

to average the scores of the two subjects for each practice period. There would be a decided plateau. Now, it is apparent that this plateau is not a function of the task learned but results from

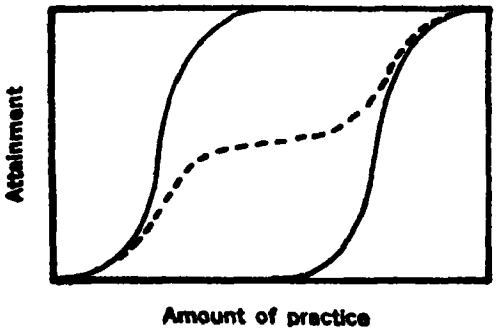
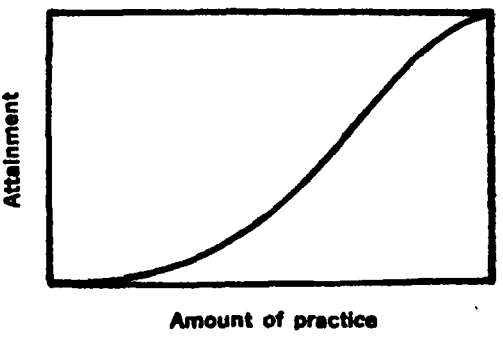


FIG. 59.—A plateau resulting from combining two curves in which the periods of rapid improvement do not synchronize. One curve represents an individual who reached his limit of learning in eight periods. The other curve represents an individual who did not show improvement until after the eighth period and came to perfection at the sixteenth. The dotted line is an average of the two and shows a plateau.

averaging, in an incorrect manner, the learning scores of two subjects of differing ability. If, on the other hand, the total practice time for each subject is divided into an equal number

FIG. 60.—A Vincent curve. The total practice for each individual is divided into an equal number of intervals and each such interval averaged. This curve represents the averaging of the two component curves in Fig. 59 after such equalization of number of practice units. Note that the plateau disappears



of intervals, and the scores for each such interval are averaged, the curve shown in Fig. 60 will be obtained. A learning curve obtained in this manner has been called a Vincent curve. [12]

Theoretical limit of efficiency or physiological limit. Every learning curve, if continued long enough, must approach

a theoretical limit of efficiency. In the ordinary learning curve, it may at times be difficult to differentiate between a plateau and the final limit of skill or efficiency. When a plateau extends itself through a long period of practice and further improvement seems impossible, the leveling of the curve may appear to indicate the approach to the theoretical limit (in motor learning, often called the physiological limit). Any designation of the limits of learning should be made with reservations. The records of athletes have been broken and speeds in more complex tasks have been changed by the introduction of new methods of performance after it had been thought that further improvement was impossible. A change in the mode of attack of a problem may change what appeared to be a physiological limit into a plateau by raising the learning curve into a new high territory.

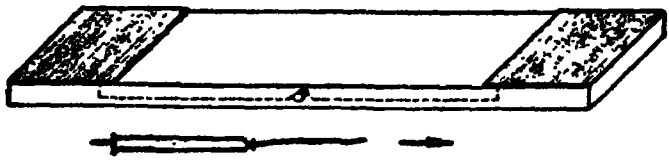


FIG. 61.—A tapping board. The metal plate on the board is tapped with the metal stylus, which is connected to an electric counter. The number of taps per unit of time is thus recorded.
(Courtesy of C. H. Stoelting Co., Chicago.)

THE TESTING OF MOTOR SKILLS

The testing of motor skills enables a person to gain an accurate picture of his abilities and limitations so that he can thereby guide himself in further practice.

Tests of simpler motor processes. A great many tests of simple motor processes have been devised. We shall review a few of these.

Tapping tests. The simplest form of tapping test consists of a metal plate tapped by a metal stylus held in the hand of the subject (Fig. 61). Each tap closes an electric contact which operates a counter. The number of taps per unit of time constitutes the subject's score. There are various modifications of tapping tests. [30] A telegraph key may be used and the key may be placed in different positions so that the subject may be

required to make either a horizontal or a vertical movement. Another modification of the tapping test, and one that can be used for testing large numbers of individuals at one time, consists in placing before the subject a paper upon which is printed

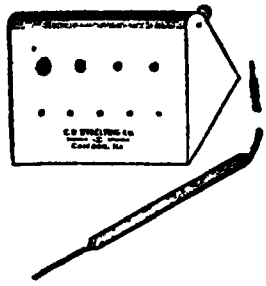
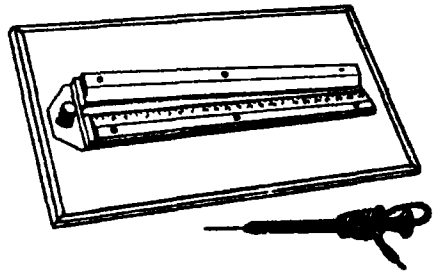


FIG. 62.—Steadiness test. The task is to hold the metal stylus in the holes without touching the side. Any contact is recorded on an electric counter. Proficiency is scored by the number of errors made in holes of different diameters.
(Courtesy of C. H. Stoelting Co., Chicago.)

a series of squares in each of which, in succession, the subject is required to make a dot with a pencil. [19]

Steadiness tests. The most widely used steadiness test utilizes a plate containing nine holes of diameters varying from 32 to 7 sixty-fourths of an inch (Fig. 62). The subject to be tested is given the task of holding a stylus in each hole during a

FIG. 63.—Tracing test. The task is to move the metal stylus between the two converging metal rules without touching the sides. The movement begins at the wide end and proficiency is measured by the distance moved toward the small end without touching. Contact gives an electric signal.
(Courtesy of C. H. Stoelting Co., Chicago.)



period of fifteen seconds while attempting to keep from touching the side. Any contact is recorded automatically. The fewer the contacts the higher the score.

An apparatus which records the swaying movements of a subject when he is endeavoring to stand motionless is called the ataximeter. It consists of threads attached to the upper part of the subject's body and extending in four directions. These

are connected with markers or other devices to record the swaying movements of the subject in any direction.

Tracing tests. For individual examination the tracing board shown in Fig. 63 is widely used. It consists of two metal plates which may be parallel with a narrow opening between them through which the subject is required to move a stylus, or the slit may be bounded by slightly converging lines, the subject beginning his movement at the wide and proceeding toward the narrow end. Other types of tracing tests utilize various forms

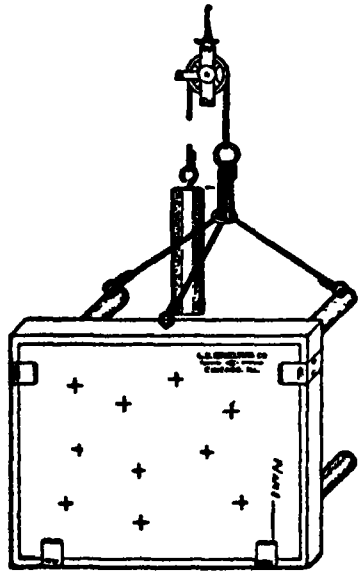


FIG. 64.—Aiming test. The targets are placed at arm level and the subject hits each intersection with a sweeping movement. Proficiency is in terms of average deviation from the point of intersection.

(Courtesy of C. H. Stoelting Co., Chicago.)

of pathways, printed on test paper, which the subject traces with a pencil. Scores may be made in terms of speed of tracing the pathway and number of errors made during the tracing. Each touching of the side lines of a pathway is an error.

Aiming tests. One form of aiming test, shown in Fig. 64, consists of a sheet of paper on which are printed some crossed lines. The subject is required, by a free arm movement, to strike each pair of lines at their intersection. Another variety of aiming test requires that the subject aim a metal stylus at holes in a fiberboard. When the stylu enters a hole it contacts a metal plate and completes an electric circuit through a counter. The score is the number of hits made in a given period of time.

Another paper aiming test consists of a regular target blank with twenty-five concentric circles, the smallest having a radius of 2 mm. and the successive circles increasing by a radius of 2 mm.

Tests of simple motor co-ordination. A great many tests of simple co-ordination (especially of eye-hand co-ordination) have been used. A few of the representative samples are as follows:

Card-sorting tests. Subjects have been given the task of sorting cards according to number, to color, or to certain geometrical forms printed on them, and dealing or sorting ordinary playing cards.

Assembly tests. These vary from such simple performances as putting matches in a box, packing spools in a box, or packing blocks in a box, to such complicated performances as assembling various mechanical devices, such as locks, bells, electric switches, and the like. [23]

Pursuit tests. One type of pursuit test requires that the subject hold a stylus upon a spot located on a revolving disk. Any movement from the spot breaks electric contact and operates an electric counter. In this test the movement of the target is a regular circular motion. [15] In another test the moving target is a pendulum. Another pursuit test consists of an oscillating target upon which the subject is required to hold a stylus. [27]

Tests of gross motor co-ordination. A number of athletic tests have been devised [5, 9] but these are difficult to standardize because they involve so many elements. [4, 8] One battery of such tests is in the nature of stunts which call for varying degrees of strength and co-ordination. [5] This battery classifies the functions as follows: (1) agility; (2) balance; (3) control; (4) flexibility; (5) agility combined with balance; (6) strength; and (7) strength combined with control.

Other investigators have classified gross motor tests according to the games in which they occur or the apparatus used: (a) Basketball tests: accuracy of passing, shooting the ball through a circle, free throws into the standard basket, corner shooting, distance shooting, and dribbling. (b) Baseball: accuracy of pitching, base running, and distance throwing. (c) Track: fifty-yard dash, standing broad jump, and shot-put. (d) Apparatus: side horse, horizontal bar, and parallel bar activities.

SUMMARY

Each skilled act requires individual treatment and it is not possible to lay down general rules which will hold for all. Nevertheless, the following summary may provide a background upon which a plan of efficient practice may be built:

The co-ordination of the large muscles. In making any movement there must be a truss or support to act as a fulcrum for the various levels of the skeletal system. Bodily trusses are not static but are being continually moved to suit various occasions; this fact lends great flexibility to motor performance. This flexibility would result in great inaccuracy of behavior if it were not for the fact that the large muscles which support the body are competent to hold them in rigid positions when such steadiness is needed and to move them with accuracy to give the body a new posture or stance. Precision is, consequently, based upon the control of bodily postures which can be brought about only by the co-ordinated activity of the larger bodily muscles.

The co-ordination of the finer muscles. In most skilled acts the highest degree of proficiency is attained by the development of greater and greater skill in manipulating the smaller muscles. Errors are made if stress is placed on these finer co-ordinations before the larger muscles become proficient. In such instances the finer muscles are placed under excessive strain and inaccurate performance is accompanied by excessive fatigue.

Ballistic movements should replace slow controlled movements. Increased skill is accompanied by an increase in the use of well-aimed ballistic movements and a decrease in the number of slow controlled movements. This lends ease and grace to movements.

The analysis of the various kinds of movements suggests that movements of fixation and slow controlled movements should be reserved as far as possible for the maintenance of posture in parts of the body which serve as braces for the swings of the more active members of the body. Hence, training in motor skills should emphasize the ballistic type of movement, and control should, therefore, be concerned largely with the aiming of the ballistic stroke. Attention should not be centered on the path that the moving member is to follow so much as on the goal or the aim

of the movement. Slow controlled movements entail tension of antagonistic muscles balanced against each other. The movements of the novice are characterized by an excess of such tensions even in groups of muscles that play no significant part in the main act being practiced. The more expert a person becomes the easier his performance seems.

Improvement in guiding slow controlled movements. The slow movement is guided by the changing of balance between two opposed muscle groups. Precision of a slow movement, therefore, must be learned by delicacy of balance between these groups. If learning is accompanied by more tension than is needed, any departure from balance is likely to cause an overextended movement which must be compensated for in turn; and if the tension is maintained, the compensation is likely to be overdone. This leads to an unsteadiness of movement. The less the general tension consistent with adequate control, the smoother the slow controlled movement is likely to be. This principle may be illustrated by the picture of a driver who steers with too much vigor. He turns the wheel in one direction but overdoes the movement; he jerks back to correct his excessive movement and finds that he has turned too far in the opposite direction. He makes a wavy path down the road, whereas the relaxed driver with smaller movements of the wheel makes a straight path.

Exercise is essential. There is a general factor of strength behind all skilled motor acts. The factor of strength is particularly important in enabling an individual to maintain the general trusswork of the body from which the flexible parts swing. The acquisition of skilled acts, consequently, requires not only the general improvement of the strength of the specific muscles involved in those acts but the building up of the gross musculature as well. Fine skilled acts are best built upon a foundation of excellent general bodily tone.

The greatest improvement in skill takes place during periods of greatest flexibility of performance. The rapid improvement manifested in the beginning stages of many learning curves indicates the utilization of previously acquired acts in new combinations. Once the combination is established, improvement comes through performing more quickly a stereotyped set of acts. Improvement from increased speed in the performance of the

same pattern or sequence of acts soon reaches a limit and a leveling of the curve takes place. The breaking through from this level comes most strikingly when some new element is injected into the situation. An illustration of this is the sudden jumps in the curve learning typewriting when the learner substitutes word habits for letter habits and again when he substitutes phrase habits for word habits. A leveling in the learning curve may be a physiological limit or it may be a plateau, the learner can never be sure which and can only attempt to devise some new pattern of behavior if he wishes to break through to a better level. Critical analysis of skills through motion-picture studies may be worth much more than dogged practice in attempting to add a tiny fraction to one's score. Even the expert may not be using the best possible technique.

Skill depends upon co-ordinations. As skill increases, there is an increase in the number of elements co-operating and in completeness of co-ordination. To the novice this may be interpreted, consciously or unconsciously, as the intense use of all parts of his body. The infant walks with his arms, his jaws, his tongue, and literally his whole body. Co-operation involves the inhibition of activity on the part of some muscles as well as the increased vigor of others. The body that is unified in some highly skilled act is one in which each part knows when to function and when to refrain from functioning as well as the exact degree of contribution to make at any one time. It is in learning such co-ordination that practice plays such an important part.

Skills are specific. Practicing accuracy or skill in operating a typewriter is a poor way to learn to shoot a rifle. Even in acts that seem to be logically related there is not much to be gained by practicing one act in order to improve skill in another. Nevertheless, there may be value in practicing skills which seem to have some relationship to the main act being learned in that such practice may keep the learner flexible. He may, by accident, be improving in some act that can later be incorporated in other skills.

Accurate timing. A basic factor in precision is accurate timing, not only of the total act but also of the components of the act. Each muscle must deliver its energy at exactly the right moment, at exactly the right place, with exactly the right force,

must continue for the exact length of time, and must be stopped or diverted in exactly the right manner. Furthermore, this timing cannot be an individual affair; it must be in relation to the timing of every other muscle involved. In some skilled acts it may be possible to get the time relations by performing them slowly and then speeding them up while maintaining the same relationships. In other acts this seems to be impossible and practice must begin at a high rate of speed. Teachers of skilled acts have not been able to formulate any general principles for teaching timing. The best methods involve taking motion pictures to detect errors which cannot be discovered as the movement is in progress and using these pictures to guide the learner in succeeding attempts.

QUESTIONS FOR REVIEW

1. Explain how antagonistic muscles behave in producing a movement.
2. Describe the following forms of movement: (a) fixation; (b) the slow or controlled movement; (c) fast movement under tension; (d) the ballistic movement.
3. In what ways may movements be conjoined?
4. Explain the advantages of the ballistic movement.
5. Why cannot ballistic movements be the only type involved in a complete act?
6. Explain how the learning of motor skills is accomplished in part by changing from one type of movement to another.
7. How does exercise affect the strength of a muscle?
8. What factors may contribute to improvement in the speed of a motor performance?
9. How is precision related to speed and accuracy?
10. What factors may affect the knee-jerk time?
11. Describe the apparatus for measuring reaction times.
12. Enumerate the factors which influence simple reaction times.
13. How does a discrimination reaction differ from a simple reaction?
14. What is meant by an association reaction?
15. In what two ways may practice periods be divided?
16. What are the three methods for measuring improvement from practice?
17. Describe the six typical learning curves that may be made from different combinations of practice intervals and measures of improvement.

18. Give some reasons why learning curves may exhibit fluctuations.
19. What inference can be made when a learning curve has a straight-line trend?
20. Give three theories that have been proposed to explain rapid improvement at the beginning of a learning curve.
21. Why would a complete learning curve probably be S-shaped?
22. What is the possible significance of a period of unusually rapid improvement?
23. What is meant by a plateau in a learning curve?
24. Describe five factors that might contribute to learning plateaus.
25. What is a Vincent curve?
26. What is meant by the physiological limit?
27. Describe four tests of simple motor processes.
28. Describe three tests of simple motor co-ordination.
29. Why is it difficult to devise tests for complex motor processes?
30. Summarize the general principles for the acquisition of motor skills.

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Chapter IX

CONDITIONED REACTION LEARNING

WE HAVE already seen how learning interacts with the processes of maturation, how it affects intelligence, modifies the drives to behavior, changes the emotional patterns of an individual, and how it enables a person to acquire motor skills. Furthermore, we shall find that learning is involved in practically all the aspects of psychology which we shall study later. The fact that learning is so important in psychology has stimulated much investigation into the nature of this process, most of which has centered in analyses of conditioned reaction learning and of memorizing. Lest the student be tempted to think that learning is a specific kind of behavior, confined to certain aspects of living, it might be well to review the different forms of learning.

FORMS OF LEARNING

Learning may be defined as the improvement of efficiency of performance by means of practice, usually measured by some such criterion as speed, freedom from error, better co-ordination, economy of effort, or perfection of form. A perspective may be secured by reviewing some of the forms that learning may take:

Associative learning. A person may learn by bringing into relation different portions of his experiences. There may be sensory combinations, such as when the child learns that the sight of his bottle is a sign or cue that he may be about to get some relief from his hunger pangs.

Multiple choice learning. One may learn through making a choice between several possible alternate responses. This method is prominent in maze learning or in solving a mechanical puzzle.

Learning by inhibition. Inhibition is a blocking or suppression of a response. One may learn to refrain from an act or he may learn to stop an act already in progress when that act is detrimental or when it fails to prove adequate for the situation at hand.

Learning improvement in specific skills. One may learn to improve his skill in such acts as typewriting, swimming, playing a musical instrument, singing, hitting a target, walking, or the like.

Learning to solve problems. One may learn to solve mathematical equations, to settle intricate personal problems, to unravel philosophical arguments, or to make business decisions.

Learning languages. The learning of means of communication both written and oral requires a special application of learning principles.

Perceptual learning. One may learn greater skill in discernment or in the perception of his environment.

Memorizing. Memorizing is the type of learning which centers largely around verbal material. It includes rote memorizing, learning how to study with greater efficiency, the technique of recalling what has been learned, and the ability to recognize persons and places.

Learning personality traits. The more complicated aspects of living involve learning. One may learn rules for living, attitudes, moral principles, prejudices, social customs, the interpretation of the activities of other persons, and other similar aspects of personal and social life.

This array of forms of learning should make it clear that a person may be doing vastly different acts and may be modified in different ways and still be learning in all of them.

THE CONDITIONED REACTION

A conditioned reaction is a response which may now be set off by a stimulus which originally was inadequate to initiate it. When a dog sits up in response to the signal "Sit up," it is making a conditioned reaction. No dog is able to perform this trick without learning. In some instances, the conditioned reaction is similar to the original reaction; in others, the response may become radically modified in the learning. For example, the first sitting

reaction of the dog may have been crude, but after he has learned to sit upon command he may do so with great skill.

What interests us is how this learning takes place; how a signal ("sit up"), which originally did not cause the dog to sit up, now will bring about the desired result. A dog may be taught this trick as follows: (a) Find some way to make the dog sit up through his own efforts. An excellent means for doing this is to hold in front of him some morsel of food which he likes. As he reaches for the food, raise it above his head and make him get into a sitting posture before giving it to him. After this has been repeated several times, it will be easy to get him to sit up in response to the presentation of the food. In other words, the presentation of the food has become an adequate stimulus (or a competent device) to get the dog to sit up. (b) Just before the food is presented each time, and while the dog is responding to the movement of the food by sitting up, give the command, "Sit up." After about ten to twenty repetitions of this sequence (being sure to give the dog the food after each satisfactory response) the dog will sit up when the verbal signal alone is given.

If it should be desired to break down the effects of this learning (that is, to teach the dog not to sit up), all that would be necessary would be to give the command but refrain from showing food, or giving any food to the dog, at such times. He would thereby learn that the signal "Sit up" does not mean food and would be likely, at least after a number of experiences, to fail to respond.

An everyday illustration in the human realm of this principle of conditioned reaction is as follows: A young man began to use an alarm clock to waken in the morning. Just before the alarm rang, this particular clock gave a preliminary click. Before very long, this young man found himself being wakened by the preliminary click and was able to shut off the alarm before it actually rang. There was no conscious intent on his part to learn to awaken with the preliminary click; he was sound asleep when it occurred.

A certain terminology has grown up in connection with experiments on the conditioned reflex. The stimulus which naturally brings about the reaction that is wanted is called the *uncon-*

ditioned stimulus. It has also been called the original, or the adequate, stimulus. These terms should not be taken to imply that the unconditioned, original, or adequate stimulus was not itself learned. We have already seen in Chapter III, how even so-called reflexes are based on past experience. All that is meant by the term "unconditioned stimulus" is that the animal or human being now responds readily to a certain stimulus.

The stimulus which was originally inadequate, but which has become adequate, to bring about the desired response through presentation in conjunction (or association) with the adequate stimulus is called the *conditioned stimulus.* It has also been called the substitute, or secondary, stimulus.

In the preceding directions for training the dog, the original, unconditioned, or adequate stimulus was the presentation of the meat in such a manner as to get the dog to sit; the secondary, conditioned, originally inadequate, or substitute stimulus was the command, "Sit up." In the illustration of the alarm clock, the ringing of the alarm was the original, unconditioned, or adequate stimulus for rising. The click was the inadequate, secondary, or conditioned stimulus. After learning, in each case, the secondary, conditioned, or inadequate stimulus became competent to bring about the response. It, in turn, could be considered as the unconditioned, primary, or adequate stimulus in a new learning situation. In other words, these terms have to be strictly defined in each experimental or learning situation in which they are used.

LABORATORY EXPERIMENTS IN CONDITIONING

The conditioned reaction technique has been widely used in laboratory work for several reasons: (a) It is easily applicable to animals and so permits controls and modifications which would be impossible with human subjects. (b) It does not require any introspective report on the part of the subject. Records can be made in a purely objective fashion. (c) It does not require conscious control or co-operation (although these are often present) on the part of the subject. (d) It involves the simplest kind of learning and so can be readily used to test various hypotheses.

The conditioning of the knee jerk. The first strictly experimental record of the conditioned reaction in this country was made in 1902. [18, p. 382] The experimenter was making a

careful study of the knee jerk. The operation of the mechanical device which gave the blow was preceded by the sound of a bell. On one occasion, it happened that, although the bell sounded, the stimulus hammer failed to hit the patellar tendon; but the knee jerk took place anyway. The experimenter repeated the situation, and found that the subject responded with the knee jerk whenever the bell sounded. The subject reported that he was not consciously kicking the foot and that the whole phenomenon was beyond his control.

That this was not an accidental phenomenon, or the peculiarity of this one subject, was proved by repeating the test with six other persons. They all reacted in similar fashion. In this situation, the hammer that gave the blow to the patellar tendon was the adequate, unconditioned, or original stimulus; the bell was the substitute, originally inadequate, conditioned, or secondary stimulus. It will be noted that the response was the same in each case—the knee jerk.

Other workers have corroborated this early, almost accidental, discovery of the conditioning of the knee jerk. In a unique study, it has been found that an individual may be taught to kick with one leg when the patellar tendon of the other leg is struck. This learning is accomplished as follows: One reflex hammer is permitted to fall on the patellar tendon of the left leg and, after approximately one-fifth of a second, another hammer is made to fall on the patellar tendon of the right leg. After a large number of stimulations, it is possible to elicit a reaction of the right leg by stimulating the patellar tendon of the left leg. [36]

Conditioning the reflex withdrawal from a painful stimulus. [3] When any part of the body is subjected to a painful stimulation, there is a reflex tendency to withdraw that part of the body from the stimulus. It has been possible to teach animals or human beings to make such withdrawal reactions to a great number of conditioned stimuli. [22]

The customary procedure with animals is to place the foot on a metal grid which is connected with an induction coil in such a manner that an electric shock can be administered at definite times and in definite degrees. [21] With human subjects it

has been customary to have the person place a finger on the electrode, as shown in Fig. 65.

The buzzer shock technique has been used to demonstrate that conditioning may take place without deliberate control or without awareness on the part of the subject. This was done by giving subjects conditioned reaction training while they were in a hypnotic trance. It was found that conditioned reactions (in which the subject was trained to make a withdrawal reaction

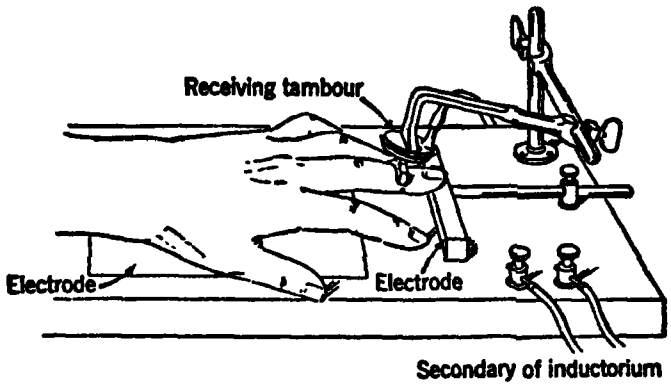


FIG. 65.—Apparatus for conditioning the reflex withdrawal from a painful stimulus. A large electrode is placed under the hand and a small one under the finger. The closing of a key by the experimenter gives the subject a shock causing him to withdraw his finger. Raising the finger operates the tambour placed above the finger and makes a graphic record of the movement. After several stimulations immediately following some conditioned stimulus, such as the ringing of a bell, the individual will raise his finger when the conditioned stimulus is given without the electric shock.

in response to a buzzer stimulation) could be set up by training during the hypnotic trance more easily than could be done when the subject was awake. In addition, conditioned reflexes set up in the trance state could be evoked in the succeeding waking state in spite of the fact that the subjects could not recall the trance training. This demonstrates that there is such a phenomenon as learning without the learner being aware of this learning. [31]

Conditioning the salivary secretions. Much of the pioneer experimentation on the conditioned reaction has been done

with the conditioning of the salivary secretions in dogs. [25] The offering of food to a hungry dog (who has already learned the meaning of food) is sufficient to cause salivary and gastric secretions. Because it is easier to observe the salivary secretions than the gastric, the former have been more intensively studied, although conditioning of the gastric reactions also has been investigated experimentally. The setup for this experiment is shown in Fig. 66.

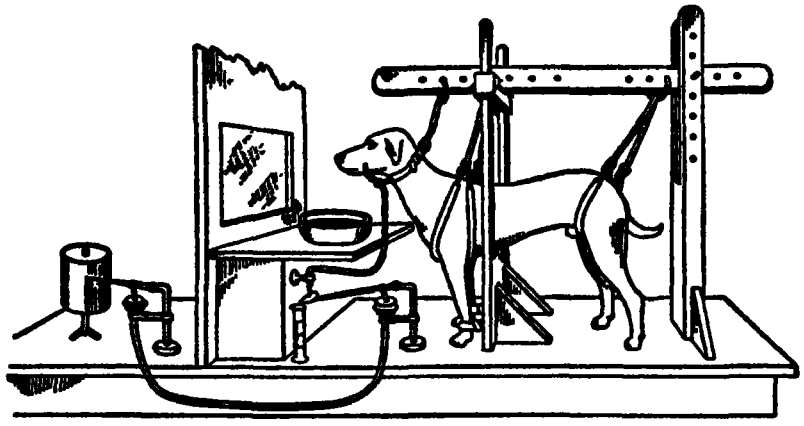


FIG. 66.—Experimental setup for conditioning the salivary secretion of a dog. The unconditioned stimulus is presented through the window. Just before the food is presented, the conditioned stimulus, the ringing of a bell, is given. The saliva flows through the fistula in the dog's mouth, drops on the disk, and then flows into the graduated receptacle. Thus, the number of drops can be counted and the amount of saliva measured. Graphic recordings of the drops are made on the kymograph to the left.

The accurate measurement of the flow of saliva has been accomplished in several ways. (a) In dogs, by means of a minor operation, the saliva has been made to flow through an inserted pipe, then through a tube, and finally made to drop upon a disk which makes an automatic record of the fall of each drop. Or, the saliva may be collected and the amount of secretion measured. (b) In man, a suction tube has been substituted for the pipe used with dogs. (c) Absorbent cotton rolls have been placed in the mouth and the secretion of saliva measured by weighing the cotton both before and after insertion into the mouth.

It has been found possible to train dogs so that they will respond with the salivary secretion to a great many different conditioned stimuli. On the other hand, it has been found more difficult to establish conditioned salivary reactions in humans.

Conditioning the plantar reflex. The plantar reflex consists of a flexion of the toes and ankle resulting from the stroking of the sole of the foot, the stimulus following the course shown in Fig. 67. There are two facts which indicate that the plantar reflex is not suitable for general experimental work: (a) Some subjects do not show any plantar conditioning after extensive training. In one experiment, for example, three out of ten subjects failed to learn. (b) A great number of human beings do



FIG. 67.—Diagram to illustrate the method for eliciting the plantar reflex. The arrows show the direction taken by the stimulus on the sole.

not respond to the plantar stimulus in a uniform manner. This can be easily verified. [32]

In spite of these limitations, an application of this method has been utilized for testing the hearing of newborn infants. [1] By presenting a sound just before stroking the foot the infant may be conditioned to respond to the sound by the flexion of the toes. After the conditioned reaction has been established, it is possible to reduce the intensity of the tone to the point where the infant no longer makes the toe response; thus it is possible to get some notion of how well he can hear. The infant's toe reaction is the virtual equivalent for saying, "I can hear that sound."

Conditioning the reflex wink. The winking reflex may be elicited by a sudden puff of air directed against the eyeball while the head of the animal is held rigid. If a light is flashed directly into the eyes of an animal, there is normally no winking reaction. If the flashing of the light (conditioned stimulus) is followed repeatedby by a puff of air (unconditioned stimulus) to

the right eye, the animal will learn to wink with the right eye to the flashing of the light. [16]

Other stimuli that have been used as unconditioned stimuli in conditioning the wink reflex are: a loud sound [16], an electric shock [6], and a mechanical tap on the lower eyelid [35].

Conditioning the breathing reactions. A sudden unpleasant stimulus, such as an electric shock applied to the finger, will produce a change in the depth of breathing as well as a change in breathing regularity, which changes will continue for about twenty seconds after the stimulation. These changes may be measured by means of a pneumograph, which is an apparatus for making a graphic record of respiratory changes. (See Fig. 33.)

It has been found to be relatively easy to condition the breathing so that it will respond to a great variety of conditioned stimuli. Merely from ordinary life experiences, the average individual has learned to modify his breathing to so many stimuli —specific words, pictures, sounds, touches, tastes, smells, and the like—that irrelevant elements will cause breathing to change continually. [12] The regularity of breathing is also disturbed continually by the physiological conditions. Hence, in an experimental setting the experimenter can be sure of his results only when he is able to produce a modification great enough (or consistent enough) to stand out from ordinary irregularities.

Conditioning of vasomotor constriction. An adequate stimulus to produce a constriction of the blood vessels is cold. Since constriction of the blood vessels in the hand will reduce the volume of that member, this reaction may be graphically recorded by an instrument, called the plethysmograph, which measures the volume of the part of the body that is being subjected to experiment. In one experiment, subjects were taught to make vasomotor reactions to such conditioned stimuli as the sounding of a tuning fork, a note sounded on a fife, and the vibration of an electric buzzer. Vasomotor conditioned reactions are not so easily established as those in some other fields; an average of twenty-five paired presentations has been found necessary to produce definite results.

The pallor and blushing reactions which persons manifest in everyday life in response to queer sounds, verbal stimuli, and

embarrassing situations are probably illustrations of conditioned vasomotor reactions.

Conditioning of the galvanic skin reactions. The galvanic skin response is a change in the resistance of the skin owing to a change in physiological activity (see page 186). It is a reaction that takes place without awareness on the part of the subject and must be measured by means of a galvanometer. This measurement is accomplished by attaching two electrodes (such as two polished silver quarter dollars) to different parts of the body, perhaps the palm of each hand, and connecting them with a sensitive galvanometer.

The galvanic reaction is extremely sensitive and is elicited by a great number of stimuli, and for this reason is somewhat unsatisfactory for experimental conditioning. Nevertheless, it has been widely used because it takes place without awareness on the part of the subject. [2]

Conditioning the pitch of the voice. It has been a matter of common knowledge that excitement tends to make an individual raise the pitch of his voice. In the experimental laboratory, it has been found that a similar rise can be caused definitely by giving the subject a rapid series of induction shocks at the same time that he is speaking. Hence, induction shocks were used as the unconditioned stimulus in an attempt to condition the pitch change of the voice. The conditioned stimulus was the flashing of the right of two small electric bulbs. The subject was directed to repeat a word (the word "sat") when either bulb flashed. Whenever the right-hand bulb flashed the subject received a shock as he was saying the word. No shock was ever given with a response to the left-hand bulb. Every individual tested, after about twenty paired stimulations of the right-hand bulb and the shock, learned to raise his voice whenever the right-hand bulb flashed alone.

Conditioning the food-taking reactions. The food-taking responses of newborn infants were conditioned as follows: The infants were never, from the first time they were fed, given the bottle unless it was immediately preceded or accompanied by the sound of a buzzer. They were fed six times each day. Of the eight infants used in the experiment, seven showed significant changes in behavior in response to the sound of the buzzer after

three to six days of training. The activities which the infants made in response to the buzzer were sucking, mouth opening, a cessation of general activity, and crying. All these activities were those associated with the feeding behavior of the infants. In other words, these infants learned to react to the buzzer as a signal for food. [23]

Another experimenter worked with children up to seven years of age. Her method was to permit the child to lie on a couch until he was quiet and emotionally undisturbed. A bandage was then slipped over his eyes from above so as to eliminate the light completely. Five seconds after the application of the bandage, the right arm, above the elbow, was stimulated with a soft brush for ten seconds, and in the sixteenth second the child was fed a bit of sweet chocolate or sweetened water. The sequence was repeated until the child gave two responses indicating that he was expecting the food after the application of the bandage or the tactile stimulation of the arm before the food was given. The learning was accomplished, on the average, in about six paired presentations. [24]

Conditioning of the alimentary tract. The successful conditioning of the defecation of a young cat has been reported. The unconditioned stimulus was an enema with lukewarm water, and the conditioned stimulus a musical sound (*mi* of the fourth octave given by a reed pipe). The sound stimulus was begun simultaneously with the entrance of the cannula into the rectum and was prolonged throughout the administration of the water. By this means the cat was taught to defecate upon hearing the sound.

FACTORS AFFECTING CONDITIONING

Conditioning takes place according to certain definite conditions, some of which have come to light through rigid experimentation. Most important are the time relations between the conditioned and unconditioned stimuli, the surroundings in which the conditioning takes place, and reinforcement or inhibition by later experiences. We shall now examine these aspects of conditioned reaction learning.

Significant time relations for conditioning. In order for conditioning to occur, it is necessary that the conditioned and un-

conditioned stimuli occur simultaneously or in close succession. Is it better for the conditioned stimulus to precede the unconditioned stimulus or for the conditioned stimulus to follow the unconditioned stimulus? Is there an optimum interval of time that should elapse between the two or should they be given at exactly the same time?

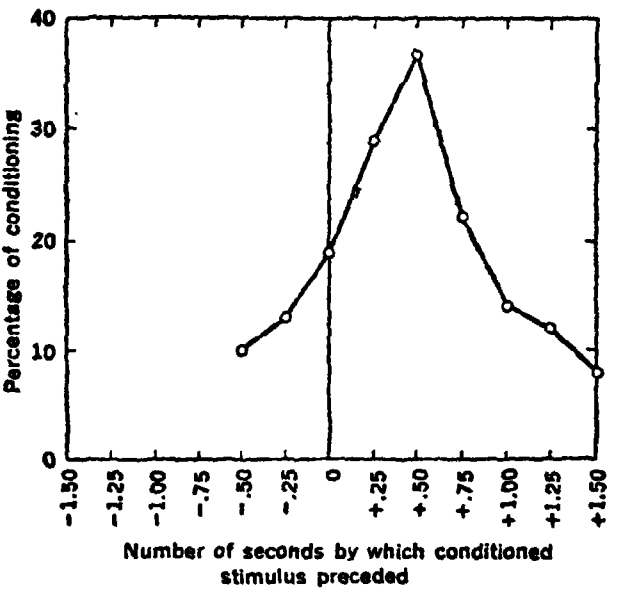


FIG. 68.—Graph showing the effect of different time relations between the conditioned and the unconditioned stimulus. The conditioning is most efficient when the conditioned stimulus precedes the unconditioned stimulus by 0.50 sec. From this optimum the efficiency drops off in both directions. In general, it is better for the conditioned to precede the unconditioned stimulus.

These questions have been answered by a carefully performed and critical experiment. [38] The unconditioned stimulus was an electric shock administered to the finger; the conditioned stimulus was the sound of a buzzer. The response was the withdrawal of the finger. The intervals were in steps of 0.25 second, beginning with the shock (unconditioned stimulus) 0.50 second *before* the sound (conditioned stimulus) and ending with the shock 1.50 seconds after the sound. The best learning occurred when the sound preceded the shock by an interval of 0.50 second.

The relations are shown in Fig. 68. From this optimal setting the learning efficiency decreased in each direction. It is less efficient to have the two stimuli occur together than to have the conditioned stimulus precede, by a short interval, the unconditioned stimulus. Nevertheless, learning does occur when the unconditioned stimulus precedes or when they come simultaneously.

These time relationships support the hypothesis that the conditioned stimulus is a sort of cue to the subject, which enables him to anticipate the results that will follow from the unconditioned stimulus. The subject learns that the buzzer will be followed by a shock to the finger and raises his finger without waiting for the actual shock to occur. This is called *forward conditioning.*

Backward conditioning is the name given when the unconditioned stimulus precedes the conditioned stimulus. Some early investigators [25] asserted that backward conditioning was impossible; but the above experiment shows that backward conditioning can be effective.

Distraction effects. Conditioned reactions may be disturbed by irrelevant events or circumstances in the external environment. Experimentalists have given these disturbances the name of external inhibitions.

For example, the playing of a phonograph record for a few seconds before the time that a conditioned salivary stimulus was applied to a dog modified considerably the amount of saliva secreted in response to the conditioned stimulus. [18, p. 436] In everyday language, the experimental animal is distracted by such irrelevant factors and his response is diverted partially as a reaction to these irrelevant stimuli. He may want to investigate these new intruders but, of course, he cannot make such an investigation and give a completely satisfactory reaction to the experimental stimulus. Consequently, in all conditioned reaction experiments great care must be taken either to exclude or to control irrelevant and distracting elements.

Experimental extinction. Experimental extinction is merely the experimentalist's name for unlearning. Suppose that, after a dog has been trained so that his mouth will water when a bell is rung, the bell is rung repeatedly without ever being fol-

lowed by food. Soon his mouth will cease to water when the bell is rung. He learns that the ringing of the bell is no longer a cue that food is coming and so fails to make the salivary response that accompanies eating food. This unlearning of a conditioned reaction by means of the presentation of the conditioned stimulus without the unconditioned stimulus has been called *experimental extinction.* It is essentially learning something new. Whereas the dog previously learned that the sound of the bell meant food, he is now required to learn that the bell does not mean food. Under such circumstances continued response to the bell by the salivary reaction is an error because the dog should learn that conditions have changed and that the bell is no longer a cue to indicate that food is coming. [13]

Experimental extinction is a laboratory verification of the principle illustrated in the "Wolf, wolf" story. When the shepherd boy cried "Wolf, wolf," his hearers made the response they had learned to make to the presence of a wolf—they ran to help the boy. When he called several times and no wolf appeared, the other shepherds learned that his cry did not mean danger—he was deceiving them; consequently they did not trouble to come to his assistance. He thus taught them to ignore his cries for help—he had extinguished their conditioned reaction to his cries; and when he did cry from actual need they did not respond.

Experimental extinction is not the same as forgetting, nor is it due to a failure to learn adequately. [37] It is an active form of adaptive learning; it is learning that the connection between the conditioned stimulus and the response is not significant. [5] The person who ceases to respond to the practical joker's false distress signal is neither failing to learn nor forgetting. He is learning something new; namely, that all calls for help are not genuine, and particularly that this joker's call is a false alarm. When an experimenter teaches an animal that a bell indicates food and then fails to give the food upon ringing the bell, the animal is actively learning something new; he is learning that the experimenter has changed the rules of the game and that he must learn what the new rules are. [8, 11]

The way in which experimental extinction takes place corroborates this point of view. In some cases there appears to be a resistance to extinction which might be interpreted as meaning

that the animal discounts those later experiences which do not harmonize with what he has learned. [33] Extinction in one instance required three times as long as the original conditioning, and even after extinction appeared to be complete there were slight movements on the part of the animal, indicating incipient responses in harmony with the conditioned reaction that had been extinguished. [11] Furthermore, it has been found that at the close of the period of training in experimental extinction, there is a sudden elimination of the last traces of the conditioning. That is, when the animal finally learns that the conditioned stimulus is not the cue it had been, the entire effect of the preceding conditioning disappears. [19]

From all this evidence, it would certainly seem that extinction is a mechanism in its own right. It is a positive form of learning. It is learning to correct the learning of the past in the light of the present. [4, 5]

Disinhibition. Disinhibition is the process of making the inhibition or extinction of a conditioned reaction inoperative. It is the process of restoring old learning which has been supplanted by new learning. Since, as we have just seen, experimental extinction consists of supplanting one conditioned reaction with subsequent conditioning, any factor that will make this latter learning ineffective will permit the previous pattern to reappear. For example, one may have learned to supplant his tendency to say "it don't" by saying "it doesn't," only to find himself blurting out "it don't" when trying to make an after-dinner speech for which he is unprepared. The excitement of the present functions as a disinhibition which counteracts the inhibition, or resistance in the form of new learning, which he had built up against saying "it don't."

This process has been checked in the laboratory. [29] Human subjects were trained to make salivary secretions in response to a light stimulus. After they had learned this conditioned reaction they were subjected to experimental extinction by repeated stimulation with the light alone. Then, after they had learned not to respond to the light with a salivary secretion, the light was presented along with a buzzer; whereupon they responded with a salivary secretion.

THE SPECIFICITY OF CONDITIONED REACTIONS

With progress in learning, conditioned reactions increase in specificity. In the early stages of training a conditioned reaction is likely to be diffuse and may be made in response to a rather wide range of stimuli. As learning advances, the individual narrows the range of stimuli which will call forth the response and he is likely to be more specific in the response that he makes.

The narrowing of the range of response, as learning proceeds, has been noted by a number of investigators. When an animal is first subjected to a conditioned reaction situation, his behavior is generalized and impulsive to a high degree. He struggles in his harness, tries to escape, crouches, hangs on the straps, looks about furtively, and makes various sounds to express his discomfort. When the animal has become well conditioned he usually assumes a posture of attention. The dog, for example, when being given tonal conditioned stimuli, will turn his head to one side in an attitude of rapt listening and will make a precise motor response.

The way in which the response of an animal narrows down is illustrated by the training of a sheep to respond to a metronome stimulus. The sheep was placed in an experimental setting, shown in Fig. 69, where he could be stimulated by a metronome (conditioned stimulus) and by an electric shock to the foreleg (unconditioned stimulus). Graphic records were made of his breathing, of the motor responses of the leg, of the head movements, and of the changes in electrical skin resistance. When the metronome was first sounded alone the sheep made no apparent response in breathing or in the movement of his leg. The electric shock brought about a definite, brief flexion of the leg. After four presentations of the metronome stimulus followed by the giving of the shock, there was a definite change in the breathing of the animal, accompanied by slight head movements, and a change in the skin resistance as soon as the metronome sounded and before any shock was given. At the sixth trial, there was a slight movement of the leg to the metronome preceding the giving of the shock. At the eleventh trial there was a definite movement of the leg before the electric shock was given. In other words, the animal made vague responses which indicated an increase of gen-

eral tension before it learned a final definite response to the conditioned stimulus. [21]

It has been possible to utilize the conditioned reaction method to measure the sensory acuity of animals, as well as of children. An illustration of the procedure with dogs is as follows: [9] The dog is restrained by a harness and frame, with one front paw resting on a grid through which a shock may be administered.

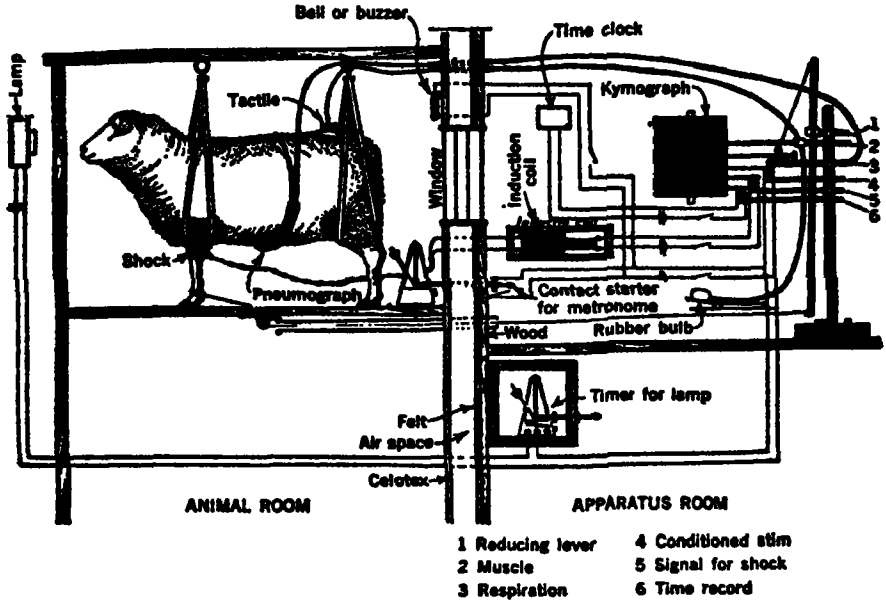


FIG. 69.—Diagram of apparatus for the study of the conditioned reaction.

(From F. A. Moss, *Comparative Psychology*. By permission of Prentice-Hall, New York.)

The sound, which is to be the conditioned stimulus, is given two seconds before the shock (the unconditioned stimulus) is begun. The dog can thus avoid shock entirely if he always raises his paw as soon as the sound is given. After the dog has been trained he listens for the sound, raises his paw in a matter-of-fact way as soon as he hears it, and replaces his foot on the grill when the time for the shock has passed. [9]

After the dog has been thoroughly trained, the intensity of the tone can be reduced and his threshold determined. When a tone is too faint for the dog to hear he will fail to raise his paw

until the shock comes. This will tend to make him more attentive to possible tones in the future and, at the same time, indicate to the experimenter that he did not hear that particular one. A dog, so trained, reminds one of an attentive child in school—carefully attending so as to do his best. By this technique it has been shown that a dog can hear tones which are too high in frequency for a man to detect.

INDIVIDUAL DIFFERENCES IN CONDITIONING

There are marked individual differences in various species of animals in the ease with which they can be trained by the conditioned reaction method. [27] In primitive organisms conditioning takes longer than in higher organisms and ability seems to be graded along the phylogenetic scale. The number of paired presentations of a touch with a light required for teaching a shellfish to withdraw into its shell in response to light ranged from 34 to 111 (with a median of 73), whereas a human infant can be conditioned in as few as three presentations of the conditioned with the unconditioned stimulus.

In human beings there seems to be an increase in the time, or number of paired presentations, required for establishing a conditioned reaction after the fifth year of age. [24, 28] This fact might be explained by the hypothesis that conditioning as manifested in lower organisms and in children is an elementary and mechanical type of learning that is superseded by more intelligent controls as the child becomes older. In other words, human conditioning should be interpreted in terms of the controlling attitudes which are related intimately with the subject's total personality. [26]

In general, three kinds of attitudes may be distinguished in human adults when they are subjected to conditioned reaction experiments. The first is the positive type—the person who can be readily conditioned. The second is the negative type—the one who responds in a contrary manner to the conditioned training. The third is the indifferent type—the one in whom no change is effected by conditioned reaction training. These three classes can be viewed as three degrees of amenability to the requirements of the artificial situation required by the experiment. Human adult behavior depends not altogether upon a mechanical arrangement

in a laboratory, but somewhat upon the attitude of the subject toward the whole experimental setting, including the experimenter. Likewise, in everyday life some individuals will agree readily to co-operate in an activity although there seems little logical justification for it; some are relatively indifferent and sit stolidly and unchanged through many activities in life; while others immediately become resistive to anything that is apart from ordinary procedures.

The behavior of animals also illustrates the great individual differences that obtain when they are subjected to the conditioned reaction experiment. For example, there is a great difference between the behavior of a sheep and that of a goat. The goat is likely to show great irritability. Often, a single tick from the metronome, when this is the conditioned stimulus, will cause a goat to raise its foreleg and to hold it, trembling, in this position for many seconds. On the other hand, the sheep, in response to the same stimulus, will do nothing more than turn its head, as if to listen, or make a perfunctory movement of the foreleg, or execute a minor change of position. At the shock (the unconditioned stimulus), the sheep may briskly flex the leg or even jump; but the goat will, in addition, butt the apparatus with its horns or bite at the wires. The sheep is a "cold-blooded" learner, while the goat is a "hot-blooded" learner. [22]

KINDS OF CONDITIONED REACTION LEARNING

It seems evident, in view of much experimental work, that conditioning must be considered as a kind of learning. It is essentially a modification of behavior through experience. The individual manifests a change which depends upon the repetition of the paired presentation of the conditioned with the unconditioned stimulus. Furthermore, there is a more or less permanent effect as a result of the conditioning experiences. [15, 36]

At the same time, it seems clear that adherence to a rigid procedure does not ensure the same kind of learning or the same degree of learning in different individuals, especially when these techniques are applied to human beings. In response to essentially the same experimental setting a person may learn almost mechanically and with no consciousness of what is taking place, or he may take a conscious and critical attitude toward the ex-

periment and his learning may be influenced radically by this conscious reaction on his part.

Most writers accept the fact that there are various kinds of conditioned reactions; but there is little agreement as to how to classify them. One writer would classify them on the basis of the latency of response. [18, p. 431] He reasons as follows: Some conditioned reactions are merely augmentations of the original unconditioned reaction and have short latent times. In these, the conditioned response follows as quickly upon the conditioned stimulus as did the original response when the unconditioned stimulus was given. These are called *alpha reactions.* In others, the conditioned stimulus acquires the power of evoking reactions which are somewhat different from the original reaction and there is a longer latent time preceding the response. These are called *beta reactions.* The alpha reactions are the mechanical and automatic conditioned reactions, while the beta reactions include those which are similar to deliberate and conscious responses. If this distinction is made, it should be recognized that both man and lower organisms may respond with both the alpha and the beta type of conditioned reactions; at the same time it would seem that mature human beings are likely to manifest more conditioned reactions of the beta than of the alpha type.

Another writer has classified conditioned reactions according to the degree of relationship between the conditioned stimulus and the reaction before the conditioning took place. Type I would include all conditioned reactions in which there was no relationship between the conditioned stimulus and the response before training. Type II would include those in which there already was some relationship before training.

The realization that there are different kinds of conditioned reactions without agreement as to how these kinds should be classified gives support to the probability that the conditioned reaction should not be considered as an entity. It is merely a convenient category into which to incorporate certain learning techniques or laboratory settings which are similar. The conditioned reaction is a method and not a physiological or psychological thing with separate existence.

The most important factor in the establishment of a conditioned reaction is not the original stimulus that sets it off but the

response that is made. For example, suppose that it is desired to teach an animal to raise its paw at the sound of a certain tone. Before such teaching can take place some means of making the animal raise his paw must be found. The important factor is to obtain the response by one means or another.

It is also important that the conditioned stimulus stand out as a significant or dominant part of the total situation. If the subject of an experiment discerns, either consciously or unconsciously, the significance of the conditioned stimulus, learning takes place easily. If the conditioned stimulus is some minor feature in the whole environmental setting, it may take an extremely long time for the learning to take place.

For example, suppose that an animal is stimulated repeatedly by means of an electric shock to make the withdrawal response. Suppose, furthermore, that the first setting in which this occurs contains the inadequate stimuli A, B, C, and D; that the second setting contains the inadequate stimuli E, F, G, and H; the third setting contains the stimuli, I, J, K, L, M, and N; the fourth setting contains the stimuli O, P, and Q; etc. If, in other words, each separate elicitation of the withdrawal response is effected in a setting in which there are no common factors (not even the same number of conditions), no one of the inadequate stimuli could ever become adequate to bring about the withdrawal reaction.

Suppose, on the other hand, that the successive settings contained combinations of factors as follows: (a) A, B, C, and D; (b) A, F, G and H; (c) A, I, J, and K; (d) A, L, M, N, O, P, Q, and R. A is a common factor and could easily become the cue, or conditioned stimulus, for bringing about the withdrawal response. It stands out because it is always present, whereas the others appear erratically.

The laboratory experiments on conditioned reaction are a sort of "hothouse" learning. The animal learns, for example, that the sound of a tone of a certain pitch means food, because this is the only stimulus connected with food; but he is by no means sure that some other signal might not also mean food. Consequently, when some distraction occurs, he is inclined to react to it in an exploratory manner to discover whether it also may be the proper cue. This is the phenomenon which we have

already discussed as external inhibition. When conditions are strictly limited, the conditioned reaction ends in an unstable connection which may be upset by the slightest distraction or minor change in the total setting.

THE CONDITIONED REACTION IN EVERYDAY LIFE

Conditioned reaction learning, or cue learning, plays a prominent part in everyday living.

1. Conditioned reactions, or learned cues, account for the great breadth and variability so necessary in making adaptations to new situations. Practically any stimulus in a situation may come to play the part of a cue. It need have no logical relationship to an act. It merely needs to be a constant part of the total situation. For example, there is no logical reason why a bell should signify dinner; but if the bell rings before dinner, any animal or human being will learn to take it as a cue that dinner is to be served.

2. The flexibility of conditioned reactions makes readjustment easy. Sometimes we find ourselves responding to a false cue. It had been a constant feature of the situation, but now it has ceased to be. In such instances, we soon learn to cease responding to that signal. When we come to study problem solving, we shall find that the tentative selection of a logical conclusion makes us tend to adhere to that conclusion in spite of evidence that we were wrong. A valuable feature of a conditioned stimulus is that it can easily be ignored when it no longer is an adequate signal.

3. Conditioned reaction learning takes place without any conscious attempt at learning, and may occur without awareness on the part of the individual that he is doing so. For example, the person who learned to awaken at the preliminary click of his alarm clock, while able to sleep through loud noises, illustrates the ease with which one may come to respond to an apparently trivial stimulus and with no conscious effort. Many of the hunches and so-called intuitions are probably of this nature. The child has made no conscious analysis of the cues by means of which he knows when he had better obey his father or when he can disobey with impunity, but he has learned just the same.

4. Conditioned reaction learning begins early and continues throughout life. Animals and children learn readily by conditioning. They learn in spite of the fact that no one is making any attempt to teach them. Often they learn what they are not supposed to learn. The little boy not only learns to use an oath but he learns to use it only in the proper setting—that is, when he is in a temper.

5. Conditioned reactions provide a background for many emotional habits and personality traits. No one of us knows why he is neat or slovenly, honest or dishonest, persistent or irresolute, rash or cautious, proud or humble, benevolent or malevolent, and the like. We take pride in some traits and attempt to eliminate others without realizing how we came by them or what to do to eliminate them. The study of developing children has shown that these qualities are acquired by the mechanism of conditioned reactions. This being so, the way to change them is to do so by the method of experimental extinction or reconditioning.

The study of conditioned reactions has made untenable the idea that human nature cannot be changed. It has shown that many of the apparently subtle and persistent influences in human life are learned conditioned reactions.

QUESTIONS FOR REVIEW

1. Criticize the popular conception of learning.
2. Enumerate and characterize the various forms of learning.
3. Define conditioned reaction.
4. How can a dog be taught to sit up in response to a verbal command?
5. Define the term "conditioned stimulus" and give synonyms.
6. Define the term "unconditioned stimulus" and give synonyms.
7. Why is the conditioned reaction method a good one for experimental work in the laboratory?
8. Explain how a person may be taught to give the knee jerk with one leg when the stimulus is applied to the other leg.
9. Give evidence to show that a conditioned reaction may be learned without conscious intent on the part of the learner.
10. Describe the different procedures utilized in conditioning the salivary secretions.
11. What is the plantar reflex? Why is it difficult to use this reflex in experimental work?

12. How can the conditioned reflex method be used to test whether an infant can hear?
13. What stimuli have been used to condition the wink reflex?
14. What facts about the conditioning of breathing make it clear that the best results in conditioning are not obtained from those reactions which are most easily conditioned?
15. What experimental findings make it seem that blushing is a conditioned reaction?
16. By what procedure can the pitch of the voice be conditioned?
17. Describe two methods of studying the food-taking response to conditioned stimuli.
18. What type of evidence do we have that nausea may be a conditioned reaction?
19. What evidence is there that a rise in temperature of the body might be a conditioned reaction?
20. What is the optimum time relation between the conditioned and the unconditioned stimulus for efficient learning?
21. What is meant by experimental extinction?
22. Why should experimental extinction not be confused with forgetting, or be thought of as a failure to learn?
23. How can pitch discrimination of an animal be measured by the conditioned reaction method?
24. What different types of learners have been distinguished?
25. Explain what is meant by alpha reactions and beta reactions.
26. Show why the most important factor in establishing a conditioned reaction is to get the subject to make a response.
27. Explain why there must be some common element in the stimulus situation in order for conditioning to take place.

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Chapter X

MEMORIZING

MEMORIZING is the process of making an immediate experience effective so that it may be utilized at some future time. Recalling is making use at the present time of what was memorized in the past. Retaining is the process of keeping intact what was memorized so that it can be recalled. These terms are used most extensively with verbal materials but they are not always so restricted. For example, we can remember forms, musical sequences, emotional experiences, or abstract relationships. Another way of restricting the use of the term "memorizing" is to confine it to those experiences which can be expressed by symbols as contrasted with experiences of learning *how*. Neither the acquiring of motor skills nor learning to solve problems would thus be regarded as memory processes. Whether such restriction is justified or not is not significant. Nevertheless, in order to avoid confusion, we shall attempt to restrict our discussion in this chapter to symbolic or verbal material.

Variety of memory problems. If memory is to be utilized effectively, it must be recognized at the outset that the best pattern of memorizing and the most effective method of recalling will vary with circumstances. A course of general memory training is sure to be ineffective unless some method is evolved of analyzing each memorizing situation and adapting a procedure to fit it.

1. *Verbatim learning.* In some cases it will be necessary to utilize the material to be learned in its exact form. Such material must be learned verbatim or by rote. Much experimental work has been devoted to this problem and we shall presently review some of the methods that have proved their worth in making verbatim learning effective.

2. *The learning of meanings.* In some instances, verbatim learning would be not only unnecessary but ineffective because the need is for meanings or logical relationships. Different methods must be used to bring out the interrelations between elements in the materials to be learned.

3. *Becoming acquainted.* In still other instances, neither rote memorizing nor the learning of meanings is the important problem. Instead, the need is to build up a general familiarity with the material so that it can be recognized upon occasion. We learn to find our way through highways and streets by the process of recognizing general aspects of the situation instead of learning the sequences of elements by rote. This is called recognition memory.

4. *The consideration of time elements.* Some materials we wish to remember only for the moment and other materials we should never forget. We need to remember a telephone number, in many instances, only long enough to dial it or to tell it to the operator. We need to remember an errand for a little longer time. If we are to take part in a play, we must remember long enough to carry out the performance. The fact that two plus two equals four we should remember as long as we live. Different procedures may be used to make a memory permanent or evanescent.

How to analyze memory problems. With these variations in mind, it is important to ask certain questions before beginning the work of memorizing:

1. For how long a time will the material be of use? For a few seconds, for a few hours, a few days, a few years, or throughout life?

2. In what connections will it be needed? Will it be necessary to recite it verbatim? Will it be necessary only to recall the general meaning of the material? Will it be useful in a variety of situations, such as solving problems? Will it be necessary only to recognize it on some future occasion?

3. Into what length of time must the learning be restricted? Must it be mastered by a certain date or can it be spread over a long period of time? We shall find that the spacing of practice and the division of materials has much to do with the memorizing

processes, but these methods should be applied differently depending upon the immediate need.

4. How will the learning of this material be affected by other activities that must be carried on simultaneously?

If the student will plan his study with these questions in mind, he will be able to escape one of the gravest dangers; the tendency to fall into the habit of adopting one memorizing technique and of using it on all types of materials and on all occasions.

RETENTION

Retentivity is considered as the capacity for retaining the effects of learning. This capacity is not well understood. It does not operate in a mechanical fashion. Instead, it is influenced by a number of factors, such as the amount of learning, the meaningfulness of materials, the methods used in study, and interest in the material. Nevertheless, after considering all these factors, there seems to be a residual which may be called the capacity of the individual to retain traces of his experiences.

Individual differences in retentivity. Give a number of individuals the same material to be learned and great individual differences will be shown by members of the group. These differences are manifest not only in the time taken to learn the material, but in the amount recalled after a stated interval.

Memory span in children improves with age. In children retentivity seems to increase with age, if memory span can be taken as an index of retentivity. Memory span is defined as the number of items of a specified character which can be correctly reproduced immediately after one presentation. The materials that have been used to test memory span are digits, nonsense syllables, discrete words, sense materials, forms, or musical sounds.

With increasing age the memory span for digits increases, as shown in Table VII, from two digits to nine. During adult life the memory span does not improve beyond the eight- or nine-digit level.

Retentivity deteriorates with advanced age. After its initial improvement, retentive capacity seems to remain on a fair level until old age or some deteriorating condition sets in and causes a change for the worse. It seems also that the material

TABLE VII

INCREASE IN MEMORY SPAN FOR DIGITS WITH AGE

Age in years	Memory span for digits
2½	2
3	3
4½	4
7	5
10	6
14	7
Average adult	8
Average college student	9

learned during the period of improving retentive capacity is retained better than that learned later.

The strongest evidence that retentivity deteriorates with advanced age comes from the study of abnormal individuals. In a condition known as senile dementia the patient has a striking loss of recent events with a surprisingly good retention of earlier experiences. One of the earliest and most clear-cut signs of deterioration with advancing age is the tendency to repeat the same stories while forgetting that they have been told to the same persons recently.

Some definitely controlled studies have demonstrated the retention of material learned in infancy over a long period. For example, one psychologist read aloud to his child, beginning at the age of 15 months, a twenty-line selection of Greek drama each day. Every three months a different set of selections was used. This was continued until the child was 3 years of age. At the age of 8½ years, after a lapse of 5½ years, this child relearned this same material and, at the same time, learned new material of the same sort. Whereas the new material required on the average 435 repetitions per selection, the material which had been presented during the first three years required an average of 317 repetitions. [10] At the age of 14 a further check was made and, while the effect of the early learning still persisted, it was not so marked. [9]

Another experiment shows that material learned between the ages of 8 and 14 may be retained over a period of years. The

subject of this experiment had learned at the rate of one per Sunday the 107 answers to the questions in the Westminster Shorter Catechism, with additional help from explanation of meanings and periodic reviews. After a period of twenty years with no intervening practice, a recall test was made: 50 per cent of the answers were recalled perfectly and only 8 per cent required any considerable amount of prompting. [57]

Some persons have argued that the basis for retention of earlier memories is the practice that the individual gains through a lifelong repetition of these early experiences. While this may be a partial explanation, it certainly is not adequate to explain the whole phenomenon. There is an apparent process of decay which cannot be explained by differences in practice.

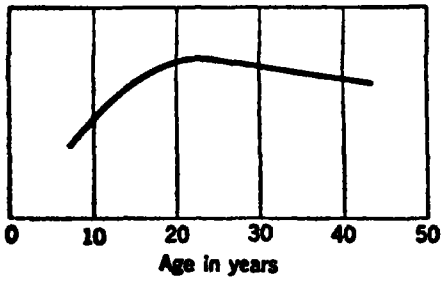


FIG. 70.—The change of learning ability with age. This curve gives the general form of the curve of ability to learn in relation to the ages indicated along the base line. (From E. L. Thorndike, *Adult Learning*. Macmillan, 1928.)

These findings have been corroborated by studies of different age groups. The ability to learn and to retain seems to increase from childhood up to the late teens or early twenties. [49, 60] From this age the ability levels off and shows a gradual but small decline up to around 50. From 50 years on the curve begins to drop, falling off more rapidly toward the final stages of senility (see Fig. 70). In one experiment where persons of three age groups were compared in their learning ability, it was found that individuals in the group from 34 to 59 years of age were slightly better than a group ranging from 12 to 17; while those with ages ranging from 60 to 89 were decidedly inferior to the other two groups in learning ability. [53]

It seems clear that retentivity is better in early life than in old age, and that the material learned in the period of greatest retentive capacity outlives the material learned during periods of lesser capacity.

Neural degeneration changes retentivity. In cases where there is neural deterioration caused by disease or the chronic use of such a drug as alcohol or morphine, there are definite losses in retentivity. The individuals so affected forget what they have learned and are unable to learn new materials with any degree of efficiency. These cases corroborate the conclusions derived from a study of senile cases. It seems that retentivity is dependent to some extent, at least, upon a healthy nervous system.

Forgetting. Retention is not a static affair. When viewed from one angle, it may be conceived of as the accumulation of

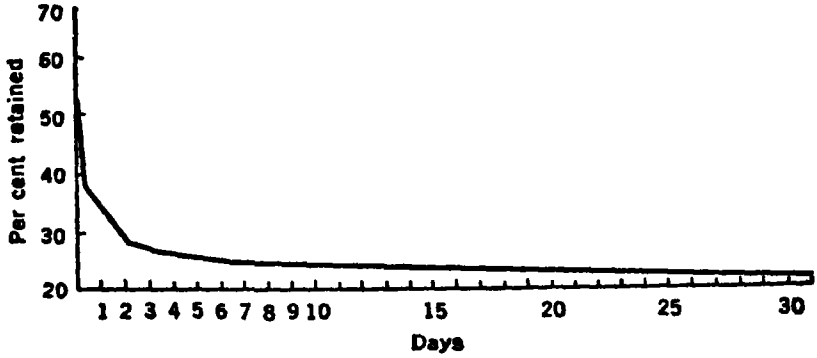


FIG. 71.—The curve of retention. The height of the curve indicates the percentage of material retained after the lapse of time indicated on the base line. The greatest loss occurs soon after learning.

what we have learned, the results of experiences in the past. When viewed from another angle, we must admit that these modifications are constantly diminishing in value—we are forgetting. Learning is the process of saving; forgetting is the process of losing. What we retain represents our present status—the balance between what we have learned and what we have forgotten that is left to our credit.

The rate of forgetting is not constant. Immediately after learning, forgetting proceeds rapidly and then more and more slowly.

The technique for producing a curve of forgetting is laborious. By a method called the relearning method, for example, it is necessary to learn material and then relearn it after one interval of time. Then an entirely new set of material must be learned

and this set relearned after another interval of time. This laborious learning of different materials for each separate interval is necessary to avoid a practice effect that would make the learning easier and easier. In the pioneer study separate materials were learned and relearned after the following intervals: 19 minutes, 63 minutes, 8 hours and 45 minutes, one day, 2 days, 6 days, and 31 days. In all, this experimenter learned and relearned over 1,200 lists of nonsense syllables, each list containing thirteen syllables. [18] The per cent of saving was calculated for each time interval and the curve in Fig. 71 was constructed. This curve shows that, after a large initial drop in the first two days, forgetting proceeds more slowly, so that there is little difference between the loss after 6 days and after 30 days. A certain minimum may stick indefinitely.

Factors which favor retention. From the preceding examination of retentivity the following conclusions may be drawn: (a) Individuals differ in their capacity to retain. (b) This capacity is influenced by age and by the condition of the nervous system. (c) Forgetting will take place under all circumstances, most rapidly immediately after learning and more slowly thereafter.

A deduction from these facts seems to be inescapable: We have little control over our capacity for retention. We cannot escape changes which are due to age nor can we alter the fact that we will forget. The benefits that may come from guarding health are general and limited in scope. We cannot do much about our capacity for retaining what we learn.

Nevertheless, we can all develop methods that will enable us to make better use of the capacity which we do possess. It is to these methods that we shall now devote our attention. We shall first consider general techniques and then those which affect certain kinds of memorizing, such as rote learning, memory for forms, and memory for relationships.

Meaningfulness. Meaningful material is quickly learned and is better retained than nonsense material. Nonsense material, barely learned, is almost entirely lost by the end of four months; whereas poetry, learned to no greater degree of perfection, may be retained for years. If the material is meaningful and also greatly overlearned it may be retained almost indefinitely. [61]

If the meaning is vivid, the permanent retention of an experience may require only one repetition. The implication from these facts would seem to be that it would be more beneficial for a person to endeavor to make his lessons vividly interesting and meaningful and spend less energy in desultory repetition.

Meaning can be injected into apparently meaningless material by two methods. One is to hunt for familiar items, relations, and suggestions in the material itself. The other is to have a ready-made schema, or skeleton, into which to incorporate the material. The skeleton would have to be different for different types of material and it might require considerable training to become proficient in its use; but those who give professional memory demonstrations usually have trained themselves to fit all new materials into some prearranged device. These devices, however, are of value only in making possible the almost immediate reproduction of large masses of material. One can use such a scheme to impress his friends at an evening party, to cram for an examination, or to assist in the early stages of learning for more permanent retention; but it should be clearly recognized that these devices are merely schemes for enlarging the immediate memory, and immediate memory is fleeting memory.

The essential principle behind the use of these devices is that rational learning is more effective than the verbatim learning of disconnected or meaningless materials. In the early stages of learning, the most efficient procedure is to give substance to the material in some manner or other, even if such a procedure requires the use of an artificial device. [64]

Freedom from interference by later experiences. Although there is a loss of retention with old age or mental deterioration, ordinary forgetting is not so much a matter of the decay of old impressions with the lapse of time as it is a matter of interferences, inhibition, or obliteration of the old experiences by new impressions or experiences. [32] It is not time that causes everyday forgetting so much as it is what occurs during the time that elapses between learning and remembering. Several kinds of evidence lend support to this statement.

1. Forgetting proceeds more rapidly during the waking hours than during sleep. If material is learned just before bedtime and compared for retention with material learned in the

morning, and corrections made for differences in efficiency for the different times of the day at which the learning is done, there is more retention of the material learned before sleep. [27, 62]

2. Intense activity may interfere with the retention of what has just been learned. [45] This phenomenon is called reproductive inhibition, or interference, implying that activity which occurs subsequent to the learning of material may interfere with the recall of that material. The term retroactive inhibition was formerly used to designate this phenomena. Since this latter term may give the suggestion that subsequent activity does something to the previous memorizing, it is better to substitute the term "reproductive inhibition," since it is the reproduction that is impeded and not the previous learning.

Reproductive interference is greatest when the activity which follows learning is similar in meaning or in form to what has been learned; [34] it is less when the material is overlearned; [44] and it operates more strongly in children than in adults. [56]

3. Forgetting irrelevant items favors retention of the more significant elements. It has been found, by experiment, that certain materials are more easily recalled as the time interval between learning and recall is increased. This phenomenon has been arbitrarily called reminiscence. [63] It can be demonstrated most clearly when the material learned is meaningful and interesting. It does not appear at all with material that is learned purely by rote, is completely lacking in interest, or is actually distasteful to the learner.

While various theories have been advanced to explain this phenomenon of reminiscence, the most plausible one seems to be that, in some manner, the material learned becomes more thoroughly organized with other learned items with the passage of time. This integration may involve partial reviews which take place in a sort of absent-minded manner; it may be helped by the formation of associations between the new materials and older learned materials; or it may depend largely upon the increased clarity of the general substance of what has been learned as the irrelevant and useless details are forgotten. [8, 39]

Stimulating conditions during learning. A challenging or stimulating situation facilitates retention. This was demon-

strated in one experiment where nonsense syllables were learned in three different settings: (a) freedom from any distraction; (b) both auditory and visual distractions; and (c) the presence of a passive spectator. In situation *a* the learning was most efficient; but under conditions *b* and *c* retention was better. It would seem that the lesson learned under difficulties is retained better. [50] This fits in with the theory that forgetting is a matter of interference, inhibition, or obliteration of old experiences by new ones. If, during learning, the influence of disturbances must be met by the learner, he may thereby build up resistances against interferences, concentrate more definitely upon the learning, and thus retain it better.

Transfer of training. It is easy to conceive of one motor habit interfering with another or of two habits being of mutual assistance or benefit to each other. Having learned to operate a typewriter with a standard keyboard, confusion would result in attempting to operate one in which the keyboard was changed around. It is also possible that, if a person learns to skate on roller skates, he could learn ice skating more easily than if he had never learned roller skating.

In connection with motor habits, such relationship between activities has been called facilitation or inhibition to designate cooperation or interference between habit patterns. In the field of verbal habits or memorizing the terms "positive" and "negative" transfer have been used. One older theory held that activities depended upon certain faculties. Memory was considered a faculty of this sort and thus memory might be trained by rote memorizing, by learning poetry, by studying languages, and the like. Thus, strengthened by exercise, the memory faculty would be prepared to perform new tasks with more ease. This theory gave rise to the educational procedure known as formal discipline. Studying was engaged in not so much for the particular materials studied but to train the various faculties. A study was valued according to the degree to which it contributed to formal development of some faculty.

Experimental evidence does not support any such faculty theory in the field of memory as can be seen from the following survey:

1. Memory is not improved by general practice. It has been

found that memorizing the poetry of one author does not make it easier to memorize the poetry of another author. [31, p. 666] When improvement has been found in the ability to memorize a particular kind of material, that improvement has been found to depend upon such factors as better learning techniques, the better selection of helpful associations, the use of grouping, rhythm, the elimination of worry and strain, and a general ability to concentrate on the task in hand. [65]

2. Memorizing one type of material has little or no effect upon the ability to learn other kinds. For example, training in learning nonsense syllables does not improve the ability to learn numbers, disconnected words, vocabularies, prose, poetry, and meaningless visual figures. [51]

3. Improved methods may carry over from one type of memorizing to another. Where any type of memorizing has been followed by improvement in other forms, this improvement has been accounted for by improved methods of study, the application of general principles, [14] the personal attitudes of the learners, and the influence of objectives or motivating factors. [28] For example, memorizing poetry trained subjects in the use of rhythm; and the ability to use rhythm helped them in a subsequent learning of nonsense syllables. Again, there may be a carry-over of attitude which may be helpful or detrimental. After studying prose passages, subjects showed a positive dislike for memorizing meaningless material and did poorer work because of this distaste. [56]

The conclusions that seems to follow from these various considerations is that practice will lead to improvement in memorizing processes, but not to improvement in some hypothetical memory faculty. Consequently, we shall turn our attention to the important problem of how to memorize.

EFFECTIVE USE OF ROTE LEARNING

The ability to repeat verbatim what has been learned has always been a prized possession. Hours have been spent learning prose, poetry, musical scores, and other serial materials. Much of this time has been wasted because the learners have not used the most efficient methods of study. Psychologists have studied the various factors affecting this type of learning; but they have used

many different kinds of materials in these studies, and have varied their procedures, so that the findings are somewhat difficult to synthesize.

Most of the studies may be organized under the following topics: (a) The best way to divide material into units for study; (b) the use of devices to facilitate learning; (c) the most effective length and distribution of practice periods; and (d) the most effective use of recitation.

Division of material into units for study. No arbitrary formula can be given for the most efficient division of memory material for study. The answer will probably be different in each situation, but we can give some general principles that may prove helpful.

1. Immediate memory span breaks down if the list is too long. Any presentation of digits or nonsense syllables definitely exceeding the span of the individual to be tested results in a total failure to reproduce the list perfectly. However, the subject can usually mention some of the items that have been given, although he has lost the sequence. With meaningful words, it has been found that the larger the number of words, the more the subject can repeat after one hearing, if he is not required to keep the proper sequence. However, while the absolute number increases with the increase in the size of the list, the percentage of recalled items decreases. Thus, a subject may reproduce 5 words if 5 have been presented; 7 words if 10 have been presented; 17 words if 49 have been presented; and 25 words if 100 have been presented. [65, p. 19]

The same results were obtained when subjects were tested as to their ability to recognize advertisements. Advertisements were shown and then mixed with an equal number of new ones, the subjects being required to select those they had seen. The number of advertisements in the original showing varied from 5 to 150. The results were as follows:

Number ads shown	5	10	25	50	100	150
Number ads recognized	4	8	18	29	52	55
Net per cent recognized	80	80	72	58	52	37

If interested in the absolute number of items that it is desirable to retain, it would seem better to present large sequences;

if interested in efficiency, the shorter sequences should be favored. If the problem is to reproduce the original list in its exact sequence, the limits imposed by the memory span of the individual cannot be exceeded. [65, p. 20]

2. Longer lists of material are learned better than shorter lists, but at greater cost. The greater the number of items in a list to be memorized the longer the time that will be required to learn the list, and the longer the time required per item in the list. Furthermore, there will be considerable overlearning of certain items in the list because of extra repetitions of these after they are learned.

It is likewise true that the longer lists are better retained than the shorter ones. This was demonstrated in a study with nonsense syllables. Lists of different length were memorized and at a later date were relearned. The amount of retention for the different lists was measured by the difference in number of readings required on the relearning as compared with the original learning. The results were as follows: [18]

12 syllables, learned in 17 readings, relearned with a saving of 35 per cent
24 syllables, learned in 45 readings, relearned with a saving of 49 per cent
36 syllables, learned in 56 readings, relearned with a saving of 58 per cent

In addition to the fact that the longer lists required more time, were given more readings, and were thus overlearned, it is true also that the longer lists were probably more stimulating and called forth more effort on the part of the learner. A short lesson can be learned with no special effort, but when a keen individual is confronted with a long lesson he is stimulated to organize the material and bind the items together by relations and meanings. He thus develops a strong structure that is more durable than the loose structure which sufficed for the immediate reproduction of a short list. [65, p. 60]

3. Long lists of undivided memory material produce distaste and discouragement in most learners. Learning long lists of material is distasteful and few individuals have been willing to attempt the more extreme lengths. One subject learned a list of

200 digits in 1 hour and 49 minutes. Two subjects memorized lists of 30 nonsense syllables in the average time of 14½ minutes. One subject memorized a passage containing 15,000 words, giving the passage one reading a day in the average time of 36.5 minutes per hundred words, a total time of 91.25 hours. One can learn a passage of 100 words in the average time of 9 minutes; a passage 100 times this long will require 4,200 minutes, or 466 times as long.

The method of learning a long list as a unit has been called the global method. It requires some practice for a learner to be able to memorize by the global method and, until the effect of such practice becomes evident, the piecemeal method is likly to be more effective. The global method certainly is a more strenuous method to use and, left to himself, it is quite likely that the learner will select the easier piecemeal method. A novice will certainly find it frightening to be instructed to learn a long passage as a unit, with no opportunity to divide it into easier parts.

One experimenter found a method which he called the progressive part method to be more effective than either the global or the purely piecemeal method. If a poem is divided into four parts, the following sequence of learning illustrates the progressive part method: 1, 2, 1–2, 3, 1–2–3, 4, 1–2–3–4. [52] Other experimenters have made still finer divisions of the progressive part method, with the conclusion that some combination of progressive parts is likely to be superior to a purely whole method. [15]

The global method is a direct attack upon the final objective when the task to be mastered requires the repetition of an entire passage. When the material to be learned need not be recited in its entirety, certainly the global method loses much of its significance. When the material to be learned is closely integrated, the whole method turns out to be superior to a method which would divide it up into disintegrated pieces. [54] A recent experiment indicates that the whole method is superior for learning poetry but that neither method seems to have an advantage in learning prose. [33]

It is probably better for the learner to decide which method to use on the basis of his own temperament and the use to which the material is to be put. If he becomes jittery at the prospect of

learning a huge mass of material he would do well to divide it into more congenial units. On the other hand, it might be to his advantage to read through the whole assignment several times before beginning intensive work in order to get the general pattern and give unity to the task. This certainly is a good procedure in ordinary studying.

It would also be well to select the procedure according to the material to be studied. One method might be advantageous with one assignment and inefficient with another. The good memorizer would do well to practice all methods (the global, the piecemeal, and the progressive piecemeal) and to use a combination of all three, or the one that seemed best, in each individual situation. The method should be a tool for the learner to use, and he should never become enslaved by one method. The experimental emphasis that has been given to this whole-part problem probably grew out of the interest of the old-fashioned pedagogue in finding the "best" method so that he could insist that all students employ "it."

The use of artificial devices to assist memorizing. When the items to be memorized have a logical or meaningful relationship no artificial scheme is necessary to assist in learning. It is when one is learning absolutely unrelated items or nonsense material that the use of some artifice becomes valuable.

1. *Grouping.* Grouping is a valuable aid in retaining a long list of digits. The list of digits 1940253613269753 could be much more readily remembered for example, if grouped 1940–2536–1326–9753.

2. *Rhythm.* To learn by mere rote memory the length of each month in the calendar year is somewhat of a chore; but it becomes easy when it is arranged into the well-known ditty:

Thirty days hath September,
  April, June, and November;
All the rest have thirty-one,
  Excepting February alone,
Which hath but twenty-eight, in fine,
  Till leap year gives it twenty-nine.

3. *Logical relationships.* Instead of learning the table of nines, it would be possible to work out certain logical relationships which would eliminate the need for rote learning, as follows:

$9 \times 1 = 09$	$0 + 9 = 9$
$9 \times 2 = 18$	$1 + 8 = 9$
$9 \times 3 = 27$	$2 + 7 = 9$
$9 \times 4 = 36$	$3 + 6 = 9$
$9 \times 5 = 45$	$4 + 5 = 9$
$9 \times 6 = 54$	$5 + 4 = 9$
$9 \times 7 = 63$	$6 + 3 = 9$
$9 \times 8 = 72$	$7 + 2 = 9$
$9 \times 9 = 81$	$8 + 1 = 9$

The rule is: The first digit of the product is always one less than the multiplier, and the sum of the two digits in the product is always nine.

Grouping, rhythm, and logical relationships are illustrations of methods whereby meaning may be incorporated into meaningless materials. In so far as artificial schemes do add meaning they are valuable. Where they are so irrelevant that they detract the learner from the significance of the material they are worse than useless. Hence, care must be used if memory aids are to be of genuine assistance.

Artificial devices are of most value where the material must be learned at once—in cramming for an examination, for example. When the learner is confronted with a larger amount of material than he can learn by the ordinary methods in the time allotted, he would do well to use artificial aids. If, however, he must retain this material over a longer period, he would do well to supplement the use of these aids with overlearning.

The rule seems to be that, if one wishes to retain material for permanent use, it would be well to utilize all sorts of devices to master the material at first; but this should be followed by overlearning in order to make one less dependent upon artificial aids. The learner need not try to get rid of these artificial devices. It is, indeed, well to retain them because he may still have occasion to use them. When the material is overlearned, they will drop off with no effort on his part. When the telephone is first installed, we may need some artificial device to help us remember the number; but after a period of time, because of overlearning, it is recalled automatically.

The distribution of practice. Experimental work is in agreement in finding that it is more economical to spread learning

over several sittings than to concentrate the learning into one continuous learning period. [47] Material to be retained over a long period of time needs to be studied and restudied with intervals between the practice periods. This effect is based on Jost's law, which is stated as follows: If two associations are of equal strength and of different ages, repetition will increase the strength of the older more than of the younger association. [63]

Nevertheless, a review of the experimental work on this problem indicates that this principle of distributed practice should not be taken too literally and applied to all kinds of material without some qualifications. The efficiency of either method seems to be a function of many interacting factors; the age and physical condition of the learner, the character of the material, the actual length and distribution of the practice periods, the method of learning adopted, the method of measuring the efficiency of learning, whether the learner was attempting to achieve permanent and perfect retention or approximate and temporary retention, and the motivation of the learner. [40]

Effective use of recitation. Recitation, after a few initial readings, is of much more value in learning than continued reading without recitation. Experimental studies are in agreement in showing that the process of memorizing and the resultant retention are both favored by early and continued recitation.

The advantage of recitation over reading is greater the more senseless and unconnected the material to be learned. The advantage is greatest for nonsense syllables, less for lists of words, and still less great for connected prose or poetry. [22]

How much time can well be devoted to recitation? In one experiment, each child had before him a sheet of paper containing a lesson to be studied. He was told simply to read the material until a signal was given, after which he was to start reciting to himself, consulting the paper as often as necessary, and to continue this recitation and prompting process until the close of the study period, which was nine minutes in all. The experimenter varied the proportion of time during which the child was actively reciting and prompting himself when he needed to do so. The larger the proportion of time devoted to reciting, up to four-fifths of the total time, the better was the immediate memory and the better the retention of the material after four hours. [22]

If the attempt to recite is carried to the point where the subject is forced to make erroneous guesses, the results do not appear to be beneficial. Eighth-grade girls were taught English-Hebrew equivalents by two methods. In one method—the "telling method"—the experimenter told the subject the meaning of each Hebrew word during each trial of learning. In the other method—the "guessing method"—the subject was forced to guess an English equivalent for the Hebrew word and was then told the correct word. The telling method produced higher scores than the guessing method. [21] This experiment does not contradict the evidence in favor of recitation. It merely shows that the attempt to recite should not be carried to too great an extreme. The value of recitation comes when the person attempts to utilize what he knows and is immediately prompted if his recitation does not proceed smoothly. Guessing is a variety of random learning and should not be confused with recitation.

From the experimental work that has been done some principles for the effective use of recitation can be stated:

1. The first readings should be an exploratory process by means of which the learner becomes oriented, sees the general nature and pattern of his task, and some general helpful connections between parts. Until this general pattern develops, reading is probably more beneficial than attempted recitation. Repeated readings after the general plan has been gathered is likely to degenerate into inattentive droning which does more harm than good.

2. The learner should, as soon as possible, see how much he can do with what he has learned. Early recitation is stimulating; it gives the learner a challenge which he otherwise would miss. These early recitations, furthermore, indicate to him what he knows and what he still must learn. It focuses his attention to the areas which need his effort. He thus fills in the rough pattern which he sketched in his first readings.

3. Recitation should be modified and adapted to the kind of material to be studied. Modified recitation may take the following forms: (a) Reading the subject matter aloud is a form of recitation. If the general sense of the material is all that is wanted, the visual impression is reinforced by the auditory. If a more detailed memory account is desired, the rereading may be

accompanied by the attempt to anticipate what is coming and the reading, in such a case, will amount to a kind of prompting. (b) Attempting to formulate the contents of a passage in one's own words is an excellent type of recitation. In some cases, speaking aloud such a free expression to an imaginary person (or even a real person) is excellent. Writing an abstract of the material studied is a still better type of recitation. (c) Asking questions of oneself or of others constitutes a way of reviewing the material. (d) Arguing about the facts either with oneself or with others fixes the significance of material when that is what is needed. This form of recitation should be given preference over verbatim repetition when the objective is to learn the substance of the material at hand rather than to learn it precisely as given. Substance learning differs from rote learning or even logical learning in that it requires fewer repetitions and more of a search for associative relationships. [19]

MEMORY FOR FORMS

Memorizing forms is a much more interesting occupation for the subjects of psychological experiments than is the task of memorizing nonsense materials, digits, or even poetry. An experimental analysis of the methods used by an ordinary individual in attempting to remember forms reveals processes which are probably used in a great many different life situations.

Procedures used in learning a visual form. Attempting to remember a form is more like solving a problem than memorizing and includes several aspects.

Exploration. When a subject is presented with a figure, knowing that he will be called upon to show evidence of his memory for that figure, his first process is one of exploration. This exploration may take either of two forms. One is the direct and critical examination of the figure, note being made of the lines, their direction, length, relative positions, and other such details. This method has been called figural analysis. The other approach, called the indirect attack, consists in asking, "What is it like?" The purpose is to name it in terms of the nearest thing it resembles. The direct attack describes the figure, the indirect attack names it.

Children are more likely than adults to use the indirect

method; a picture must be a picture of something and learning that figure consists, for them, of fitting this specific illustration into its proper class. Adults tend to be more analytical in their approach; they take note of symmetry, repetition of parts, relative sizes, rhythm, and the like.

Utilization of past experiences. Familiar forms are easily learned. A figure that conforms exactly to common geometrical forms is easy to learn. The easiest are: semicircle, circle, square, diamond, oblong, and triangle. [20] Almost as easy are those figures which differ from a well-known form in some easily described manner, such as: a triangle with a gap at each corner, an oblong with a gap on one of the long sides, a small square placed askew in a larger square.

Correction of first impression. Fitting a new figure into familiar patterns is accomplished at the expense of details or any new element. Classifying a dog as such means that the characteristic features of a dog are observed and the specific details which distinguish this particular dog are ignored. The next step in learning is, consequently, to correct the first vague impression by attention to the details. The line of development is from an unstable form to a more rigid and accurate knowledge. The specific way in which this is accomplished is not fixed but varies with the particular task and with individuals. Some examine a figure from left to right, others from right to left; some take it a segment at a time; some emphasize a general outline into which the new details are fitted. [20]

The memory will conform largely to the degree of accuracy with which the form has been correctly seen. If only a vague outline has been seen, the subject will remember a vague outline. If he has noted a few details on that outline, he will remember the outline of those details.

Factors affecting memory for form. The memory for the form shows the influence of several factors. Some of these may be outlined as follows:

Omission of details. An attempted reproduction of a form from memory will never contain all the features of the original. Sometimes these reproductions will even out irregularities and sometimes they will accentuate them. [29] The amount of distortion will depend upon the degree of complexity

of the picture, its resemblance to some known pattern, the distinctness with which it was shown, and the length of time it was exposed. This corresponds somewhat to the limitation in immediate memory that was found in the memory span for digits or nonsense syllables.

Time produces distortion. After a lapse of time, attempts to reproduce a figure indicate that a process of forgetting has been at work. One group of theorists has asserted that, as time passes, the memory of a figure changes in the direction of a good, stable figure—one more regular and more symmetrical. Experimental evidence argues against any such theory. In several elaborate experiments, it has been shown that the kinds of changes that occur are too varied to be subsumed under the category of better balance, form, and symmetry. [29] With a lapse of time, those figures which were originally symmetrical tended to become more symmetrical; the less symmetrical figures became less symmetrical; some became more sketchy than the original; some tended to become more like the associated object with which the original was classed; some showed the extended accentuation of some aspect that had appeared prominently in the original.

Alterations once made tend to persist as long as the figures can be reproduced at all. [24] The forgetting of a figure with time tends to eliminate those details which were not well fixed and to accentuate those aspects which were more rigidly fixed or more simple or general in nature. [7] Also, it has been found that any noticeable characteristic tends to be exaggerated with successive reproductions, that is, loops are enlarged, small inserted segments lengthened, dots on a line enlarged, and the like.

Naming the figure. A name or verbal description given to a figure when it is seen will affect the memory of that figure. In one experiment with nonsense figures the subjects, in many instances, gave the figure a verbal description when it was shown to them. In these instances the attempted reproduction showed definite influences of the verbal description. [24]

In another experiment, the subject was told before each presentation in a series that he was going to be shown a figure that resembled some object; for example, a curtain in a window, a diamond in a rectangle, a bottle, a stirrup, a beehive, a hat, etc. After an interval the subject was asked to draw as many of the

figures as he could. The reproductions showed definite influences of the names which had been assigned to the figures when they were presented (see Fig. 72). [11]

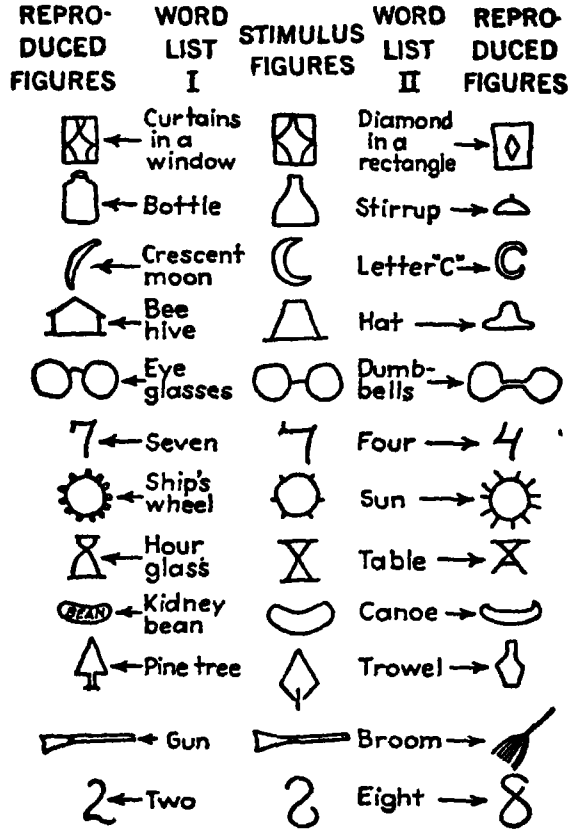


FIG. 72.—The effect of a name on the memory for form. When the central stimulus figure was presented along with the name in the word list No. I, the reproduced figure tended to be as shown in the left column; whereas, when the same stimulus figure was presented with the name in word list No. II, the reproduction tended to favor the figure to the right.

(From L. Carmichael, H. P. Hogan, and A. A. Walter, "An experimental study of the effect of language on reproduction of visually perceived form," *J. exper. Psychol.*, 1932, 15, 73–86.)

MEMORY FOR RELATIONSHIPS

In immediate memory, in memory for specific sequences, and in memory for forms the subject is presented with materials and then tested for his ability to recall, to recognize, or to repro-

duce that material in the exact form in which it was presented. What is measured, in such cases, is the specific retention of assigned items or exact sequences of items.

In many situations such exact memory is essential. For example, it would be of little value for a person to remember that six came somewhere near eight in the numerical series, or that three times seven was somewhere around twenty, or that one's birthday was sometime in December, or that the person to whom he was speaking had a name something like Fullerton (when in reality it was Lightfoot). In other instances, the important factors to be retained are not the specific aspects of the material but its setting, its relationships, and its significance in relation to other items or situations.

Memory in problem solving. Solving a problem involves memory for relationships. As an illustration, a man who is working on a heavy machine drops a bolt into a hole in a part of the machine. How to get it out is the problem. He first gets his associative memories to work. He had learned something about gravity and it occurs to him that if he turns the machine upside down the bolt will drop out; but the machine is too heavy. He thinks of tweezers, but they are too short; he thinks of pliers, but they are too big; he thinks of putting sticky substances on a rod (chewing gum, molasses, glue), but they are not strong enough; if the bolt were softer he could drive a spike into it. Isn't there anything else that will grip iron? A magnet. He has it! He gets a magnet only to find that the magnet will not go into the hole, it is too big; but then he remembers that a magnet will hold up one piece of metal and that another can be attached to this dangling piece. He gets a nail long enough to reach from the top of the hole to the top of the bolt, touches the magnet to the nail and pulls the bolt out. He has utilized memories but not in any rote manner; he has dug into his memories for items related to the present problem.

In the attempt to facilitate the learning of relationships, recent educational procedures stress the practical applications of material to be learned. The danger in this procedure lies in the fact that the students may merely recognize the few applications that are presented, whereas the objective is to discover as many lines of relationship as possible. The essential feature is not

application, but to teach the pupil to discern a multiplicity of relationships. The ideal would be to teach one fact, principle, or situation and then to follow this with problems which involve the utilization of this fact. Add another and follow with problems which might utilize either item already learned or a combination of them. Another valuable procedure would be to stimulate students to search for lines of relationship so that when some item is presented they would try to formulate situations in which this item might be utilized.

Analysis of associative memory. The older psychologists attempted seriously to discover the fundamental principles that could be invoked to account for the way in which items of experience were related. They attempted to reduce them all to one law, which was called the law of contiguity. According to this law, if two experiences have occurred close together in time or space, the recurrence of one leads to the reinstatement of the other. In order to account for the fact that some elements occurring together seemed to become more closely knit than others, they evolved subsidiary laws which stated that the closeness of association could be influenced not only by (a) time and (b) space, but also by (c) similarity, (d) contrast, (e) primacy of occurrence together, (f) recency of occurrence together, (g) frequency of occurrence together, and by (h) vividness, which would include factors of pleasantness and unpleasantness.

Which of these principles seems to operate depends more upon the setting of the individual experiment and the purposes involved than upon the nature of the principle itself. In rote learning, frequency is important; in a highly emotionalized experience, vividness; in lists of nonsense syllables, primacy and recency stand out; in conditioned reaction experiments, time and space are important; and in problem-solving experiments, similarity and contrast seem to be important.

More recently, psychologists have stressed the degree to which associations are restricted rather than the factors which might be accountable for their being associated. Classified in this manner, associations are either (a) *free,* or unrestricted, associations or they are (b) *controlled,* or restricted, associations.

Free association. In the typical free association experiment, or free association test, the subject is not limited by pre-

vious instructions to some specific kind of relation or to some sequence of items that he has been required to learn, but may respond with any word that comes to him. The memory experiment is concerned with the learning process, whereas the association experiment attempts to discover what associations have been formed in the ordinary course of life.

Two general methods are used: (1) In the continuous method the subject is merely given a start and is told to continue a sequence of words as long as he can do so; (2) in the discrete stimulus method, the subject is given a word and is told to respond with the first word that comes to him. The continuous method is used more in clinical situations than in psychological laboratories. It does not lend itself to quantitative analysis as much as does the discrete method although it does give the subject more freedom to wander where he pleases in his reactions. (See page 196.) The discrete stimulus method is the most widely used in laboratory experiments and various refinements of technique have been evolved. In the most elaborate setting the stimulus word is exposed mechanically and the subject responds into a voice key. The presentation of the stimulus automatically starts a chronoscope and the voice key stops it. In this way the experimenter not only obtains the response word but is able to measure the reaction time.

If a thousand persons are given the same stimulus word, there will be striking individual differences in the response word. When the word "needle" was given to 1,000 adults of both sexes, 72 different responses were given: 160 persons responded with thread, 152 with sharp, 147 with pin, 134 with sew, 107 with sewing. No other response was given by more than 53 persons and 35 words were given by one person only. These variations illustrate the great diversity of associations that may occur. [36]

Many attempts have been made to classify responses into various categories. The most general distinction is between (a) the objective, matter-of-fact, or impersonal responses and (b) the emotional or personal responses. Some words lend themselves to one type of response more than the other. For example, such words as table, chair, and salt tend to bring out objective responses. Some of the words likely to give rise to personal

and emotional reactions are: love, marriage, friendship, quarrels, injustice, ridicule, contempt, pity, danger, expense, money, and death.

Certain individuals tend to give individualistic responses to more stimulus words than do others. If a particular individual tends to give personal reactions to a large number of stimulus words, this fact can be used as a means of making a clinical evaluation of his personality. In order to accomplish this purpose, frequency tables have been constructed which indicate the number of persons in a thousand actually tested who responded to each stimulus with other words. [36]

Controlled association. In the controlled association experiment the subject is given instructions which restrict his response to certain categories. In some situations the response is completely restricted and in others there is opportunity to select from equally correct alternatives. The subject may be instructed to give the word that bears the following relationship to the stimulus word:

Relationship asked	Stimulus	Possible response
opposite	tall	short
synonym	eat	devour
part-whole	book	library
whole-part	house	room
verb-object	eat	apple
verb-subject	swim	fish
genus-species	animal	dog

Where the restrictions permit of only one reply, the fixity of the association is usually measured by the reaction time. Such restricted associations appear when a person reads a passage; when he multiplies, adds, or divides numbers; when he gives the capitals of states; when he names forms or colors; and the like.

RECALL

Recall has been utilized as a means of determining the relative efficiency of different methods of learning and to measure the degree of retention. If we can recall practiced material, the assumption is that we have retained it; and if we can recall material better when it has been learned in a certain manner than when learned in another, we can conclude that the first method

was more efficient. On the other hand, if we fail to recall some material, it does not follow that it was not well learned or that we have failed to retain it. In other words, recall is not an automatic process that comes inevitably and mechanically. Everyone has been unable to recall some learned facts at one moment, only to have them come back with great clearness later on. It is, consequently, important to know something about the process of recall and to understand those influences which favor recall and those which interfere with it.

Circumstantial recall. Whether we are learning intentionally or merely drifting from one activity to another, there is usually some memory of the temporal sequence of acts. An individual can relive a series of events in his memory even though he did not consciously try to learn that sequence as the acts were occurring. Circumstantial recall is the type of recall determined largely by the order in which the events occurred previously. In children, and in adults of inferior intelligence or little education, this type of recall is common. Living to these persons is a sort of straight-line, single-track process with few collaterals; they recall events as they lived them.

Nevertheless, this type of recall may be of great value in finding some lost article. For example, a student happened to miss his fountain pen. All attempts to recall directly where he had placed it failed. So he started from the time he last remembered having it and traced, in memory, his every act from that point on. By this method he recalled where he had left it. The direct question, "Where is my pen?" did not evoke the proper memory, whereas a review of the sequence of events did. He had not tried to remember the sequence of acts he had executed at the time he performed them, but there was enough incidental memory to enable him to recall them in proper order.

Effect of set or attitude on recall. Recall is definitely affected by the general set, attitude, or mood of the individual. The closer this set corresponds to the set which normally surrounds the material to be recalled the better the chance of recalling it. For example, suppose it is decided to recall the name "Steinberger." There is a gap, but the gap has a certain form into which the correct name must fit. There is a general feeling, perhaps, that the name begins with an S, that it is a long name,

that it has a German atmosphere, that it has the feeling of a large building, etc. Stay in this atmosphere, keep in this set, and eventually the name "Steinberger" may come out. When the right name does not come directly and immediately, the right kind of name is likely to come, a name that is right in some particular—the first letter, the length, some outstanding syllable.

In such situations there is often the feeling that one is just upon the name, that it is "on the tip of one's tongue," that a little extra push in the right direction will get it. Experimentally, it has been shown that a push in the right direction but too weak to be noticed by the individual will, nevertheless, enable him to recall it. This experiment was done with nonsense syllables. The subjects learned paired associates and then were given the first word with the task of recalling its proper associate. When they did not recall the proper nonsense syllable it was given through a telephone receiver or shown on a screen so briefly and so faintly that the subject could not discern it directly. This prompting, which was too weak to be discerned as a real perception, nevertheless enabled the individual to recall correctly. That is, a memory that is too vague to be recalled may become clear when reinforced by a stimulus that in itself is inadequate to be perceived. [65, p. 231]

A certain set may, on the other hand, interfere with recall. When, in searching for a name, for example, the wrong name comes up, it is likely that this same name will continue to recur and will interfere with the recall of the correct one. At such times we may have the feeling that the recurring name is not correct, but we cannot get away from it. It is well to get clear away from the attempt to recall until the presence of the wrong name loses its effect. For this reason, recall is sometimes facilitated by a cessation of the attempt to recall. This temporary giving up enables us to escape the influence of the wrong association, the wrong clue, or the wrong set.

Emotions may influence recall. The problem of the relation of emotion to recall has been investigated in several different ways. One method has been to assign subjects the task of learning material possessing differences in feeling tone from pleasant, through indifferent, to unpleasant. These experiments show that recall is most efficient for pleasant words, next for unpleasant

words, and least efficient for indifferent words. This tendency to recall pleasant more easily than unpleasant material has been found to exist both in children and in adults, [13] although one experimenter concluded that it is more evident in adults than in children. [25]

Another method has been to test the emotional reactions of the subjects while memorizing, by measuring the electrical skin resistance. By this means it was found that words showing higher emotional values were more efficiently recalled than the emotionally indifferent ones. [5] Such an experiment does not distinguish between pleasant and unpleasant values. [35]

Still another method has been to determine whether experiences which the individual regarded as pleasant were more easily recalled than those which were indifferent or unpleasant. For example, students were tested for their ability to remember good grades better than poor grades. After each quiz the student was told his grade and was asked to record his emotional reaction when hearing the grade. Later they were tested on a five-point scale for recall. Pleasing grades were recalled relatively more frequently than displeasing ones. Pleasant and unpleasant grades were remembered better than the more indifferent ones. [37] Personal experiences are recalled more easily than nonpersonal incidents, and emotionally toned events more readily than indifferent events. [12] There is some evidence that unpleasant events are forgotten more readily than pleasant events but this difference is not so striking as the advantage of emotionally toned events over indifferent events.

Individual differences in the effect of emotional values are striking. One experimenter divides people into: optimists, who forget more unpleasant than pleasant experiences (about 56 per cent); pessimists, who forget more pleasant than unpleasant experiences (36 per cent); and indifferents, who forget the two equally (8 per cent). [48] The influence of emotional tone upon recall might be considered an extension of the general principle that recall depends upon the proper set or attitude of the individual. An indifferent attitude is probably least conducive to recall because it does not have the vitality to organize the directing influences which lead to a direct recall. In general, an unpleasant emotion would be less conducive to reinstatement of

a previous experience than would a pleasant emotion. This would depend, nevertheless, upon the nature of the experience and upon the make-up of the individual. [58]

Imagination in recall. When recall takes the form of a particularly vivid or lifelike reproduction of the original sensory experience, the result is a memory image or an imaginary process. The use of an image as a basis for recall gives the individual a sketchy outline which serves as a starting point for detailed recall, but is ostensibly faulty as a guide for recalling specific incidents. In utilizing such a device the recaller is likely, therefore, to rearrange parts, to fill in gaps, and otherwise distort facts. [26] This leads to what has been called retrospective falsification. It is the process of making a good story from a few isolated remembered incidents. The narrator may be unable to distinguish the memory components from the fabricated part and may have a feeling of familiarity with the whole story as he tells it. A repeated story is especially subject to such distortion.

Imagination leads to greater distortion in the recall of visual material than in the recall of verbal or motor experiences. The image is much more vivid than an abstract word symbol or the motor pattern. Hence, what we are all tempted to do is to take the word or gesture as a tool upon which to build recall and then to attempt to reinstate the memory in its original vividness. We read a story in which a villain plays a dominant role. From his behavior we catalogue him a villain and may, at first, recall some of the specific situations where he demonstrated his low character. As time goes on we forget what he did or why he is a villain, and merely substitute the visual image of some character with the facial characteristics of the traditional villain. It is risky business to judge the fidelity of recall by the vividness of the memory image revived.

RECOGNITION

In recognition, the essential problem is to identify an object or to localize it in the setting in which it occurred in previous experience. There are varying degrees of clearness in recognition, ranging from a vague feeling of familiarity to the ability to recall the former time and place in which the object was experienced. Hence, recall and recognition may merge into each

other, the recall being involved in the more specific aspects of recognition, and recognition being the more simple process. The two are not necessarily involved in every instance of memory. There may be recognition without recall; as when you recognize a person, but cannot recall when or where you met him or his name. There may, likewise, be recall without recognition; as when you recall something you have heard or read, with no recognition. In fact, you may believe that the words you utter are your own when, as a matter of fact, you recently read them. Unconscious plagiarism is probably recall without recognition.

Recognition easier than recall. The fact that recognition is easier than recall has been demonstrated by having subjects learn material under standardized conditions, and by following the learning with a recall test (by the method of retained members), or by a recognition test (in which the learned items are mixed with new items), or by both. With all kinds of materials the advantage is in favor of recognition.

	Syllables	Words	Proverbs
Recall score	12%	39%	22%
Recognition score	42%	65%	67%

When the cues used by a subject for recognition are obvious and distinctive, recognition is decidedly superior. Nevertheless, the superiority of recognition over recall may be materially reduced by making the new items that are interspersed with the old ones so similar that they can be distinguished only with difficulty. [46]

In one experiment using colored designs where the new items were dissimilar to the old ones, the subject could recognize the original figure in 92 per cent of the cases. Where the new figures were similar to the old ones the correct recognitions were reduced to 29 per cent. [55]

Recognition often utilizes vague cues. Recognition may occur when some minor feature or some combination of features, which was a part of a previous experience, is perceived in the present situation. These may act as a sort of cue that one is "warm" or may be the starting point for a more specific recall. When material is learned verbatim, such factors as primacy,

recency, length of list studied, and the like are more important than when they are learned for the general meaning. In the latter type of learning recognition is at a decided advantage as compared with rote learning. [1] In other words, if there is a need for recognition, the learner should stress the general feeling tone that goes with an experience without too much emphasis on specific detail or on verbatim repetition.

Incidental memories. The alert individual takes in a great many details of his various experiences without making a definite attempt to discern or to memorize them. On the other hand, most persons ignore much that goes on and distort when called upon to report what they have observed.

Inaccuracy of testimony. The ordinary person observes details inaccurately. For example, it has been shown that great errors are made in identifying persons. A workman came into the classroom during a class period and tinkered with the radiator. Sixteen days later this same workman and five others were brought before the class and the students were required to identify the one who had fixed the radiator at the previous session. This situation duplicated the customary police roundup. Of 117 students present at the second session, 69 per cent identified the workman correctly. This looks like a good proportion; but some glaring errors were made, enough to warrant skepticism about the validity of such identification. Seventeen students had not been present when the radiator incident occurred, yet five of these said they recalled the incident and tried to identify the man. [6]

The reliability of testimony has been studied in a more formal fashion by exhibiting a test picture for about one minute and then obtaining a report upon what was seen. [59] Whether the events are staged as an incident, are presented in the form of a still picture, or are given in motion-picture form, the results confirm the fact that testimony is unreliable.

The observer may be tested by obtaining from him a free report as to what he has seen or he may be asked specific questions about his experiences. The free report method lends itself to the making of a consistent story. The subject tends to simplify and generalize by combining similar items; he modifies details to make them more meaningful, he omits superfluous and incon-

gruous items; and he carries out the general meaning as he discerned it or as he happens to remember it.

When specific questions are asked, the errors depend largely upon the nature of the question. [59] From least to most confusing, the forms of questions are:

(1) Determinative type of question. Example: Did the man wear a hat?
(2) The disjunctive type of question. Example: Did or did not the man wear a hat?
(3) The expectative type of question. Example: The man wore a hat, didn't he?
(4) The implicative type of question. Example: What color was the man's hat?

Children with a lower degree of intelligence are more likely to report incorrectly than children of higher intelligence. The effect of intelligence is greatest when the children are asked to report events they have witnessed and least when they are called upon to report material demonstrated on an object-card. [41]

Temporary set affects incidental memory. When a person is set to memorize in a certain manner, or to observe certain aspects of a situation, he tends to ignore other aspects even though they may be essential. The performances of the magician or the sleight-of-hand performer are based upon this principle.

A popular illustration of the influence of temporary set is this: "Listen carefully! A man was driving along a country road delivering and gathering milk cans. He had twenty-five cans in his wagon at the start. At the first farm he unloaded five and took on three. At the next farm he unloaded two and took on five. At the next he unloaded two and took on eight. At the next he unloaded four and took on three. At the next he unloaded three and took on five. At the next he unloaded four and took on four. At the next he unloaded four and took on one. How many times did the man stop?" If the questions are stated deliberately the listener will be concerned with counting the number of cans and, at the end, will be at a loss to know how many stops were made.

This has been tested in the laboratory by giving the student one type of memory test and then calling for recall of another

type. For example, have the student learn paired associates and then ask him to repeat the entire list as though it were one series. Show him a card upon which are printed various objects and ask him to recall the objects he has seen, and then ask him to describe the border of the card or some irrelevant factor. All these experiments illustrate the fact that most of us tend to go through life with our intake limited by attitudes and specific sets, and to classify items into categories already established. This procedure may have some value but, at the same time, it limits the uses to which such experiences may be placed at a later time.

Students are likely to specialize in specific memorizing or relationship memorizing. Instead, from the viewpoint of practical importance, they should learn to utilize both. Too often the student who makes an excellent record in memorizing materials makes a poor showing when he tries to utilize those materials in new combinations; while the one who enjoys utilizing new combinations disparages memorizing and so has little to recombine. The medical student who is best in memorizing anatomy may be a poor diagnostician, while sometimes the student who made a rather poor record in the first two years of medical school may turn out to be an excellent diagnostician. The best individual is the one who can memorize and then can utilize these memorized facts in solving a problem requiring a reconstruction of the elements.

QUESTIONS FOR REVIEW

1. Define the following terms: (a) memorizing; (b) recalling; (c) retaining; (d) learning how.
2. Describe the different kinds of problems that memory is called upon to solve.
3. What questions should be asked as a preliminary to organizing a memorizing program?
4. How does retentivity change with age?
5. Describe a striking characteristic of the memory deterioration which comes with old age.
6. What effects result from neural deterioration?
7. What are the essential characteristics of the curve of forgetting?
8. What factors favor retention?
9. Explain how meaning affects retention.

10. How does reproductive interference operate?
11. Define reminiscence.
12. What is meant by transfer of training?
13. What conclusions can be drawn about the operation of transfer of training?
14. What are two effects which occur when a person is given a longer list of material to produce after one hearing than he can remember?
15. What are the consequences of attempting to learn by rote long lists of materials?
16. What attitude do learners take toward long lists to be memorized?
17. What general conclusions can be accepted as to the dividing of material for rote learning?
18. Describe artificial aids to rote memorizing.
19. What is known about the economical distribution of practice?
20. How much time can be effectively devoted to recitation?
21. State the principles for the effective use of recitation.
22. Outline the procedure used by subjects in learning visual forms.
23. What factors influence memory for form?
24. What is meant by associative memory?
25. Describe the typical free association experiment.
26. Distinguish between free association and controlled association.
27. Distinguish between the continuous method and the discrete stimulus method for testing free association.
28. What are the characteristics of circumstantial recall?
29. Explain how an individual's attitude may affect recall.
30. Describe the effect of emotions on recall.
31. What part does imagination play in recall?
32. What are the essential characteristics of recognition?
33. What is meant by an incidental memory?
34. Describe an experiment to test the accuracy of testimony.
35. What conditions may affect incidental memory?

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Chapter XI

THE CENTRAL NERVOUS SYSTEM

THE part of the body that makes possible the various psychological processes which we have been studying is the central nervous system. Up to this point we have made only incidental references to this system except in our study of the emotions. There we pointed out that there are two parts to the nervous system: the skeletal, or cerebrospinal, system and the autonomic system. Since it is difficult to understand the workings of emotional processes without reference to the autonomic nervous system, we gave a description of that part of the total nervous system in Chapter VII. The student is urged to review that section before proceeding with this chapter. What was given there will not be repeated here.

Thus far we have been studying the activities of an individual which can be observed by others—his behavior; now we plan to turn to a study of the ways in which an individual is able to receive messages from the external world—his sensations. In order to prepare for such a study of sensory processes, it is important that something be known about the central integrating agency—the central nervous system.

STRUCTURE OF THE CENTRAL NERVOUS SYSTEM

In order to understand the workings of the central nervous system, some general picture of its structural arrangements is essential. [12] It can be divided for purposes of study into brain, spinal cord, and nerves. A general view of the nervous system is shown in Fig. 73.

Nerves. Nerve fibers may be grouped into sensory, motor, and association fibers. The sensory, or afferent, fibers carry impulses from the sense organs into the central portions of the

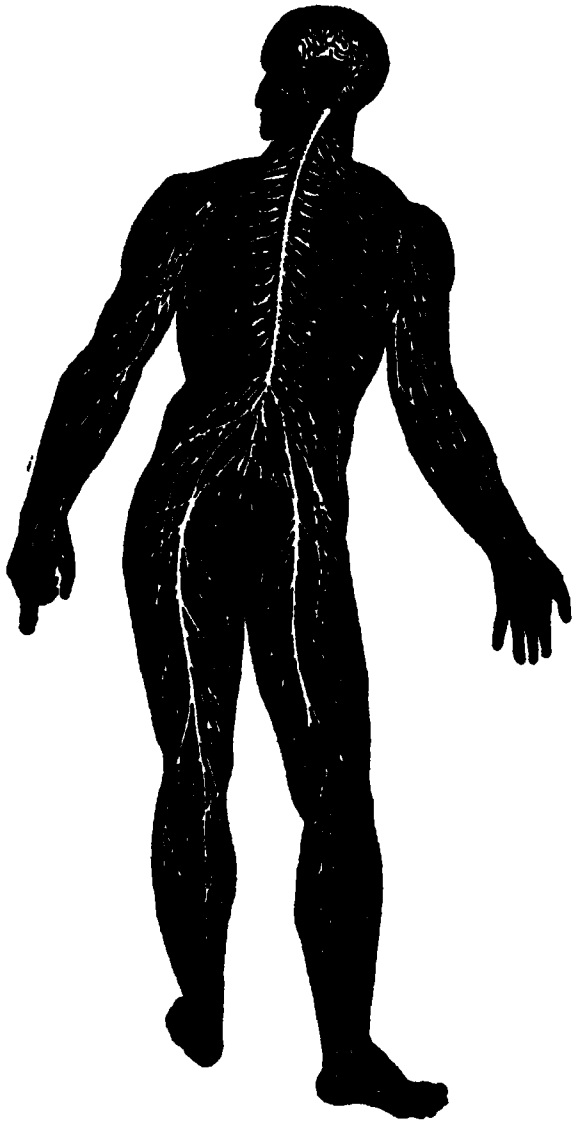


FIG. 73.—General view of the nervous system, showing brain, spinal cord, and branching nerves.
(From Martin.)

nervous system. They are widely distributed and extremely fine at the sense organs themselves, but are organized into groups or bundles as they approach the central portions, and thus form the nerves.

The motor nerves, also called efferent nerves, carry impulses out from the central system to the muscles and glands of the body. They begin in large bundles and branch out as they approach their destinations.

Association fibers are found in the spinal cord and most profusely in the brain. They carry impulses between various other parts of the nervous system, thus making possible all sorts of intricate patterns of nervous activity. [17]

The spinal cord. Most of the sensory nerves have their first switching center in the spinal cord; and most motor nerves pass out to the muscles from centers in the spinal cord. These centers in the cord are connected with other centers in the cord and with the brain centers by association fibers.

The spinal cord thus has at least three functions: (1) It acts as a center for local action patterns. For example, in a reflex the impulse comes in through the sensory fiber to a spinal center and is sent out from that center to the responding muscle, as shown in Fig. 76 (page 318). Such a reflex can take place without any action on the part of higher centers, or on the part of the brain. (2) It connects centers at different levels of the body. For example, it connects the centers for the arms and legs by means of association fibers. (3) It acts as a nerve trunk line by means of which the fibers from the brain are connected with the local nerve centers.

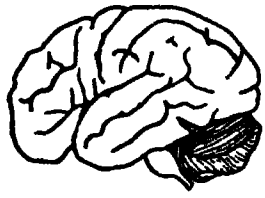


FIG. 74.—The human brain. The shaded portion to the lower right is the cerebellum. All the rest, except the little part of the spinal cord, is the cerebrum.

The brain. The brain is the mass of nervous tissue within the skull. Its general appearance can be seen from Fig. 74. Its main parts are: (a) The cerebrum, which comprises the portion most highly developed in man and by far the largest portion of the entire brain. It is the center for most of the processes studied in psychology, such as perception, reasoning, learning, remembering, and the like. (b) The cerebellum, which lies at the back

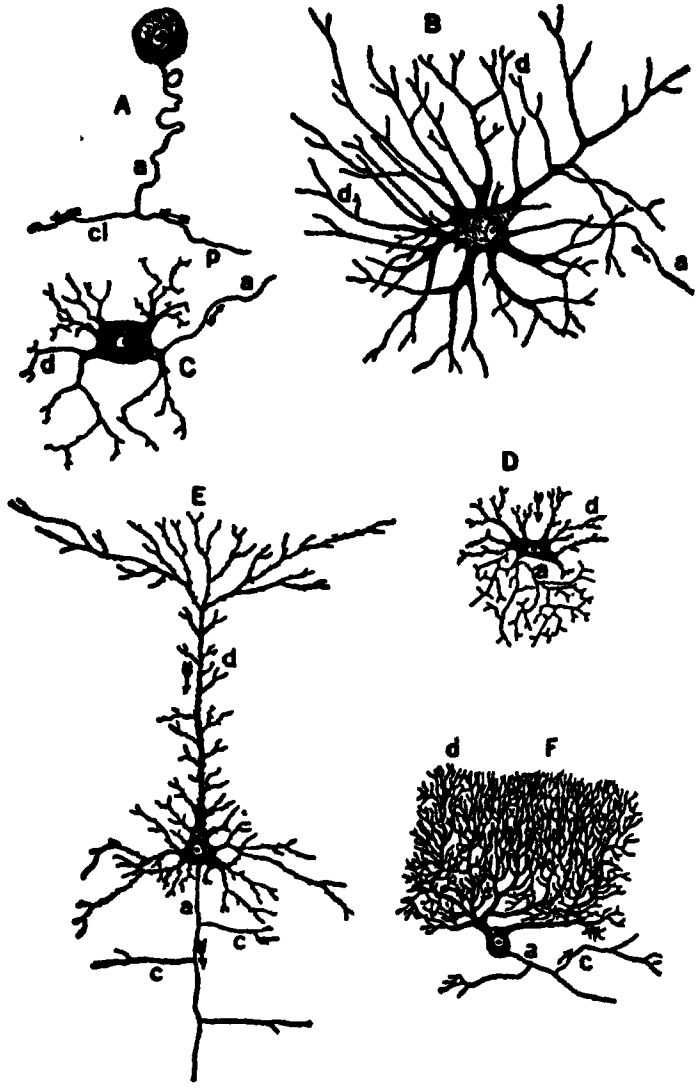


FIG. 75.—Diagram showing some varieties of neurons. A, sensory cell from spinal ganglion; B, motor cell from spinal cord; C, cell from autonomic ganglion; D, association cell from spinal cord; E, motor cell from the motor area of the cortex of the cerebrum; F, cell from the cortex of the cerebellum; a, axons; d, dendrites; c, collaterals; p, peripheral part of fiber; cl, central part of fiber. Arrows show direction taken by the nerve impulse.

part of the brain and below the rear portion of the cerebrum. It is probably the main center for muscular co-ordination. [5]

The neuron. The nervous system is composed of some 14 billion highly specialized nerve cells. The mature nerve cell is called a neuron. It consists of a cell body and the nerve fibers which extend away from the central cell. The forms that these extensions take are very numerous. Some of these are shown in *Fig. 75.*

The cell bodies are usually found in clusters with their branches intermingling with the branches of other cells. These groupings are most extensive in the outer layers of the brain and in the central portions of the spinal cord. They are the integrating centers to which sensory impulses are brought and from which motor impulses are sent. The processes which lead away from these centers are arranged in bundles of varying size. Even the slenderest nerve contains many nerve fibers; some contain as many as a hundred thousand. They vary in length from microscopic branchings to long fibers extending from the brain far down into the spinal cord, or from the spinal cord to the tips of the fingers or toes. Whether long or short, these nerve fibers end in fine branchings in the nerve centers in the spinal cord and brain, the branchings of many fibers all intermingling as the branches of the trees intermingle in a dense forest. This dense interlacing of the branched ends of the nerve fibers makes for a functional continuity between neurons, so that each neuron is so closely associated with other neurons that no part of the nervous system can be considered as functioning separately from the rest. The region of intermingling of the nerve branchings of one neuron with others is called the synapse. While the synapse provides a region of intimate functional relationship, there is no anatomical or protoplasmic continuity of neurons at the synapse. The different neurons come close together; they do not fuse.

FUNCTION OF THE NERVOUS SYSTEM

Anything that can be said about the functioning of the nervous system must be highly speculative. No one has seen a nerve function and all that can be done is to make inferences from secondary data. Two essential problems are the nature of the

nerve impulse and what happens to this impulse at the nerve centers or synapses. [3]

The nerve impulse. A nerve fiber may be excited by chemical, mechanical, thermal, or electrical stimuli when these are applied at any point along the nerve fiber. Normally, however, stimuli are received only at the terminal branchings of the neuron. Those branchings that receive the impulses are called dendrites; those branchings which transmit nerve impulses to other neurons, to muscle fibers, or to glandular cells, are called axons. Normally, the nerve impulse will go only in one direction across the synapse; namely, from the axon of one neuron to the dendrites of another. [4]

The speed of transmission of nerve impulse varies with different nerves and in different animals, and may vary in the same nerve under different conditions. In human nerves it may be as rapid as 120 meters per second. The total time that would be required for passage through the fibers involved in an ordinary simple reaction is somewhere about 20 milliseconds, whereas the total reaction time is not less than 100 milliseconds and may run to nearly 200 milliseconds. Most of this excess time is taken up with delay in the nerve centers. In other words, something happens in the nerve centers which consumes considerably more time than would be required were the cord and brain merely switching centers. This makes it important to know what happens in the nerve, what happens in the synapse, and to understand the significance of the difference between the two.

The impulse which traverses the nerve on the way to the brain or from the brain is slower than an ordinary electric current and is faster than would be the case were the transmission purely chemical in nature. Every nerve impulse is, on the other hand, accompanied by an electric change which can be recorded by suitable instruments (see Fig. 80). These electric reactions have been called action currents. There is also a chemical change because the passage of a nerve impulse requires oxygen and generates carbon dioxide, although the amount is extremely small. The conclusion from these facts is that a nerve impulse is some sort of electrochemical change.

The nearest analogy to nerve conduction that is familiar enough to be commonly observed is the action of a fuse. Once

the fuse is ignited the passage of the action is determined by the internal constitution of the fuse and it travels onward in full force until it reaches the end of the line, or until some unusual circumstance stops it. Whereas a fuse is completely exhausted after it has fired, the nerve uses only part of its energy and recovers immediately. During this period of restoration it is unable to carry another current. This period of inexcitability immediately after the passage of a nerve impulse is called the refractory period. If a stimulus is applied during the refractory period, it is ineffective. It follows, then, that if a stimulus is continually applied to a nerve fiber it will produce an intermittent impulse. The nerve will conduct one impulse, take time for recovery, conduct another, take time for recovery, transmit another, and so on.

Since the transmission of a nerve impulse is dependent upon internal changes in the nerve fiber itself, it functions with full force once it is set off. This is called the all-or-none law. If the stimulus is too weak to arouse the nerve fiber, or if it is not applied long enough, no response is made. Once it is set off, the individual nerve fiber responds completely. Although the all-or-none law holds for the individual nerve fibers, a measurement of the action currents generated in nerve trunks shows that these vary in magnitude. The amount of action-potential increases as a larger number of fibers are stimulated, as is the case when a strong stimulus is applied. Variations in the strength of a nerve current in a nerve trunk can be considered as a function of the number of fibers in operation.

Activity at the synapse. The stimulation of the dendrites of a neuron by an adequate stimulus sets going an impulse which does not stop until it reaches the branched axon end of the same neuron. What happens at the synapse is another story. The stimulus may be so weak, or may meet so much resistance at these junction points that it ends there. Or, it may co-operate with another nerve fiber which is already set to explode, and so start another current (or a number of other currents) which can be even stronger than it was. [16]

To give a concrete illustration: A person may be almost unresponsive to the noise in a boiler factory and yet that same person may let out a blood-curdling yell if stimulated by a little

scratching sound when seated alone in a big dark house. To put it in still other words: The force of an explosion is determined by the amount of powder fired rather than by the size of the fuse.

What happens at the synapse? That the synapse is a kind of switching center there can be little doubt. The microscopic structure of the neurons would make this seem plausible. The simplest type of connection that can be imagined is illustrated in Fig. 76. In actual living organisms, however, the central junction is filled with the branchings from hundreds of other sensory and motor neurons. No center can be affected only by a single sensory impulse from one neuron, and it is impossible for a nerve center

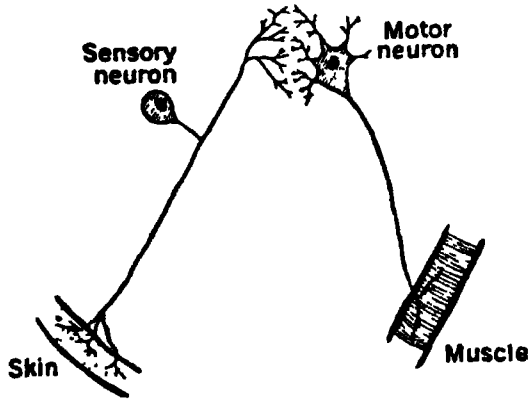


FIG. 76.—Diagram of connection between sensory and motor neuron at the synapse.

to affect only one motor neuron. A sensory impulse consists of a volley of impulses which reaches the center as a sort of pattern of stimulation, and the switching into other neuron stimulations must also be in a complex pattern.

By operative and experimental procedures, it has been possible to study the conduction through the synapse as compared with conduction along a nerve trunk. Compared with conduction along a nerve trunk, reflex conduction which involves passage through synapses: (a) is slower; (b) is more subject to fatigue; (c) shows a greater variability in the intensity of stimulus necessary to get a response (i.e., a greater variability in threshold); (d) is more subject to reinforcement by other influences; (e) is more subject to interference from other influences (that is, more subject to inhibition); (f) is more dependent upon blood supply and oxygen and more easily influenced by anesthetics; and (g)

permits current to pass only in one direction from the axon of one cell to the dendrites of another, whereas a nerve current will travel in either direction along a nerve fiber.

This group of facts can be understood only on the assumption that the synapse is a switching center of a *unique* sort. Psychologists have sought here the explanation of many psychological processes: perception, learning, shifts of attention, memory, and the like. Their efforts have advanced little beyond the speculative stage, and the beginning student should be warned that when he reads about how certain mental processes are produced by some specific type of neural process he is reading speculation and not fact.

VARIETIES OF NEURAL ACTIVITY

In an intact human organism the interrelations of neurons are so intimate that the complications are tremendous. The varia-

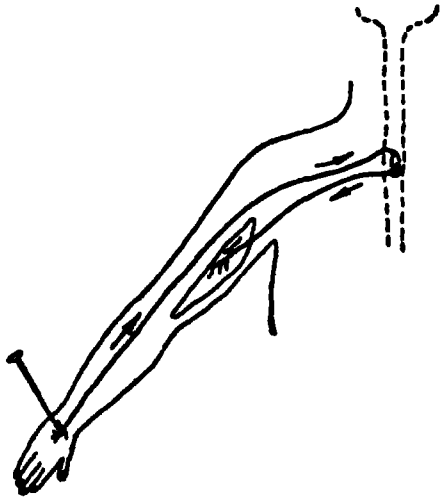


FIG. 77.—Diagram to illustrate simple reflex. The sensory impulse from the pinprick is carried to the spinal cord, affects the motor neuron, and the motor impulse returns to the biceps muscle, causing it to contract and pull the hand away from the pin.

tions in such processes as reasoning, problem solving, performing highly skilled acts and the like provide evidence for this. In order to attempt to visualize what takes place in the nervous system, it is valuable to simplify conditions and attempt to construct what may happen in simple situations.

The simple reflex. The simplest reaction which we can imagine is the simple reflex. If we could isolate a reflex pathway, it might be organized as illustrated in Fig. 77. The sensory

neuron carries the impulse caused by the pin pricking the sense organ in the hand to the nerve center. At the synapse a dendrite of the motor neuron is affected, the motor impulse passes out to the muscle and produces a reaction.

Such a simple reflex action pattern is a purely imaginary abstraction—a device to clarify our thinking. The student should bear in mind that every action in the functioning organism is complicated by all sorts of interactions with other processes going on at the same time.

Simple co-ordinated movement. A single sensory impulse can affect a number of motor neurons at the same level and thus produce a co-ordinated response because of their combined response. The use of the hand for a co-ordinated act illustrates such a reaction. On the other hand, several sensory impulses might both converge on the same motor neuron and produce a common result.

Cerebral control. The more intricate the central connections the greater is the variety of complex behavior patterns which may be executed by the same organ. At the same time, these diverse connections restrict that organ so that it cannot be completely involved in some isolated type of behavior. To illustrate, the hand has various uses. Suppose that it became completely involved in writing and that such employment would make it totally impervious to any other need. An emergency might arise which would best be met by the individual's making a fending movement with his right hand. If the hand could not be diverted from writing, the fending movement would not occur and the person might suffer injury. However, there are neural connections to take care of such a situation. While the hand may be busy with one occupation, there are numerous higher brain centers which make it possible for nerve currents coming from the brain to stop such an activity as writing and to inaugurate some totally different kind of movement. While a motor organ may be relatively independent, it is also at the beck and call of other parts of the body.

This hampering of freedom by higher centers is illustrated in a simple manner by the results of severing the brain from the spinal cord. In an animal whose spinal cord has been severed, reflex behavior is not only possible, but the reflexes will be more

pronounced when the brain influence has been removed than when it is present. Being connected with the brain acts as a damping influence on the free activity of lower neural connections.

Active inhibition or conflict. A good illustration of a conflict on the spinal level may be demonstrated by stimulating a spinal dog to scratch himself with both hind legs at the same time, as follows: If such a spinal dog is stimulated to scratch, he will shift his center of gravity and raise the paw on the stimulated side and scratch. If he is subsequently stimulated on the other side, he will raise the other paw and scratch on that side. If he is stimulated on both sides simultaneously, he cannot raise both hind paws. A conflict is thus brought about. What does he do? At first there is a delay, then he will scratch with one paw as though that were the only stimulus activating him. The winning of the one reflex totally submerges the other. After scratching, however, there is a refractory phase, during which the nerve that was just operative becomes inoperative. During this refractory phase the other reflex comes to the forefront and works at full tilt. If the stimuli are continued, therefore, the resultant behavior will be a sort of compromise so far as the observer from the outside is concerned. The dog will scratch alternately with each leg. [17]

In short, the operation of one reflex is accompanied by total suppression of processes which antagonize that reflex act. Such ascendancy is short-lived. As soon as there is a completion of the ascendant process, it subsides and its antagonist takes the stage.

Learning. Learning of any sort implies that the individual is modified by experience and that these modifications are retained long enough to influence subsequent activities. By far the greatest part of such modification and retention takes place in the centers where the neurons meet. This much is known for certain. Just what takes place at the nervous centers to bring about these changes is not so clear. Some theories that have been advanced are given here: [11]

The new growth theory. This theory maintains that there is a growth of new processes at the synapses as a result of the passage of nerve currents. The main reason for rejecting this

theory is that learning is much more rapid than could be the case if it depended upon the actual growth of tissue.

The movement theory. The movement theory holds that there is a physical movement of the dendrites or axons resulting from exercise by means of which they come into closer proximity. This theory has never received much favor because the branching ends of the neurons are so closely intermeshed that movement with exercise seems out of the question. For a time it was thought that there was actual continuity between neurons; but this idea has been definitely discarded.

Electrical resistance theory. The electrical resistance theory holds that there is a change in electrical resistance with exercise. This view has taken various forms but, in general, the synapse is viewed as some sort of electrical condenser in which the two plates become charged, and the passage of current depends upon the capacity of the particular center. Exercise is supposed, in some manner, to change the capacity of the centers involved. This view might be credited if it were known that the nervous current is primarily electrical. We have already seen that it is not, but is a sort of electrochemical change.

Chemical theory. According to chemical theories, exercise of a center is supposed to produce a chemical substance which has a semipermanent effect upon the ease of transmission. Chemical views are receiving more and more support by investigators.

The advocates of chemical theories base their contentions on the fact that when a nerve impulse arrives at a neural connection, there is set free a chemical substance (called acetylcholine) which is effective in inducing nerve currents in other nerves which it contacts, or capable of causing muscular contraction when it contacts a muscle. They also contend that this substance is quickly destroyed by another substance (called cholinesterase). There is little doubt about the presence of these chemical substances. The argument centers around their significance. Those maintaining that neural processes are essentially electrical say that these chemical substances are merely by-products of the electrical activity; the advocates of the chemical theories, on the contrary, believe that they are the essential factors and that electrical changes are by-products. At any rate, the presence of both chemical and electrical processes is certain.

THEORIES OF BRAIN FUNCTIONING

If one could imagine a novice, with no knowledge of radio and little knowledge of electricity, attempting to discover how a complex radio receiving set functions, and if one could multiply his confusion by millions, some idea might be obtained of the difficulties which scientists have had in trying to unfathom the workings of the human brain.

The operation of any apparatus, no matter how complex, depends upon the interaction of its various parts, a process involving both spatial and temporal relationships. Parts must be placed properly in relationship to each other and their interactions must be timed properly. It has been difficult to study the anatomy of the nervous system because of its complexity, but great strides have been made in this direction. To understand the time relationships is exceedingly more difficult for a number of reasons. The greatest obstacle is the fact that the brain cannot be observed in operation. All that anyone can do is to observe the stimulus combination which activates the nervous system and then to observe the resulting activity. What happens between these two can only be conjectured. For these reasons, early theories of brain function were based largely on structural conceptions. The attempts were directed mainly toward localizing functions in various parts of the nervous system.

Methods used in the attempt to localize functions. Various methods have been used to trace nerve fibers and to determine how they function.

The embryological method. Nerve fibers in adults are covered with a white sheath called the myelin sheath. This sheath is not acquired until some time after the nerve fiber has developed, and different tracts obtain their sheaths at different periods. By examining a series of spinal cords and brains at different stages of embryonic life, individual tracts may be recognized.

The method of degeneration. If a nerve fiber is severed, the fibers which are cut from their nerve cells degenerate; the part between the cut and the cell body remains alive, as shown in Fig. 78. By treating the nervous tissue with special stains after cuts have been made, the degenerated fibers can be traced through a series of microscopic sections.

The physiological method. In animals, or in human beings who have suffered head injury, different portions of the cortex may be stimulated and observations made of the resulting muscular responses.

Extirpation method. By this method certain portions of the brain or spinal cord may be removed and the resulting effect upon sensory discrimination or motor behavior observed. [2]

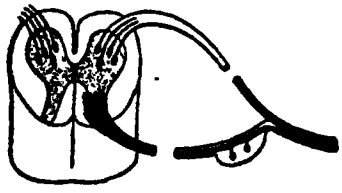


FIG. 78.—Diagram to show the direction of degeneration on section of a nerve fiber. The cell body for the lower section is in the ganglion to the right outside the spinal cord. The fiber disconnected from its cell dies, that is, the black area toward the cord. In the upper cut the parent cell is in the cord and the fiber dies to the right as shown by the black portion.

Clinical method. The clinical method is especially applicable to the study of human brain functioning. When a patient is suffering from some known injury to the brain or from some disease which affects the brain in a known manner, the clinical symptoms which the patient manifests may be correlated with the disturbance caused by the disease. [9]

Specialized areas in the nervous system. These methods have demonstrated beyond any doubt that certain portions of the nervous system have definite functions. A general outline of some of these general functions is illustrated in Fig. 79.

Anatomical and histological studies have shown that the fibers from the eye go to areas in the occipital (back) region of the brain. If these fibers are destroyed, the individual becomes blind. The auditory nerves from the ears go to the temporal regions of the brain. If they are destroyed, the individual becomes deaf. If the fibers from the motor area of the brain to the vocal organs are destroyed, the individual becomes aphonic (voiceless). If the motor fibers to the hands are destroyed, the person becomes so paralyzed that he cannot use his hands to write or to perform any other manual function. There is no question about these functions, because pathological conditions in

human beings and experiments with animals have amply substantiated them.

The localization of functions within the brain is more complicated. Various areas have been suggested as association areas where the incoming impulses are co-ordinated and patterns of behavior organized. Destruction of vast areas supposedly necessary for such co-ordinating activity has been carried out with relatively little effect upon the behavior of the individual. There seems to be a higher relationship between the amount of cerebral

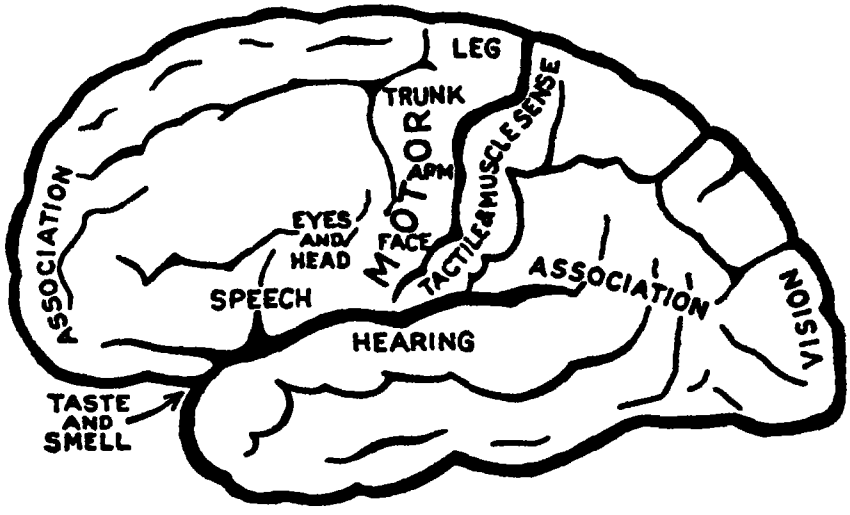


FIG. 79.—Diagram to show general areas concerned with certain functions in the brain. Functions are not located at these places, but the functions are disturbed by destruction of the areas indicated.

tissue destroyed and the degree of loss than between any certain area and specific losses. [10] It would seem that the central function of co-ordination does not depend upon specific fibers in certain locations but that this is a complex process of patterning which can be successfully performed by alternative areas. The general areas for the reception of visual, auditory, cutaneous, and olfactory stimulations are known. There is a region where motor impulses tend to originate. The greater bulk of the brain seems to have no specific function but to co-operate in many activities. [9]

Since it has been demonstrated that a function cannot be

localized in a particular area of the brain, a theory has been proposed, called the theory of equipotentiality, which assumes that each part takes an equal part in each operation. This extreme view is no more required by the known facts than is the extreme localization view. Parts may co-operate in a function without all being equal in importance for that function. For example, legs are part of the mechanism needed to run a maze. One experimenter extirpated a part of the neural tissue of rats so that they became unable to use their legs. Instead of failing to go through the maze at all because part of the needed pattern was destroyed, the paralyzed animal dragged himself through the maze by pulling himself along with his front legs. You cannot localize the function of an automobile in the wheel, in the piston of the engine, in the spark plug, or in the battery. It takes the complete assembly for perfect operation, even though the car might limp along with part of its mechanism eliminated. [11]

The function of timing in neural processes. Whereas a great portion of experimental work and speculation centered around brain anatomy for so many years, more recent emphasis is concerned with time relations in neural activity. This interest is the result of several groups of undisputed facts: (a) The discovery of brain waves has given impetus to a study of the importance of timing in neural processes. (b) It has been found that the impulse through a nerve fiber is customarily made up of a volley of impulses, which may be the composite of a number of other impulses of different frequencies.

BRAIN WAVES

It is an undisputed fact that rhythmic electrical impulses arise almost continuously from the neural centers (the gray matter) within the brain and spinal cord. This continuous rhythmic activity occurs independently of incoming neural excitation and thus provides a background or pool of excitation which may act as a selective factor to incoming nerve currents. The facts about these waves, which we shall presently review, make impossible the old notion that the brain is merely a sort of relaying center which is inactive until stimulated by some incoming excitation. [3]

Records of brain potentials may be obtained from electrodes

placed on the outside of the skull at widely separated places, as shown in Fig. 80. These records have been customarily designated electroencephalograms. They may also be obtained from electrodes placed directly in the brain tissue. These have been

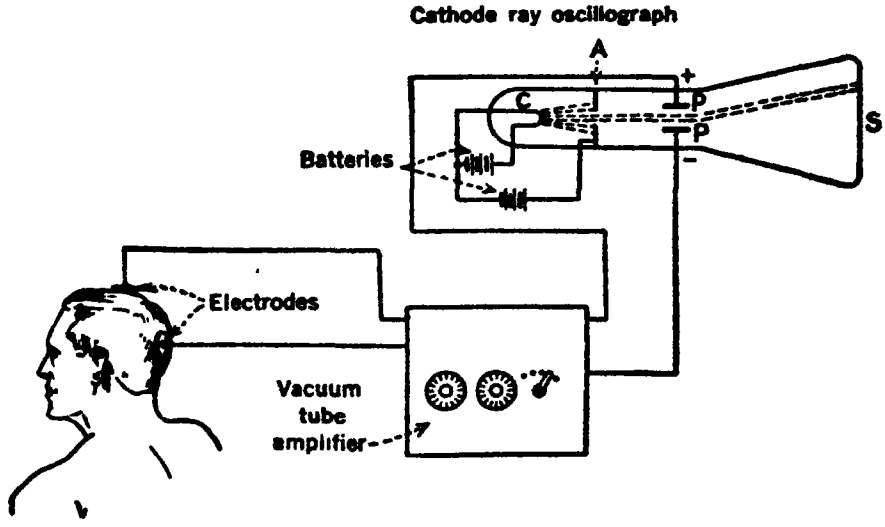


FIG. 80.—Diagram to show how electroencephalograms are secured. In the cathode ray oscillograph, C is the cathode, from which electrons are emitted. A beam of electrons passes through an opening in the anode, A, and falls on the screen, S. When changes in the electrical potential of plates + P and — P occur, the beam of electrons is deflected, and when a succession of changes occurs, as in the case of brain rhythms, curves are traced on the screen. A camera, mounted to face this screen, will take permanent pictures of the waves. A sensitive galvanometer may be used in place of the cathode ray oscillograph, in which case records are made of the beam of light reflected from the galvanometer.

(From L. W. Crafts, *et al.*, *Recent Experiments in Psychology*. New York: McGraw-Hill Book Co.)

called electrograms. In both cases the waves are greatly enlarged by means of vacuum tube amplifiers. [8, 14]

Results of experimental studies of brain waves. Some general facts concerning brain waves may be expressed as follows: [6]

1. They are present throughout the neural centers at all times. They are altered in character by different circumstances;

but from the highest degree of excitement, through sleep, to the deepest anesthesia, they are still present.

2. Different kinds have been distinguished. They are: (a) The alpha rhythms. When an individual is in a condition of relaxation, waves with an average frequency of 10 per second are found, with a range of 8 to 13 per second. These are called alpha rhythms. (b) The beta rhythms. Beta waves are secondary rhythms superimposed on the slower alpha waves. They have an average frequency of 25 per second, with a range between 17 and 30. (c) The gamma rhythms. While not so universally found, there are sometimes waves with a frequency of 35 to 50 per second which have been called gamma rhythms.

3. Children differ from adults in brain wave patterns. Brain waves are not found in infants less than a month of age. Infants below three or four months of age show slow, random waves with an occasional rhythm of three to four a second. The rhythmic waves do not appear before about six months of age and are then only about four or five per second. Not until about ten years of age does an individual show alpha waves of the typical ten-per-second frequency. [13]

4. Adults manifest individual differences in brain wave patterns. These differences show themselves in the presence or absence of the basic alpha waves, changes in the frequency or regularity of the alpha rhythms, the way in which the alpha waves change in various situations, the frequency and change in beta waves, and the regional differences in these and other complex patterns. [18]

These individual differences are not due to any regular differences in structure. Instead, they seem to show some relationship to such personality differences as: differences in general tension, emotional stability, metabolic rate, aggressive-docile behavior, and the like. Such studies have not been carried far, but those that have been made suggest the interesting possibility that those characteristics that have been called basic personality traits may be related to differences in brain wave patterns.

5. Circumstances affect brain waves. Numerous conditions have been found to affect brain wave patterns. Two of them are here discussed: (a) Relaxation is most conducive to a simple uncomplicated alpha rhythm. That alpha rhythms are indepen-

dent of external stimulation, and show themselves best when uncomplicated by other factors, is demonstrated by the fact that they increase in regularity and amplitude when the brain is completely severed from the rest of the nervous system. Sleep, sedative drugs, deep etherization, or any other condition which depresses cortical function tends to produce a slowing in the alpha waves. Conditions of worry, emotional excitement, acidosis, and sensory stimulation tend to increase the frequency of the rhythm or to cause it to disappear altogether in the welter of irregular rhythms produced by hyperexcitement and excessive cortical activity. [1, 15] (b) Intense mental effort will depress the alpha rhythm. Those stimuli have most effect which have attention or arousal value. That is to say, the brain waves seem to be related to psychological functions. When there is little activity, the waves slow down or disappear. When there is heightened activity, the waves no longer appear in regular rhythm but break up into all sorts of complex patterns.

Theoretical considerations related to brain waves. The experimental facts concerning brain waves, which we have just outlined, have given rise to all sorts of speculations. These may be no more correct than those based on brain anatomy, but they are more exciting because newer and because they have injected a spark of life into what had become a sterile attempt to correlate mental functions with the details of neural anatomy.

At least it seems logical to suppose that incoming sensory impulses, when they reach the brain, encounter neural processes already in operation, in the nature of waves varying in frequency and amplitude. It seems reasonable to suppose that the process involved in the reception of incoming impulses by the neural centers involves some sort of adjustment between the wave action already in process and the incoming wave action. The outgoing motor impulse can be interpreted in terms of the resultant of this fusion.

In other words, the brain can be viewed as a kind of variable oscillator. The oscillations in operation at any one moment are the product of previous stimulations, other impulses acting at the time, general structure, metabolic processes, and the like. The incoming processes are due partly to the make-up of the specific

neurons involved but more strikingly to the stimulation of the sensé organ.

According to this theory, cortical activity should be regarded as the product of a whole mass of oscillators whose activity can be expressed only as a spectrum of frequencies. Incoming nerve currents disturb the slow rhythms that exist in this spectrum in conditions of relaxation, and an adjustment must be made between the cortical spectrum and the volley of incoming waves. The motor discharge represents the resultant of this adjustment. This is all highly speculative and no details have been worked out, but it fits surprisingly well into many of the known facts of psychology. [7]

In brief, the brain seems to be more like a radio receiving set than like a telephone exchange.

QUESTIONS FOR REVIEW

1. What are the essential parts of the nervous system?
2. Distinguish between afferent and efferent nerve fibers.
3. Describe the three main functions of the spinal cord.
4. What are the general functions of the brain?
5. What is a neuron? Describe the essential parts.
6. What can be said about the nature of the nerve current?
7. How does the all-or-none law apply to nerve conduction?
8. Enumerate the phenomena which characterize the passage of a nerve current over a synaptic connection.
9. Explain the nervous connection for a simple reflex.
10. What is involved in the neural mechanism for a simple co-ordinated movement?
11. How does cerebral control affect the freedom of simple movements?
12. Show the way in which conflict may be set up in the nervous system.
13. State four theories of nervous functioning designed to explain the facts of nerve transmission and learning.
14. Describe five methods that have been used to study the functioning of the nervous system.
15. What are some of the general brain areas whose function has been determined?
16. What is the theory of equipotentiality?
17. Why is a compromise view better than one which holds for

minute localization of brain function or one which maintains equipotentiality?

18. How have brain waves been examined?
19. Summarize the results of experimental studies of brain waves.
20. Summarize what is known about the importance of timing in neural functioning.

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Chapter XII

VISION

MAN receives impressions from the outside world, and from within his own body, by means of sense organs. Without such receiving devices he would have no way of adjusting to his environment. He would be about as isolated from life in general as a man without a radio receiving set would be from the radio programs which fill the ether.

Several factors about man's sense organs are quite advantageous. (a) He has a variety of sense organs, so that he is not dependent upon one type of external disturbance to give him information about the world. He takes in waves of radiant energy through his eyes; he discerns sounds with his ears; he is aware of certain chemical stimuli through the sensations of smell and taste; he can discern heat and cold and touch by receptors in the skin; and he experiences pain when certain injurious situations are encountered. (b) His sense organs are selective. This selectivity enables him to respond to specific situations while remaining oblivious to others. It enables him to devote his energies to those stimuli which he does sense while ignoring others. Man has made up for many of the disadvantages which may arise from selectivity by devising apparatus to enlarge the range of his sensory capacity. He uses lenses to increase his visual range; he uses various electric contrivances to extend his hearing range. Such creations have more value than ready-made sense organs would have, because the latter cannot be shut off so readily.

Man's most complicated and probably most important sense organs are his eyes. They are in the form of a receiving set designed to respond to light; that is, they respond to radiant energy within the wave-length range of 400 and 760 millimicrons, which travels through space at the rate of 300,000 kilometers,

or 186,000 miles per second. Being a good receiving set, the eyes are highly selective and are unresponsive to forms of energy other than light.

DESCRIPTION OF THE HUMAN EYE

The human eye consists of the eyeball with its adjustment mechanisms. It is connected with the central nervous system by means of the optic nerve. In front, it is shielded by the eyelids

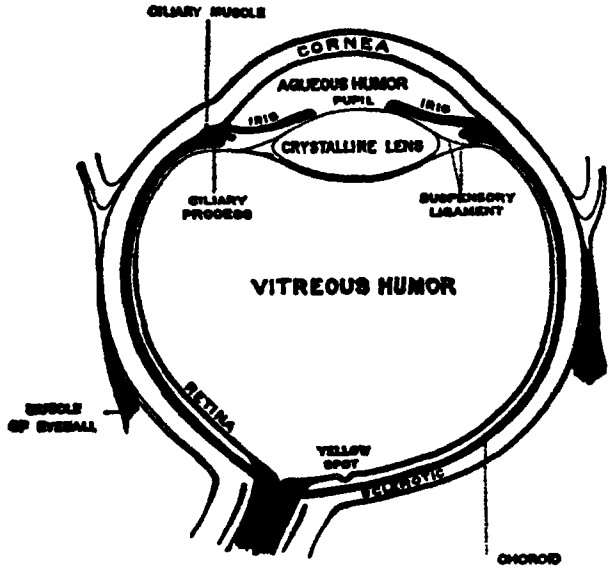


FIG. 81.—Schematic section of human eye.

and moves in a bed of loose fat which, in turn, is encased in a bony socket known as the orbit. [6]

Parts of the eyeball. In principle, the eye operates in much the same manner as a camera. It is a dark chamber which receives light (radiant energy) through a tiny aperture, known as the pupil; refracts, or bends, that light by means of a lens so as to bring it to a clear focus on the retina; and transforms the light waves into nervous impulses which are then carried by the optic nerve to the brain (see Fig. 81).

The wall of the eye consists of three layers: (a) The outermost coat is the sclerotic (hard) coat, which provides strength to keep the eye properly shaped. At the front portion of the

eyeball this coat takes on a slight bulge, which forms the cornea. (b) The middle coat is the choroid coat. It contains pigment cells which give it a dark-brown color and also contains many blood vessels and nerves. The front section of this coat is the iris, the colored part of the eye around the pupil. (c) The inner coat of the eyeball is the retina (Fig. 82). It is an exceedingly

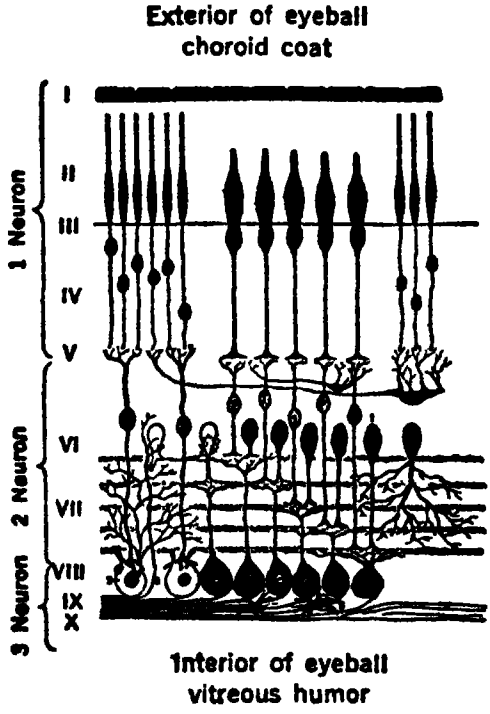


FIG. 82.—Diagram of the retina of the human eye.

complex structure in which ten different layers have been differentiated.

The main body of the eye is filled with a jellylike transparent substance called the vitreous humor, while the part in front of the lens and behind the cornea is filled with a thinner transparent fluid called the aqueous humor.

Organization of the retina. The ten layers of the retina can be grouped into three general parts: (1) the part nearest to the vitreous humor of the eye is composed largely of nerve fibers; (2) the middle part of the retina is composed of connecting nerve cells; (3) the part nearest the choroid coat, that is, the part

farthest from the front of the eye, is composed of the only parts which are sensitive to light, the rods and the cones.

The rods of the retina of the human eye are 0.04 to 0.06 mm. long and about 0.002 mm. in diameter. It is estimated that there are 130 million rods in the human retina.

The cones of the retina are shorter and thicker than the rods, as their name implies. In the human eye they are 0.022 to 0.085 mm. in length and 0.0025 to 0.0075 mm. in diameter. There are approximately 7 million cones in the human retina.

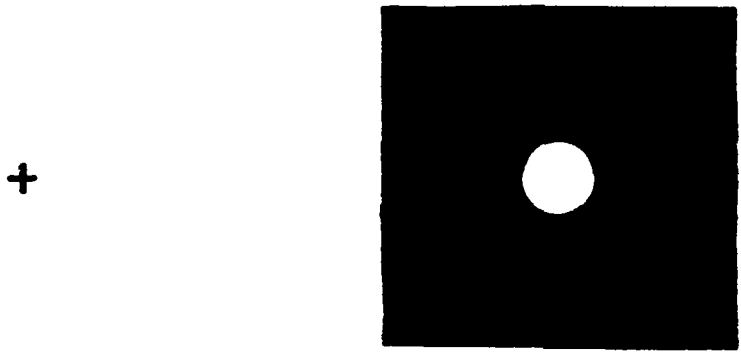


FIG. 83.—The blind spot. Hold the page in front of and about 10 inches away from the right eye. Close the left eye. Stare directly at the cross and move the book slowly toward the face. When the book is about 8 inches from the eye, the white spot will disappear.

The central part of the retina, immediately behind the lens, is different from the peripheral areas. This central part (about 2 mm. in diameter) is called the yellow spot (macula lutea) because of its yellowish color. In the center of this spot is a small depression (a horizontal ellipse), called the fovea (fovea centralis), which is the area of sharpest vision and the center of fixation. The only light receptors in the fovea are cones which are closely packed. Passing from the fovea out toward the periphery of the retina the ratio of rods to cones increases until, in the outermost portions, there are very few cones.

In each retina there is a small area that is not sensitive to light stimulation, which is known as the blind spot. It is the place where the optic nerve leaves the eye and is about 18° to the nasal side of the fovea. It contains neither rods nor cones.

The reader can easily demonstrate its presence in each eye by following the directions under Fig. 83.

The lens. The lens of the eye is suspended just behind the pupil. It differs from the glass lens in a camera in that it can adjust its degree of curvature and thus change in refracting power, whereas the curvature of the lens in a camera is fixed. The lens of the eye "accommodates" for distance by becoming thicker as objects move nearer to the eye (thus increasing the degree of refraction) and thinner as objects move farther away from the eye. Adjustments for distance in a camera are made by changing the distance between the lens and the sensitive film. The nearer the object to be photographed the greater must be the distance between the lens and the film.

EXPERIENCES OF LIGHT AND COLOR

The adequate stimuli for vision are the light waves which strike the retina of the eye. These waves vary in length and in intensity, and by variations in these qualities produce experiences of light and color in the individual whose eyes are affected by them. The light waves themselves do not possess qualities of light and color; they merely affect the eyes in such ways that the individual experiences these sensations.

Surface, expanse, lustrous, and luminous colors. The kind of color or light which a person experiences is determined in part by the source of the stimulus. (a) There are surface colors, or object colors, which are determined in large part by the light reflected from objects in the field of vision. These surface colors are deceptive because we all tend to see a given object as though it had the color we are accustomed to attribute to it. For example, we will see the same rose as though it had the same degree of redness even though changes in lighting may produce radical changes in its coloring. (b) There is expanse color, free color, or film color, which is experienced when one looks at a clear sky, into a dense fog, when one's eyes are closed, or when one looks at a perfectly uniform surface through a tube. (c) There is the lustrous color that results when one looks at polished metal or at silk. The luster seems to be something added to the color reflected from the object. (d) There is the glow or luminous color that is experienced when one looks at an object

which produces as well as reflects light. A glow results when one looks at a bit of red-hot metal, into a flame, or at the luminous letters on the dial of a watch.

Brilliance, hue, and saturation. Regardless of whether a light stimulus is reflected from a surface, whether it is a film color, a lustrous color, or a luminous color, it may possess different degrees of three other qualities: brilliance, hue, and saturation.

Brilliance is that quality of a color experience in respect to which it may be equated to some member of a series of grays ranging from white to black. Every color, no matter what other characteristics it may have, has some degree of brilliance. Absence of the ability to sense brilliance would mean blindness. Brilliance is determined most significantly by the energy of the light wave, although it is also affected by the wave length of the stimulus.

Hue is color tone. It is the sensory quality which varies primarily with the wave length of the light stimulus. It is illustrated by those qualities of a color which we designate by such terms as red, yellow, green, blue, and the like.

Saturation is the degree to which any color possessing a given hue differs from a gray of the same brilliance. Saturation is often referred to as the richness of the color. For example, two reds may be alike in brilliance and in hue and, at the same time, one may be a rich, saturated red, while the other is a washed-out red barely distinguishable from a neutral gray.

COLOR MIXING

Colors may be mixed in various ways in the psychological laboratory. The one most commonly used is the color wheel (Fig. 84). It consists essentially of a motor that twirls cardboard disks which can be intertwined so as to provide various proportions of component colors. When this composite disk is rotated with sufficient rapidity the component colors fuse. Another method is to extract different rays from a spectrum and superimpose them on a dead-white surface or throw them directly on the same part of the retina. Or, various hues may be obtained by the use of filters. [4] The different results of color mixing may be formulated as follows:

1. The combination of all the spectral colors will produce a neutral white. This principle is obvious. Since the spectrum is obtained by segregating the different component colors of white light, the recombination of these should produce the original light. Because we have no device with which to recombine colors per-

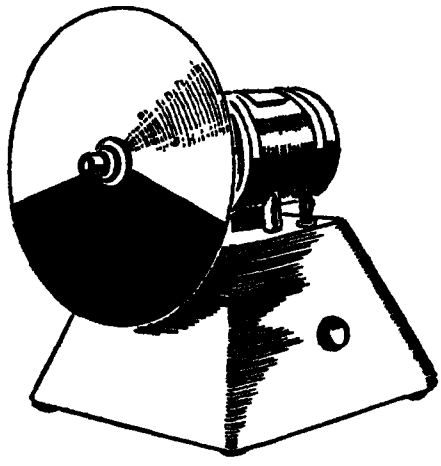


FIG. 84.—A color wheel.

fectly, mixing usually produces a neutral gray instead of pure white light.

2. There are certain pairs of colors which, when mixed, give rise to the sensation of neutral gray or white. Such pairs of colors are called complementary colors. Some complementary pairs are given here:

Red	666 millimicrons	and	Blue-green	497	millimicrons
Orange	610 "	and	Green-blue	492	"
Yellow	585 "	and	Blue	485	"
Yellow-green ...	570 "	and	Violet	430	"
Green	505–533 "	and	Purple (mixture of red and blue)		

There is no spectral color that is complementary to green. To get a neutral gray with green two other colors, red and blue, must be used. Red and blue mixed together give purple, which is the complementary to green.

3. When two colors not too far apart on the spectrum are mixed they give an intermediate spectral color. Mixing red and yellow gives orange. By mixing red and green in varying pro-

portions different hues of orange, yellow, and yellow-green may be obtained.

4. When colors are mixed which are farther apart on the spectrum than their complementaries, they give a resultant purple.

5. A color diminishes in saturation when it is mixed with a smaller proportion of its complementary color than is necessary to produce a neutral gray.

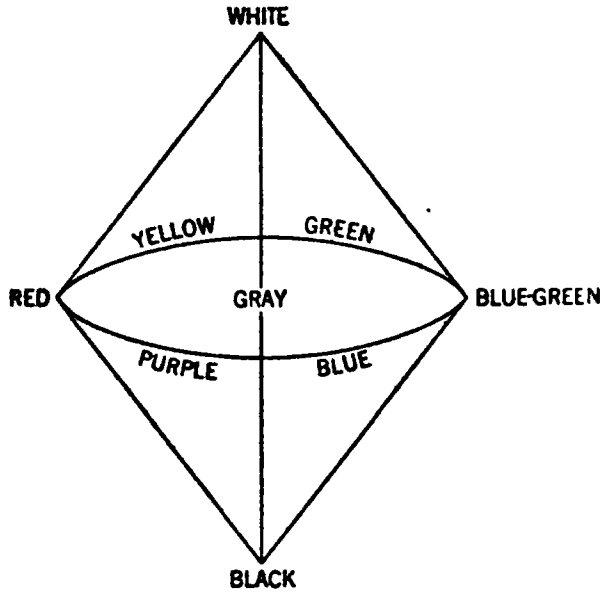


FIG. 85.—The color solid.

6. A color changes in both brilliance and saturation when it is mixed with a black, a white, or a gray differing in brilliance from the color.

All these facts of color mixing may be represented in the color solid (see Fig. 85). Three variables are represented in this double cone. The various degrees of gray are located along the line running through the center from white at one end to black at the other. The spectral colors are represented by the external band around the bases of the abutting cones with the complementary colors located opposite to each other. As one passes from the outside toward the center, there is a decrease in saturation; as one passes around the outside, midway between the black and white ends there is a change in hue; and as one passes from black to white, there is an increase in brilliance.

ANALYSIS OF VISUAL PROCESSES

There is no doubt that the most important factor making for visual experiences is the radiant energy affecting the eye. The way in which a person senses light, however, depends upon a number of factors: individual differences in the presence and distribution of rods and cones, degree of general illumination, the part of the eye stimulated by the light, the way in which adjoining areas of the retina are being stimulated, what has preceded, the sequence of impressions, the similarity or difference of the stimuli affecting the two eyes, and the habits of sensing in certain ways. Since the influence of these various factors are interlaced they cannot be isolated for discussion, but they will come out in the discussion to follow. [10]

Distribution of rods and cones. Anatomically there are two types of receptor cells in the human retina, the rods and the cones. It is pretty well accepted that the rods are responsible for vision when the illumination level is low, or at twilight levels, and give rise to light-dark sensations but not to sensations of color. The cones, on the other hand, are considered the receptors for color or daylight vision and are inactive under twilight conditions. It is further thought by most investigators that the cones vary in their function, some being more responsive to certain color stimuli than to others. It is almost imperative to postulate some difference in the cones in order to account for the facts of color vision.

The fact that the ratio of rods to cones varies in different portions of the retina and that there are only cones in the fovea makes possible some crucial observations which support the theory that the rods and cones have these different functions.

1. The totally color-blind person has poor foveal vision. In color-blind persons, since the cones are the receptors for color vision, the fovea is either inefficient or inactive. Such individuals often manifest unsteadiness of fixation and must turn the eyes so that the object image falls upon the periphery of the retina to one side of the fovea. In order to see they must move their eyes to such a position that their rods can function.

2. Night-blind persons have defective rods. Night-blind persons cannot adapt their vision to weak illumination and conse-

quently they cannot see at night. It has been found that such persons have a defect in the pigment layer of the retina which supplies the visual purple, that is, the chemical material utilized by the rods. This defect of the pigment layer may result from vitamin A deficiency.

3. When the normal person is in a weak light he sees inefficiently with the fovea of his eyes. This has been definitely tested in the laboratory but a crude demonstration can be found in looking at a faint star. When the star is fixated directly, that is, when its image falls upon the fovea, it disappears. When the eye is shifted a little to one side, so that the image falls outside the fovea, it can be seen.

All these facts point to the conclusion that what an individual sees depends upon the kind of visual receptor that is stimulated. The rods are receptors which are limited in their function to brilliance discriminations, while the cones enable an individual to discriminate between colors as well as to give sensations of gray, white and black.

Light and dark adaptation of the eye. The eye adjusts itself to changes in illumination by compensating changes in the size of the pupil and by changes in the sensitivity of the retina.

The area of the pupil changes from about 3 mm.^{2} (or 1.9 mm. in diameter) in bright light to about 52 mm.^{2} (or 8.1 mm. in diameter) in dim light. That is to say, in extremely dim illumination the pupil adjusts so as to admit seventeen times more light than it does in extremely bright light. While this seems to be a striking adjustment, it is relatively inefficient, for at different times of night and day the light affecting the eyes may change in the ratio of millions to one.

The retina goes much further in meeting changing situations than do the pupils. As the light increases, the retina becomes less responsive. When there is a sudden change in illumination, vision is not so acute as it is after one has become used to (or adapts to) the new amount of light. This process of adaptation affects both the apparent illumination of the object seen as well as its hue or color.

A light-adapted eye is one that has been exposed to bright or intense general illumination. Such an eye becomes relatively insensitive to dimly illuminated objects and the same object seems

less brilliant than it did before the increase in general illumination took place. Walking into a motion-picture theater on a bright afternoon illustrates these effects.

A dark-adapted eye is one that has been exposed to general illumination of weak intensity. Such an eye becomes more sensitive to faint stimulation and the same object seems more brilliant than it did before the eye became dark-adapted. The increase in ability to discern objects in the motion-picture theater after one has been there for some time illustrates these changes. As one emerges from the darkened theater into daylight, ordinary objects appear abnormally brilliant.

The vision which occurs in faint light, or after dark adaptation, is called scotopic, or twilight, vision. The vision which occurs under illumination sufficiently strong to permit discrimination of colors is called photopic, or daylight, vision.

That this adaptation takes place in the eye and not in the brain is evidenced by the fact that one eye can be light-adapted and the other eye simultaneously dark-adapted.

A dark-adapted eye and a light-adapted eye see the spectrum differently. When a beam of sunlight is passed through a prism and is projected upon a neutral gray surface, the different wave lengths of radiant energy become segregated and lie spread out in regular order. These wave lengths range from 400 to 760 millimicrons and give rise to color sensations ranging from red to violet. The wave-length values of the various colors are about as follows:

Wave length in Millimicrons	*Color*
640 to 760	red
590 to 620	orange
533 to 590	yellow
505 to 533	green
415 to 505	blue
400 to 415	violet

In the light-adapted eye (that is, in photopic vision) the brightness value of the spectrum rises from each end and reaches its maximum at 560 millimicrons. With weak illumination (that is, in scotopic vision) a weak spectrum loses all its visible color and shows only a gradation of brilliance. In this situation the

spectrum shortens, because the red end becomes invisible beyond 640 millimicrons. At the same time that the red end disappears entirely the point of maximum brightness moves toward the violet end to about 500 millimicrons, or green. This changing aspect of spectral colors with changes in illumination is called the Purkinje phenomenon. It is illustrated by the fact that roses will disappear from view in a garden in twilight while the green leaves still remain visible.

Another simple way to test the different aspects of colors with different illumination is to match a bit of red paper with a bit of green paper so that they appear to have the same brilliance in a bright light and then reduce the illumination. The green paper will appear brighter than the red with the decrease in general illumination as soon as the eyes become somewhat dark-adapted.

It is an interesting fact that the brilliance values of spectral colors is the same for totally color-blind persons as it is for the normal person in dim illumination. Since the totally color-blind person has only rod vision, this would seem to provide further evidence that the retinal rods sense brilliance values only. The normal man in twilight vision and the totally color-blind man are both utilizing the same mechanism (the rods). Both discern only brilliance values and fail to see colors.

Dark adaptation not only changes the values in spectral colors but it also changes the sensitivity of the retina to light. As adaptation proceeds there is an increasing ability to see fainter and fainter stimuli. Both rods and cones take part in this changing sensitivity, but the rods play a much greater role than do the cones. Foveal adaptation (that is, cone adaptation) is very, very rapid and ends in about three minutes, after which time the eye can discern a stimulus that is about one-fiftieth as intense as the minimum stimulus before adaptation began. The adaptation occurring after this first three-minute period is wholly an adjustment of rod sensitivity. This rod adaptation proceeds rapidly at first and then more and more slowly, reaching near-completion in about 30 minutes. The change in sensitivity is enormous. The dark-adapted eye (after about 30 minutes of dim illumination) is able to discern a stimulus 1/50,000 of the value of the weakest

stimulus that could be seen at the beginning of the adaptation process.

The significance of sensory adaptation lies in the fact that it is an automatic adjustment to the environment. The sense organs are not merely gateways through which external stimuli must pass; instead, they are adjusting organisms which respond, without any conscious control on the part of an individual, to changes in the external environment.

Flicker and fusion. When successive visual stimuli come with sufficient rapidity they fuse, and the experience seems to be continuous. When they come more slowly they do not fuse completely, and there results a flicker. The frequency at which all flicker disappears is called the critical fusion frequency (or the critical flicker frequency) and depends upon several factors.

1. An intense stimulus has a higher critical fusion frequency than a weak stimulus. With a visual stimulus of extremely low intensity, fusion may occur with a frequency as low as 5 cycles per second. With high intensities, the necessary frequency may run as high as 55 cycles per second. In motion-picture projection, freedom from flicker is secured when the pictures are shown at the rate of 15 to 20 frames per second unless the picture happens to be very bright.

2. A stimulus that covers a large area has a higher critical fusion frequency than one covering a small area. That is, the parts of the retina seem to combine in a summation effect so that the stimulation of a large area has an effect similar to increasing the intensity of the stimulus over the same area.

3. The fovea of the eye has a higher critical fusion frequency than the peripheral areas. For example, if a small beam of light is used as a stimulus, with an illumination strong enough to require a critical frequency of 36 cycles when it strikes the fovea, the critical frequency will be only about 22 cycles when the same light strikes the retina at a point 20 degrees above the fovea.

4. The critical fusion frequency declines during dark adaptation and rises during light adaptation.

5. The critical fusion frequency depends upon the relative duration of the light and dark periods. It is highest when the light and dark periods are approximately equal and declines when

either one becomes significantly longer than the other. For example, a motion picture would not have to show so many frames per second if the dark periods were much shorter than the light periods nor if the dark periods were much longer than the light periods.

6. Once fusion is obtained, a further increase in the frequency of presentation neither improves nor impairs the excellence of the fusion effect.

Whereas the effect of fusion in the production of motion-picture effects has been popularized, the use of fusion to make motion appear static has been largely confined to scientific laboratories. The instrument for effecting a static effect from a rapid series of visual stimuli is called the stroboscope. Everyone has seen a moving vehicle in a motion picture in which the wheels seemed to turn backward or in which the spokes stood still while the vehicle moved on. This is a stroboscopic effect. Its principle of operation can be made clear by a simple illustration. Suppose we have a disk which can be rotated on a color mixing motor and upon which is drawn a line extending from the center to the circumference. If, as this wheel is turned, it is illuminated by momentary flashes of light which occur only when the radial line is in the vertical plane above the center, and at other times the wheel is not visible, the illusion will be created that the line is stationary and is always vertical. It seems so because that is the only position in which we can see it. Now, if the wheel is turned at such a speed that the line comes to this position sixty times a second and the disk is illuminated by a light which flashes on at the same rate of sixty times a second, the line will appear to stand still. If the light flashes remain at the rate of sixty a second while the wheel is rotated fifty-nine times a second, it will appear to be turning counterclockwise at the rate of one revolution a minute. If the wheel is rotated at sixty-one times a second, it will appear to be moving clockwise at the rate of one revolution a minute. The stroboscope is used for such practical purposes as observing vibrations in high-speed machines, torque in crankshafts, the pitch of tones, and the like.

Visual aftersensations. Flicker and fusion demonstrate the fact that vision is not an instantaneous process. Instead, with each visual stimulation there is a time factor, during which the

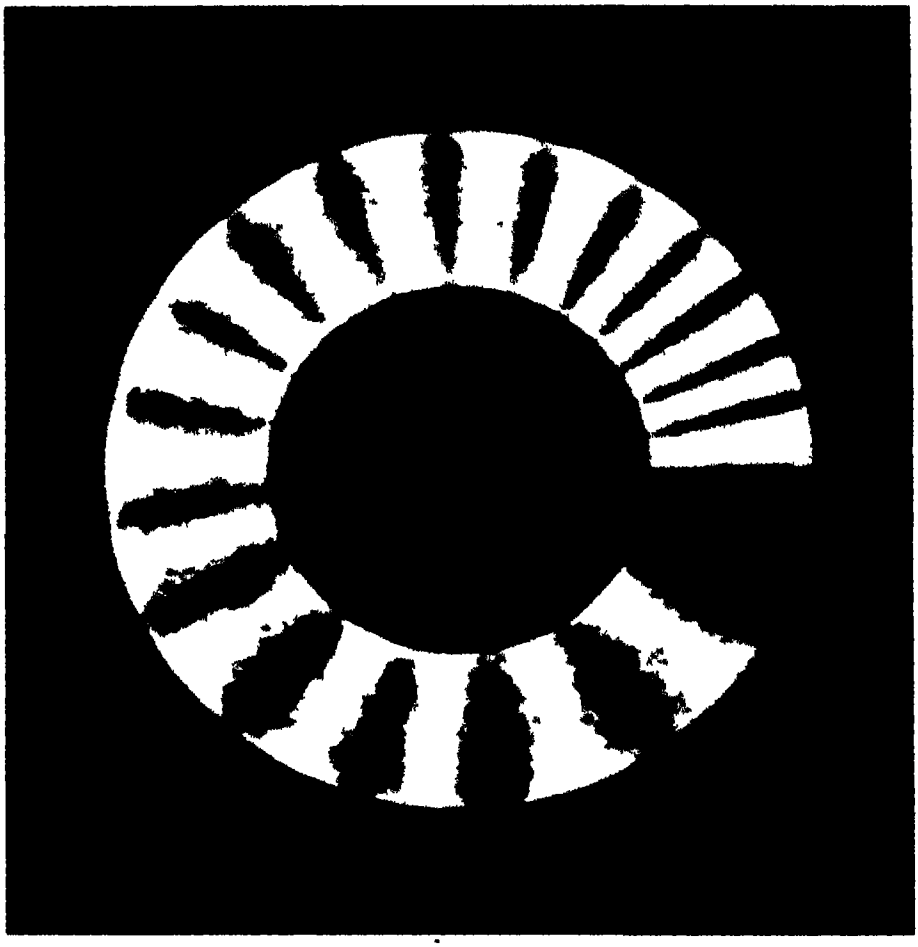


FIG. 80.—Charpentier's bands. The reported effect produced by a brightly illuminated 12° slit rotating in a clockwise direction at the rate of two revolutions per second before a resting eye.

effect progresses from a minimum to its full value; and there is another time factor involved after the stimulus is removed, during which the effect of the stimulus recedes to zero. When the stimuli are not applied in rapid succession, this time lag produces other effects which are known as aftersensations or afterimages.

When a single visual stimulus is instantaneously applied, the brilliance sensation rises rapidly at first and then more and more slowly until a maximum is reached. The total time for reaching this maximum is never more than one-fifth of a second. After this maximum is reached, the brilliance turns down rapidly and is followed by certain aftereffects. Most of these aftereffects are ignored in ordinary life and are apparent only when they are carefully sought. The train of effects can be described as a series of pulses of different speed and may be differentiated as follows:

1. *Charpentier's bands.* If the stimulus is very weak there may be but one pulse. As the intensity increases there may be more pulsations which are briefer, more intense, and follow each other more rapidly. These can be demonstrated by rotating a brightly illuminated slit at the rate of two revolutions per second before a single resting eye. The reported effect is in the form of bands as shown in Fig. 86. They are known as Charpentier's bands.

2. *Purkinje afterimage or Bidwell's ghost.* Next in order is the afterimage which has been named Bidwell's ghost or the Purkinje afterimage. It is best observed when the eyes are dark-adapted, when the stimulation is brief, and when the eyes are fixated a little to one side of the object observed. It appears as a continuation of the object seen and is often of a complementary hue. It is probable that both rods and cones are involved. However, it is likely that the rods play the predominant role because: (a) It is seen most clearly when a peripheral area is stimulated (where the rods are most numerous). (b) It is very weakly present, if at all, in foveal vision. (c) It is best observed when the eyes are dark-adapted.

3. *The positive afterimage.* The positive afterimage corresponds to the original impression in hue, saturation, and brightness. It can be ascribed to a continuation of retinal activity in the same direction after the stimulation has ceased. It is brief

in duration and is usually followed by a negative afterimage in which the qualities are reversed.

4. *The negative afterimage.* Since the positive afterimage is so fleeting, it is hard to observe; but the negative afterimage may be clearly seen with a little practice. Look steadily at a square of red paper for sixty seconds, then at a neutral gray surface. There will appear a blue-green afterimage of a hue complementary to the original red. In other words, the negative afterimage is the complementary to the original stimulus.

5. *The flight of colors.* Even more persistent is the aftereffect that follows the steady fixation of a bright white light. There is a flight of colors which may include any or all the colors of the color circle (red, orange, yellow, yellow-green, green, green-blue, blue, violet, purple, and gray) which follow each other in no orderly sequence and in a variety of patterns. During the first part of the period following the removal of the light, yellow may predominate over the other colors, then red, blue, or purple may gain the upper hand, and finally dark green. The changes occur most rapidly at first, then more and more slowly. There may be a core of one color surrounded by rings of others with a gradual interchange of places. Finally, the colors become darker and less saturated and end in a dull gray or black.

Contrast. Visual contrast effects are usually classified into two categories: (1) Successive contrast refers to the changes in visual sensations which result from the influence of one stimulus on what follows. Those phenomena which we have discussed as adaptation and negative aftersensations are illustrations of successive contrast. (2) Simultaneous contrast refers to the mutual interaction between stimuli presented at the same time.

Contrast effects may also be classified into monocular and binocular contrast effects. Monocular contrast occurs when the two stimuli involved affect different parts of the retina of the same eye. Binocular contrast occurs when one of the stimuli affects one eye and another stimulus the other eye at the same time. We shall consider binocular contrast later as a phenomenon of binocular vision.

Simultaneous brilliance contrast may be demonstrated by placing a small bit of paper on a background differing from it in brightness. If the background is darker, the paper will appear

lighter. If the background is lighter, it will appear darker. This can be clearly shown by placing a three-inch black square next to a three-inch white square. In the middle of each place a one-half-inch square of neutral gray paper and cover the whole with a sheet of tissue paper. The bits of gray paper which are really of the same brightness will show a marked difference; the one on the black ground will look lighter than the one on the white ground.

Simultaneous color contrast may be demonstrated by using backgrounds of different colors and placing the same bits of gray paper on the different backgrounds, covering the whole each time with tissue paper. It will be found that the following facts obtain: (a) The neutral gray square will tend to take on the hue that is the complementary of the background. If the background is red, the gray paper will appear to be blue-green. If the background is blue, the gray square will appear yellow. If the background is yellow, the gray square will appear blue. (b) Color contrast is greatest when the background and the small test square are of equal brightness, that is, color contrast is lessened by the presence of brilliance contrast. (c) The contrast effect is lessened if the two fields are separated by dark boundary lines and is heightened when the two fields are of the same texture. (d) Saturated colors produce a greater contrast effect than do unsaturated colors.

These principles should be given due consideration in the practical applications of the laws of color and brilliance contrast. In short, to enhance a color, place it in the company of its complementary. A red looks redder on a blue-green background; a white looks whiter on a black background; a blue looks bluer on a yellow background. The greater the difference between the color and the background the greater the contrast effect.

BINOCULAR VISION

When a robin looks for a worm, it attempts to see the worm clearly by turning its head so that one eye is directed toward the ground while the other one is turned upward. A bird's clear vision apparently involves the use of one eye to the exclusion of the other. When a person wants to see an object with the greatest clearness, he directs both eyes toward the object.

The way in which the two eyes co-operate in human vision has been the subject of intensive study. [2] Such co-operation is important in the perception of depth. We shall, however, postpone consideration of this subject until we take up other aspects of perception in Chapter XV.

If the eyes are in the primary position (the position they assume when the head and body are erect and the eyes fixated upon an infinitely distant point in the median and horizontal planes), any stimulus will affect a certain area in each retina. Such paired areas are called identical retinal areas. If the stimulus is a single point it will stimulate identical points in the two retinas. Since the eyes are usually not in the primary position, the same stimulus ordinarily strikes points on the two retinas which are not identical. Nevertheless, the point will not be seen as a double point, even though nonidentical points on the two retinas are stimulated. That is to say, it is not necessary that identical points be stimulated to create a fusion of the two retinal stimulations. A pair of points in the two retinas which, when stimulated simultaneously, give rise to binocular fusion, or single vision, are called congruent points.

When a visual stimulus falls on noncongruent points on the two retinas, it is seen as double; when it falls upon congruent points, it is seen as a single object. The reason that an intoxicated man sees double is that he has lost control of his eye muscles and cannot make them turn so that a single object will fall upon congruent points in the two eyes. Single vision, when congruent points are stimulated, is an illustration of teamwork between the two eyes; whereas seeing double demonstrates that such teamwork is limited and breaks down under certain circumstances. It is an interesting problem to determine to what degree the eyes act as independent units and to what degree they are unified in their action.

Binocular fusion. Under what conditions does binocular fusion occur? In ordinary conditions congruent points are stimulated by the same object and fusion is merely combining nearly identical images in the two retinas.

When different stimuli fall on congruent points, what happens? When a stimulus of one brightness falls on one eye, and a stimulus of another brightness falls upon the congruent area of

the other eye, the resulting experience has a brilliance value lying between the two stimuli. It is a compromise between the two and not an addition of the two. This experiment shows that the stimulation of one retina is not added to the stimulation of the congruent point of the other retina. Binocular fusion is a compromise reaction and not one of summation.

Mixing colors produces a similar result. If red light falls upon one retina and yellow light falls upon the congruent area of the other eye, the result is an orange sensation. If one eye is

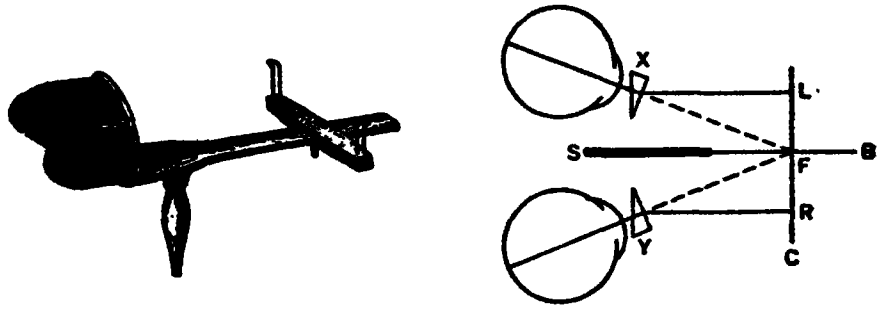


FIG. 87.—A stereoscope and diagram showing its operation. C is a card containing the stereoscopic pictures. L is the center of the left-hand picture; R, the center of the right-hand picture. B is an arm on which the picture holder can slide so as to secure distance adjustment. S is a screen between the two eyes. F is the point on which the eyes converge. X and Y are prisms which bring the points L and R to a focus on the foveae of the respective eyes while they are converged on the point F.

stimulated by a yellow and the congruent area of the other by a blue, the resulting sensation will be a neutral gray. The two mix as they would on a color wheel.

Binocular rivalry. When radically different colors or figures are presented simultaneously to congruent areas of the two eyes, they may refuse to combine in any manner; instead, they alternate so that the individual sees first one stimulus and then the other in fairly rapid shifts. This phenomenon is called retinal rivalry and can be readily demonstrated by means of the stereoscope (Fig. 87). The ordinary stereoscope is a device which places a prism before each eye in such a manner that one stimulus

can be seen by one eye and another by the other. Rivalry is best observed when the stimuli are not too intense.

With the stereoscope, two colors which are near together on the spectrum may combine and give the sensation of an intermediate color. When the two components are farther apart on the spectrum, they tend to alternate; the subject sees first one and then the other.

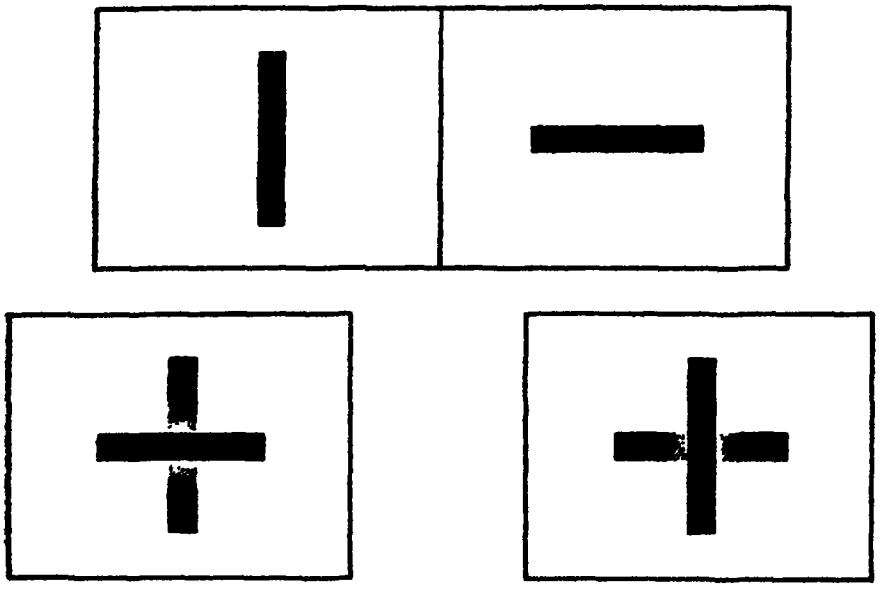


FIG. 88.—Binocular rivalry. If the stereoscopic slide, as shown in the upper part of the figure, is presented, the subject will see alternately the combination shown at the left, in the lower part of the figure, and the combination shown at the right. That is, there will be an alternation in dominant position between the horizontal and vertical bars.

One interesting type of rivalry results when one eye is stimulated by a white surface and the other by a black. Instead of getting a plain neutral gray the result will be a lustrous effect.

Rivalry is seen even more clearly when two incongruous contours are presented, one to each eye. If a heavy black horizontal line is shown to one eye and a heavy black vertical line is shown to the other they will not form a cross. The subject will see the ends of both lines but the point of intersection will change

so that alternately the vertical one will appear solid and then the horizontal one (see Fig. 88).

Binocular flicker. What happens when one eye is presented with a flickering stimulus and the other eye with one having the same rate of flicker but arranged so that it is bright while the other is dark? Do the two combine and thus eliminate the flicker or reduce the critical fusion frequency? Experiments have given a negative answer. There is some reduction, but it is so small that it can be said that the two eyes do not add together the alternating stimuli to form a continuous whole.

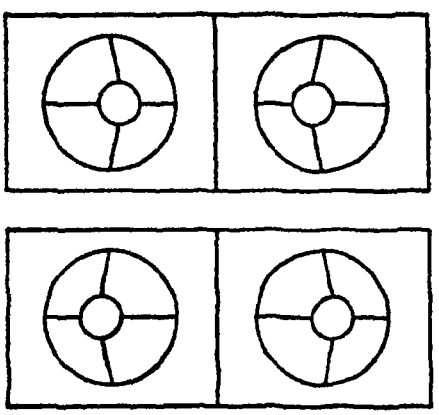


FIG. 89.—Binocular perspective. If the upper slide is viewed through a stereoscope, it will appear as a truncated cone. If the lower slide is viewed through a stereoscope, the subject will seem to be looking into the large end of a funnel.

Perspective by retinal combination. The rule for binocular fusion and rivalry evolved thus far is: When the stimuli to the two eyes can combine in some manner, they tend to supplement each other; when they are too incongruous to combine, they alternate with each other.

Under certain circumstances disparate retinal images combine and give the observer the impression of distance or depth of an object. Such experiences probably are based on the fact that, when a near object is seen, it is not seen the same with both eyes. Stereoscopic pictures illustrate such differences. Take two pictures of the same scene by means of two cameras placed apart by a distance equivalent to the distance between the two eyes and minute examination will show that the pictures are different. When these pictures are seen through a stereoscope, one picture falling on each eye, the observer will get the impression of depth.

Look at the small end of a truncated cone with each eye, and

the difference in retinal images will be readily observed (Fig. 89). To the left eye the small section will be closer to the right rim of the more distant and larger section. To the right eye the small section will be closer to the left rim of the larger and more distant section. Seen together these two retinal images combine and the small section is seen to be nearer. Look into the large end of a funnel and the situation is reversed. With the right eye the small and more distant section moves to the right rim of the nearer and larger section. With the left eye the small and more distant section moves to the left rim of the nearer and larger section. When seen together the two images combine and the small section looks more remote.

Various effects may be obtained by reversing the pictures on a stereoscopic slide. For example, suppose the scene is a man sitting with his feet on an ottoman directly between him and the stereoscopic camera. The right camera would show the feet relatively nearer the right and the left camera would show the feet relatively nearer to the left in the picture. Seen through a stereoscope the observer would get a true perception of depth and would see the feet in front of the body. Suppose the pictures are reversed. The disparity of the images would tend to make the feet appear behind the man's body. But one does not ordinarily see the soles of a man's feet behind the body. The observer may see first the feet, then the body of the man; he may seem to see a transparent body with the feet behind; or, if there is enough incongruity resulting from the reversal of the two pictures, the observer will see merely a flat picture with no depth at all.

These various phenomena of binocular vision suggest the conclusion that the combination of the sensations from the two eyes into a unified whole is the result of experiences of the individual which can be accompanied with success only when such a combination fits in with what the individual has learned about objects about him. The eyes supplement each other rather than add their experiences.

We shall refer to the part that binocular vision plays in the perception of depth again in Chapter XV. Depth perception is a complicated process and binocular vision is but one contributing factor.

EYE MOVEMENTS

Clear and distinct vision is possible only when and if the optical image of an object is motionless upon the retina of the eye. Vision is a chemical sense and time is required for a chemical reaction. Since the body is in continual motion and since external objects move, the eyes must be equipped with devices that will make continual adjustments possible if distinct vision is to be achieved.

Vision during eye movements. At one time it was thought that the eyes could not see during movement and that vision consisted of short periods of seeing interrupted by periods of blindness. Experiments have definitely shown that this is not the case. [12, pp. 576–594] When the retina of the eye is stimulated by a quick succession of stimuli (either because the eye moves, or because the objects move, or both), vision is blurred. If the eye moves at exactly the same pace as an external object in such a manner that the object stimulates the retina as though both were still, vision will be just as clear as though there were no motion.

A simple demonstration in the laboratory will provide convincing evidence of this fact. If a disk containing a series of converging lines, is whirled fast enough (in a clockwise direction) so that the lines blend, the observer will see only a uniform surface. If he fixates his vision on a point to the left of the disk and above the center of rotation and then quickly shifts to another fixation point to the right of the wheel and also above the center of rotation, he may see one or more of the converging lines of the disk as though it had stopped momentarily. He will see these lines clearly only if he happens to move his eyes with a speed equivalent to the speed of the disk and thus enable that part of the wheel to stimulate one portion of the retina during the movement of the eyes over the disk. Several attempts may be necessary before the two synchronize. The spokes of a wheel on a moving vehicle may sometimes be seen in a similar manner.

Because movements of external stimuli and movements of the eye do not often synchronize, most vision during eye movements is blurred and hence ignored by the observer. Unless he

tries some definite experiment, such as the one just described, he believes he cannot see during eye movements.

Methods of observing eye movements. The study of eye movements has been motivated largely by interest in increasing

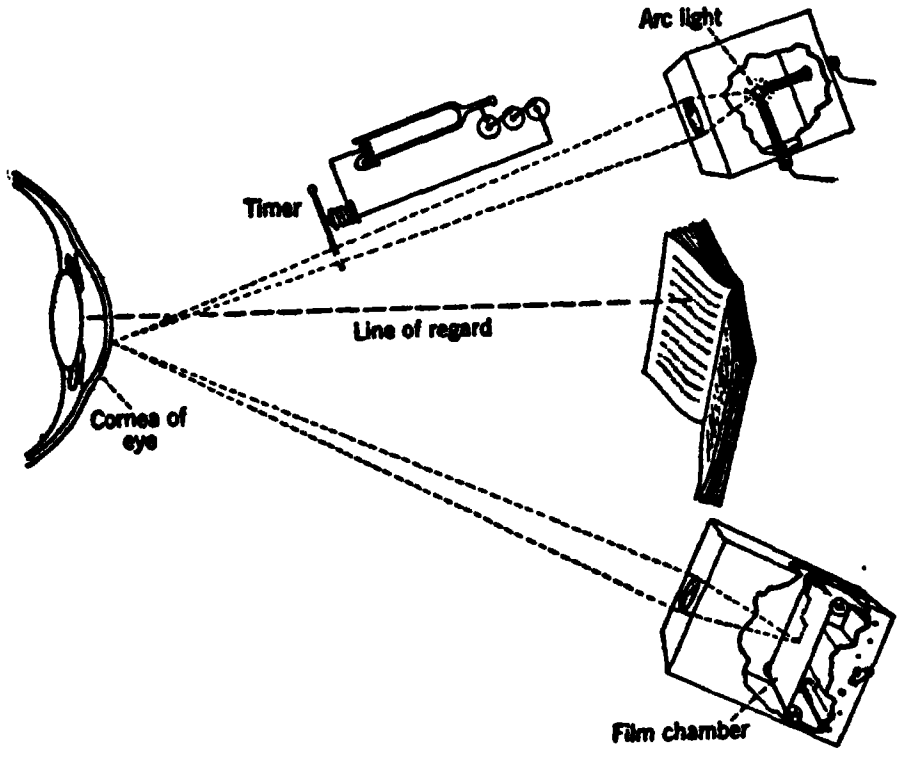


FIG. 90.—Apparatus for photographing eye movements. The light is reflected by the cornea of the eye to the moving film in the camera. A timer interrupts the beam of light and thus gives a time record. When the eye moves along the printed line, the reflecting surface changes and the beam of light is reflected to a different part of the film.

efficiency in reading. Owing to this stimulation, some ingenious methods for the examination of eye movements have been devised by psychologists.

Mechanical registration. One of the first methods was the attachment of a light rod to the eyeball by means of a polished bit of plaster of Paris. This rod then moved upon the surface of a smoked kymograph drum and provided a graphic record of

the eye movements. This method has been discarded for more efficient devices.

Photographic registration of light reflected from the cornea of the eye. A beam of light is projected upon the cornea of the eyeball and the reflection thrown on a moving film (Fig. 90). The operation of this device depends upon the fact that the eyeball is not a perfect sphere. If it were, there would be no change in the direction of the reflected light with a turning of the eyeball. Since the cornea projects forward, any movement of the eyeball changes the angle of its surface to the incident beam of light and thus changes the point at which the reflected light strikes the sensitive film. The film, of course, is moved in a vertical direction.

Motion pictures. It is easy enough to take motion pictures of eye movements, but some difficulties are involved in measuring them. In order to obtain a point of reference it has been found valuable to put a small flake of China white on the cornea over the iris. When the pictures taken with this reference point are projected, frame by frame, onto a sheet of drawing paper it is relatively easy to obtain an accurate graphic record of the eye movements. Since some part of the movement may be lost between frames, it has been valuable, in some instances, to utilize two motion-picture cameras, each camera taking a picture during the movement, or dark period, of the other.

Types of eye movements. The function of most eye movements is to achieve the objective of obtaining clear images upon the retina and to maintain these for a long enough period to give clear vision. There are a few movements which do not directly contribute to this end, such as the slight upward movement of the eyeball during winking and the upward turning of the eyeball during sleep. Our main concern, however, is with the adjustments of the eye when it is being utilized as an organ of vision.

Movements during attempted fixation of the eyes on a stationary object. The eyes do not remain motionless when a stationary object is fixated for as long as a second on one fixation point. Instead, they move continually. Related to this is the fact that when the eyes turn repeatedly to the same object they are inaccurate in their ability to bring the object to the exact center of vision. This can be easily demonstrated. If an observer looks

at the setting sun, looks away, at it again, and away for a number of times, he will get aftersensations of the sun which do not coincide. The relative positions of these aftersensations give a graphic portrayal of the inaccuracies of his successive adjustments. Since the fovea is an area and not a mathematical point, this inaccuracy of fixation and unsteadiness of fixation does not interfere in any noticeable degree with clear vision.

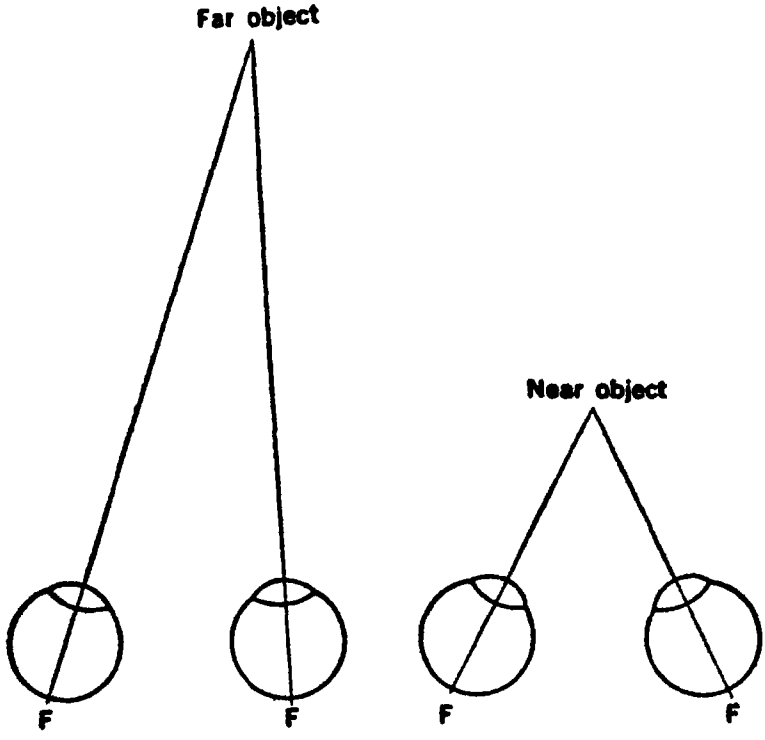


FIG. 91.—Convergence. When an object is moved toward the eyes, the eyes rotate so that the object remains fixated on each fovea, the optic axes converge, and the angle made by them becomes greater.

Movements of convergence and divergence. Movements of convergence and divergence can best be understood by considering the movements of the optic axes. The optic axis is the straight line passing through the center of the lens and the center of the fovea. When a person looks at an infinite distance the two axes would theoretically be parallel. As the point of regard moves toward the observer, the eyes turn so that the optic axis for each eye is still on the object and the angle made by the two

becomes greater the nearer the object of regard approaches. This movement is a convergent movement. As the object moves away, the optic axes diverge, the angle between the two becomes smaller, and the two axes become more nearly parallel. These movements are illustrated in Fig. 91.

There are some significant facts about adjustments of convergence and divergence. (a) Convergent-divergent movements take considerable time and are often interrupted by pauses. (b) The two eyes do not always keep step; one may pause while the other is moving; one may reach its destination and remain there while the other is still feeling around. (c) Convergence is a sort of tentative reaction and the object may appear double until corrections are made. Such readjustment may involve changes in the position of one or both the eyes.

These facts have an important bearing on ease and efficiency in reading. If the book or printed matter is so held that one part of the printed line is farther from the eyes than the other, convergent-divergent movements would have to be made as the eye moves along the line. It would be more efficient and more restful to the eyes to make sure that the printed matter is so held that such movements are at a minimum, that is, have all printed matter equidistant from the eyes, especially from left to right.

Saccadic movements. The sudden movement of the eyes from one fixation point to another is called a saccadic movement. It involves co-ordination of the two eyes and is the most frequent

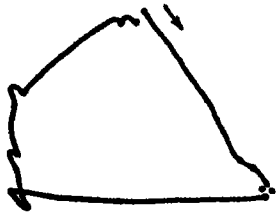


FIG. 92.—Record of eye movements made when the eye "sweeps around a circle." The lines are saccadic movements and the dots are fixation points.

sort of eye movement. It is the type of movement that takes place in reading or in looking at various parts of a stationary object or scene. In reading a line of print the eye jumps from one fixation point on the line to the next and does not move evenly along the line. In "sweeping the eyes" around a circle the eyes make jumpy movements, stopping at various points, so that a graphic picture of such movements would be somewhat as shown in Fig. 92.

Improvement in reading depends in part (a) upon the improvement of saccadic movements in reading, (b) upon making fewer fixation points per line, (c) upon increasing the accuracy of such movements, and (d) upon increasing the speed of such movements. Certain facts about eye movements will show why improvement is not so easily accomplished as it might seem to be.

1. They are only crudely recognized by the subject and are not directly subject to voluntary control. Nevertheless, a person may consciously determine the approximate location of his next fixation point and may attempt to space these points uniformly along the line of print. These saccadic movements are closely analogous to the ballistic movements described in the chapter on motor skills and are improved by corrections in aim and not by trying to make them into slow controlled movements.

2. They start and stop quickly. Photograph records show that slow readers often take an undue amount of time at each fixation point and that this time is taken up with the sort of jumpy movements which take place when one tries to keep his vision fixed on a single point. Good reading, consequently, involves quick apprehension of what one sees as soon as the eyes come to a stop and the quick beginning of the next saccadic movement. The poor reader may continue to jump around at one spot before moving on.

3. The speed with which the eyes move during the saccadic jump depends upon various factors. It is more rapid for longer jumps although the total time taken for the longer movement is greater than for the shorter movement. For example, a movement of 5° (which is the extent made to cover one inch on a page held a foot from the eyes) requires about 29 msec., whereas a movement of 20° (an extent of four inches) takes about 55 msec. The speed of saccadic movements is also affected by the reader's organic condition. These movements are slower when the reader is drowsy or under the influence of alcohol.

Pursuit movements. In following a moving object, the eyes can continue to fixate upon that object and to keep pace with it by means of pursuit movements, provided the movement of the object is neither very slow nor very fast. Such pursuit movements are seldom perfectly synchronized with the movements of the objective stimuli; there is some tendency for the eyes to lag

behind and then catch up again by a saccadic jump. The combination of pursuit movements with saccadic movements can be seen when a person looks from the window of a moving vehicle. The eyes stay fixed on one object for a time by means of pursuit movements, and then jump to another object.

A little experiment will demonstrate that, regardless of whether the eyes remain fixed or follow in a pursuit movement, clarity of vision will remain the same so long as the object remains fixated. Superimpose a sheet of transparent paper, upon which there is some printed matter, upon another sheet of paper containing printed matter. Move one sheet over the other. When a word on either sheet is fixated, the words on the other sheet are blurred. It makes little difference whether the fixated word is on the stationary or the moving sheet so far as clearness of vision is concerned. For clear vision the object must be stationary on the retina of the eye; it need not be stationary in space.

Compensatory eye movements. If the head moves to the right, the eyes must turn to the left in their sockets to keep an object fixated. If the head moves up, the eyes must move down. If the head moves to the left, the eyes must move to the right. These compensatory movements appear, on the surface, to be merely the reverse of pursuit movements. In pursuit movements, the object moves while the head remains still; in compensatory movements, the object remains still and the head moves. In either case, the eyes remain fixed on the object by means of the turning of the eyeballs in their sockets. In the pursuit movement, however, the adjustment is imperfect; it has a long latent time—requiring about one-fifth of a second to get going; and it must be corrected continually by the help of saccadic movements. In contrast to the awkwardness of pursuit movements, the compensatory movement starts simultaneously with the head movement, continues with the head movement, and maintains almost a perfect fixation on the object. The whole process works as though it were a single integrated unit. The head and eyes work together almost perfectly. This can be checked by reading while turning the head. There is practically no blurring. By way of contrast, watch a person attempt to follow the swinging of a pendulum by pursuit movements. A number of saccadic corrections will be seen; and

the observer will report difficulty in keeping the pendulum fixated clearly until he gets accustomed to it.

Movements of nystagmus. Rotation of an individual causes a complex set of compensatory eye movements. When the head is rotated to the right, the eyes turn reflexly to the left and then, as the rotation continues, jump back by a saccadic movement. This alternation between a compensatory eye movement in the direction opposite to the rotation and the saccadic jumps in the direction of rotation has been given the name of rotation nystagmus. If the rotation continues long enough, the subject becomes dizzy and the eyes cease their movements and stare straight ahead. When the rotation stops, the movements reappear, but in reverse. The smooth movement is in the direction of the preceding rotation and the saccadic movement in the opposite direction. This is called post-rotation nystagmus. Movements of nystagmus are dependent upon the semicircular canals—organs in the inner ear which are concerned with sensations of bodily movement and balance. They will be studied in more detail in Chapter XIV.

QUESTIONS FOR REVIEW

1. What advantages arise from the fact: (a) that man's sense organs have a variety of forms? (b) that they are highly selective?
2. Describe the following parts of the human eye: (a) the pupil; (b) the three coats of the eye—the sclerotic, the choroid, and the retina; (c) vitreous humor; (d) aqueous humor; (e) lens; (f) rods; (g) cones; (h) macula lutea; (i) fovea; (j) and blind spot.
3. Define three essential characteristics of radiant energy.
4. Differentiate between expanse color, lustrous color, and luminous color.
5. Describe six different results that may be obtained by color mixing.
6. What are complementary colors?
7. Enumerate some factors which affect visual processes.
8. Differentiate between the rods and the cones.
9. Summarize the evidence which points to the conclusion that the rods are the receptors for brightness and the cones are the receptors for color.

10. To what extent can the pupil adapt to changes in illumination?
11. What is meant by a dark-adapted eye? A light-adapted eye?
12. How does the view of the spectrum differ to a dark- and to a light-adapted eye?
13. Explain the relative contribution of the rods and cones to the adaptation process.
14. What is the essential significance of the facts of sensory adaptation?
15. What factors affect critical fusion frequency?
16. Explain the operation of a stroboscope.
17. Describe: (a) Charpentier's bands; (b) the Perkinje afterimage; (c) the positive afterimage; (d) the negative afterimage; (e) the flight of colors.
18. Distinguish between successive and simultaneous contrast.
19. Outline the salient facts about simultaneous contrast.
20. What are identical retinal areas?
21. What are congruent points?
22. Describe an experiment in binocular fusion.
23. What conclusion may be drawn as to the manner in which congruent points interact?
24. What is a stereoscope?
25. What is meant by binocular rivalry?
26. Under what conditions will binocular rivalry produce a lustrous effect?
27. What happens when the sides of a stereoscopic slide are reversed?
28. What evidence is there that the eye can see when it is in motion?
29. Describe how one may see the spokes of a moving wheel.
30. Describe the different methods that may be used to study eye movements in reading and in similar tasks.
31. When a person attempts to keep his vision fixed on a single point, what happens?
32. Summarize the important facts connected with movements of convergence and divergence.
33. What practical suggestion for effective reading comes from the study of convergent and divergent movements?
34. What are saccadic movements?
35. What are some important eye movement factors relating to reading efficiency?
36. What happens during pursuit movements of the eyes
37. How can compensatory eye movements be produced?

38. Contrast compensatory and pursuit eye movements.
39. Describe movements of nystagmus.

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Chapter XIII

HEARING

THE development of sound motion pictures and the radio has stimulated intense interest in the subject of hearing and, at the same time, has provided apparatus and techniques for the study of the physical and psychological aspects of sound. The progress from the crude squawkings produced by the first talkies and radios to the present smooth and pleasant performances has necessitated not only a perfecting of sound-producing apparatus, but an understanding of the hearing process by means of which sounds are heard.

Hearing depends upon the creation of a mechanical disturbance, the transmission of the effects of such disturbance to the ear by means of the air or some other conducting medium, and the reaction of the ear to this mechanical disturbance. Accordingly our order of study will be: (a) an analysis of fundamental characteristics of the mechanical disturbances which give rise to sound waves; (b) a description of how the ear operates; and then (c) a consideration of the significance of certain characteristics of sound such as pitch, intensity, and quality.

THE FUNDAMENTALS OF SOUND

All sounds, no matter how complex, may be conceived as the projection of uniform circular motion, called simple harmonic motion. [6]

Simple harmonic motion. The most elementary kind of vibration is simple harmonic motion. It is the kind of vibration produced by a tuning fork or by a pendulum, the only essential difference between the two being that of frequency. The undulating movement of a pendulum can be readily seen but is too

slow to make a sound that can be heard. The tuning fork, on the other hand, vibrates too rapidly for its oscillations to be seen clearly by the naked eye, but with sufficient frequency to be heard.

If pendular motion is examined it will be found to have certain characteristic features: (a) Its swings are in a straight line; (b) it is vibratory, moving to and fro; (c) its movements are repeated regularly; (d) there is an instant of rest at each extreme of movement; and (e) starting from the rest at one extreme, the movement accelerates until it reaches the central point of its swing, after which it slows down until it comes to rest momentarily again at the other extreme. If a marking device is attached to a tuning fork so as to trace its swings upon a paper moving at a uniform speed, as is illustrated in Fig. 93, these characteristics of pendular motion can be readily seen.

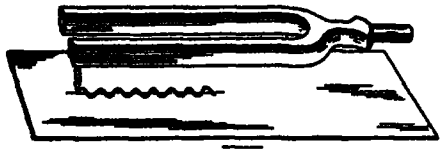


FIG. 93.—Graphic record of the oscillations of a tuning fork.

An analysis of such a record of pendular motion will reveal that it is a true sine curve. Since a sine curve is the graphic record of circular motion, this fact enables us to make an accurate analysis of pendular motion and thus to determine the essential components of sound waves.

Simple harmonic motion is produced exactly when circular motion is transformed into rectilinear motion. This can be accomplished by tracing the path of a shadow (the light, of course, being at an infinite distance) produced by a rotating knob, as shown in Fig 94. A sample of the curve traced on the paper, moving at uniform speed, by such a shadow is shown at the lower part of the figure. When the knob is at the top position, the shadow will fall directly on the straight axis at A. If the wheel rotates in a counterclockwise direction for one-fourth of a revolution, or 90°, the shadow will be at B. When the knob has rotated one-half a revolution, or 180°, the shadow will be at C. When it has rotated three-quarters of a revolution, or 270°, the shadow will be at D. And when it has moved one complete revolution, or 360°, the shadow will be at E. Each complete revolution of

the knob is called a cycle. The sine wave representing such a cycle comprises one complete S-shaped curve.

Such circular motion may vary in three ways: (1) It may vary in the speed with which the rotation occurs. One cycle per

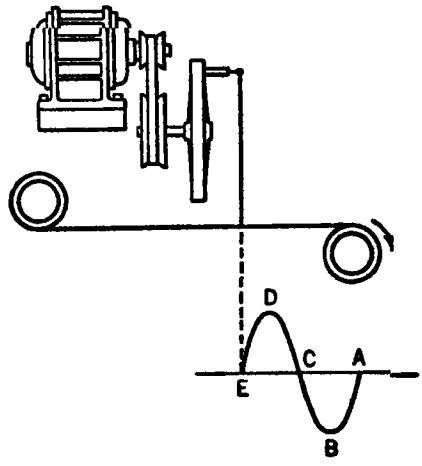


FIG. 94.—Simple harmonic motion. Simple harmonic motion may be represented by the path of a shadow cast by a rotating knob on a moving paper or film. The curve shown at the lower part of the figure represents the sine curve produced by the rotating knob. A cycle is the part represented by the distance from A to E.

second indicates that the wheel completes one revolution in a second. One hundred cycles per second means that the wheel completes one hundred revolutions in a second. (2) It may vary in amplitude. The distance on the curve in Fig. 94 from the central axis to B or to D will vary according to the distance of

the knob from the center of the rotating wheel on which it rides. These variations are known as differences in amplitude. If the knob is close to the center, the amplitude will be smaller than if it is farther from the center. (3) There may be differences in phase. The phase is an indication of the position of the knob at any one moment of its circuit. When the shadow is on the axis it is either zero phase or a phase of 180°. When the knob has turned one-quarter of a revolution from its starting point it is at a 90° phase. These characteristics of harmonic motion, namely, frequency, amplitude, and phase, are the essential factors which account for differences in sound waves.

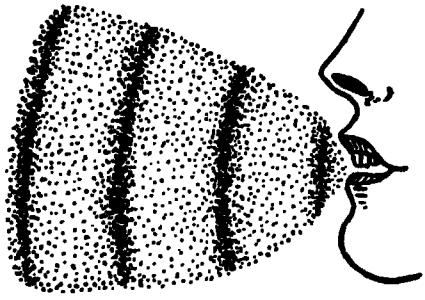


FIG. 95.—The effect of a human voice wave on the air particles in front of the mouth. The shaded parts are areas of condensation; the lighter parts, areas of relative rarefaction.

The production of a sound wave by harmonic motion. [7] A sound wave is produced when harmonic motion affects some material substance capable of being moved by pulsations or pistonlike movements. Any material which can be affected by these pulsations can also transmit these effects; and a sound wave is formed. The effects of pulsations from the human voice upon the air particles in front of the mouth are illustrated in Fig. 95.

The most common medium for sound conduction is the air. The vibratory motion of the sound source may be conceived as giving a "push" to those particles in front of it, jamming them together until the stroke comes to its maximum point. On the return stroke of the piston, the particles tend to spring back and fill the space left by the recoil of the piston. If the stroke is repeated periodically, as occurs when we have a tone, there is an alternating period of condensation and rarefaction of particles and it is this series which constitutes a sound wave.

The speed with which sound travels depends upon the medium through which it is passing. In air it is about 332 meters

(1,090 feet) per second. A rise in the temperature of the air increases the velocity. On other substances sound travels at vastly different speeds: in water it travels at the rate of about

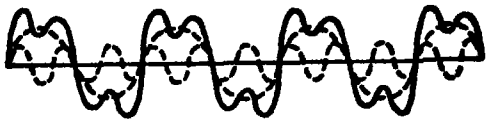


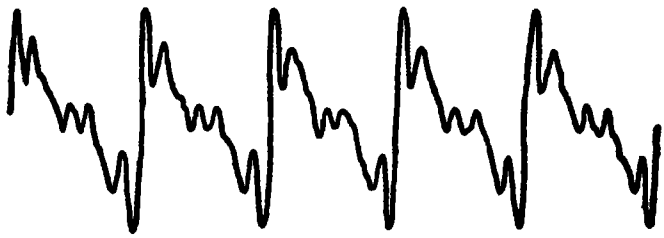
FIG. 96.—The combination of simple harmonic waves. The solid line represents the wave that results from combining the two waves represented by the dotted lines.

4,730 feet per second, while in iron it travels about 15,700 feet per second.

The effect of combining simple harmonic waves. Ordinary sounds are usually not simple harmonic motions but are a



A. Street noise



B. The vowel ah



C. A pure tone

FIG. 97.—Graphic representation of tone character.

complex mixture of a number of harmonic waves differing in frequency, in amplitude, and in phase. In Fig. 96 the solid line represents a wave that results from a combination of the two simple harmonic waves represented by dotted lines. It is possible to analyze a complex sound wave into its simple harmonic com-

ponents by means of a harmonic analyzer. When a mechanical harmonic analyzer is used, the curve is traced with a stylus, the machine giving information which can be used to determine various components of the original curve. [6] Modern sound analysis makes use of electric wave analyzers. [7]

The character of a tone is determined by the number of component harmonic waves, by the relative intensity of each, and by the pattern that they form. In the case of a noise, the components are so numerous, the patterns so variable, the components nonperiodic in form, and the duration of each so brief that the resultant is a hopeless jumble and the listener usually gets a feeling of unpleasantness from hearing it. On the other hand, a pure simple harmonic wave gives the auditor the impression of emptiness. A rich musical tone usually has a fundamental frequency combined with other higher frequencies which blend with it. The graphic representation of a street noise, a vowel sound, and a pure tone (in Fig. 97) will make clear these distinctions.

Overtones. Most bodies not only vibrate as wholes but various parts vibrate simultaneously with different frequencies. The basic vibration, usually the lowest audible one, is called the fundamental tone, whereas the tones produced by parts of the resonant body are called overtones. A stretched string, for example, will vibrate not only over its whole length, as shown in the top illustration in Fig. 98, but various segments will simultaneously vibrate at different rates, as shown in the other three diagrams. When the string vibrates as a whole, it gives its fundamental vibration, or its first harmonic tone. If the vibrating string is touched at its mid-point as shown at *a*, in Fig. 98, it will vibrate in halves as well as over its entire length. This will produce a tone of twice the frequency of the fundamental, and is called the first overtone or second harmonic. When touched at point *b*, it will vibrate at three times its fundamental rate, and this is called the second overtone or third harmonic. When touched at *c*, it will vibrate at four times its fundamental rate, and this is called the third overtone or fourth harmonic.[1] This illustration oversimplifies the facts. When a violin string is

[1] Musicians commonly use the term partial instead of overtone or harmonic. Thus, the fundamental may be called the first partial as well as the first

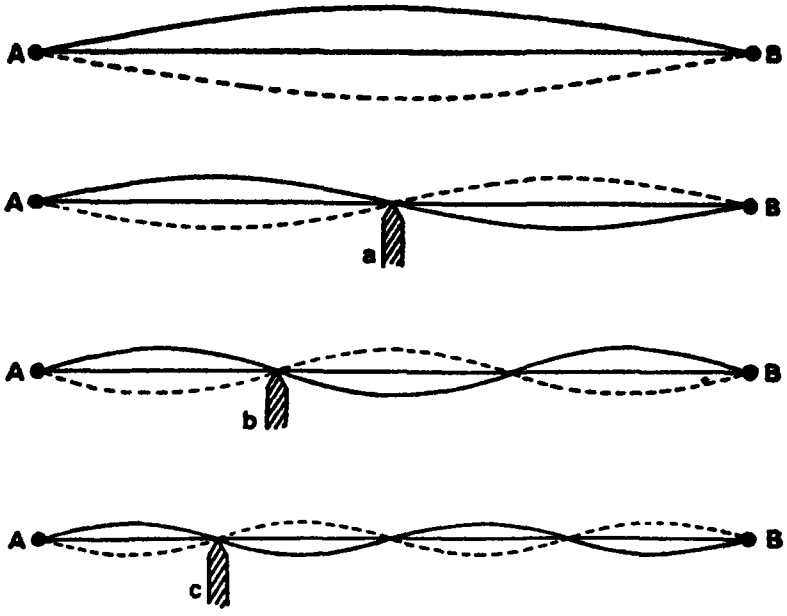


FIG. 98.—Harmonic tones produced by a string. A and B show the points of attachment of a string. The top diagram shows the string vibrating as a whole and producing the first harmonic or fundamental tone. When *a* touches the middle of the string, it vibrates in halves as well as a whole and produces a tone of twice the frequency of the fundamental: the first overtone or second harmonic. When touched at *b*, it also vibrates at three times the fundamental frequency, giving the second overtone or third harmonic. When touched at *c*, it vibrates at four times the fundamental frequency, giving the third overtone or fourth harmonic.

bowed, for example, the bowing is done near the bridge, that is, near to one end of the string span, and the string vibrates in a great many different frequencies. The good player is distinguished from the poor player not so much by the fact that he produces the proper fundamental vibration of the string, but by the fact that he can, at the same time, set up a pleasing set of partial vibrations. The string may be made to vibrate in wholes, in halves, in thirds, in fourths, in fifths, and in other segments as well. A harmonic overtone results when the overtone is an

harmonic; the first overtone may be called the second partial or the second harmonic; the second overtone may be called the third partial or the third harmonic, and so on.

exact multiple of the fundamental frequency. If the overtone is not an exact multiple of the fundamental, it is called an inharmonic overtone.

Beats. When two harmonic waves of identical frequency and amplitude are out of phase by one-half a revolution (or

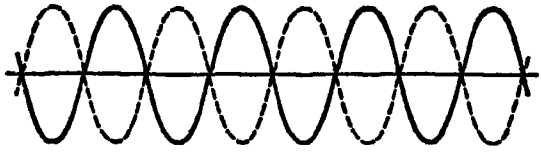


FIG. 99.—Tones that produce silence. The solid line and the dotted line each represent a tone of the same frequency and amplitude but in opposite phase relation. The axis represents the resultant of these two, which has no movement.

180°), the crests of one wave will correspond exactly with the troughs of the other wave and the two will neutralize each other, resulting in silence. This is illustrated in Fig. 99. When they are exactly in phase, of course, they reinforce each other, as in Fig. 100, and will be heard as an increased intensity. Now, suppose we have two harmonic waves varying in frequency by such

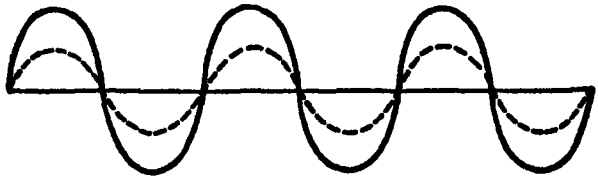


FIG. 100.—Illustration of two tones of same frequency reinforcing each other. If two tones are represented by the dotted line, both of the same frequency and amplitude, they will strengthen each other and the solid line will be the resultant tone.

a small amount that they will be in phase at one moment and out of phase at another. An example of such a situation is given in Fig. 101. The outcome of such differences will vary in accordance with the difference in rate in the two harmonic waves.

Suppose the two tones of 256 cycles each are sounded together. They will be heard as one tone. If the frequency of one is changed gradually, beats will be produced whose frequency

corresponds with the difference in vibration rate between the two tones. If one is 256 and the other 259 cycles, there will be three beats a second. Such a slow beat will be heard as a change in intensity. It will be heard as a single tone which alternately swells out and subsides. This single tone has a pitch intermediate between the two components; it is called the intertone.

As the difference between the two tones is increased, the beats increase in frequency up to about 16 per second, when they take on an unpleasant character and are experienced as a thrusting against the ear. The thrusting phase passes into a rattle when the difference is increased to about 30 per second. When the difference in frequency is increased beyond 30 per second, the

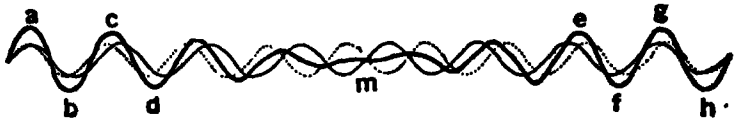


FIG. 101.—Representation of beats. The light solid line completes eight cycles while the dotted line completes nine cycles. At the areas marked abcd and efgh they are nearly in phase and reinforce each other. The resultant solid line is louder than either of the component tones. At m they are out of phase and tend to neutralize each other. The solid line is, therefore, almost motionless. The effect is heard as a change in intensity of a single tone.

subject no longer hears the single intertone; instead, the two components are heard, but with a characteristic roughness.

A good way to tune an instrument is to make use of this phenomenon of beats. Sound the standard pitch alone, and then sound the instrument to be tuned along with it. If beats are heard, they will indicate that the two are close together, but still mistuned. If a change in tuning increases the frequency of the beats, it indicates that the adjustment was made in the wrong direction.

Combination tones. Whereas small differences in frequency between the harmonic components of a tone will produce beats, larger differences will produce secondary tones called combination tones. The two most important combination tones are difference tones and summation tones. An illustration will make clear how they are produced. Suppose two tones, one of 400

cycles and one of 256 cycles, are sounded together. In addition to the two component tones there will be heard a difference tone of 144 cycles (produced by a high-frequency beat between the two components—400 minus 256 gives 144), a summation tone of 656 cycles (400 plus 256 gives 656), a difference tone produced by the difference between 656 and 144 (656 minus 144 gives 512) of 512 cycles, a summation tone produced by the sum of 656 and 144 (656 plus 144 gives 800) of 800 cycles, and a great many more such combinations of frequencies. That is to say, when a tone of 400 cycles and a tone of 256 cycles are produced together, tones of the following frequencies will be heard: 144 cycles, 256 cycles, 400 cycles, 512 cycles, 656 cycles, 800 cycles, and many others besides. Furthermore, there will be differences in intensity of all these tones. Some will be dominant and others so faint as to be almost indiscernible. These combination tones plus the component harmonic tones provide what is known as tone quality.

Musical instruments producing the same fundamental tone will, because of their structure, produce different combinations of overtones, difference tones, combination tones, and incidental sounds. One would never fail to distinguish between a bell, a violin, and a cornet although we all three were sounding the same fundamental tone.

Resonance. Resonance is the vibratory response of a body to harmonic motion imposed upon it. Resonance may be of two kinds: (1) tuned resonance, or sympathetic vibration, and (2) forced resonance.

Tuned resonance, or sympathetic vibration, results when the resonating body has a characteristic frequency that is the same as the inducing sound wave. Most solid objects have peculiar frequencies of their own; they are particularly responsive to their favorite frequencies and relatively unresponsive to others. The tuned resonance of such bodies can be well illustrated by the activity of a pendulum. The time required for the swing of a pendulum is a function of its length. Shorten it and the frequency of its swing increases. Suppose a pendulum whose rate is one swing a second is pushed by a force which acts once a second. The first impulse will give it a slight motion, but each succeeding push will be cumulative and increase the ampli-

tude of the swing (up to a certain optimal limit) because it comes at the right time. On the other hand, a succession of pushes will be relatively ineffective unless their rhythm corresponds in frequency with the natural rate of the pendulum or unless it is some multiple thereof. A tuned resonator is effective in the reception and interpretation of sounds, but it is a poor device to transmit sounds because it will distort while transmitting them. It will accentuate those components which correspond with its characteristic frequencies and dampen those which do not.

Forced resonance takes place when the receiving body has a different frequency from that of the inducing sound wave. The best sound transmitters are those which have no characteristic frequencies of their own and will respond only by forced vibration. Air is such a transmitter. It is very responsive to sound waves without contributing much to the form of the waves which it transmits because it has no inherent favoritism for any harmonic frequencies. The eardrum membrane vibrates with forced vibration; within certain limitations, it does not tend to accentuate any sounds nor does it tend to dampen any.

A resonator whose period is 100 cycles a second will be set in motion by a frequency in the surrounding air of 100 cycles and will respond only indifferently to other frequencies. If, then, we had a sound composed of a great many harmonic components and wished to discover what these were, we could make such an analysis by testing the effect of the sound upon resonators of all frequencies. Whenever we used a resonator whose frequency corresponded with one of the harmonics in the sound to be analyzed, it would be set in motion. A radio receiving set is based upon this principle. A highly selective set is tuned so that it will select waves of a certain frequency and will fail to respond to others. The ear is supposed, according to the resonance theory of hearing, to have a large number of resonators, each one tuned to a particular frequency. In a complicated manner, these analyze the incoming sound waves and transmit impulses to the brain in such a manner that the individual is able to discriminate tones and noises of various pitches, intensities, and qualities.

However, some students contend that the process of hearing is not that of the analysis of incoming sounds into components

by a set of resonators. Instead, they conceive of the ear as discerning differences in total sound patterns.

MECHANICS OF THE HUMAN EAR

The human ear is a masterpiece of mechanical engineering. The sound waves that reach the ear are a complicated mixture of harmonic components. Their reception requires a specialized kind of mechanical system, which will be sensitive enough to

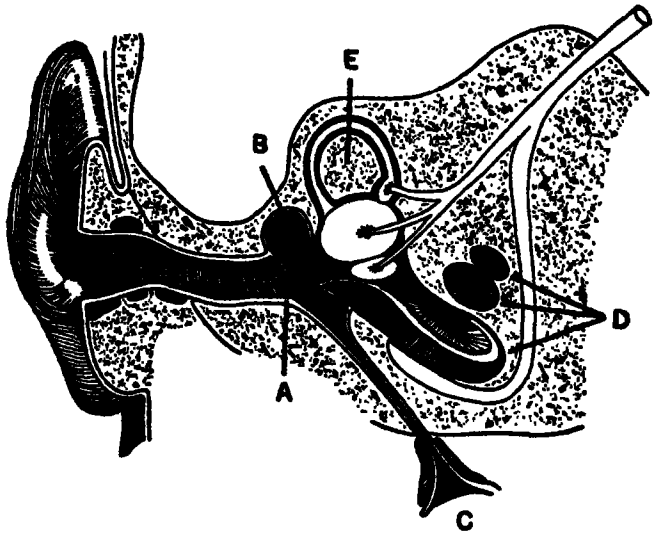


FIG. 102.—Cross section of the ear. A, the eardrum; B, the middle ear, containing the three ossicles; C, Eustachian tube, connecting the middle ear and the pharynx; D, cochlea; E, semicircular canals.

respond to displacements smaller than the diameters of molecules, which will be able to function as a harmonic analyzer and separate these wave forms into their essential components or to respond differentially to different sound patterns, and which will be competent to change these mechanical forces into nervous energy. The ear does all these things. The essential parts of the ear are shown in Fig. 102.

General description of the ear. [7] The only parts of the ear that can be observed are the auricle (or shell-like outer ear) and the canal, called the external meatus, which conducts the sound waves to the eardrum (tympanic membrane).

Behind the eardrum is the middle ear, which contains three small bones (called the ossicles) which articulate with each other and conduct the sound impulses to the inner ear (see Fig. 103). The middle ear is filled with air and is connected by means of the

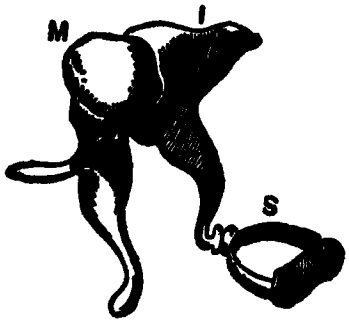
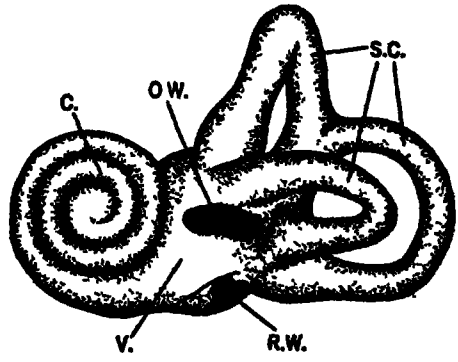


FIG. 103.—Bones of the middle ear. The diagram (greatly enlarged) shows the ear bones (ossicles) in their natural positions. M, the hammer (malleus); I, the anvil (incus); S, the stirrup (stapes).

Eustachian tube with the throat. The Eustachian tube is closed at the lower end but opens in the act of swallowing, thus equalizing the pressure in the middle ear with the pressure outside. If the pressure in the middle ear and that of the external world are very unequal, as may happen when one ascends to a high alti-

FIG. 104.—Cast of the inner ear. The inner ear is a cavity in bone. This cast was made by filling the entire cavity. C, cochlea; V, vestibule; R.W., round window; O.W., oval window, into which the stirrup fits; S.C. semicircular canals.

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tude quickly, the resultant discomfort can be alleviated by swallowing.

Behind the middle ear is the inner ear, or labyrinth, which is hollowed out of the temporal bone and is filled with fluids called the perilymph and endolymph. Figure 104 represents a cast made by filling all the spaces and canals of the inner ear. Only part of this inner ear cavity has to do with hearing—the cochlea, which is the part at the left of the diagram. It has the appearance of

a coiled snail shell. The entrance to the cochlea from the middle ear is through the oval window, into which fits the last bone in the chain of ossicles in the middle ear. The round window also opens into the middle ear and is covered with a membrane. [10]

The semicircular canals, the three large loops to the right of the cast in Fig. 104, have to do with the sense of position and balance and play no part in hearing.

A schematic diagram of the parts of the ear is shown in Fig. 105. The sound travels from the external world through the external auditory canal and strikes the tympanic membrane (the eardrum), setting it into vibration. Connected with the tympanic membrane is the first bone of the middle ear, the

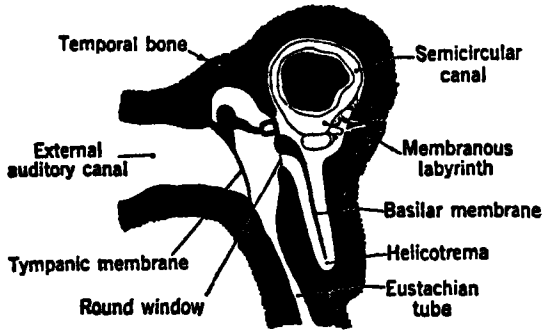


FIG. 105.—Schematic diagram of the internal ear. The cochlea is represented as straight instead of coiled.

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hammer. It articulates with the anvil, the middle bone, which in turn is connected with the stirrup. The stirrup can be seen fitting into the oval window of the inner ear. By means of these three bones the vibrations of the tympanic membrane are conducted to the oval window. The vibrations of the stirrup at the oval window set up disturbances of the fluids in the inner ear, and these disturbances are transmitted through the cochlea to the sensitive hearing elements mounted on the basilar membrane. A violent movement of the stirrup may be compensated for by movements of the membrane at the round window. It will be noticed that the closing of the oval window by the stirrup and of the round window by a membrane also keeps the fluids of the inner from escaping into the middle ear, which is filled with air.

The movements of parts which take place during the hearing process are better shown in Fig. 106 where the solid black lines and solid figures indicate the position of the parts at rest, whereas

the dotted lines and other outlines show the same parts after being displaced by a push by air particles. The arrows show the direction taken by the movement causing the displacement. An in-

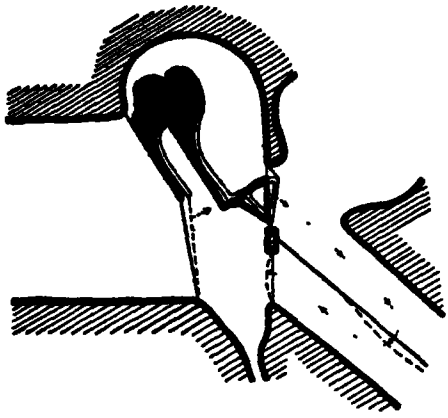


FIG. 106.—Diagram to show the movement which takes place when a sound wave affects the hearing mechanisms. Black lines represent the mechanism at rest. The dotted lines and light parts show the position after an impulse has given them a push.

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coming sound wave sets the whole system into motion in such a manner that the stirrup is made to rock back and forth like a bell-crank lever in the oval window.

If the cochlea were unwound, a cross section would look somewhat like the diagram in Fig. 107. The sensitive fibers for

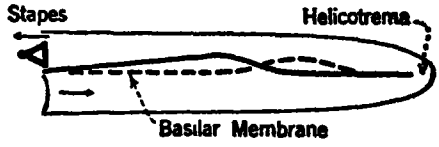


FIG. 107.—Diagram of unwound cochlea

hearing are supported upon the basilar membrane which extends nearly the whole length of the cochlea. At the apical end there is a passageway (the helicotrema) between the upper and lower parts. The stirrup fits into the oval window above. Sound waves push it inward and outward starting waves in the liquid with which the cochlea is filled. The membrane in the round window moves in and out to adjust to movements of the stirrup. However, the essential process of hearing is the commotion set up in the organ of Corti (see Fig. 108) which extends almost the entire length of the cochlea.

The range sensitivity of the ear. [4] Although the ear is most sensitive to sounds in the approximate range from 800 to

4,000 cycles per second, it can sense sounds ranging from about 20 cycles to about 20,000 cycles. These limits vary considerably

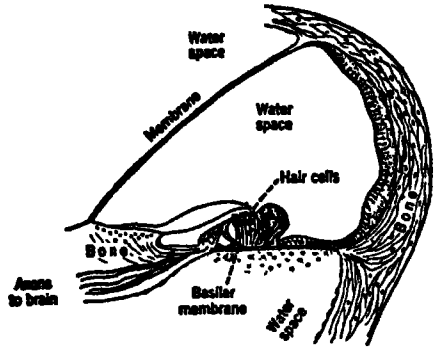


FIG. 108.—Cross section of the cochlea. This shows a single section of the hair cells from the organ of Corti, which are supported on the basilar membrane. There are about 5,000 such rows.

with different individuals and may be modified by disease and age. The sensitivity depends upon the intensity of the sound as well as upon the frequency (see Fig. 109).

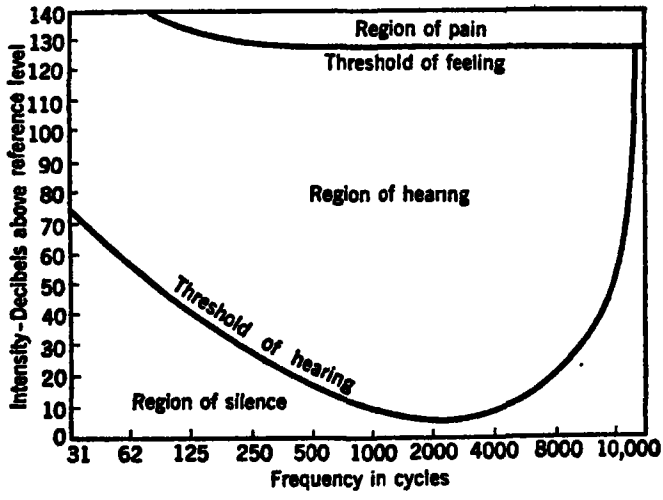


FIG. 109.—Diagram to show the range of hearing.

PITCH

The most important factor in determining the psychological experience of pitch is the frequency of the sound wave. The relationship between frequency and pitch is so striking that it is often regarded as the only determining factor in pitch sensations.

Nevertheless, there is not a perfect relationship between pitch and frequency; other factors are involved.

Factors which affect pitch. Some of the factors which influence pitch are as follows:

The relationship between pitch and intensity. When the frequency of a tone is around 2,000 cycles per second, there is little change in the pitch of the tone with changes in intensity. As the intensity of a low-pitched tone (that is, a tone appreciably lower in frequency than 2,000 cycles) is increased, the pitch decreases. Conversely, as a high-pitched tone (above 2,000 cycles) is increased in intensity, the pitch becomes higher. In other words, as the intensity of a tone is increased, its pitch tends to shift away from the central hearing range.

The effect of duration on pitch. The duration of a tone affects its apparent pitch. In general, the apparent pitch of a tone falls when the duration of that tone decreases below 10 msec., the fall being especially rapid below 3 msec.

Stated another way, a tone must last a certain length of time in order for it to be identified with any accuracy. If a tone of 1,000 cycles is sounded for less than 2 msec., it will be heard not as a tone but as a toneless click. If it lasts a little more than 2 msec. it takes on some tonal character but the pitch is rather indefinite. As its duration is increased the ability to discriminate its pitch improves. Furthermore, if two successive tones of equal frequency are separated by less than about 10 msec., they will be heard as one continuous tone. Lower tones may be separated for even longer intervals and still be heard as one uninterrupted tone. For example, two 100 cycles tones will be heard as a continuous tone if separated by as much as 30 msec.

The effect of complexity on pitch. With an increase in the complexity of a sound it becomes increasingly difficult to distinguish its fundamental pitch. Sounds may vary all the way from the most simple tone, which is a single harmonic wave, to the most complex sound, commonly called thermal noise. We have already described a simple harmonic wave. Thermal noise can be obtained by amplifying and impressing on a loud-speaker all the random motions of electrons in an electrical resistance. If the amplifier and speaker have uniform characteristics, the resulting noise contains all audible frequencies at equal intensity.

It sounds much like a hiss or a *shhh*. It should be clear that the ear cannot distinguish any one pitch in a thermal noise, whereas it should be relatively easy to distinguish the pitch of a pure harmonic wave. In short, the more simple the tone the more easily can the ear distinguish its fundamental pitch.

Moreover, the fundamental pitch that is heard need not be dependent upon that sound being produced directly by some instrument. For example, when a complex tone is composed of frequencies differing by a constant amount of 100 cycles or more, the apparent pitch of the complex mass of frequencies is that of a tone whose frequency is equal to the constant difference. Thus, if frequencies of 700, 800, 900, and 1,000 cycles are sounded together, the listener will hear them as a 100-cycle tone. If 400, 600, 800, and 1,000 cycles are sounded together they will be heard as a 200-cycle tone. If to 400, 600, 800, and 1,000 cycles is added a group containing 500, 700, and 900 cycles, the apparent pitch will drop from 200 to 100 cycles. Many radio receivers drop out the low fundamental tones without changing radically the apparent pitch of the tones that are heard. The same process can be observed in the laboratory by playing a phonograph selection from which the low tones have been filtered.

Differential discrimination of pitch. Pitch discrimination is best in the range of keenest sensibility: between 2,000 and 3,000 cycles. In general pitch discrimination improves with an increase in intensity of the tones to be compared. The ability to discriminate between tones is poorest at low frequencies and at low intensities. In the entire auditory area, as shown in Fig. 109, if tones covering the whole area are presented, varying them by minimum amounts in intensity and in pitch, the human ear can distinguish about 340,000 separate tones.

There are great individual differences in the ability to recognize a certain pitch. Some individuals are so far superior to others in this respect that they have been given credit for the ability to name precisely the pitch of a musical note without the aid of any standard of reference. Even those individuals who claim absolute pitch have been found to be subject to the following types of errors: (1) confusion between octaves; (2) constant errors of a half tone in one direction; (3) errors of a half tone

downward in the highest part of the musical scale and a half tone upward in the lowest part.

LOUDNESS

Loudness refers to the intensity characteristics of sound as experienced by an individual. Sounds of high sensory intensity are variously described as strong, loud, or intense; those of low intensity are roughly described as weak, faint, or mild. Loudness is chiefly a function of the intensity of the physical disturbance, but it also depends upon other factors, such as the pitch of the sound, the masking effect of other sounds, the overtone content, and the sensory acuity of the listener. [4]

The measurement of loudness. The creation of a scale for loudness had to take into consideration the fact that the ear can detect an enormously wide range of energies. The ear can support a sound whose energy is a million-million times the least sound it can detect. Since the ordinary arithmetic scale could not easily cover such a wide range, a logarithmic, or ratio, scale has been developed. According to such a scale one sound is not described as containing so many more units than another but as having a certain ratio to another sound, such as twice as loud, ten times as loud, etc. Such a scale requires a definite reference level and that level has arbitrarily been placed at the threshold of hearing for a 1,000-cycle tone. That is, the faintest 1,000-cycle tone that can be heard by the average human ear.[2]

The logarithm of the ratio between two sound intensities has been given the name *bel* and has come to be used as the unit of measure of sound energy. Since the bel is a ratio, it has no meaning unless the reference value is stated. Hence, it is important in using the bel in connection with hearing to remember that there must be a given reference point. The *decibel* is one-tenth of a bel.

When the threshold of hearing is used as the reference intensity, and with decibels indicating the power to which a threshold sound must be raised to equal the other sounds, the following scale of values holds.

[2] In terms of physical energy such a sound can be stated as a sound whose energy is equivalent to the root-mean-square pressure of 0.0002 dyne per square centimeter.

Decibels	
120	thunder
	airplane engine
100	boiler shop
	elevated train
80	pneumatic drill
	busy street
60	conversation
	quiet automobile
40	average office
	average dwelling
20	whisper
0	threshold of hearing

Factors affecting loudness. Loudness is primarily a function of the amplitude of vibrations, but it is also influenced by the frequency, by masking, and by the overtone content.

The factor of amplitude. The wider the swings of a vibrating body the louder will be the sound produced by its oscillations. It takes very little to demonstrate this fact. If a violin string, for example, is plucked gently, it will swing through a small space and the tone will be weak. Pluck it vigorously and it can be seen to swing violently and the sound will be more intense.

The factor of frequency. While the loudness of a tone is primarily a function of the amplitude of the physical sound wave, it is, nevertheless, partly dependent upon the frequency of the sound wave. The same difference in the physical intensity of two tones will be heard as a greater difference in loudness when the tones are of low pitch than when they are of a high pitch. Because of this fact the same musical selection will change in character with a change in the loudness with which it is reproduced by such a device as a radio transmitter or a phonograph. With an increase in the intensity of reproduction, the low tones will increase in loudness more than the high tones, whereas with a decrease in intensity, the low tones will decrease in loudness disproportionately.

Effect of masking on intensity. Masking is the partial or complete obscuring of a given tone by the simultaneous presentation of a tone of different frequency. We have already seen

that when two tones have nearly the same frequency and nearly the same intensity they interact with each other and produce beats, rattles, or roughness (depending upon the actual difference between them). Such beating effects might be considered as an alternate reinforcement and masking. Masking is, then, a sort of interference between two tones. What factors favor such interference?

1. Masking is greatest when the two tones lie close together in frequency but not close enough to give beats.

2. A tone is masked more effectively by a loud tone than by a weak one.

3. A tone of low frequency masks tones of a higher frequency, whereas a tone of high frequency does not act as a mask for a tone of lower frequency. Even when the high tone is very loud its masking effect on lower tones is slight.

4. Masking has been explained by some students as the result of interference in the physical sound waves; [7] by others masking is attributed to interference within the individual. [2] Those who argue for internal interference cite the fact that a tone heard in one ear may be masked by a tone heard in the other ear (a phenomenon called binaural masking). Those who contend for interference in the physical sound wave explain binaural masking by bone conduction.

A good analogy to enable the student to visualize effects of masking is the action of waves on the water. Large swells (corresponding to low tones) can easily overcome the effect of ripples (corresponding to high tones). Ripples can hide broad swells only if the swells are not very deep (not very loud) and the ripples are quite vigorous (very loud).

The overtone content changes the loudness of a tone. It is easy to increase the loudness of a musical tone by increasing its overtone content. Laboratory tests have shown, for example, that when a pure tone of 100 cycles is enriched by adding ten harmonic components, all equally intense, the loudness is increased to sixty times the loudness of the pure tone.

Factors which influence the ability to discriminate loudness. The least amount of change of a given sound which is necessary to produce a noticeable change in sensation is influenced by several factors. [7]

1. The region of greatest differential sensitivity of the ear for loudness corresponds to the frequency range of greatest sensitivity; namely, the region of about 2,000 to 3,000 cycles. For the average ear it is possible to distinguish about 325 just-noticeable steps in loudness within this frequency range. This number diminishes as the pitch is increased or decreased.

2. As the intensity of the tones to be compared is increased, the ability to discriminate differences in intensity improves.

3. The ability to discriminate between the loudness of the two tones is better when both ears are used than when only one ear is used.

4. Loudness discrimination is improved when the duration of the two tones to be compared is increased.

5. Discrimination is best when the transition between the tones to be compared is instantaneous and silent.

6. The readiness of the observer for making the discrimination is important. Keenness is increased when the individual himself operates the key that makes the change between the two tones, and when he is permitted to listen to the tones as often as he wishes before making his decision.

AUDITORY LOCALIZATION

There are several facts which indicate that auditory localization is essentially a function of the two ears. In the first place, a normal person can localize sounds much better when they are to the right or to the left of the median plane. Many errors are made when the sound source is exactly in the median plane, and when each ear is, consequently, stimulated in exactly the same way. In the second place, a person deprived of the use of one ear shows poor sound localization immediately after his loss, although he is able to make some improvement after a lapse of time. These facts would indicate that the main factors in sound localization are those in which the two ears hear differently when there is a single sound source.

Factors which influence the localization of sound. Under different circumstances, the following factors play varying roles:

Intensity as a factor in sound localization. When two tones, differing only in intensity, are led separately to each ear,

the listener tends to image the source as located toward the side of greater intensity. It can be shown that, when a sound comes from a source not in the median plane, the intensity of that tone is different at the two ears. Such differences are greater with tones of higher frequency than with tones of low frequency. The difference in intensity between the two ears is about 1 decibel for a 300-cycle tone, while it is about 10 decibels (or a power ratio of ten to one) for a tone of 15,000 cycles.

Phase differs at the two ears. When a sound comes from the median plane, it stimulates both ears in the same phase. When it comes from a source outside the median plane, the ears hear it in different phase relations. In an experimental test, when two tones, differing only in phase, are led one to each ear, the listener tends to image the sound source as located toward the side of the leading phase. Since phase differences become less with an increase in frequency of the sound, this factor should operate less as the frequency increases. Since phase effects disappear at frequencies above 800 cycles, the factor of phase can be operative only with sounds of low frequency.

Time differences at the two ears. For complex tones and for noises, difference in the time of reception by the two ears becomes an important factor in sound localization. As the time difference in reception by the two ears increases, the source of the sound seems to move from the median plane toward the ear that is stimulated first.

Complexity of sound. It is much easier to localize complex sounds than it is to localize a pure tone. When both low and high frequencies are present in a sound, the low frequencies probably provide cues in the form of intensity differences. In addition, the qualitative sound pattern comes to be connected with certain known sources, and this helps.

Stereophonic effects. While localization is often tested in the laboratory with limited sound effects, in actual life the presence of multiple sources of sound gives an auditory perspective to most of our hearing. When listening to an orchestra one hears not only the summation of effects from the different instruments but effects based on their spatial relation. Pick up the music from an orchestra with one microphone and its broadcast will be flat and without perspective. Two or more microphones

set at different positions will add greatly to the quality of the broadcast. It is probably the difference in auditory depth, or perspective, that is most disturbed when a person is deprived of the hearing of one ear.

AUDITORY FATIGUE

The ear suffers little from fatigue, in spite of the fact that we have no means of closing our ears against the constant bombardment of unwanted noises which may persist through both day and night. Violently extreme sound pressures may injure the auditory mechanism, but there is little temporary loss of sensitivity because of previous stimulation.

There is some evidence that there is more fatigue from high-pitched tones than from tones of low frequency. After an ear has been exposed for 2 minutes to a 94-decibel tone of 100 cycles, it will recover in 20 seconds; a tone of the same intensity but of 4,000 cycles may take as long as 6 minutes for complete recovery.

On the other hand, there seems to be an augmenting effect that works counter to any fatigue effects. After exposure to a loud tone the individual may not only return to normal but show increased acuity for tones of the same level of intensity and frequency.

QUESTIONS FOR REVIEW

1. What is simple harmonic motion?
2. Describe how simple harmonic motion may produce a sound wave.
3. How does the speed with which sound travels depend upon the transmitting medium?
4. In what ways may harmonic motion vary? Describe each.
5. What are the effects of combining simple harmonic sound waves?
6. What are overtones?
7. What are beats?
8. What are upper partials?
9. How may beats be used to tune instruments?
10. What are difference tones?
11. Upon what factors does tone quality depend?
12. What is resonance?
13. Show how the principle of resonance may be used to analyze a complex tone into its simple components.

14. Explain how mass, stiffness, and resistance affect resonance.
15. Give a description of the ear, explaining the location and function of each of the following: external meatus, ossicles (malleus, incus, and stapes), Eustachian tube, labyrinth, endolymph, cochlea, oval window, round window, basilar membrane, organ of Corti, and helicotrema.
16. What factors other than frequency affect pitch?
17. What is thermal noise? How is it produced?
18. Explain how tonal complexity affects the recognition of pitch.
19. What are some of the factors that influence the differential discrimination of pitch.
20. What is meant by absolute pitch?
21. Why was it necessary to use a logarithmic scale to measure loudness?
22. Define the unit of loudness.
23. What factors besides amplitude affect the loudness of a sound?
24. State the effect of frequency on loudness.
25. What is masking?
26. How does masking affect the loudness of a sound?
27. What is the effect of increasing the complexity of a tone on its loudness?
28. Enumerate the factors which affect differential sensitivity for loudness.
29. What factors affect the localization of sound?
30. What is the relation between frequency and auditory fatigue?
31. What may be the aftereffect of long exposure to sound?

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Chapter XIV

SMELL, TASTE, AND SOMESTHESIS

IN ADDITION to the senses of vision and hearing, there are a number of other sense modalities which enable humans to receive and interpret impressions from the external world. These include: olfactory (smell) sensations, gustatory (taste) sensations, cutaneous sensations, pressure and pain, visceral sensations, and sensations of movement and position. Somesthesis is a general term which includes all the body senses of the skin and underlying tissues and sensations from the internal organs.

SMELL

The sense organs for smell are located in a little alcove in the upper part of the nose. They consist of nerve cells embedded in the mucous membranes of the nose with slender fibers branching out to the surface of this alcove. This alcove is off the main air passage to the lungs and it receives only eddy currents; hence, sniffing has value when one wishes to test the odor of any substance (see Fig. 110). [2]

In ordinary life odors are usually mixed with other sensations and an untrained person is unable to distinguish between smells and the taste, pain, and other sensations combined with the odors. Moreover, extensive experimentation has not enabled psychologists to reach any agreement as to the number and delineation of basic odors. It has been estimated that there are about 60,000 different odorous substances, but it is quite likely that many of these owe their effect to such other sensations as taste, touch, pain, warmth, cold, and the like. If all extraneous influences could be removed, it has been estimated that the substances

which have no other sensory value than smell might be reduced to fifty.

The specific stimulus which affects the sensory end organs for smell are molecular particles which are liberated from their



FIG. 110.—Diagram to show the location of the olfactory end organs.

basic substances either through evaporation or by some chemical action. These particles spread out in gaseous diffusion and are effective in extremely small amounts. For example, camphor can be perceived when in a dilution of 1 part to 400,000; or musk, 1 part to 8,000,000.

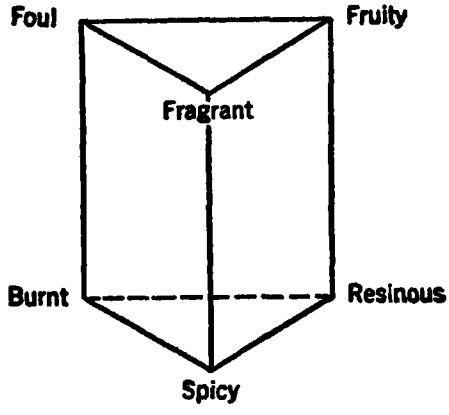


FIG. 111.—The odor prism.

Various lists have been presented as representing the primary odors. One which has been widely accepted is based on six qualities which may be arranged in the form of an odor prism as shown in Fig. 111. These six primary odors are.

Fragrant: as in lily of the valley, roses, or violets.
Spicy: as in cloves, anise, or cinnamon.
Fruity: as in lemon, orange oil, or ether.
Resinous: as in turpentine, pine needles, or juniper.
Foul: as in decayed animal matter or hydrogen sulphide.
Burnt: as in tar.

When odors are combined with other sensory qualities the following may be obtained:

Odor plus sweet taste: as in chloroform, bromoform, iodoform, ethyl chloride.
Odor plus sour taste: as in acetic acid, propionic acid, butyric acid, and valerianic acid.
Odor plus cold sensation: as in camphor, menthol, phenol, eucalyptol, sassafras.
Odor plus warm sensation: as in ethyl alcohol, propyl alcohol, amyl alcohol.
Odor plus pain: as in ammonia, chlorine, bromine, iodine, nicotine.

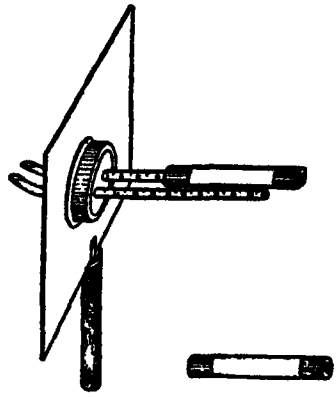


FIG. 112.—The olfactometer. The bent tubes at the left are inserted into the nostrils of the subject. Tubes lined with some odorous substance are drawn over the straight parts of the tubes at the right. The amount of exposed surface is indicated on the scale.

The olfactometer, as shown in Fig. 112, is the standard instrument for conducting experimental work on the sense of smell. Tubes lined with aromatic substances are slipped over glass tubes leading into the nostrils. The strength of the stimulus is regulated by the amount of exposed surface over which the air must pass on its way to the nostrils.

There are wide individual differences in sensitivity to odors. Some individuals are anosmic, that is, they are permanently

insensitive to odors of all sorts. Some have different values for ordinary odors. It also happens that the same odor may have a totally different quality for the same person depending upon whether it is received in small or in large quantities. For example, indol, when strong, has a fecal odor; but when properly diluted, it has a pleasant flowery odor.

When different odors are experienced together they may blend, they may coexist side by side, they may neutralize each other so that the individual smells nothing, or one may entirely mask the other. Furthermore, adaptation to odors is rapid. Upon entering a room, one may be struck by the unpleasant odors but, after a short time, he becomes oblivious to them.

For the most part, odors are in bad social and aesthetic standing. While we are all influenced by odors in a subtle manner, it would be bad form to comment too bluntly on most food or house odors. A girl may use perfume, but never to such an extent that it is obvious to others. It must seem that one is affected by her "personality" but never by her odor; even though it is the perfume that turns the trick.

In recent years odor engineers are beginning to realize that odors have a powerful influence upon human behavior provided they are presented in the right manner. Sales of a great variety of products have been increased by the simple expedient of substituting a pleasing odor for an unpleasant one. For example, smelly raincoats are made odorless, shower curtains are perfumed to give a pleasantly fragrant odor when water strikes them, stenographers are provided with spicy-smelling pencils and scented typewriter ribbons, shaving creams are made to smell fresh and less soapy, and hospitals are made to smell inviting instead of greeting the visitor with the ordinary smell of unpleasant drugs.

These odor engineers have found that the introduction of perfumes must not be overdone, and that the individual is often unaware that the odor of an article has anything to do with his purchase of it. When women were asked if they liked perfumed hosiery, they all were against it. When, on the other hand, they were permitted to choose between stockings, identical except for the fact that one box was perfumed and the other retained the usual smell of finishing oils, they preferred the perfumed article. [5]

TASTE

Most of the experiences which appear to be taste are, in reality, a combination of other sense experiences than taste. This can easily be demonstrated by holding the nose in such a manner as to eliminate smell when a substance is tasted. Without odor a meal would be insipid indeed. With smell eliminated it is almost impossible to distinguish a bit of onion from a bit of apple. [2] Heat and cold, pressure, kinesthesis, and pain all help to complicate tastes. In fact, tastes are modified by the social atmosphere of a meal, the aesthetic effects, worry, and a number of other factors.

After all these extraneous influences are eliminated there remain four elementary tastes: bitter, sweet, saline, and sour. The typical stimuli which will give rise to these primary tastes are:

For sour: weak hydrochloric acid
For saline: common salt
For bitter: quinine
For sweet: cane sugar

While the relationship between these four primary taste qualities has not been definitely determined, they may be tentatively related as shown in the taste tetrahedron in Fig. 113.

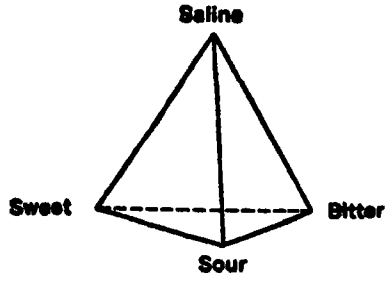


FIG. 113.—The taste tetrahedron.

Taste results from the stimulation of specialized cells in the small nipple-shaped elevations (papillae) of the tongue and in certain parts of the mouth and throat (see Fig. 114). Some of these papillae respond only to sweet, some only to sour, some only to bitter; but many of them respond to all four tastes, some to two or three.

Different parts of the tongue are differentially sensitive. The upper front part of the tongue is not sensitive to any tastes. Salt is best sensed at the forward tip of the tongue; sensitivity to sweet is highest at the tip and is lower at the back; sensitivity to bitter is low at the tip and increases around the side edges,

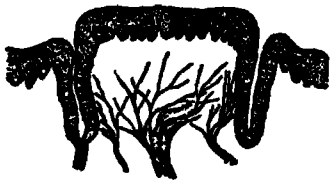


FIG. 114.—Transverse section through a small portion of the sensitive area of the tongue. The taste buds are in the grooves toward the center of the diagram and are connected with the branched endings of the nerves.

becoming highest at the back; while sensitivity to sour is low at both tip and back and highest along the side edges. The general areas of sensitivity are shown schematically in Fig. 115.

Some phenomena of taste. It is particularly difficult to conduct exact experimentation in the field of taste. The receptor organs are in grooves and can be reached only by chemicals in solution. After one stimulus has been used it is difficult to

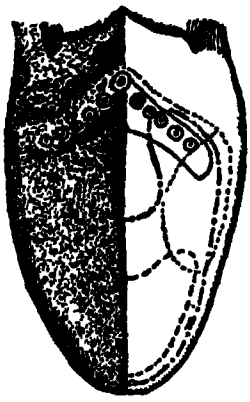


FIG. 115.—Diagram of tongue showing various taste areas. Area sensitive to bitter (———); to acid (.....); to salt (—.—.—.—.); and to sweet (- - - -).

remove all traces of it before applying a second. Mere rinsing of the mouth does not reach the bottom of the grooves containing the taste buds. It is almost impossible to exclude such extraneous factors as smell and cutaneous impressions. In addition, most subjects rebel against acting as subjects in taste and smell experiments. In spite of these difficulties, the following taste phenomena have been observed.

1. Certain tastes may fuse with each other and form taste

blends. As already noted, most taste blends contain smells, touch, and temperature stimuli as well as taste. When these other sense modalities are excluded, there are still blends which depend upon the combination of primary taste qualities. For example:

Carbonate of soda	saline and sour
Potassium bromide	saline and bitter
Alkali	saline and sweet
Acetone	sweet and bitter
Acetate of lead	sweet and sour
Potassium sulphate	bitter and sour

Some component tastes in a blend can be readily distinguished, whereas others are difficult to analyze. Mixtures that involve bitter are usually more easily analyzed than those which do not. Salt-sweet blends are difficult to analyze. The flat taste of unsalted oatmeal is not easily recognized by the untrained person as a lack of salt. Add salt and the effect seems to be an increase in sweetness.

2. Some tastes tend to neutralize other tastes. Mix salt and sour tastes and the resultant fusion tends to mask the components so that each is less intense than it would be alone. In maple sugar season, after one has eaten too much maple sugar, he may overcome the effect by eating something sour; and thus be able to eat more of the sugar.

3. Adaptation for tastes is rapid. After tasting a substance for some time, some of its flavor is lost. Such adaptation is greatest for sweet, next for bitter, and comparatively slight for salt and sour. It reaches its maximum effect after about two minutes, and is much more of a factor when the taste is strong. In addition, it has been found that a salty substance tastes more salty after one has become adapted to a sweet taste.

KINESTHETIC SENSATIONS

Kinesthetic sensations are those attending movements of any members of the body whether those movements are actively initiated by the individual or are passive responses to outside forces. The muscles, tendons, and joints are sensitive to pressure, pain, strain, fatigue. When these are added to information derived from the skin senses, which we shall examine shortly, the

individual is able to gain important information about the weight of objects, their resistance to manipulation, their hardness or softness, their relative positions, the position of members of the body, and the like. Furthermore, vision contributes to our knowledge of position and movement.

It has been definitely established that there is no simple sense of weight, or sense of the amount of force exerted in the execution of a movement. A sensation of position or movement is a learned pattern. Some individuals become adept in learning delicate muscle cues. For example, in the ordinary parlor game of "mind reading," the individual whose mind is to be read grasps the wrist of the person who is to do the reading and then thinks of what the "reader" should do next (such as go forward, go backward, or stoop). Involuntary muscular movements give cues which a sensitive person can interpret and follow with success.

CUTANEOUS SENSATIONS

Most persons do not use their skin senses as extensively as they do their hearing and vision for the simple reason that they do not need to do so. In cases where persons have been deprived of vision or hearing, remarkable abilities in the use of touch have been developed. Blind persons can read Braille by the expert use of their finger tips. Deaf persons have been able to interpret speech by placing their finger tips upon a vibrating diaphragm. Since most of us do not need to develop our cutaneous senses to an extreme degree, we have an inadequate notion of the possibilities of cutaneous sensory development. [6] All psychologists are agreed that there is not a single sense of touch. There is less agreement upon how many separate cutaneous senses there are. Four have been distinguished: warmth, cold, pressure, and pain.

Punctate skin sensitivity. If a small area of the skin is explored, spot by spot, by different stimuli (such as a tiny bit of cotton, a sharpened horsehair, a heated piece of pointed brass, and a cooled pointed piece of brass), it will be found that the skin is not uniformly sensitive to these different stimuli. It will be sensitive to pressure at certain points, to pain at others, to warmth at others, and to cold at still other points.

The frequency of these spots varies. For example, on the

volar or palmar surface of the forearm, there will be, per square centimeter, about 200 pain spots, 15 touch spots, 6 cold spots, and 0.4 warmth spots.

The discovery of these spots led to the theory that "touch" was composed of four separate senses, each with its own peculiar sense organ in the skin. This theory has been questioned on the following grounds:

1. The spots are not fixed and stable. The location of the spots shifts on different trials. Furthermore, intensifying the stimulus will increase the number of spots found, and may even change the qualitative nature of the resulting sensation.

2. Careful search has failed to reveal specific end organs at the spots. In other words, histological examination of the skin has not disclosed one type of nervous end organ at the pain spots, another type at the touch spots, another at the warm spots, and another at the cold spots.

In addition to these two negative arguments, there is some positive evidence that cold and warmth are based on the same receptor organs, and that pressure and pain are closely related.

The two-point threshold. When two points in the same region on the skin are stimulated simultaneously, they will feel like a single point unless separated by a sufficient distance. The amount that they must be separated in order to be felt as two points is called the two-point threshold. This threshold varies strikingly for different parts of the body, as shown in Table VIII.

TABLE VIII

APPROXIMATE VALUES OF THE TWO-POINT THRESHOLD FOR DIFFERENT REGIONS OF THE BODY

	mm.
Tip of tongue	1
Palmar side of finger tip	2
Mucous membrane of lips	5
White part of lips	9
Cheek	11
Forehead	23
Back of hand	31
Kneepan	36
Forearm and lower leg	40
Neck and chest	54
Middle of back	68

These thresholds may be tested by the use of a pair of dividers or, better, an esthesiometer as illustrated in Fig. 116. If the points are very close together, the two will be felt as one point. If they are gradually separated and applied at each change,

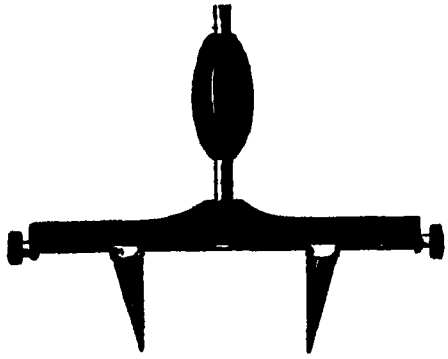


FIG. 116.—Double-point esthesiometer for the determination of the two-point threshold.

the two will be felt as an ellipse, then the sides of the ellipse contract, and finally the two points separate into two distinct parts. A representation of the way the sensations appear to the observer as the points are separated is shown in Fig. 117.

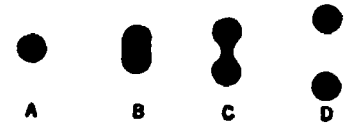


FIG. 117.—Diagram to illustrate experiences of one- and two-point threshold. A, reported experience when two points are together; B, when points are slightly separated, subject feels breadth but cannot distinguish two points; C, when points are separated still farther, breadth increases and two points almost felt as distinct; D, two points clearly distinguished.

The conclusion from the two-point threshold experiments seem to be that the adjacent areas of the skin combine to give a total sensory pattern and that the different points do not have distinctly isolated and separate functions. [7]

WARMTH AND COLD

The sensitivity of the skin to changes in temperature varies with different parts of the body; it also varies in the same area

with such factors as health, degree of activity of the individual, surroundings, the general tonus of the body, and adaptation.

For any specific area of the body an indifference point may be found. For example, an average person, in a room with a temperature of about 70° F., will be indifferent to a temperature stimulus of 98.6° F. applied under his tongue, to a stimulus of about 95° F. applied to a normally clothed part of his body, to a stimulus of about 92° F. applied to his hands, or to a stimulus of about 79° F. applied to the lobes of his ears. The contrast between the indifference point of the hand and the ear lobe can easily be demonstrated by grasping the lobe with the fingers. The ear lobe will feel cool to the fingers and the fingers will feel warm to the ear lobe.

If the temperature of the air or other contacting surface is raised above the indifference point of the area it strikes, it will be felt as warm. This sensation of warmth will grow in intensity (for an ordinarily clothed area of the body, for example) up to about 115° F. As the stimulus is raised above 115° F., the sensation of warmth is lost and the experience becomes a complex mixture of pressure and pricking until about 125° F., above which only pain is felt. A similar change occurs as the temperature of the stimulus is decreased below the indifference point. A stimulus will feel increasingly cold until about 54° F., when it will become a complex of pressure and pain, the sensation of cold gradually disappearing. At about 35° F. and below the individual will feel only pain. [6]

However, these ranges of sensitivity can readily be changed by adaptation. If the hand is placed in water whose temperature is 98° F., the water will feel definitely warm at first. Soon it will not feel warm but, if the hand is put into water of 92° F., which would ordinarily feel neither cold nor warm, it will feel cold.

Furthermore, the same temperature may feel warm to one hand and cold to the other. This may be effected as follows: Have three bowls of water whose temperatures are 65° F., 85° F., and 105° F. Hold one hand in the warm water (105° F.) and the other in the cool water (65° F.) for several minutes and then transfer them both to the medium water (85° F.). The water of medium temperature will feel cold to

the hand that has been in the hot water and warm to the hand that has been in the cool water.

The cold points in the skin respond differently from the warm points. The cold flashes out quickly, clearly, and vigorously, whereas the warm comes in slowly and wells up in a leisurely fashion. The average reaction time for warm is about twice that for cold. [3]

Another interesting phenomenon is that of paradoxical cold. A pointed warm stimulus may sometimes arouse a sensation of cold when applied near a cold spot. Although not so easily obtained, it is possible to arouse a sensation of warmth by the application of a cold stimulus to a warm spot. This mistaking of heat for cold and cold for heat is more pronounced when the stimuli are intense, that is, near the pain point. In other words, as warmth and cold approach the pain region they become qualitatively alike and may be mistaken for each other.

While no specific end organs have been found to correspond with warm and cold spots (although the Krause end-bulb has been suggested as the possible sense organ for these sensations), it has been found that these cold spots are always near tufts of blood vessels. One interesting theory to explain these facts is that cold sensations result from the sudden contraction of the blood vessels in the skin and that warmth sensations come with their relaxation. Extreme heat or cold will cause spastic contraction of these vessels and give the experience of pain. [6]

This theory also accounts for various other facts: (a) The puncture of arteries is accompanied by cold and hot flashes which could correspond with vascular contraction and relaxation. (b) The reaction time for cold corresponds with the contraction time of smooth muscle, while the reaction time for warmth corresponds with the relaxation time of smooth muscle. (c) The blood vessels are controlled by the autonomic nervous system and so may be affected by events ordinarily called emotional. For example, the cold chill that comes from certain screechy sounds may be explained on this basis. The chill during a fever does not depend upon the cooling of the skin but upon the autonomic contraction of the smooth muscles in the blood vessels. (d) Mechanical rubbing of the skin may cause a warm glow because of the relaxation produced.

It does not follow that all constriction of blood vessels is felt as cold, nor all relaxation as warmth. There are probably certain patterns of constriction and dilation that produce these sensations. Those which do not conform to these patterns do not give rise to conscious experiences of cold or warmth.

PRESSURE AND PAIN

The sense of pressure varies greatly at different parts of the body, depending partly upon the thickness of the skin and partly upon the amount of nerve supply. The amount of pressure necessary to produce a touch sensation varies from 2 grams per square mm. on the tip of the tongue to 250 grams per square mm. on the thick part of the sole. The sensation of pressure is produced only when the skin is forced inward, pulled outward, or deformed in some manner. When the pressure is too light to indent the skin, the sensation may be produced by the movement of a hair. [6]

There is some reason to believe (although there is still controversy on this point) that the sense organs for pressure are the free nerve endings in the skin and that these same organs mediate sensations of pain. The difference comes from a difference in intensity of stimulation. Strong pressure may cause pain while light pressure at the same spot may cause only a sensation of contact.

However, pain is not limited to excessive stimulation of the pressure end organs. Pain may be caused by excessive warmth or cold, destruction of tissue by chemical action, the action of foreign substances in the blood, electrical stimulation, and the spastic contraction of a muscle. In short, pain may be explained as resulting from continuous stimulation at relatively high intensities. A single application of an intense stimulus may not cause pain, whereas a number of successive applications of the same stimulus will. In other words, there is a summation effect in pain.

Most of the common words used to describe pain refer to patterns in which pain is combined with other factors: (a) Pain mixed with other qualities: cold-pain, warm-pain, smart, severe tension, cramp, pressure-pain. (b) Pain limited to certain areas:

crick, headache, stitch. (c) Those referring to temporal changes: throbbing pains and pulsating pains.

VISCERAL SENSITIVITY

Visceral sensitivity is vague and rather inaccurately localized as compared with cutaneous sensitivity. It is dependent upon elaborate patterns involving sensations of pressure, pain, warmth, and cold. The visceral sensitivity is so inadequate as compared with the sensitivity of external portions of the body that, for a time, it was thought that the viscera were completely insensitive to surgical manipulation. Later studies have shown that there is a slight amount of sensitivity to violent abdominal disturbance.

It is probably not true that visceral organs may be cut, burned, pressed, stretched, or torn without sensation. However, even though there is some evidence for visceral sensitivity, there is no evidence for a visceral sense. Most afferent impulses from the viscera are not accompanied by conscious states.

An interesting phenomenon is that of referred pain. It is the localizing a pain at one place when the stimulus is actually located at another. It may depend upon irradiation in the nervous system, a strong stimulation spreading to remote parts, or it may depend upon a strong sensation overshadowing a smaller one and being felt at the site of the weaker pain. When a place of low sensitivity located near a place of greater sensitivity is stimulated painfully, the experience is felt at the place of greater sensitivity if the two places are supplied by the same spinal nerve.

SENSATIONS OF POSITION AND MOVEMENT

A reference to the model of the inner ear as shown in Fig. 104 will serve as a reminder that only a part of the inner ear (the cochlea) is connected with hearing. The other parts, notably the semicircular canals and the vestibule, are concerned with sensations of position, of movement, and of balance. [7]

The peculiar position of the semicircular canals has given rise to a theory that the movement of fluid in them, which must take place with changes in the position of the head, provides the essential stimulation for their functioning. From Fig. 118 it will be clear that they occupy the three planes of space, each at right angles to the others. They all open into an enlarged

space, called the ampulla, containing a transverse membrane on which are sensitive hair cells. It is supposed that the nerve endings in these hair cells are stimulated by the changes in pressure of the fluid which fills the canals. This fluid (called endolymph) contains small hard particles (called otoliths) which impinge upon the hair cells with any movement of the fluid in which they float. When the head is moved, the fluid, because of its inertia, lags behind and thus presses against the sensitive

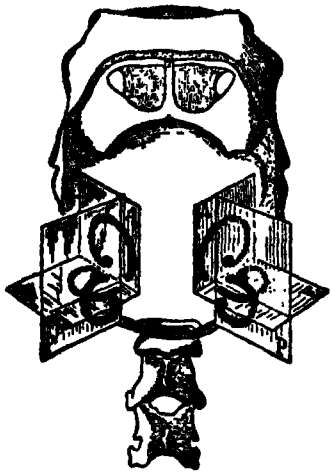


FIG. 118.—Diagram to show the position of the semicircular canals in the head. The external, or horizontal, canals (E) of the two sides are in the same plane. The canal A on one side is in a plane parallel to P' on the other side.

cells. If this theory is sound, only the starting and stopping of a movement of the head or a change in relative speed of movement would be effective. When the head moved at a constant rate there would be no inertia or lag of the fluid behind the walls of the canal. Some experiments seem to show that this is the case.

There are some other arguments which seem to contradict the theory. One is that the tubes are so tiny that adherence of the fluid to the walls would more than counterbalance any force exerted by inertia. Movement is not the only stimulus that can affect the canals. They can be effectively stimulated by irrigations of the external ear by hot or cold water, by an electric current, by certain drugs, by reflex excitation from the eyes or the stomach.

Stimulation of the semicircular canals affects movement or position in different ways.

1. Movement of the body causes compensatory movements of the head and body. This can be observed by the balancing movements made by birds when they are perched on a swaying wire. A test of this same type of compensatory movement can be observed in the laboratory. If a person sits in a barber's chair with his eyes closed, his head will tend to turn in the opposite direction from any turn given to the chair. If the chair is made to turn at a uniform rate, the subject will become adjusted to the movement and report that he is not rotating at all. Then, as the chair is stopped, he will report that he has been turned in the opposite direction.

2. The canals assist in the maintenance of muscular tonus. Animals deprived of the canals will show a marked decrease in tonus. It is probably the shock imparted to the semicircular canals by a knockout blow to the jaw that causes the boxer to lose his tonus and fall to the floor.

It has been made clear, however, that the ability to maintain tonus, to be aware of movement and position, and to compensate for turnings by muscular readjustments is not wholly dependent upon the semicircular canals. When pigeons, for example, have had the canals removed by surgical operation they show marked disturbances. They will flop to the floor when they attempt to walk or to fly. If they attempt to peck at a grain of corn their head is likely to turn to one side and they will miss the grain. They lack tonus and appear to have lost all motor control. However, after a period of time they will recover and will gain remarkable control over their postures and movements.

It is quite probable that the normal person uses his semicircular canals rather extensively but in co-operation with kinesthetic sensations, visual cues, and cutaneous sensations. Should he suddenly be deprived of the semicircular canals, he is greatly disturbed for a time but has the ability to substitute the other means of control for the cues he ordinarily would receive from the semicircular canals.

QUESTIONS FOR REVIEW

1. Describe the sense organ for smell.
2. What kinds of substances are adequate for olfactory stimulation?
3. What are the six primary odors?

4. Indicate how combinations with other kinds of sensation modify odors.
5. What can be said about individual differences in olfactory sensitivity?
6. Describe the phenomena of olfactory blending and adaptation.
7. What are the primary taste qualities?
8. Describe the organ of taste.
9. How are the different taste qualities distributed on the tongue?
10. What is known about taste blends?
11. To what extent do tastes neutralize each other?
12. What is known about gustatory adaptation?
13. What are the essential cutaneous senses?
14. What elements contribute to kinesthetic sensitivity?
15. How may punctuate cutaneous sensitivity be tested?
16. What are the characteristics of cutaneous "spots"?
17. What is meant by the two-point threshold?
18. How do different parts of the body vary in the two-point threshold?
19. What is essential for the sensation of temperature?
20. What is meant by paradoxical cold?
21. Summarize the evidence for the theory that sensations of heat and cold result from contraction and relaxation of blood vessels.
22. What is essential for sensations of pressure?
23. What various stimuli will cause pain?
24. What is known about visceral sensitivity?
25. Describe the phenomenon of referred pain.
26. Describe the semicircular canals.
27. What is the significance of the position of the canals with relation to each other?
28. Explain the inertia theory of semicircular canal functioning.
29. How do the canals help the individual to compensate for changes in body position?
30. What evidence is there that position and balance do not depend wholly upon the semicircular canals?

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Chapter XV

PERCEIVING

PERCEIVING may be defined as the process of becoming aware of external objects, qualities, or relations. It is a complex procedure involving several factors. (a) It presupposes general awareness. A person cannot perceive when he is in a coma. He perceives dimly when half asleep. He perceives most clearly when keenly alert. (b) It involves some sort of immediate interpretation of the objective world. When perceiving, a person makes such remarks as: "I see a dog." "I taste an orange," "The apple is red." Even when there is no clear interpretation, there is an attempt to arrive at some significance. It may not be clear whether a noise is thunder, the backfire of a car, or a gun; but the experience does not stop with a mere auditory sensation. (c) A perceptual interpretation seems trustworthy. In most cases a perception is uncritically accepted as the last word in evidence of reality. Even when we discover that we have been deceived by some queer arrangement of things or events, the perception does not seem less real. We are bewildered by the fact that we were deceived. We may think it odd that it seemed so real when it actually was unreal, but it did seem real nonetheless. (d) A perception provides the basis for action. When we perceive, we act accordingly.

ANALYSIS OF THE PERCEIVING PROCESS

We have perceptual problems but they seem different and are handled differently from logical problems. A perceptual problem may lead to such a question as: "What do I hear?" "What do I see?" "What do I taste?" The answer is reached not by logic, but by listening, looking, or tasting again.

Untrustworthiness of perceptions. Not every perceptual experience is accompanied by any such clear-cut question. Instead, there is usually emphasis upon the answer, often with such a degree of confidence in the answer that the observer does not even realize there was a question. The answer comes so spontaneously, so quickly, and with such assurance that there is often a refusal to admit that there could have been any other interpretation. The observer says, "I saw the man on the stage pull a rabbit out of the hat . . . I saw him eat a whole paper of needles and then pull them out of his mouth again all strung on a thread." He may admit bewilderment as to how the trick was done, but he does not question the fact that he saw it done. As a matter of fact, he did not see it done; he merely thought he did. The magician fooled him.

Our perceptions are continually fooling us; but the mistakes we make do no harm so long as we do not take them too seriously. Perceptions are hypotheses at best, usually mere guesses. There is this distinctive difference between logical hypotheses and perceptual hypotheses. Logical hypotheses lead to delay and further investigation before action is taken. Perceptual hypotheses lead to immediate action.

The selection of significant cues. It is an undisputed fact that many of the elements in our environment pass unnoticed, not merely because they are too weak to affect our sense organs, but because we tend to select only certain aspects of the total situation for our consideration and response. If our selection includes the proper combination of factors, we will make a satisfactory response. If we select the wrong ones, failure will follow. An interesting parlor game is based upon this principle. Select some ordinarily trivial or incidental element and make it the dominant one in a problem situation and watch the guests fumble in their attempt to be more observing. For example, go through some complicated movements with the hands and ask the guests to imitate the pattern. If the significant factor is a clearing of the throat (or some similar other apparently irrelevant act), the guests will not be very likely to discern this coughing and will become increasingly zealous in their attempt to move their hands in exactly the correct manner.

Many situations in life are of a similar order. The success-

ful man is the one who can discern the significant factor that others do not see. However, it is possible for one to take this lesson too seriously and to go through life looking for all sorts of irrelevant details. Such an individual becomes "scatter-brained."

Essential characteristics of perceptions. This sketchy description of a perceptual process needs to be rounded out by an examination of some of the essential characteristics of the act of perceiving. [1]

Perceiving involves jumping at conclusions without weighing the logical justification for such conclusions. For example, suppose that a prankster tickled a man's neck with a feather. Without hesitation the man would brush at the bug he perceived crawling over his neck. He would not stop, propose to himself the various possible interpretations of his tactile sensations, consciously decide it might be a bug, and then tentatively brush at the spot in order to verify his hypothesis. To him it was a real bug. He responded with all the violence that would ordinarily go with complete knowledge that it was a bug. Only after he saw the grinning boy did he find it necessary to revise his interpretation of what he felt. Even so, after he knew it was a feather he still knew it felt as real as though it were a bug.

In other words, in perceiving we act with complete conviction and with little regard for the completeness or accuracy of knowledge concerning the circumstances. Intuitions, hunches, and convictions are all part and parcel of the same process. Why do we jump at conclusions? Merely to shorten the process of living. A great proportion of living is taking things for granted. If you hear a horn behind you, it will pay you to jump for the sidewalk; and then find out later whether it really was an approaching car or some friend playing a trick on you.

A perception may or may not conform with objective reality. Perceptions are working hypotheses with major emphasis on the working aspect and little on the justifying reasons for accepting them. They are premature conclusions and, consequently, need not conform with reality. Perceiving a thing is no reason for believing it.

Individuals differ in the way in which they perceive the same objective facts. The observer distorts what he takes in

through his sense organs in order to make these incoming impressions conform to what he has come to believe they should be. A rose looks red regardless of the way in which it is illuminated, and it takes a trained artist to observe that it changes color in different settings. A wheel looks round no matter from what angle it is seen. We make allowances for a great many distortions, and are aware of these distortions only when some unusual circumstance makes them apparent. We shall see this principle clearly demonstrated in some of the illusions which we shall shortly study.

When an individual develops a certain attitude, distortions may become even more marked. Lovers may be intrigued by the sounds of crickets, tree frogs, and owls, and by the moon shadows; the boy who has run away from home may perceive them only as fateful warnings of danger. Just how much any perception is determined by objective circumstances and how much by the attitude of the observer it is almost impossible to detect.

Perceptions vary in reliability. Certainly no perceptions are infallible, and probably none are absolutely untrustworthy. Since this is so, it may be of some value to know some of the factors affecting the degree of dependability of perceptions.

1. The various senses differ in their ability to give accurate information. In general, vision is the best source for information as to spatial relations. We can more easily see where an object is than hear where it is or smell where it is. Ventriloquism is an illustration of how easily we can be deceived as to the location of a sound source. We can sense wetness better by feeling than by seeing. We can hear rhythms and music better than we can see them. We can gauge the time taken in the execution of a movement more accurately than we can determine the energy consumed in making the movement. Sometimes we must make a perceptual response when deprived of the use of the sense best suited to give accurate information. In such cases, our degree of error is sure to be greater and due allowances must be made.

2. The past experiences of an individual are highly important in present perceptual interpretations. If a child has had little experience he will make many errors in attempting to adjust to various situations. He will have all kinds of accidents because he has not learned to interpret spatial relationships: he will fall

down stairs, he will bump his head, he will push his toys and dishes off the table, and attempt to reach for remote objects. Some of these accidents and errors may be due to motor awkwardness, to be sure, but many of them depend strikingly upon perceptual inexperience.

The confusion that a child manifests when he first adjusts to using a mirror illustrates the forcefulness of past experiences in guiding perceptual interpretations. The child has learned to look at his mother directly and to hear her speak to him and has thus built up certain expectations and reactions to his mother's acts. Let the mother stand behind him so that he can see her by looking in the mirror and then let her speak to him. He will show the greatest confusion. He acts as though he might expect to creep into the mirror to her, turns his head when he hears her voice and then looks at her alternately by turning his head and by looking at the image in the mirror. Having learned one set of spatial reactions, he must now learn new ones to fit this strange new situation. The reactions of the child in such a situation are certainly different from the smooth reactions of the adult who uses a mirror to guide his movements while shaving or combing his hair.

3. Momentary conditions affect perceptions. The setting in which an experience occurs, the events which led up to the experience, and the attitude of the individual, all affect his perceptions. There is, for example, the factor of contrast. A tall man looks shorter when in the company of a taller man. A color looks brighter by contrast with a dull color. A dollar seems bigger to a poor man than to a wealthy one.

Then there is the phenomenon of irradiation. A man who has just heard of the death of his best friend is likely to see everything in drab tones. A man who has just received a promotion is likely to observe how brilliant everything seems. Everyone is familiar with the importance of what is called a "build-up." A girl who has just heard tales of housebreakings will hear all sounds as burglars, especially if she is alone in her home. A yell is always more startling after one has been prepared for it by a good ghost story.

4. The unreliability of perceptions is accentuated by the fact that we are usually in ignorance of the cues upon which our

perceptions are based. When we recognize that attitudes affect perceptual interpretations, it should make us skeptical when things appear the way we want them to be or the way we are afraid they might be. We glibly admit at one moment that our perceptions are distorted, if the situation is not of vital importance; and then at another time we try to convince ourselves that they are not affected by our desires. We admit in general that we see the world through colored glasses; but we refuse to try to discern the color at each particular moment and to make allowances for the distortion.

5. Furthermore, there is a tendency for us to develop a perceptual intolerance. We know an event is so, we assert, because we saw it, we heard it, we tasted it, and the like. We are sure of our own perceptions and doubtful of the perceptions of others. We would come nearer the truth if we were to reverse the process and say: Our prejudice colors our perceptions; perhaps the other fellow is nearer right than we are.

Perceptions are continually changing. The incessant changing of perceptual interpretations has long been known and universally recognized. These shifts have been given the popular name of attention. The reasons for changes in attention can be divided into two general groups: (2) factors inherent in the external stimulating circumstances, or objective factors; (2) those dependent upon the perceiving individual, or subjective factors. [5]

1. Objective factors of attention. We are all familiar with the objective methods for gaining the attention of a person. We call his name, yell, wave something at him, nudge him, or punch him if he is unresponsive to milder stimulations.

(a) Other things being equal, an intense stimulus will be more effective than a weak one. A loud sound, a bright color, a pungent odor, a sharp pain are more effective than weaker stimulations would be. A large display heading in the newspaper gains attention quicker than a heading in small type would do. Anything that gives a situation intensity value gives it attention value. While it might be desirable to give each possible stimulus a quantitative attention value, this has not been done. We cannot say that a bright light is more effective than a certain loud sound, nor how much more effective the bright light is than a weaker

one. One reason for this is that attention factors shift in themselves and never have any constant value.

(b) A changing stimulus is more effective than a stationary or constant one. This factor has been utilized extensively in advertising. The ordinary man is constantly bombarded by signs which jump on and off, which portray all kinds of activities. The locomotive or the fire truck with a rotating headlight clears the road much better than one with a stationary light, even though they may be of equal luminous value.

(c) Repetition makes a stimulus more striking. Even when the repetition becomes annoying, as often happens when a radio advertiser repeats the same phrase incessantly, the words arrest attention in spite of the antagonistic appeal. In fact, the irritation may help in gaining attention.

(d) All these objective factors may be summed up by the term "novelty" or "change." It is probable that change is the most effective objective determinant of attention that we can discover. Even a striking stimulus will lose its value if repeated monotonously or if kept at the same intensity. A person will go to sleep to the regular ticking of a clock at his ear but may be wakened by the sudden stopping of the clock.

2. The subjective factors of attention. The subjective factors that favor attention may be summed up in the word "interest." Other terms have been used to express the same condition. Set, attitude, or priming may be used to indicate a readiness on the part of an individual to be responsive to a certain pattern of stimuli. These may all have value in designating a condition that is easily observable but they do not explain the process. The fact is, we cannot derive any formula to explain the fact that certain situations are favored, because each experience is a specific one and is effective because of a unique combination of factors which probably never will be duplicated exactly. Life is a changing process and each perceptual process is merely one step in living.

There is an objective constancy behind perceptual change. An interesting factor that stands out in all this welter of change is the ease with which an individual attributes constancy to objects and circumstances involved in his perceptual world. An object changes appearance with position and circumstances and yet it

continues to be the same object to us. The sensations which give us information about objects in our world change in value, but the objects from which these sensations originate are perceived as unchanged. We see a wheel from different angles, and it may change from a round object to an oval object; and yet it continues to be perceived as a round wheel. We see snow as white no matter how much illumination is reflected. Such constancy of objective perceptions must make allowance for all sorts of changing circumstances. Such qualifications are made without any conscious intent to do so. Indeed, the process is just the reverse. We are so sure of the constancy of the object perceived that, in many cases, we do not realize that the stimulus values are different.

Perception is, consequently, a reaction to cues which are accepted as significant and any irrelevant factor that would tend to distract us from the immediate interpretation of a situation is distorted or ignored. Perception is thus a laborsaving, timesaving, and efficient way to meet our environment. It comes to be utilized because it is an efficient working basis for behavior. To avoid egregious error, however, it must be tempered by a willingness to change when it becomes apparent that our interpretation has been incorrect.

Rules for making perceiving more adequate and reliable. On the basis of these general characteristics of perceptual processes, certain rules for adequate perceiving can be formulated. If they are carefully kept in mind, their value will be vindicated as we examine the way in which perceptions operate in the perception of form, space, time, and the like.

1. Be alert to sense all the cues that are present. Alertness is relative. It varies all the way from the unresponsiveness of the man who goes through life almost asleep to the individual who misses nothing.

2. Be willing to change when it is discovered that an interpretation is incorrect. The best guesser is the one who does not stick to a guess any longer than succeeding events warrant.

3. Play with different interpretations. Even if one meaning seems to be correct, it is of practical benefit to play with the possibility of other interpretations.

4. Avoid emotional prejudices. When a perceptual inter-

pretation comes, it often does so with a queer feeling of satisfaction or relief. One says, "Aha, I have the answer." What a person may fail to realize is that the "Aha" experience of satisfaction may just as easily accompany a mistaken perception as a correct one. Once the satisfaction comes, it provides an obstacle against change.

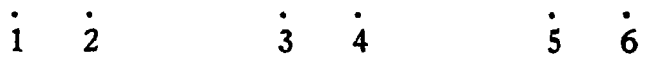
5. Avoid habitual interpretations. Habits are prejudicial to good perceptions. The essential element in a good perception is plasticity and when a person gets into the security of a habit he is thereby avoiding any further perceptual development. He learns only by getting a rude jolt, whereas the slightest cue should be enough.

THE PERCEPTION OF FORM

When a number of elements are grouped and are perceived as a whole, the whole presents characteristics which cannot be explained by the parts into which the whole can be analyzed. Squareness or roundness is not an essential function of the elements which make these forms. The tune transposed into another key is made up of different notes, but it is still the same tune. The form of an object does not reside in the constituent elements but in their patterning and mutual relations. [21, pp. 623–650]

Factors which affect form perception. In some instances the possible forms which a grouping of stimuli take is limited; in others, the possibilities are almost innumerable. In most situations a number of factors operate; hence, our outline of the influence of different features should not be construed to mean that each perception should be traceable to any one or even to a small combination.

The factor of nearness. Elements in close proximity are more likely to be conjoined in a perception than elements more widely separated.



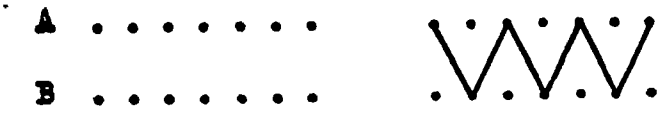
It is easier to see dots 1–2, 3–4, and 5–6 as units than it is to see 2–3, or 4–5. If the series is tapped out with time intervals corresponding to the spatial separation, the taps which are closer together will be more easily conjoined as units.

The factor of likeness. Dots of the same shape, color, or size are more likely to be seen as a group, unit, or pattern than dissimilar dots. This is illustrated in the following grouping:

```
0 . 0 . 0 . 0          . . . . . . .
0 . 0 . 0 . 0          0 0 0 0 0 0 0
0 . 0 . 0 . 0          . . . . . . .
0 . 0 . 0 . 0          0 0 0 0 0 0 0
0 . 0 . 0 . 0          . . . . . . .
```

In the grouping to the left it is easier to see vertical patterns, while in the grouping to the right it is easier to see horizontal patterns because of the operation of the factor of similarity.

The factor of continuity. Any suggestion of uninterrupted connection in space, time, operation, or development conjoins the elements embraced by this continuity.



In the grouping at the left, each row tends to be grouped as a unit. The addition of the diagonals in the grouping at the right gives a different suggestion of continuity and an entirely different pattern.

The factor of inclusiveness, good pattern, or compactness. Elements which fall into some pattern are more likely to be grouped as a unit than those falling outside such a pattern. The two zeros at the right are likely to be seen in relative isolation.

```
0  0  0  0  0

0              0      0

0              0         0

0  0  0  0  0
```

The factor of familiarity. Through past experience an individual may have learned certain forms which affect his perceptions of present patterns. Acquaintance with words enables one to group letters into word units even though they may be

run together. Thus: Franklikescandy. One would scarcely group them in this fashion: Fra nkl ike sca ndy.

The factor of immediate preparation, present set, or attitude. If a person is told that he is to be shown a hat and then is presented with the figure in the center of Fig. 119, he will tend to see it as shown in the right of the figure. If he is told he is to be shown a beehive, he will perceive it as shown at the left. This can be tested by having the person draw from memory what he has been shown. He will tend to remember it as he perceived it and his perception will be colored by his expectation.



FIG. 119.—Effect of set on perception. When a subject is told that he will be shown a hat and then is shown the figure in the center, he will tend to see it as shown at the right. When he is warned that he will see a beehive, he will tend to see it as shown at the left.

The factor of need. Gasoline stations will be passed unseen until the driver notices that his supply is about gone. When one has stopped by the roadside with a flat tire and discovers he has no jack, a casual inspection of the landscape will reveal a rock and a fence rail that otherwise would have not been noticed.

Ambiguous figures. With the same objective setting, an observer may be impressed by some aspects more than by others. This dominance does not persist, for features which were unnoticed a moment ago may now be the salient features. As pointed out at the beginning of the chapter, shifting characterizes all perceptions; ambiguous figures merely illustrate this general principle.

There are wide individual differences in this shifting from one aspect to another. Some persons are very distractable and cannot prevent themselves from jumping from one thing to another. Others seem to be oblivious to most of the conditions around them and are lost in the contemplation of an event that happened an hour ago. For example, a student complained that it took him half a class period to get his attention fixed upon the subject at hand because he found he was absorbed in reviewing

in his mind what had taken place in the preceding hour. After the present class was half over he could get his attention shifted, only to find his mind reverting to this material in the following hour. In short, he was so slow in shifting his attention from subject to subject that he found himself always about half an hour behind time.

By way of contrast, the distractable person shifts his attention so quickly that he misses little, but is unable to utilize what



FIG. 120.—Ambiguous figure. The nose of the hag becomes the cheek and chin of the pretty girl; while the ear of the girl is the left eye of the hag.
(By courtesy of E. G. Boring.)

he experiences because he never takes time to integrate his various observations into workable units. On the other hand, the perseverator (a person in whom any experience continues to repeat itself unreasonably) misses much because he is absorbed in his own mental processes. He soon becomes an "old fogy."

The pretty woman-ugly woman picture in Fig. 120 illustrates this principle of shifting when a situation is ambiguous enough to permit it. The necklace of the pretty woman becomes the mouth of the hag; the eye of the hag becomes the ear of the pretty woman. After they are both clear, one wonders that it was so hard to see the hidden face in the first place.

The less the preference for any one aspect the greater the

tendency to shift. Shifting decreases when experience gives preference to one particular interpretation. Hence, shifting and habit work in opposition. If one wants to shift easily, he must overpower habit; if one wants to avoid shifting, he must develop a fixed way of viewing the object.

Figure and ground. We do not react in a uniform or a constant manner to specific stimuli. Instead, the nature of the setting in which they are found determines the mode of response to some extent. Normally, when an observer looks at Fig. 121, he



FIG. 121.—Figure-ground reversal.
(After E. Rubin.)

sees only a plain black vase on a white background. After a period, longer or shorter, the perception of the figure may change and he sees no longer the vase but, instead, two white profiles facing each other across a black background. The experience is quite similar to that which comes from inspection of the ambiguous picture in Fig. 120. After considerable practice, the observer may see either the profiles or the vase alternately or he can maintain one to the exclusion of the other; but he cannot see both at the same time. One cannot see the same part of a situation as figure and ground simultaneously. [12]

This simple figure illustrates a phenomenon that is continually operating in all perceptual fields. From the conglomeration of impressions, certain aspects stand out as figure and the remaining parts retire into the background. The distinguishing characteristics of a figure as contrasted with the background are as follows:

1. The figure has form, whereas the ground is relatively without form. This does not mean that the background has no form in and of itself but that at this particular moment it appears formless to the observer.

2. The figure has definite limits, whereas the ground seems to extend continuously behind the figure and not to be interrupted by it.

3. The figure has the characteristics of a thing, whereas the ground appears to be unformed material.

4. The figure tends to stand apart from the ground. It more often appears to be in front of the ground but the direction of the differentiation is not the important factor.

5. The figure is more impressive, better remembered, and more likely to suggest meaning. There is a tendency to see the same figure on a second observation of the same situation than to see a new figure.

To state these facts in a slightly different manner we can say: An object is that part of the environmental setting which has form, definite limits, individuality, contour, and impressiveness to such a degree that it can be identified as standing apart from the rest of the situation, and can be remembered and recognized on some future occasion. We see things or objects and not sensations, and these figures or things are real to us. We need get into no discussion as to the objective existence of these figures or things; as psychologists, we need not prove that they have eternal existence. For the individual they are vital experiences.

These facts are most clearly observed in visual perceptions but the same factors hold in other fields. For example, the melody can be regarded as the figure in a musical composition and the accompanying sounds as the ground. In a musical composition the figure is likely to be higher in pitch, louder, have a different timbre, to be played by a different instrument, to move differently, to have a different rhythm, or to start and stop at different times than the ground. In some way the figure must be given individuality and meaning. In fact, one of the pleasures in listening to symphonic music arises from trying to recognize the figure (or theme) when it appears in different settings or grounds.

Factors favoring the perception of a figure. What are the factors which tend to make a certain part of an experience stand out as figure? [8]

Time. Experiments in the field of vision demonstrate that it takes a certain amount of time for the figure to emerge from the background. If a subject is shown an irregular enclosed white patch, as in Fig. 122, for a period of time less than 10 msec., he will see little differentiation between the white and the black. With an exposure of 14 msec., he will see good contour; and after

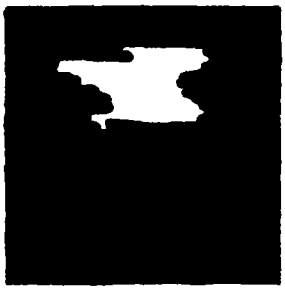


FIG. 122.—Figure to illustrate time factor involved in distinguishing figure from ground. See text.

about several seconds he will see the white figure distinctly and may even imagine it to be a flying witch or other object. The amount of time required to get a good figure-ground distinction depends greatly upon the nature of the situation; but time is an important factor even though no definite rules have been discovered.

Contrast between the figure and ground is an important factor. In the field of vision the greater the brightness differences between the figure and ground the easier it will be for the subject to get the figure-ground experience.

Clear-cut characteristics will make a figure stand out. In the visual field a figure is more likely to emerge from the background if it has sharply projecting points. In music a quickly struck note, a loud note, or an unusual rhythm will make the figure easily apparent.

Size. It is easier to see a small concise part as the figure and a large broad expanse as ground.

Perspective. If the situation can be viewed in three dimensions so that the object may be nearer to the observer or farther away than the ground, the figure stands out more easily than if the whole situation is two dimensional.

Meaning. The ability to give the figure a name or relate it to some known group of objects makes it easier for it to separate itself from the ground.

Masking of figures. From the preceding analysis it would seem that the whole process of distinguishing figure from ground can be viewed as a method for getting meaning from a situation. The observer tends to select objects from a background; and when one thing emerges, it is usually difficult to replace it except with some other object or figure.

It is also clear that there is much in our environment that we never perceive. There are combinations and patterns that we never discern because they are concealed or masked by others which claim our interest or attention first, and which then dominate the field. At the same time that we are interpreting our environment in terms of dominant figures, there are other parts which are thereby lost. Many sleight-of-hand tricks are based upon this principle. The performer masks the essential part of his trick by getting the observer to attend to another aspect of his act.



FIG. 123.—The figure at the left is present also in the figure at the right; but is masked by the projecting corners.

The principles that operate in masking are well brought out in concealing geometrical figures by various means. Most persons think that concealing involves taking away or covering parts,

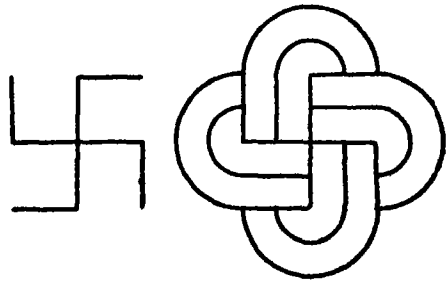


FIG. 124.—The swastika, as shown on the left, is successfully masked by the lines connecting with the free ends in the figure at the right.

whereas they can be hidden by making some other aspect more dominant. [21, pp. 638–642]

1. A projecting corner may be concealed by prolonging lines beyond the corner. An illustration of this is given in Fig. 123.

2. A free-ending line can easily be concealed by connecting other lines with the free end. The swastika at the left in Fig. 124 is present also in the figure at the right; but is successfully masked by the added lines.

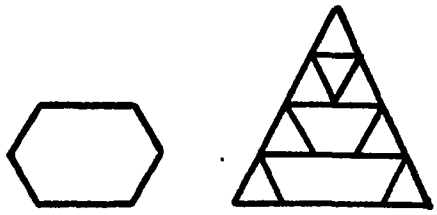


FIG. 125.—The flat ends of the left-hand figure are masked by the outlying lines in the right-hand figure.

3. A flat end can be concealed by placing other lines out beyond it. One would be unlikely to select from the diagram at the right of Fig. 125 the form shown at the left unless his attention was called to this hidden form. Even when he sees the left form, it is hard to discern it as an outstanding feature when masked as shown at right of the illustration.

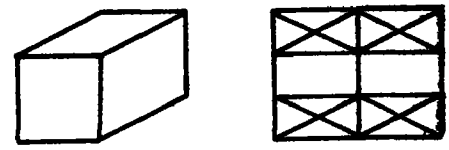


FIG. 126.—The figure at the left is concealed in the mass of parallel lines in the figure at the right. Even when one knows it is there, it is hard to discern.

4. A figure can be concealed by embedding it in a mass of parallel lines. As the number of added lines increases, the original figure tends to become completely lost. Even when one is directed specifically, by being shown the form at the left in Fig. 126, he finds it hard to isolate it from the form at the right. Besides, after being found, it is difficult to discern as an outstanding feature.

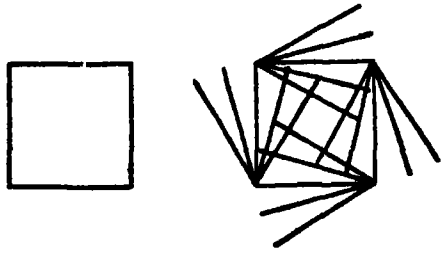


FIG. 127.—The square is successfully masked by the radiating lines.

5. Radiating lines may conceal the contour of a figure. This is illustrated clearly in Fig. 127.

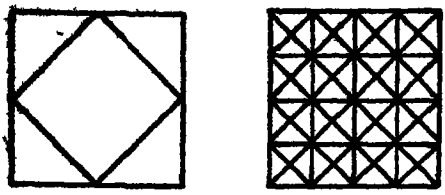
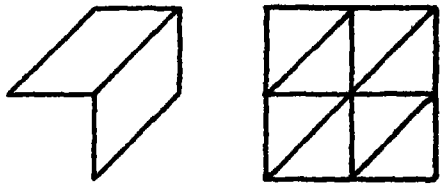


FIG. 128.—The clear spaces of the left-hand figure are filled in the figure at the right, thus masking the simpler figure.

6. A figure may be concealed by filling an interior clear space. Figure 128 illustrates this principle.

7. A figure may be concealed by giving a three-dimensional aspect to an original flat figure or by giving a flat effect to an original three-dimensional figure. Figure 129 illustrates a form that suggests three dimensions concealed by lines which make it appear flat. Figure 130 illustrates a flat form concealed by added lines and shadows which suggest perspective.

FIG. 129.—The figure at the left gives a three-dimensional aspect, but is made to look flat by the added lines on the right.



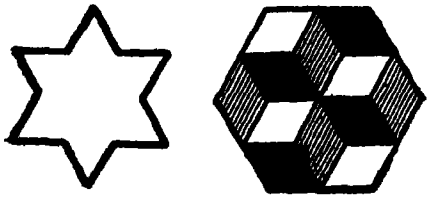


FIG. 130.—The flat figure at the left is given solidity by the addition of lines and shadows in the figure at the right.

VISUAL PERCEPTION OF DISTANCE OR DEPTH

The eyes have often been appropriately called our most important "distance receptors." Some have argued that we get our early conceptions of space from tactile and kinesthetic sensations and have contended that vision comes in merely to supplement these cues. Experimental evidence has not vindicated these arguments. Instead, it has been shown fairly conclusively that the eyes play the predominant role in space perception. [4]



FIG. 131.—Attached shadows suggest solidity. This is a picture of the Devil's Punch Bowl in Yellowstone National Park. The shadows show the rim of the bowl raised above the level of the ground. Turn the picture upside down and a crater will be seen below the ground level.



FIG. 132.—Cast shadows, covering of distant objects by near objects, dimness of outline and haze all play a part in this picture of the triple tunnels on the Cody Road to Yellowstone National Park.



FIG. 133.—Superposition. One hand covers the other and is thus perceived as closer to the observer.

It is clear that a child is not born with a knowledge of spatial relations, of distance, or of the solidity of objects. He learns these relations. The way in which this learning takes place and the contribution made by the different visual factors is an interesting study. The usual method for determining the significance of any one factor is to keep all other factors as nearly constant as possible and then to vary the one under consideration. This method has demonstrated the importance of a number of visual processes in space perception.

Any characteristic of an object or a situation which changes consistently with changes in distance can be used by an individual as an index of distance. Nevertheless, although different factors may be isolated experimentally, it is not likely that an individual, in judging distance, isolates these same factors. Instead, he utilizes a number of cues in combination at any moment, without any analysis on his part and usually without awareness of the factors he is using.

The factors contributing to the perception of distance, depth, or solidity may be divided, for purposes of discussion, into two kinds: (1) those which can be utilized with a single eye—monocular factors; (2) those which depend upon the mutual activity of both eyes—binocular factors.

Monocular factors in the perception of distance or depth. There are eight monocular factors that may be distinguished: (1) attached shadows; (2) cast shadow; (3) linear perspective; (4) detail perspective; (5) superposition; (6) movement parallax; (7) relative size of familiar objects; (8) the shape of familiar objects. [17]

1. *Attached shadows.* A shadow above a high light indicates a dent; a high light above a shadow indicates a bulge. Experience probably teaches this because we are accustomed to viewing objects illuminated from above. If Fig. 131 is turned upside down, the effect of shadows will be clearly seen.

2. *Cast shadows.* A cast shadow is one cast by an object on the ground or on a near-by object and thereby reveals spatial relationships between objects. The effect of cast shadows is clearly seen in Fig. 132.

3. *Linear perspective.* With increased distance there is a diminution of angular size of objects; at the same time parallel

lines seem to run together as they recede from the observer. In Fig. 134 there is a conflict between these two factors, giving an illusory effect. The three blocks are actually the same size; but

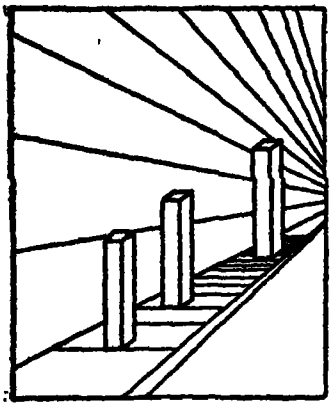


FIG. 134.—Relation of apparent size to perception of distance. The converging lines suggest distance. The block at the right would therefore appear smaller if it were the same size as the block at the left. The three blocks measure the same size, but the one at the left is much smaller perceptually.

perceptually the one at the right is much larger than the one at the left.

4. *Detail perspective.* As objects recede from the observer they lose some of their clearness of detail owing to loss of visual acuity with distance, the haziness of the atmosphere, fog, or smoke. Consequently, haziness in detail suggests distance. The effect of this factor becomes evident when one attempts to drive a car in a fog. When an approaching car is first seen it is judged to be much farther away than it really is, and then suddenly it seems to jump from a distance right upon one. This accounts for many an accident in foggy weather. Distance also changes the colors of objects, so that a change in the hue of objects judged to be the same color gives a distance cue. [19]

5. *Superposition.* If an object cuts off part of another object in the visual field, the observer judges the covering object to be nearer. In Fig. 133 there is little doubt that the right hand is in front of the left, or that both hands are on top of the unholstered object.

6. *Movement parallax.* As we move forward, nearer objects increase in size more rapidly than more remote objects; hence, the relative change in the size of objects as we approach them gives the observer a clue as to their relative distance. A forward motion also changes the clearness of outline, detail, and

coloring of objects in the field of vision and the observer through experience learns to judge those that change in these particulars with the greatest speed to be nearer than those that change more slowly.

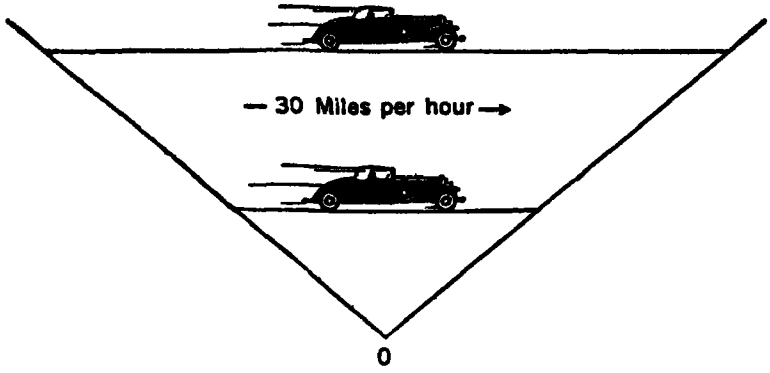


FIG. 135.—Effect of sidewise motion on judgment of distance. If the observer is at O, and traffic is moving at a fairly uniform speed, changes in the relative positions of the two cars will give information as to their relative nearness. (After Dockeray.)

The greatest advantage of movement parallax comes from sidewise motions. If the movement is made by the observer while the objects in the field remain stationary, there will be a change in

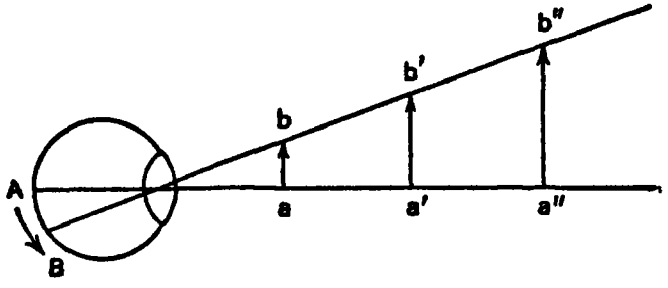


FIG. 136.—The size of the retinal image is proportional to the distance of an object from the eye. A retinal image of the size AB may be caused by ab, by a′b′, or by a″b″.

covering of the more remote objects by the near ones; the closer the near object in relation to the remote ones the greater the rapidity of change in covering. If the observer remains stationary, changes in objects in the visual field will give him a cue as to their relative distance. This is illustrated in Fig. 135.

7. The relative size of familiar objects. The size of the retinal image made by an object depends upon the distance of that object from the eye. In Fig. 136, for example, ab, a′b′, and a″b″, while different in length, all project an image of the same



FIG. 137.—Illusion based on size and distance distortion. The man in this picture was standing on the top of a house in the distance and the cow was farther away than she seems to be. These factors make the pineapple look absurdly large.

size, AB, on the retina. Conversely, if ab should remain the same size and be moved farther away from the eye, the distance AB would grow smaller in proportion to the increase in distance. If an object maintains a constant size, the retinal image grows larger as the object approaches. Curiously enough, movements to

and from the eye do not change the apparent size of an object. If a herd of cows are grazing in a field, the near cows do not look larger than the remote ones. They all appear to be the same size. The fact that the near cows subtend a larger retinal

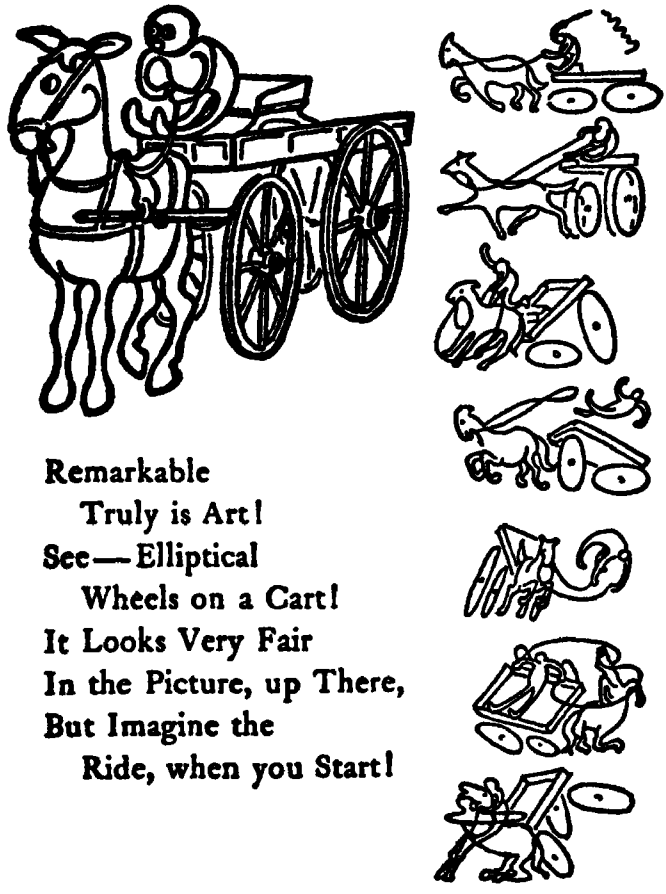


FIG. 138.—A study in perspective. The cart wheels appear circular, although they are actually drawn as ellipses.
(From Gelett Burgess.)

image than the distant cows can be used by the observer as a cue to relative distance. He judges the cows which produce a large retinal image to be nearer than those which produce a smaller retinal image.

The illusory effect produced in Fig. 137 depends in part upon this principle. Certain perspective factors make it seem as

though the man were standing on one of the pineapple spines, and as though the cow were standing just behind the pineapple. This makes the pineapple seem to be enormous in size. If the man were perceived as standing on a distant spire, as he actually is, and the cow were perceived as in a remote field, as she actually is, the illusion would not exist and the pineapple would seem to be normal in size.

8. *The shape of familiar objects.* When a familiar object is rotated so that some parts are moved farther away while others are relatively closer, the shape of the retinal image of the object changes. This is clearly seen when one changes the angle at which he views such an object as a cart wheel. If he looks at it squarely, it will actually be seen as a circular object. Rotate it and the retinal image is actually an ellipse. The wheel does not seem to change, however. It stays perceptually a round wheel no matter what the shape of the visual image which it forms. To make the wheel seem natural when drawn on a flat surface an artist must draw an oval if the other features of the picture suggest that it is not seen directly in front of the observer (see Fig. 138).

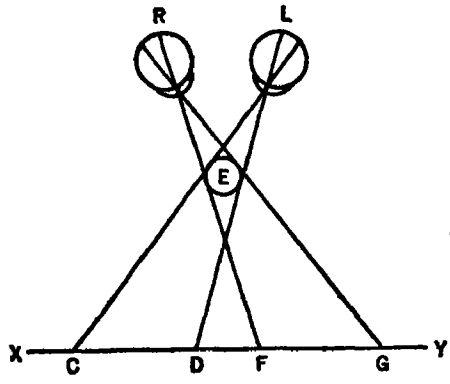


FIG. 139.—Binocular parallax. In binocular vision the observer really looks around and behind a near object. The eye R cannot see the space FG, nor can the eye L see the space CD, but both eyes can see space DF, XC, and GY. No part is hidden from both eyes.

Binocular factors. The binocular factors which influence our perception of distance or depth are: (1) binocular parallax and (2) binocular disparity (see page 353). Some psychologists have added a third binocular factor: the tactile-kinesthetic sensations that come from the adjustments of accommodation and convergence of the eyes. Experimental tests have shown that these sensations play a small part, if any, in the accurate perception of distance. [4]

1. *Binocular parallax.* Binocular parallax is operative only with near objects. When an object is close to the observer he can virtually look around it and see some of the objects that would be hidden by the object in monocular vision. This is illustrated in Fig. 139. If R and L represent the two eyes, and E an object on which they are fixated, and the space from x to y the background, then eye R will see all of this background except the space from F to G, while eye L will see all of the background

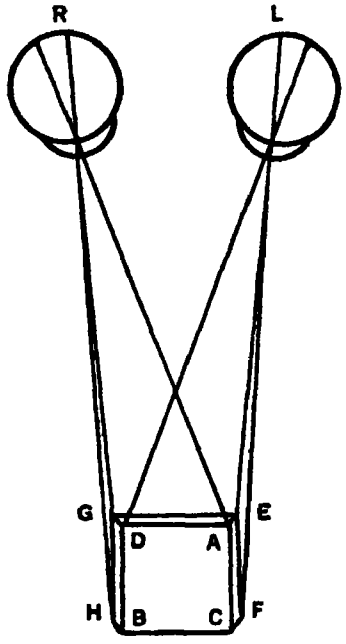


FIG. 140.—Binocular disparity. The eye R will see the surface GDBH, but none of the surface AEFC; the eye L will see the surface AEFC, but none of the surface GDBH. When both eyes are used, the observer will see both sides and interpret this as evidence of solidity.

except the space from C to D. Since FG does not overlap CD, the observer can see the whole of the background. That is, he actually sees behind the object.

2. *Binocular disparity.* Binocular disparity refers to the fact that when a person views a near object with his two eyes he gets a different view of the object in each eye. This is illustrated in Fig. 140. If the two eyes are fixated on the cube DACB, eye R will see the surface GDBH, but none of surface AEFC. Eye L, on the other hand, will see AEFC, but none of GDBH. The student can test out the facts illustrated by this figure by holding a closed book directly in front of him with the back toward him. With his right eye he will be able to see

the back and part of the front cover; with his left eye he will be able to see the back and part of the back cover. With both his eyes he will recognize it as a three-dimensional object.

Ambiguous three-dimensional figures. Shifting is well illustrated by observing certain figures which may be seen in three dimensions but which have ambiguous perspective.

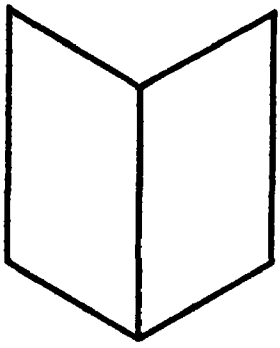


FIG. 141.—Ambiguous perspective. The figure may appear as follows: (a) a flat two-dimensional figure; (b) the outline of a book with the binding nearer than the edges of the pages; (c) the outline of a book with the binding farther away than the edges of the pages.

A simple illustration of this type of drawing is seen in Fig. 141. It may be seen as a two-dimensional drawing but it is also possible to see it as the outline of a book. Furthermore, at one time the fold in the book (the middle vertical line) may appear near the observer (that is, as though the back of the book were

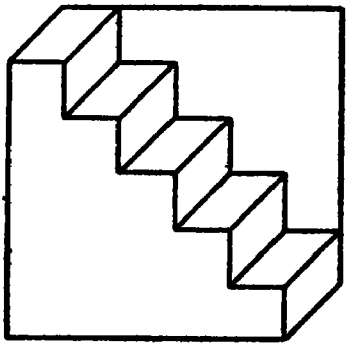


FIG. 142.—Staircase figure. The staircase may appear to be below the field of vision or the observer may seem to be looking at the stairs from below. The two views alternate with each other.

toward him) and at another time the book may appear open (with the vertical line farther away). In more complicated form the same principle is seen in the staircase figure in Fig. 142. The observer may at one moment be looking from above at a staircase and at the next be looking from below at the underside of a staircase. Again, the symmetrical six-pointed star in Fig. 143

may be seen as a flat geometrical design or as a rather complex three-dimensional figure.

The factor of experience emerges as we study these ambiguous figures. True, there is a shifting tendency, but this tendency gives way to a decided preference in certain circumstances. If

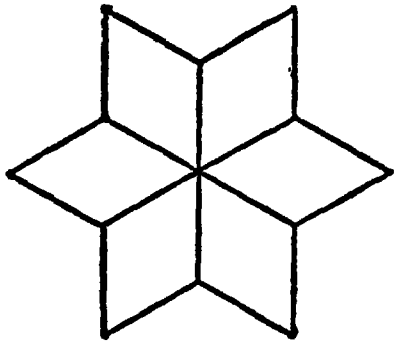


FIG. 143.—The star versus folded paper figure. The figure may be seen as a flat geometrical design or as a three-dimensional figure. Furthermore, the three-dimensional figure changes its perspective.

our past experience makes it easier to see a figure in a certain way, that interpretation will dominate. For example, it is much easier to see the staircase in Fig. 142 as viewed from above than as viewed from below. Even after we see both views, the upper view tends to predominate and to stay for longer periods than the reverse. At first it is hard to see the three dimensions in the star in Fig. 143; but after it is once seen thus, it is easier to see three dimensions; and after some practice it becomes almost impossible to see it as a flat figure.

PERCEPTION OF MOTION

Anyone who has driven a car knows that individuals differ strikingly in their ability to judge motion. What appears to be reckless driving may be caused by sheer inability on the part of the driver to compare the speed of an oncoming car with that of the car in front of him. This practical need for skill in the perception of motion is enough to stimulate the psychologist to study this complex problem. Other practical interests are involved in sign displays and in the development of better motion pictures. [6]

Conditions under which motion may be perceived. Motion may be perceived under different circumstances.

1. When a single object is observed to change its position

in relation to other objects it is seen to move. This gives the clearest perception of motion. If an object is seen at A and then gradually changes its relative position and finally stops at B, the observer not only gets the perception of change of position but is able to follow the course over which that change of position was attained.

2. When an object is seen at one position and then at another position, after having been invisible in the interim, the observer gets practically the same perception of motion as though he had seen it change position. If the time interval between exposures was long, the perception of motion may be dependent upon logical inference, but when a single object is seen in rapid succession at two different but relatively close places, the observer has a perception of movement that is just as real to him as though he had followed it from one spot to another, although it has really been invisible to him between exposures. [14]

Apparent movement. Apparent movement, called the phi phenomenon, has been studied extensively by an analysis of the ways in which temporal and spatial factors may be manipulated to give illusory perceptions of motion. [10] Various types of apparent motion have been described, as follows:

Alpha motion. Alpha motion is the type of apparent motion produced when there is an illusory change in size owing to a change in some part of the total pattern. This is illustrated by changing the direction of the wings on a figure known as the

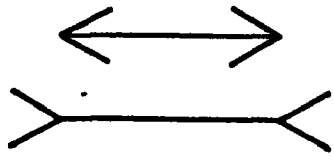


FIG. 144.—The Müller-Lyer figure. The lines between the points where the feathered lines join are equal in length.

Müller-Lyer figure. This figure is shown in Fig. 144. If in successive exposures of the figure the wings change in the sequence shown in Fig. 145, and the central horizontal line remains the same, it will seem as though the line between the two centers of rotation grows larger and smaller. It will seem longer when the wings extend outward and shorter when they are turned inward.

Beta motion. When two successive figures are shown which actually differ in size or position, the observer will get

the perception of actual growth or movement. This is called beta motion.

Gamma motion. Gamma motion is a type of apparent motion that results from sudden exposure or withdrawal or a change in the illumination of a single figure. When a simple form is exposed rapidly, there is an appearance of movement from the center outward; when the exposure ceases, there is apparent movement from without toward the center. When a dark figure is exposed on a white ground, the dark figure spreads out; or when one looks at a large uniform surface illuminated by

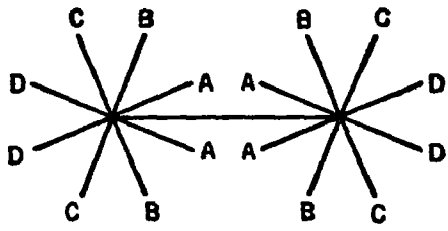


FIG. 145.—Figure to illustrate alpha motion. Let this complex figure represent the Müller-Lyer figure with the oblique lines circling to occupy successively the following positions: AAAA, BBBB, CCCC, DDDD, CCCC, BBBB, AAAA, BBBB, CCCC, etc. The line between the rotation centers will appear to grow correspondingly longer and shorter.

a momentary flash of light, the light appears to spread from the center to the periphery and then to shrink toward the center again.

Delta motion. When two figures are shown successively in adjacent areas, one of which is more impressive than the other (that is, one is larger, more intense, or more complex), the more impressive member tends to move toward the less impressive; the two then unite and seem to return to the position of the more impressive one. For example, if one exposes two lights successively, the first being more intense than the second, there is an apparent movement from the second to the first and back again.

Epsilon, or positive-negative, motion. When a white line on a black ground is succeeded by a black line on a white ground with a change in position, motion is seen from the first to the second.

Factors affecting apparent motion. Apparent motion is influenced by a number of factors:

Time factors. The phi phenomenon is modified by the time between successive exposures, and the length of time that each stimulus is shown. For example, if two parallel lines, as shown in Fig. 146, are presented at the same time or at an interval



FIG. 146.—Beta motion stimuli.

of less than 30 msec., they will appear as two lines. If the interval between presentations of the two lines is somewhere around 60 msec., the first line will appear to move to the second. If the interval exceeds 200 msec., the two lines will be seen in succession with no apparent movement between them.

The length of time that each of the component stimuli is shown is important. If they are exposed briefly, the observer may not clearly get the identity of either but seem to see only a movement. If they are exposed long enough, the observer may see first the one line, then it may disappear and he sees only the second.

Furthermore, the optimum time interval between exposures is affected by the distance between the two stimuli and by their intensity.

The distance between the two stimuli. If intensity is kept constant, the greater the distance between the two stimuli (that is, the larger the visual angle subtended by the two stimuli) the longer must be the time interval between exposures in order to get good apparent movement.

The absolute intensity of the stimuli. Other factors being equal, the greater the intensity of the stimuli the longer must be the time interval between exposures in order to get the best apparent movement.

The relative intensities of the stimuli. If, for example, the second stimulus exposed is more intense than the first, the apparent motion begins between the stimuli, goes toward the stimulus first exposed (the weak one), and then returns to the posi-

tion occupied by the second, or stronger, stimulus. This is the delta movement.

The character of the stimulus. The simple lines that have been used in experimental studies are not conducive to the most effective demonstrations of apparent movement. The more nearly the object seen in movement has correspondence to our everyday perceptions of moving objects the greater will be the ease of seeing movement even if the other factors of time, space, and intensity are not at their optimum values.

For example, when one holds a pointed object between his fingers and strikes some other object with the end, it is customary for the object to penetrate the object that is struck. Consequently, if one holds a cigarette in his fingers and stabs it at his ear, the cigarette may be slipped behind the fingers but the observer will get the impression that the cigarette has penetrated the ear.

Another illustration is the "Yogi" toy shown in Fig. 147. This is a circular toy with a sword or ax pivoted from the center much as the hand of a watch is pivoted. At the position which

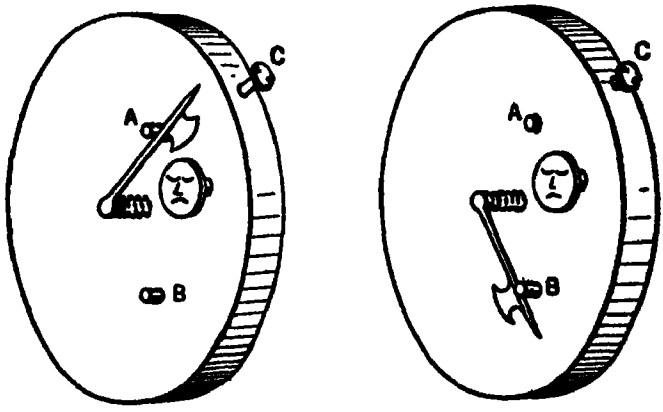


FIG. 147.—Diagram of "Yogi" toy. Explanation in text.

corresponds with III on a watch face is projected the head of a girl. The sword is placed at the position corresponding to II. At the push of a trigger the hand swings counterclockwise and stops at the position corresponding to IV on the face of a watch. It seems to the observer that the sword has gone directly, in a clockwise direction, from II to IV and thus has cut off the head

of the girl. He is mystified to see the head unharmed. In reality the sword has traveled the long way round, in a counterclockwise direction, from II to IV. He sees the sword only at the beginning and at the end of its movement, but he has the definite impression that he has seen it move from one spot to the other. [16]

The experience, attitude, temporary set, or expectation of the observer. Whereas movement may be seen when the observer takes a naïve attitude toward the situation, a searching or analytic attitude may eliminate or impair the apparent movement. On the other hand, whereas a movement that is not natural may not be seen by an instructed subject, he may see the movement easily when told what to expect.

Retinal factors. A change in the visual fixation point may change the character of the apparent movement. The waterfall illusion is an illustration of the influence of this factor. Let an individual first fixate his vision on any portion of a waterfall and then shift his gaze to some portion of the surrounding scenery. The scenery will appear to move in the opposite (upward) direction.

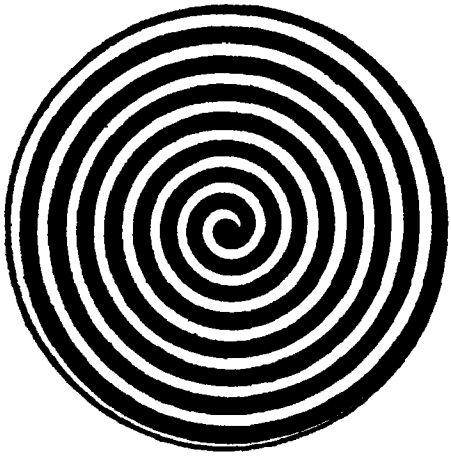


FIG. 148.—Spiral illusion. Reproduce this figure on a circular card, spin it slowly on a pin through the center, for about ten seconds, then quickly stop it, and continue to look at it after it is stopped. It will seem to expand or contract, depending on the direction of rotation.

(From M. Luckiesh, *Visual Illusions.* New York: D. Van Nostrand Co.)

The afterimage of movement may best be produced as follows: Let an observer fixate the center of a disk containing a spiral as shown in Fig. 148, while it is rotated at the rate of one or two revolutions per second for about twenty seconds. Let him then turn his gaze to a blank object the same distance from

him as the disk. He will see a spiral moving in the direction opposite to that of the motion when the disk was fixated.

From all these facts it seems clear that the perception of motion depends upon temporal and spatial factors, as suggested at the beginning of this section. If two objects appear simultaneously, no motion is perceived. The two objects merely stand side by side. If too long an interval is allowed to elapse between exposures, and the stimuli are separated far enough in space or are different enough in some other characteristics, the observer sees first an object here and then an object there. If he sees an object and then, after a suitable time interval, sees the same object or one not too much changed, at a different spot, he gains the experience of motion whether he sees the actual motion or not. The truth of the matter is that, in ordinary life, we actually see very little motion and most of our experiences of motion in external objects are based on the principle of perception set forth at the beginning of this chapter; namely, that perception is a guess or immediate inference.

PERCEPTION OF TIME

Time is ordinarily perceived with great inaccuracy. Experimental evidence seems to favor the opinion that learning modifies skill in judging time intervals and that accuracy of judgment is affected by apparently irrelevant factors. [2, 9]

Perception of time dependent upon succession of events. Time can be conceived only by reference to a certain succession of events. Physical time implies a succession of irreversible changes in the physical universe, such as the movement of the earth in relation to the sun. Physiological time might be conceived to imply a succession of changes in the physiological universe, and psychological time might imply a succession of psychic processes. There is evidence that the perception of time is influenced by all three types of succession.

1. The estimation of time is probably affected by physiological activity. If physiological activity is retarded, physical time will appear to move more rapidly by contrast. This may be a factor in the familiar fact that time flows more quickly in old age than in youth. This effect can be understood if physical time is represented by one train moving at constant speed and

physiological time by another train moving on a parallel track. In youth they might be running neck and neck; as the person becomes older, the physiological train will slow down and the other increase its relative speed.

Experiments dealing with the effect of drugs on time estimation substantiate this point of view. Drugs which accelerate the metabolic rate—that is, cause the individual to live faster—cause an individual to underestimate a definite time interval; drugs which slow down the metabolic rate lead to overestimation of a definite time interval.

2. Estimation of time depends upon some frame of reference. Suppose that a subject is given the task of estimating the interval between two sound stimuli. If the first sound is prolonged, the interval between it and the second sound is judged to be longer than if the first sound is short. That is, the observer tends to judge the total interval including the sounds as well as the silent interval between them.

3. The happenings during an interval of time affect the judgment of time. Filled time seems shorter than empty time. An interval of time filled with rhythmic music seems shorter than time filled with a monotonous tone. If an individual is made totally unconscious for a period of time by means of an anesthetic, the interval between going to sleep and waking will appear shorter than an interval of wakefulness because of the complete emptiness of the period during which the anesthetic operates.

The perception of rhythm. Rhythm is a regular recurrence of groups, of patterns, or of successive impressions. It can take the form of a pattern of movement, as in dance steps; of a pattern of sounds, as in music; of a visual pattern, as in a decorative border; or of a pattern of words, as in poetry.

Some rhythms may be inherent in objective events. This occurs in music, where the sequences of tones may be stressed by time relationships, by relative stresses, or by regular changes in pitch. Rhythm may occur in such movements as marching, swinging on a bar, waving a part of the body, or the like. It occurs naturally in poetry where the stress on different syllables gives the words a pronounced regularity. From a study of such natural rhythms it appears that they are perceived because they correspond to some real or fancied movement. If a person is

observed closely when he is attempting to interpret some complicated rhythm he can be seen to move different parts of his body. Those rhythms which he can follow with his hand, arm, foot, or head are most easily recognized.

When a series of impressions have absolute uniformity, the recipient does not usually perceive them as a succession of unitary events occurring in sequence. He tends to group them, to stress certain ones, and to introduce rhythm into the series. In other words, he gives a subjective rhythm to physical events which are spaced identically in time and stressed equally in force. This tendency makes it easier to perceive a long string of events, it makes it easier to recall them, and it makes them more interesting so that attention can be maintained for longer intervals. In other words, rhythm is a way of introducing meaning into successions of events. When there is a natural rhythm inherent in the events themselves, this process is easy. When such a natural rhythm is absent, the observer creates one in order to assist him in perceiving these events.

The tau effect. The tau effect is the name given to an illusion in which judgment of spatial intervals is influenced by the temporal intervals involved. For example, if three stimuli are presented in succession at equal spatial but unequal temporal intervals, and if the time between the first and second stimuli is shorter than that between the second and third stimuli, then the first and second stimuli appear to be closer in space than the second and third stimuli. The tau effect can be observed in vision and in touch. It persists even when the observer attempts to allow for it.

In vision the tau effect can be brought out by the following procedure: Three discrete points of light are successively presented. The distance between the points of light are equal but the time interval between the first and second points of light is greater (or less) than the time interval between the second and third. The perceived space between the first and second will be greater (or less) than the perceived space between the second and third points of light.

This tau effect is a neat illustration, which may be used as a parlor trick or game, of the relationship of time and space.

ILLUSIONS

An illusion is a misinterpretation of the sensory impressions upon which a perception is based. We have already examined a number of situations in which the observer is likely to have difficulty in interpreting his sense impressions correctly, some in which a number of different interpretations are possible and some in which his perceptions did not agree with the external stimulating conditions. These illusory factors were most striking in the perception of movement, or the phi phenomenon.

It happens in some situations that the observer recognizes such errors while they are being made. He sees the discrepancy and attempts to effect some sort of compromise. His reaction to such situations is characterized by bewilderment or amusement, and is usually accompanied by a recognition of his error. He usually experiments in some manner, repeats his experiences if possible, or tries in some way to determine the true state of affairs. His attitude is the same as that of a person witnessing a sleight-of-hand performance. He perceives events which are incongruous with other known events or which violate his reason. He attempts to understand but, when he cannot, is willing to admit that there is something wrong even if he does not know what causes the incongruity. We shall review some typical illusions and examine some of the theories advanced to explain them. [15]

Geometrical illusions. Geometrical illusions result from misinterpretations of total geometrical figures owing to errors in determining the length, area, direction, or curvature in patterns of lines. They make an interesting study because they are common to practically all individuals and so must depend upon some common characteristics in human beings. They are, however, so diverse that it would be a mistake to attempt to explain them all by means of one general or common principle. Since there is disagreement about the factors accounting for them, the beginning student can do little more than become acquainted with the different kinds.

1. Vertical distances are perceived as greater than physically equal horizontal distances. A pole or a tree is generally judged to be longer when it is standing than when it lies on the ground.

In Fig. 149 the vertical line appears longer than the equal horizontal line.

2. Small angles are relatively overestimated, and large angles are relatively underestimated. This distortion of angles shows

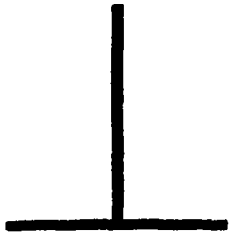


FIG. 149.—The vertical line appears longer than the horizontal line.

itself in various situations. A continuous straight line, when broken at an acute angle by other lines or by some object, seems no longer to be a continuous line; instead, the two projections seem to be separate lines. This illusion is shown in various forms in Fig. 150.

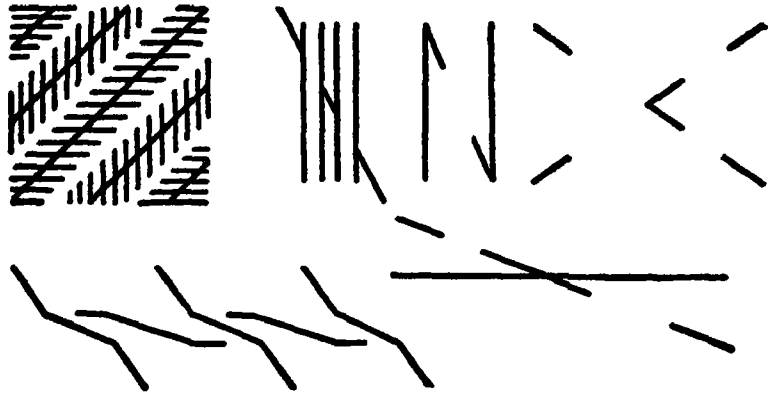


FIG. 150.—The angle illusion. Small angles are relatively overestimated, and large angles are relatively underestimated.

3. Simple perceptual judgments may be made inaccurate by the addition of misleading and complicating lines. This is well demonstrated in Fig. 151. The two lines at the top of the figure are equal in length. In the rest of the figure, lines of the same length are repeated, but with the addition of other lines, thereby destroying the ability of the observer to make an adequate comparison of the original lines.

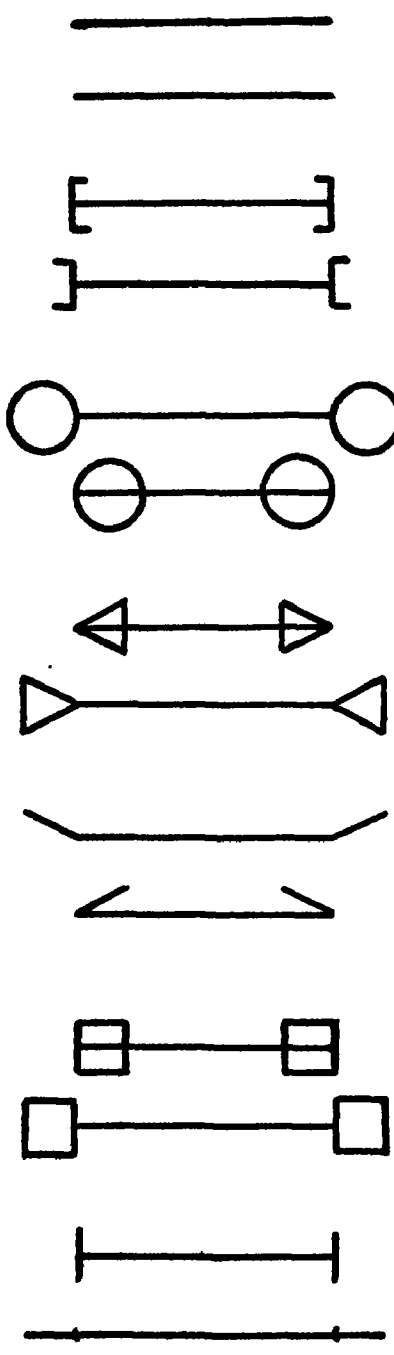


FIG. 151.—Complicating lines distort simple perceptual judgments. The isolated lines at the top are easily judged to be about equal in length. Judgments are made almost impossible by the addition of various complicating lines.

4. Optical limitations make illusory effects. If a symmetrical checkerboard effect is held close to the eye, the central squares appear larger and seem to bulge in toward the eye. Conversely, if

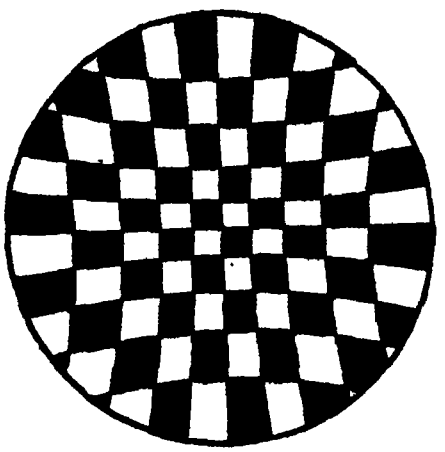


FIG. 152.—Checkerboard illusion. Hold the figure close to the eye and the tiles will appear to be square.

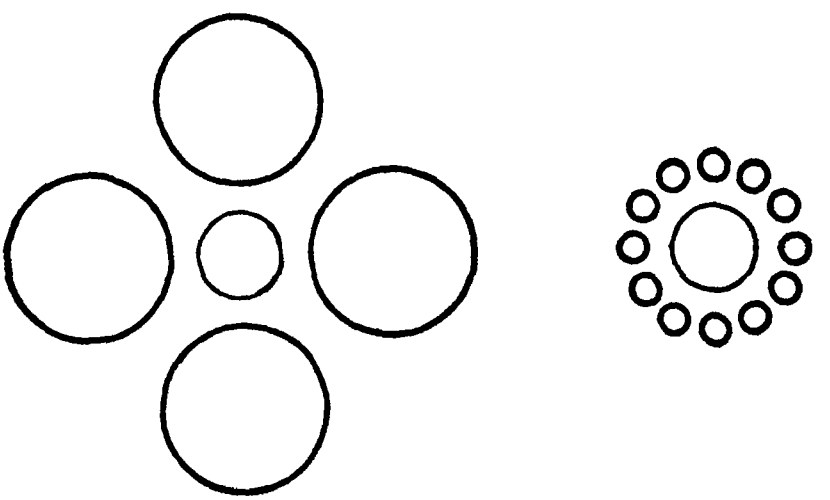


FIG. 153.—Contrast influences judgment of size. The inner circles are of the same size. Large surrounding circles make the enclosed circle appear smaller, whereas small surrounding circles make it appear larger.

Fig. 152, in which the squares are smaller in the center and larger on the periphery, is held close to the eye, it appears as a symmetrical checkerboard.

5. Contrast effects influence perception. The apparent size is partly determined by the objects surrounding it. In Fig. 153, for example, the inner circles are equal in size, but the one at the left seems much smaller than the one at the right. The influence of this contrast effect in a practical situation is shown in Fig. 154.

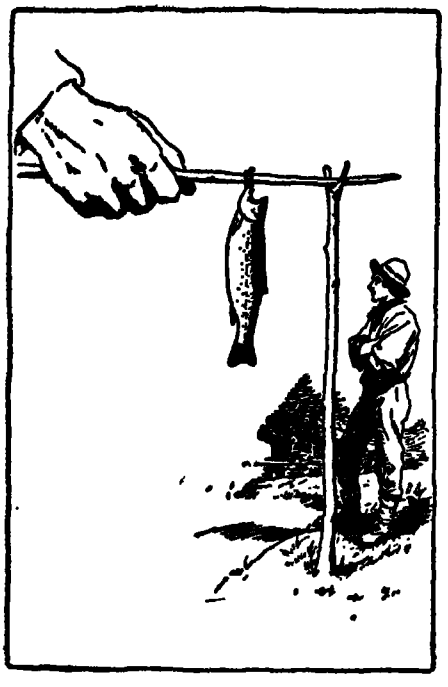


FIG. 154.—The influence of contrast. Cover alternately the hand, and the man and forked-post support. Note the change in the apparent size of the fish.

(From H. E. Bennet, *Psychology and Self-Development*. Boston: Ginn & Co.)

Explanations of illusions. Psychologists have been concerned with discovering one general principle to explain all geometrical illusions. It should be apparent that such an undertaking is destined to fail because each illusion probably depends upon a different combination of factors. Nevertheless, the student should know what theories have been advanced to explain them.

The eye movement theory. This theory assumes that the impression of length is obtained by moving the eye along a line from one end to another. If vertical movements are more strenuous than horizontal, a given vertical distance calls for more effort than the same horizontal distance and therefore seems longer. The strongest argument against this theory is that numerous experiments, in which the eye movements have been photographed, show no such movements of the eyes during examination

of the figures as this theory would require. If eye movements play any role, it certainly is a minor one.

The perspective theory. It is a fact that a line drawing readily suggests to the observer objects in three dimensions and, while studying the perception of depth, it is shown that the perception of depth in line drawings is subject to error. However, many other geometrical illusions cannot be explained by this factor.

The empathy theory. Empathy means the imaginary projection of oneself into some objective situation. Applying this theory to such an illusion as the vertical-horizontal illusion, it is contended that a vertical line by resisting gravity suggests effort and thus appears longer to the observer. This theory is purely speculative and is not backed by any experimental evidence.

The good-figure theory. Those who would explain illusions by the good-figure theory define a good figure as one which expresses some characteristic fully, or is complete in its meaning. When one observes a figure having some characteristic, his tendency is to see this characteristic as fully as the conditions will allow. A near-circle is seen as a true circle or as a better circle than it is; if compactness is suggested by the figure, it will appear to be more compact than it is. This is merely a description of what seems to happen in some illusions and is not an adequate explanation of illusions in general.

The wrong-response theory. This theory is not so satisfying to some individuals as some of the others but it seems to get at the root of the matter better. If a person sees a figure incorrectly, he has no notion of his error unless that is forced upon him by some other aspect of the situation. He measures a line and finds it is not curved as it seems. He finds the center of a circle and completes the part omitted or distorted and thus proves that he saw it incorrectly. He measures two lines which appear unequal and finds that they are equal. Thus, he finds by experiment, by the test of other senses, or by evidence of some sort that he was wrong. An illusion is not an illusion until it conflicts with other perceptual data.

The explanation of any illusion must be an account of why the observer's first reaction and subsequent data do not correspond. The actual facts will probably be different in every case.

To attempt to explain them all on one basis is equivalent to explaining every trick of a clever sleight-of-hand performer by the same device. Illusions are tricks our senses and past experience play upon us and these tricks are probably extremely numerous.

The impossibility of deriving some simple principle to explain all illusions will become still more apparent by an examination of some illusions involving factors other than geometrical distortions.

The size-weight illusion. The size of an object has a definite influence upon judgment of its weight. If two objects are the same in weight, while one is larger than the other, the larger weight will be judged lighter. A pound of lead will feel much heavier than a pound of feathers. Load two pillboxes, one much larger than the other, with paraffin and shot so that they both weigh the same. Your friends will invariably judge the smaller one to be the heavier.

This illusion is usually explained on the basis of set or expectation. Since the two boxes are of the same material, one unwittingly judges them to be of the same specific gravity. Having picked up the smaller one, the observer expects the larger one to be heavier. When he finds that it is not so heavy as he expected it to be, it actually seems lighter. In short, it is judged lighter than the other box because it is lighter than he expected it to be.

Cyclorama illusion. An interesting and useful illusion of spatial relations can be produced by placing in the foreground a number of solid objects and have them melt into a painted background, so that the observer seems to be in the midst of a great open area. Objects of natural history are often mounted in glass cases in such a way that they occupy the foreground with an almost imperceptible transition to painted scenery in the background. This illusion probably depends upon the fact that the perception of depth is definitely created by the disparate images and binocular parallax of the near objects and the use of other monocular cues for the painted wall effects.

The confused finger-movement illusion. This illusion illustrates the fact that visual and kinesthetic cues may combine in a perceptual situation and, when the visual cues are reversed,

confusion results. With the hands held in the position indicated in Fig. 155, have someone instruct the subject to move a specific finger by pointing to it. He is likely to move the corresponding finger of the other hand.

When the subject closes his eyes and is instructed to move a certain finger he can do it without error. In other words, when he looks he uses visual cues and moves the finger that would

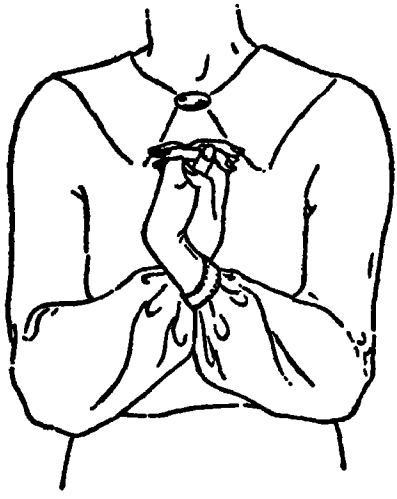


FIG. 155.—Illustration showing the position of the fingers ready for a demonstration of the confused finger-movement illusion.

ordinarily be pointing in the direction of the finger designated but which is now reversed.

With practice the illusion disappears, not so much from a conscious differentiation between right and left hands as from gradual and almost unconscious fusion of visual cues with the correct kinesthetic and tactual cues.

HALLUCINATIONS

A hallucination is a perception that occurs when there is no objective stimulus to give rise to the perception, or a perception that is so gross a misinterpretation of the objective stimulating factors as to have little or no apparent relation to them. In an extreme and pathological form a person may hear voices talking to him when there is no objective source of such voices; he may see visions when there is no objective visual stimulation; he may feel objects touching his body when there is nothing in contact with the area indicated by his perceptions; or he may feel himself

being transported through space when absolutely motionless. However, the term "hallucination" should not be limited to pathological conditions. Since misinterpretation is a relative term, there is no possibility of making sharp distinctions between illusions, hallucinations, and pathological hallucinations.

Factors which contribute to hallucinatory experiences. While it is true that everybody is sure to misinterpret his sensory experiences to some degree, it is also significant that each individual attempts to correct any perceptual errors that arise so that his final interpretation of objective conditions be as nearly accurate as possible. This being true, an examination of some of the factors contributing to hallucinatory experiences may indicate what precautions an ordinary person should take in order to avoid being deceived too completely by his perceptual mistakes. [13]

Predominance of subjective components characterize hallucinations. In any perception there are individual factors. In a hallucination these subjective components are given undue weight. For example, the lone person in a large house at night, after having been told of recent burglaries in the neighborhood, is more likely to interpret a sound as the entrance of a burglar than if the fear of burglars were not so pronounced.

Resistance to contradictory evidence contributes to gross distortion of perceptual interpretations. Persons who have pathological hallucinations demonstrate clearly the presence of this factor. For example, if a person is tempted to do some immoral act, he may be frightened by the very thought of such an act. Instead of recognizing the temptation as a part of his own thinking, he may interpret it as the suggestion of some outsider. If he can interpret it as a voice coming to him he thus escapes self-condemnation. Any evidence against the reality of the voice is rejected because such evidence would make it clear that his temptation was part of his own personal thinking. He rejects evidence against the error of his perception because such an error is more comfortable than the truth would be.

A hallucination is likely to be acted upon as though it were real in spite of evidence of its falsity. Action is the final test of how seriously a person takes his perceptions. In a simple illusion the person is not likely to act on the basis of a perception that he

knows is wrong. He takes objective checks as the final test and acts accordingly. When a person rejects factual evidence and acts on his own errors, he certainly is evidencing an unwholesome interest in maintaining such errors. For example, when a woman leaves her real husband to live with an imaginary husband and considers this fictitious man the only real husband, she is manifesting an extremely morbid hallucinatory trend. When a young man sees only the beauty in his chosen girl he is doing a similar thing, although there is a vast degree of difference in the amount of distortion involved.

It should be apparent, from the numerous kinds of perceptual errors that are possible, that the normal man should never be sure of what he sees, hears, tastes, smells, or touches. He is continually checking his perceptions by additional evidence from the various senses, by experiment, and by the ways in which others around him behave. At the same time he must act as though his perceptions were accurate. The normal procedure is to make the best interpretation that one can, but at the same time accept corrections without hesitation. It is when one does not accept corrections that he develops pathological hallucinations. If I hear a voice calling my name and, upon investigation, find no source for the sound, I should admit that I was mistaken. If I insist that it was a departed loved one speaking to me I am giving an unwarranted interpretation to an error.

Sometimes it may be difficult to determine whether a perception has or has not a relevant sensory basis. An interesting illustration came to light in one case when a man heard radio broadcasts without being near a receiving set. It appeared that these broadcasts could not be wholly subjective, for they corresponded in content and time with broadcasts actually being given. Investigation showed that the fillings in his teeth combined with carborundum deposits on his teeth to form a crystal receiving set. He was not hearing hallucinations; he was hearing actual broadcasts.

Factors which cause hallucinations. Genuine hallucinations require a set of conditions which permit drastic distortion of sensory experiences. They cannot all be explained upon the same basis, any more than any perception can be attributed to the operation of any one factor. Causal factors may be divided

into two main groups: (1) those producing a malfunctioning of the sensory processes and (2) those depending upon an attitude or set in the individual which makes it advantageous to him to distort his sensory experiences.

1. *Physiological factors favoring hallucinatory experiences.* Any condition that impairs the efficiency of the sensory mechanism may contribute to perceptual distortion. Some of these conditions are: fatigue, fever, deliria, diseases of the sense organs, and poisoning by such drugs as alcohol, cocaine, morphine, mescal, or hashish.

Such hallucinations frequently take a form corresponding to the nature of the physiological disturbance. For example, alcohol may disturb the ears and thus make it easier for an individual to experience auditory hallucinations; cocaine may cause a disturbance of the touch sense organs and be interpreted as the activity of tiny animals crawling over the skin; mescal may stimulate acute visual imagery. Unless the disturbance is extreme, however, the individual who has a hallucination based on a purely physiological background is likely to have some notion that his perception is not real. The man with delirium tremens sees snakes, but at the same time he has a suspicion that they are not real snakes. When subjective factors dominate, the individual is more likely to believe that his perceptions are real.

2. *Attitudes which favor hallucinations.* When an individual has a need for a certain interpretation he is likely to distort his perceptions in a direction that makes it more adequate to meet the need. Three subjective factors which favor such distortion may be outlined as follows:

(a) The habit of daydreaming. Individuals vary in the ease with which they can let their imaginations play. When such imaginings are so clear that the observer claims they equal actual sensory impressions in vividness and liveliness, they have been called eidetic images. Such images occur most frequently in uncritical children, almost never in adults who have an objective, critical, and unemotional outlook on life. Although no such relationship has been demonstrated, it would be logical to suppose that a person who finds it easy to develop eidetic images would also find it easy to have hallucinations.

(b) Emotional tensions. In inflammation of the ear

caused by fatigue, disease, or drug there may be buzzing sounds that will be heard as simple sounds by an emotionally stable individual. Suppose, on the other hand, that certain emotional tensions are added to the physiological disturbance. A person who is afraid that he may be caught in a lie he has just told may hear the buzzings as voices calling him a liar. A person who is having difficulty in making an important decision may hear the buzzing as an answer to his problem. The mother who is worrying about her son on the battlefield may hear the buzzing as his voice.

(c) Persistent temptations. All individuals have impulses to commit acts or at least to think thoughts which they would rather avoid. When such impulses become too unpleasant, it may be easy to explain them on the basis of impressions from the outside world. Such projections free the subject from guilt. If someone puts the ideas into his head, he is not to blame, so he feels. When he is tempted to steal he can deny any impulse by stating that some voice from outside told him to steal. Having resisted such a suggestion, he may feel genuinely virtuous. Thus, the hallucination has value for him and he wants to believe it.

QUESTIONS FOR REVIEW

1. Define perceiving.
2. Enumerate some of the factors involved in perceiving.
3. What part does the selection of cues play in the process of perceiving?
4. Differentiate between logical and perceptual conclusions.
5. To what extent do different individuals perceive the same situation uniformly?
6. What factors influence the reliability of perceptions?
7. Describe the various factors that influence attention.
8. How is objective constancy affected by perception?
9. State the rules for making perceiving more adequate and reliable.
10. Describe the factors affecting form perception.
11. What do ambiguous figures reveal about the significance of shifting in perceiving?
12. State the distinguishing characteristics of a figure as contrasted with the background.
13. Enumerate the factors which favor the perception of a figure and make it distinct from the background.
14. State the principles that may be operative in masking.

15. Explain the operation of each of the factors involved in the perception of distance or depth.
16. Under what conditions may motion be perceived?
17. What is the phi phenomenon?
18. Outline the conditions for each of the following types of apparent motion: (1) alpha motion; (2) beta motion; (3) gamma motion; (4) delta motion; and (5) epsilon motion.
19. Explain the effect of the following factors on apparent motion: (1) time; (2) distance between stimuli; (3) absolute intensity of stimuli; (4) relative intensity of stimuli; (5) character of stimuli; (6) attitude or set; and (7) retinal factors.
20. What is the prime essential for the perception of time?
21. What factors affect the perception of time?
22. How may rhythm be regarded as a form of meaning?
23. Explain the tau effect.
24. What is an illusion?
25. Describe some geometrical illusions.
26. What theories have been advanced to explain illusions?
27. Describe the size-weight illusion.
28. Describe the cyclorama illusion.
29. Describe the confused finger-movement illusion.
30. What is a hallucination?
31. State three essential characteristics of hallucinations.
32. What factors contribute to the development of hallucinatory experiences?

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Chapter XVI

PROBLEM SOLVING

A PERSON may be said to be confronting a problem when he is in a situation containing some elements, factors, or conditions that are known and others that are unknown; and when he is somehow stimulated to achieve a result that depends upon his discovery of how to utilize some of the unknown elements, factors, or conditions. A problem involves uncertainty and the solution of a problem entails clearing up the uncertainty, the finding of a path or course of action that has not been clear and open. Problem solving is a type of adjustive behavior.

KINDS OF PROBLEMS

Variations in clearness. Problems vary greatly in the clearness with which they may be formulated. The most clearly formulated problems can usually be answered by a simple yes or no. For example: Shall I take the road to the right at this fork? Shall I buy this article? In some problems a simple discrimination is all that is required. For example: Which of two colors is more pleasing? As the factors involved in a problem increase in number, the part played by each element becomes more obscure and, for this reason, the formulation of the problem itself becomes difficult. In the most intricate problems, the individual confronting the situation usually does not know much more than that he is uncomfortable and must do something; but what to do he cannot discern. [57]

Variations in openness or accessibility of relevant factors. In some problems, success is largely dependent upon ability to select from a great many elements those which are most relevant in the present situation. Some brain-teasers and puzzle problems give false cues as to the importance of various factors, and thus tempt the one who is trying to solve them to make

continued false responses. On the other hand, a person may become so intent in searching for some hidden or intricate solution that he fails to discern a correct procedure that is clearly apparent. An interesting parlor game illustrates this principle. Various objects, such as a penny, a hairpin, a cigarette, a match, a piece of string, are placed around a room in plain sight, so that nothing need be moved to see them. Each member of the group is given a list of the "hidden" objects and is required to designate where they are. Searchers will mill around, hunting for these objects, and frequently will look straight at them without discerning them. When an object is noticed, the finder is usually surprised that he had such difficulty in seeing it.

Variations in the number of processes necessary for solution. Some problems involve only one step. Once the point of the problem is discerned, that one step may be taken and complete solution effected. After such a solution, repetition leads to no improvement, except possibly a slight decrease in the time required to repeat the correct act. A simple puzzle illustrates this principle: This puzzle consists of a trough in which are two BB shot. The problem is to get one in a socket at one end of the curved runway and the other shot in the socket at the other. If the whole puzzle is tipped toward one end the shot will drop into one socket. When the puzzle is tipped in the opposite direction far enough to permit the second shot to drop into its socket, the first shot will come out into the runway. The correct solution is to spin the puzzle so that centrifugal force will throw each shot in a separate direction, and each will fall in its appropriate socket. Once the trick is learned, it takes but one flip to solve it, whereas the novice will toy with the apparatus indefinitely trying to roll one shot into its socket without dislodging the other.

On the other hand, a problem may involve so many movements or factors that even after all the essential steps are known their operation takes considerable time, skill, and patience. An example of such a problem is the disk transfer puzzle. [48, p. 472] In this problem, ten disks would require 1,023 moves; twenty, over a million; and thirty, over a billion. Certainly, the learner cannot go about solving such a complicated problem in the same manner that he would set out to solve a puzzle which depended upon one trick act.

Variations in urgency. Problems differ in the degree of intensity of the demand for solution. To extricate oneself from a wrecked vehicle would be a problem; but the need for a solution would become much more urgent were the wreckage to catch fire. An emergency should not be regarded merely as a single new element added to a systematic problem that would customarily be solved by fixed methods; the emergency transforms the routine problem into a totally new situation requiring different treatment. New techniques in industry, new procedures in surgery, and the like, have often arisen when it has been discerned that the present situation could not be met adequately by a speeding up of old methods. Emergencies have contributed extensively to human progress and invention.

Variations in ability of challenged individual. Problems vary in relation to the training and ability of the individual who confronts the problem situation. No problem exists except in relation to an individual to whom it is a challenge. If the situation is so far removed from the experience of the individual that he has no comprehension of its significance, it certainly is not a problem so far as he is concerned. The two-year-old boy cannot be made to search for a solution to the problem of unemployment or surplus production, but he can be very much alive to the need for recovering the ball that has rolled under a hot radiator beyond his reach.

Variations in methods for solving problems. There is no one solution for any problem. Instead, most problems have more than one solution, and these can be reached by different routes. One solution may be better than another, or one method may be more expeditious than another; two facts which suggest that we probably do not have the ultimate answer to any problem. Problem solving is thus an intriguing game. Even if we have a solution, there may be a better one if we hunt long enough, and with sufficient experience and intelligence; and even if we have found what appears to be the best answer, there may yet be a better way of reaching that goal.

Having arrived at a solution for a problem, the problem solver is losing much of the benefit of his endeavors if he becomes self-satisfied. The greatest value of success is not success itself, but the guidance it may provide for the finding of a better

solution or the reaching of a goal by different routes. We shall find that success may be a matter of chance or may be the result of careful analysis and clear thinking. If an individual complacently congratulates himself for a chance success he is less likely to advance from random methods to more rational procedures than he is if his interest is centered in problem solving as a game. Success should be only a temporary stopping place; it should be a period of respite during which to get one's wind, a time during which one may pause long enough to analyze his methods critically.

TOOLS FOR SOLVING PROBLEMS

A good mechanic may need few tools, but the expert knows how to use the finest of tools. Since problem solving is the most important task that confronts a human being, it is important for him to utilize the best tools that are available and to select the correct ones to fit each need.

Random activity. Could an individual be placed in a totally new situation, one in which he had no conceivable cue as to what kind of behavior to favor, he probably would respond in a random fashion. Purely random activity would imply that there was as great a probability of any one act being made as any other act; a person would show no preference for any of the innumerable possible responses he might make. Since we all have been modified by past experience, we never act in a purely random fashion. If we see a puzzle we are more likely to manipulate it with our hands than to use our feet, to begin to scream, eat, go to sleep, or sing a song. In other words, there are all degrees of specificity of behavior from sheer chance or random behavior to completely directed and specific acts. The newer a problem, that is, the less apparent relationship there is to past experience, the greater will be the random nature of any attempts to solve the problem.

Random activity may be in the motor realm and easily observable to an outsider, as is the case when an animal is confined in a cage and tries to escape; or it may be in the thinking of an individual who is confronted with a reasoning problem that is strange to him. [49]

Random activity is a substitute, and a good one, for giving up. Suppose that one never tried a problem until he knew what

to do; he never would accomplish much. Instead, he begins floundering around, trying any hunch he may have. Eventually, if he varies his activity enough he may happen upon some act which gets him nearer his goal. He takes advantage of this lead and makes his floundering a little more specific until he falls upon another happy move.

When, in psychology, we speak of random behavior, we do not imply that there is no direction. Instead, we mean that the individual is in a dilemma from which he would be unable to extricate himself should he wait until he knows exactly what to do, and that he resorts to undirected activity with the hope that he may happen to do the correct thing. He watches closely, if he is intelligent enough to do so, the relation of his various acts to success and failure and, in the long run, tends to avoid those acts which he learns lead only to failure and to repeat those acts which seem to be related to success. [35]

Such behavior has been variously named "trial and error," "trial and success," and "fumble and success." It is a valuable tool and the good problem solver usually has learned when and to what extent to "take a chance." It is valuable in the solution of puzzles or games engaged in for pure fun. [12] It becomes rather dangerous and costly in solving problems which involve human life or human welfare. It may be a sensible thing to make a random trial in the attempt to solve a puzzle, but an unintelligent act to stake one's fortune on the turning up of a card in a poker game.

Past experiences. Utilizing past experiences in problem solving is more than repeating an act in a habitual manner. As a matter of fact, habitual behavior is inimical to problem solving. If all a person does in a new situation is to act in the same manner that he did in similar situations in the past, he thereby ignores the new elements in the present situation and, consequently, fails. Instead, a problem demands that the benefits of more than one past experience shall be somehow combined and used in the present situation. We shall see how sagacity in recombining past experiences is a most important element in solving problems.

Orientation. In problem solving, orientation is used to mean the act of determining or correcting one's relation to the goal or objective of the problem situation. Various terms have

been used by different psychologists to express the same factor: set, schema, direction, pointing. They all imply more or less the same set of processes. To keep oriented one must have a clear conception (as clear as possible) of the goal to be reached, one must be alert to the effects of various acts in relation to that goal (do they bring one nearer or take one farther away?), and one must be alert to cues in order to keep one's bearing. [65, p. 137]

Incentives. Before an animal will run through a maze he must be hungry or uncomfortable enough to be stimulated to do something. The best setup for giving an individual an incentive to solve a problem is to make the separation from the goal the direct cause of the discomfort and to make the attainment of that goal a direct relief from the discomfort. This will not only stimulate the individual to do something, but will give his activity some point or direction. Where the goal is not clearly seen in relation to the challenged person's activity the result will be activity, but activity of a more or less random nature.

In Chapter V we learned how certain physiological processes incited the individual to activity. In Chapter VI we found that the experiences of an individual modify the strength of certain drives. Furthermore, in Chapter VII we learned that emotional tensions, which result from certain maladjustments, are essential to problem solving. The individual has to do more than perceive a goal in order to make active attempts to get it. He has to want that goal to such an extent that he will continue his efforts to attain it in spite of temporary defeats, the need for delaying final gratification of his desires, the temporary failures which meet his efforts, and the necessity for giving up of other desires which are more immediate.

In human individuals who have had much experience in solving problems of various sorts, the mere presence of a problem is challenge enough to enlist their finest efforts. The so-called pure scientist is probably a person of this sort. He is not so much concerned with the immediate application of what he discovers as he is in the fun of solving the problems that confront him. He will forget his meals, his sleep, or his appointments with friends in the search for some elusive answer to an abstract problem. The outsider cannot understand this zeal because he

has not learned that a problem itself can be the greatest challenge to prolonged effort.

Language. As we proceed with our study of problem solving we shall make some comparisons of the problem-solving ability and methods of animals as compared with human beings. These studies will make apparent the tremendous advantage that language gives to the problem solver and to the thinker. Of all the tools that man uses in his thinking processes, language stands out in a unique way. At this point we shall merely point out some of these advantages so that the tremendous significance of language will be more apparent as we proceed with our survey of problem-solving methods.

By means of language (a) we are able to name objects so that they can be more readily identified on future occasions; (b) we can compare objects and experiences more easily with each other; (c) we can state relationships between objects and experiences; (d) we can classify information for future reference; (e) we can formulate abstractions and deal with abstract concepts in a manner that would be impossible without language; (f) we can state general principles or laws; (g) we can carry out logical deductions which enable us to make correct statements about situations we have never experienced on the basis of what we have learned in the past.

THE SOLUTION OF SIMPLE PROBLEMS

A puzzle is a complex combination of objects or circumstances that is mystifying or perplexing. In a sense every problem is a puzzle, but the term "puzzle" is more appropriately used when the challenging situation presents a novel arrangement of familiar elements. Once a puzzle is solved it usually looks absurdly simple.

Puzzles involving a hidden element. A common illustration of a puzzle of this sort is the picture in which there is a hidden figure. Until the figure is discerned it may be hard to locate; once it is discerned it is almost impossible not to perceive it. In many situations the significant element is embedded in apparently irrelevant factors and is consequently overlooked. This fact was clearly seen in our study of perceiving. In order to discern which elements in a situation are significant and which

are not, the individual must be able to shift his attention quickly over all possible factors, not slighting any and not becoming fixed on any one. Alert attention, keen discrimination, and minute comparisons are essential.

For example, one experimenter created a situation in which a monkey was fed whenever the experimenter picked up the food with his left hand, but was never fed when it was picked up with the right hand. The monkey had to learn to discriminate between the two hand signals, to learn that the raising of the left hand was a cue or signal that food was to be given, and to learn that the raising of the right hand was a cue or signal that no food would be received. [58] This same experimenter tried a more complicated arrangement of the same process with a kitten. The kitten was accustomed to climb up the wire netting of his cage whenever it expected to receive food. Whenever the experimenter said aloud, "I must feed those cats," the kitten was always fed; whenever the experimenter said, "I will not feed them," the kitten was never fed. It took the kitten 380 trials to learn to distinguish between the two verbal signals and to climb up the netting only when it heard the words, "I must feed those cats." [58] The student will recognize that this process of comparison and the acceptance of one factor as a cue for food involves the same sort of learning that was involved in the conditioned reaction discussed in Chapter IX.

In such an experiment the learner is helped because of the fact that the experimenter is consistent. He always arranges matters so that food will come with one signal and will never come with another. The difficulty is accentuated when the signal is one that is strange to the animal. Should the experimenter always give three signals—raise his right hand, stamp his left foot, and open his mouth—when the animal is fed, and should he never feed the animals unless all three signals were present, such a complication would tremendously increase the difficulty of the problem.

Whether the deception in a puzzle is purposely introduced by an experimenter or whether it merely happens to be present does not change the significance of the problem to the one required to solve it. In fact, most problems are deceptive and are difficult for this very reason. They give the investigator a false clue, a

suggestion which he must be able to override before success can be achieved. If one knows he is being tricked, he can give his attention to trivial incidents and details; but in natural problems one never knows whether the solution is to be found in a trivial incident or in some factor which appears to be important.

Puzzle-box experiments. In order to analyze the procedures involved in problem solving, investigators have placed dogs, cats, chicks, monkeys, and children in cages of various sorts from which escape could be gained only by performing some specific act or series of acts prescribed by the experimenter. Some boxes require the pulling of various strings or loops, or the utilization of certain objects within the cage. In some situations the essential act is simple, in others it is made complex. An illustration of a difficult puzzle box is given in Fig. 156.

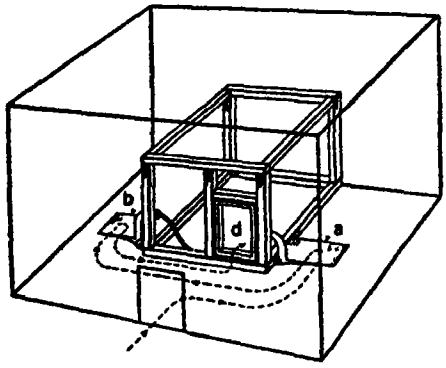


FIG. 156.—Double-platform puzzle box used with white rats. The rat enters in front of the door *d*. This door opens only after platforms *a* and *b* are successively pressed down.

A fact of first importance that appears in these experiments is that individuals differ in the way they act under such circumstances. Not only do animals of different species behave differently, but animals within the same species vary in their reactions. Some quietly lie down and must be taught the need for getting out of the pen to get the reward (for example, something to eat) by being taken out and fed and then returned. Some are violent in their attempts to get out, while others are relatively docile. Some work intermittently and others continuously. To attempt to generalize and say that all animals do certain acts in response to a problem is obviously an error. They do what their individuality, past experience, and present stimulations and irritations make them do.

When the experimenter succeeds in setting a problem that is quite new to the animal, or very difficult for him, the animal is likely to resort to trial-and-error, or fumble-and-success, behavior. That is, when the animal does not know what to do, his behavior is helter-skelter, performed in a hasty, disorderly, and confused manner.

More critical observations have shown that, after his first success, the behavior of the animal in the puzzle box is not purely random. Instead, the animal tends to give more of his time, and to devote more of his attention, to the parts of the box where he succeeded in previous trials; and to abandon, or give less attention to, those aspects of the problem which were apparently unrelated to his successful performances. In other words, there is a gradual change from aimless and random activity to restricted acts. After an animal has released himself from a puzzle box by turning a certain button, he is likely to spend much more of his time in the vicinity of that button than in some remote portion of the cage, even though he has not learned just how to turn the button to release himself. [35]

Sometimes the animal wil persist in an act that is useless; but this is probably because it has not been made clear to him that it is useless. For example, suppose that an animal is pulling at the wrong bar with his right paw, when his left paw accidentally pushes the correct bar, and the door opens. Is it strange that, on succeeding trials, he continues to pull at the wrong bar with his right paw? Such persistence should not be called random behavior. Instead, he is adhering to a false cue or hypothesis.

The problem solver, be he animal or man, often deceives himself by accomplishing his end in some unnoticed manner while devoting his attention to some irrelevant feature. Furthermore, if some new element is added after he has solved a problem in one way, this success tends to interfere with an adequate regard for the new feature. Because new parts of a situation are similar to a familiar one, an individual tends to ignore the new features and to act as though the new situation were identical to the known situation in all particulars.

This tendency was clearly demonstrated in an experiment with door-button manipulation by a chimpanzee. The chimpanzee saw a banana placed in a box through a doorway. She set about

trying to open the door by pulling, pushing, and shaking it, but with no specific attention directed toward the button which held the door shut. Eventually, after much banging and shaking, the button was pushed into the vertical position so that the door could be pulled open. From then, in succeeding trials, she devoted her time to the button or to the door near the button, and after three trials was able to open the door by a prompt turning of the button. Then another button, just like the first one, was added at a higher position, as shown in Fig. 157. The chimpanzee

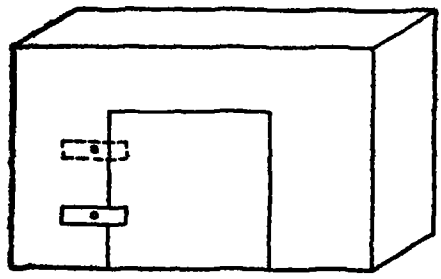


FIG. 157.—Diagram of a door-button puzzle box. The box was first presented to the chimpanzee with only the lower button. After this problem was mastered the upper button was added. The animal did not immediately note this addition. Instead, her failure to open the door by turning the lower button led to increased excitement and to a reversion to random activity.

neglected this new button and continued to devote all her energies to the first button which, she had learned, held the secret to opening the door. When this did not succeed she became more energetic in her attack on this first button, turning it back and forth and pulling at the door. Only after a considerable amount of time did she discover the second button. [65, p. 755]

We might state the situation something like this: The chimpanzee learned that a certain button had to be turned before the door could be opened. She did not learn that doors in general may be opened by turning buttons in general. When button B was added, it was not immediately grasped as a specific instance of a general principle. Nevertheless, learning the second button was easier than learning the first one, and there was some carry-over from the first problem to the second. There was also some interference because of a tendency to adhere to the type of behavior that had already proved of value.

String-pulling problems. In string-pulling problems, the lure is attached to a string, and the animal or child secures the



FIG. 158.—Illustration of string-pulling problem.

(From H. F. Harlow and P. H. Settlage, "Capacity of monkeys to solve patterned string tests," *Jour. comp. Psychol.*, 1934, 18, 425. By permission of The Williams & Wilkins Co., Baltimore.)

reward by pulling the string. In the simple type of problem there may be only one string and one lure. In others there may be two or more strings with a lure attached to only one; the problem in such cases is for the subject to determine which string to pull to get the lure. [18] Figure 158 shows a monkey confronted with a string-pulling problem, and Fig. 159 illustrates problems of varying complexity.

In an extensive experiment, in which fourteen cats were used as subjects, it was found that, even in a problem involving only one string, the cat showed no initial ability to discern the continuity of the string or to recognize that the lure could be obtained by a direct pull. Instead, there was much scratching at the barrier,



FIG. 159.—Samples of string-pulling patterns used with monkeys. The square represents a lure fastened to the end of the string. Each animal was given 100 trials with each of these patterns. The percentage of errors for each pattern is indicated. [18]

and the initial pulls were the result of accidental swings of the cats' paws. With the multiple-string problems the elimination of useless responses proceeded gradually. [61]

Another experimenter used similar methods to test the ability of infants from 28 to 52 weeks of age to solve the string-pulling problem. Small toys were tied to the string and placed on a table and separated from the child by a grill through which he could see readily. The customary responses of the child were to bang his hands on the table, to scratch around the string, to pick it up, to drop it, to grasp the string by accident while his attention was elsewhere, and to swing his arms, until finally the toy was accidentally jerked within reach. [44]

An analysis of the behavior of infants in such problems shows: (a) the child may be interested in the string with little attention to the lure attached to it; (b) the child may be interested in the toy without interest in the string attached to it; (c) he may show interest in both the string and the lure but with no insight

into the relation between them; or (d) he may experiment with the string while watching the effect of such manipulation upon the position of the toy. The last type of behavior is more unusual, but becomes a characteristic method of the older children, or of the younger children after some practice. The problem is learned in all cases by the child's own experimentation. Children



FIG. 160.—A chimpanzee fitting a small stick into a larger one so that he may thus obtain a stick long enough to reach a lure.
(From W. Köhler, *The Mentality of Apes.* New York: Harcourt, Brace & Co.)

do not discern the significance of string-pulling problems in advance of such experimental practice. [53]

Stick-reaching problems. Stick-reaching problems involve the placement of a lure beyond the reach of the subject (animal or child) but with a stick at hand by means of which he may pull the lure to him. In complicated settings, there may be a short stick at hand, which must be used to pull in a longer stick; which, in turn, may be utilized to pull in the lure. In these situ-

ations, the lure is too far away to be reached by the short stick. In still more complicated problems the sticks must be fitted together in the manner of a fishing rod to make one stick long enough to reach the lure (see Fig. 160). [1, 34]

In an elaborate experiment an ape of 12½ months of age and a child of 15 months were studied as they learned to pull an

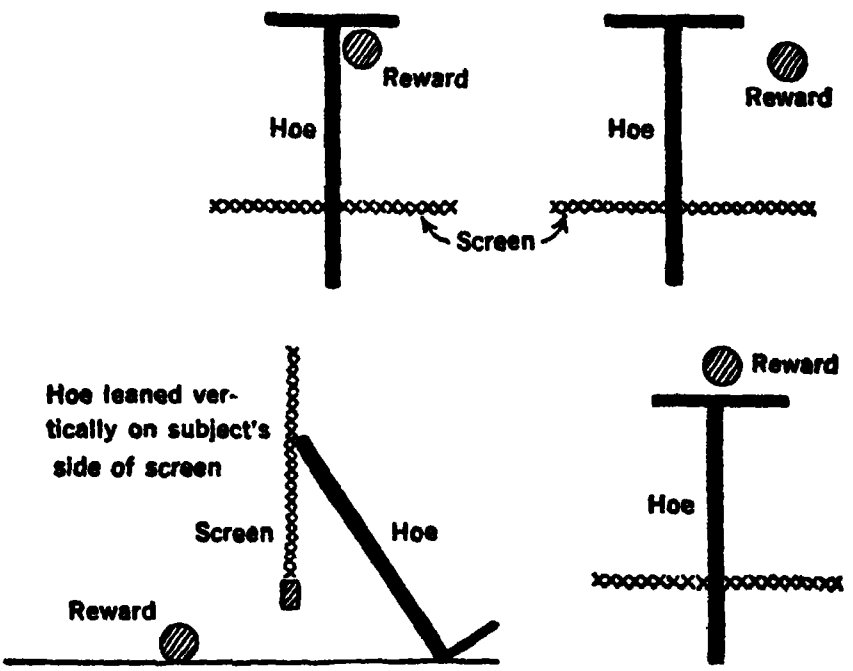


FIG. 161.—Diagram of various hoe experiments. The securing of the reward with one position did not ensure success when the positions were changed. Actual assistance was necessary before the ape or the child learned to make a lateral movement or a roundabout movement.

(From W. N. and L. A. Kellogg, *The Ape and the Child.* New York: McGraw-Hill Book Co.)

apple with a hoe from a spot beyond arm's reach on the far side of a screen. If the apple was placed so that it was between the blade of the hoe and the subject (either the ape or the child) it was easily secured by a mere jerk on the hoe handle. When the apple was placed at one side of the blade of the hoe, a jerk was insufficient and the subjects had difficulty. It took 120 trials for the child to get the apple from this side position, and the ape

99 trials. It was apparent that even these successes were accidental and after 200 trials the child had secured the apple from the side position only seven times and the ape nine times (see Fig. 161). [32]

They learned much more readily when some help was given by moving the hoe to one side while they were holding it. This assistance was not given while the subjects remained passive, but when they were actively engaged in the attempt to secure the apple. The assistance was merely a bit of guidance of an energetic movement already in progress by the subject. This would indicate that help in solving problems does not consist in doing the problem for the perplexed individual but in guiding him while the major part of the response is his own.

Once the problem was learned, additional problems were solved rather quickly. When the hoe was left standing against the screen or when the apple was placed beyond the hoe, the ape and the child both learned to secure the apple quickly.

Detour problems. Many problems cannot be solved directly. Instead, they require either deliberation or some roundabout activity. The more intelligent solver is able to turn his back upon the goal when he discerns that a direct approach is

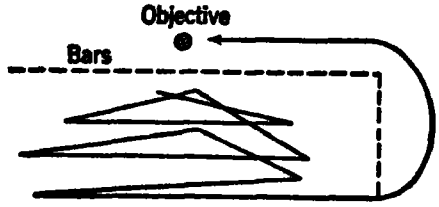


FIG. 162.—Detour problem. The broken line represents a fence separating a hen from the objective. The solid line represents the sort of back-and-forth movements made by the hen before she happened to find the way around the fence.

futile (especially when there is a direct barrier in his way) and search for roundabout methods of meeting the situation. Important factors in problem solving are the recognition of an error when one has been made, and the substitution of some other line of action to replace the erroneous one.

One experimenter tested the ability of chickens to solve a problem which demanded a detour. Hens were separated from a visible supply of food by a fence through which they could project their heads without being able to reach the food, as shown

in Fig. 162. At some distance from the food was an opening in the fence through which they could pass and thus obtain the food. They attempted to get the food by craning their necks through the fence, by rushing against the fence, or by running up and down along the fence in the vicinity of the food. Solution came when a hen, in her excitement, extended the length of her runs and, by accident, ran far enough from the food to come to the gate. Such an experiment indicates that the hen has a difficult time making a detour and, from the observer's viewpoint, is acting very unintelligently. [34]

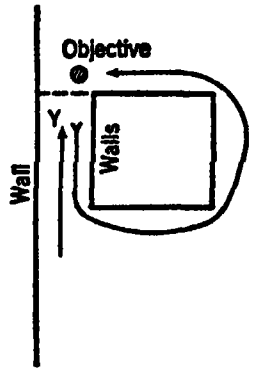


FIG. 163.—Detour problem as solved by a dog. When the dog reached the point Y and discerned that he could not reach the objective directly, he faced about and ran around the walls with little hesitation.

On the other hand, a dog when placed in a situation where he finds he cannot get to his goal directly because of an interposed barrier will make an about-face and go around the obstacle, as shown in Fig. 163. The dog's behavior appears more intelligent because he quickly realizes that he must change his approach if he is to gain his objective, and sets about doing so even when his activity takes him away from his goal. [34]

We shall encounter the same principle when we study the thinking processes in human beings. The intelligent thinker is the one who can discard a hypothesis, a theory, or a method of attack when he has evidence that he is in the wrong and can consider some factor that may appear to be taking him away from the problem itself. The unintelligent thinker is dominated by habit and tradition. The intelligent thinker is willing to do unusual things, to try anything once; but he is also willing to discard a procedure once he finds that it is erroneous.

Box-stacking problems. The setting for the box-stacking problem is to suspend some coveted object, a bit of food for an animal or a toy for a child, beyond the reach of the subject and, at the same time, place a box in the vicinity which, if properly used, will enable the subject to reach the food with its help. In one experiment a hungry chimpanzee was placed in a cage, from the ceiling of which was suspended a banana, with a box thrown casually on the floor of the cage some distance from the point where the fruit hung suspended. The chimpanzee spent many hours in his unsuccessful attempts to get the fruit, jumping up toward it, climbing the walls, and the like. After the animal had shown that he was incompetent to cope with the situation, the experimenter dragged the box across the floor of the cage to a point beneath the banana, climbed upon the box, reached the banana, and then got down and threw the box to one side of the cage. The animal profited from this example, pulled the box over under the banana, climbed upon it and reached the banana. The same experiment, when tried on a stupid ape, was not successful. He climbed upon the box, raised it over him, but never learned to use the box as an instrument for obtaining the banana. [34]

Another experimenter tried a similar test using both a child (age 15 months) and an ape (age 12½ months) as subjects. A cooky was suspended from the ceiling and a chair was used as the tool upon which the subjects could climb to get the cooky. The preliminary instruction consisted of placing the chair beneath the cooky and permitting the subjects to climb upon the chair and get it. After these preliminaries they were given trials of five minutes each, during which they could manipulate the chair as they saw fit. The ape secured the cooky in the first trial, the child in his fourth trial. The ape failed only once in twenty attempts, the child four times. Furthermore, the ape seemed to grasp the significance of the problem more clearly than the child, keeping his eye on the cooky while manipulating the chair, whereas the child would push the chair around without much regard for the location of the cooky and seldom looking at it (see Fig. 164). [32]

Once a subject, animal or human, has learned how to utilize one box or chair as a means for reaching a dangling object,

it is relatively easy for him to carry over this learning to situations where two or more objects must be stacked, one on the other, to attain the necessary height. In doing so, however, the subject has to learn that his previous methods are ineffective in the present situation. [34]

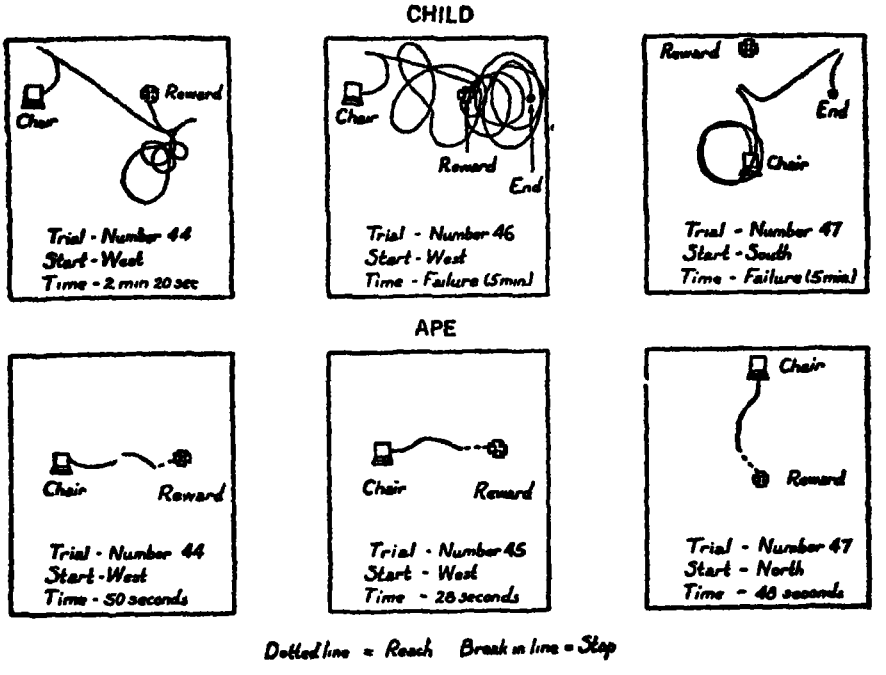


FIG. 164.—Critical trials of the suspended-cooky test. When the chair was placed in the positions shown, it was moved around as indicated by the lines by the child or the ape in attempts to get the cooky suspended at the point indicated by the cross. It will be seen that the child often failed to get the reward at all, and pursued such devious and winding pathways that he appeared quite lost. Yet the ape usually solved the problem without delay.

(From W. N. and L. A. Kellogg, *The Ape and the Child.* New York: McGraw-Hill Book Co.)

Delayed reactions. It is a wise man who knows when to act and when to wait. In some situations it is profitable to act even though the outcome of activity may not be clear. When an animal is placed in a puzzle box, it pays him to get up and move around and try to get out even though he has not the remotest idea of how his release may be effected. When a man is attempt-

ing to solve a typical mechanical puzzle, he will accomplish more by manipulating the puzzle in a haphazard manner than he will by attempting to solve it by purely analytical methods. On the other hand, mistakes may be costly, and, in such cases, it pays to delay when uncertainty exists.

Delay should not merely be idle waiting; it should be occupied with a comparison of one suggestion with another so that, when a final act is made, it may be more suitable than would have

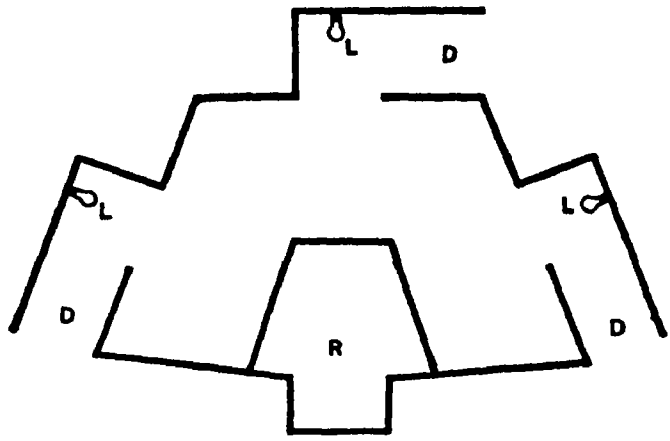


FIG. 165.—Diagram of apparatus for testing delayed reactions. The subject is placed in the release box (R). One of the three lights (L) is flashed on a sufficient time for the subject to see it and is then turned off. After an interval of time the subject is released. If he goes to the light which flashed he finds the door (D) open and gains food or some reward. If he goes to one of the other lights, he finds the door (D) closed and he gets no reward.

(From W. S. Hunter, *Behavior Monogr.*, 1913, 2, 23.)

been the case had not deliberation preceded it. It is, consequently, an important consideration how long an individual can retain the benefits of a cue or a hypothetical solution without acting upon it.

This can be tested with animals by a simple type of experiment. [25] An animal is taught that he can get food only when he goes to one of three boxes. This correct box may be distinguished by a light, a geometrical figure, a color, or some similar means. After the animal has learned that the lighted box always contains food, he is placed where he can see all three

of the boxes but cannot reach any of them. Such an apparatus is shown in Fig. 165. One box is lighted, and then the light extinguished. After prescribed intervals of time, the animal is released and permitted to choose any one of the three boxes, which now are all dark. If he chooses the right one consistently, it would appear that he profited from seeing the box lighted even though he was prevented from going to it at once.

The length of the period of delay with animals varies from a few seconds up to about 20 when there are three alternatives from which to choose, but increases to 30 seconds when the number of alternatives is reduced to two. The interval of delay is also lengthened as one advances in the animal scale, that is, there is an increase with the intelligence level. With three alternatives rats were able to delay 10 seconds, a raccoon could delay 25 seconds, a 2½-year-old child 50 seconds, and a 6-year-old girl twenty-five minutes. [67]

In another experiment, all the doors were exactly alike except for position. An animal has no means of identifying relative position by language. He cannot say to himself, "that was the middle door" or "the door to the left," or "the door to the right." He merely is given the cue that a certain door leads to food and then the means of distinguishing that door from the others is removed. How does he then make the distinction and go to the right door when he is released? In these early experiments the animals were observed to maintain a posture which oriented them in relation to the correct door. Sometimes they pointed their heads toward the door and kept them there. Whatever part of their body was used, the essential element was to maintain a constant postural relationship to the correct door. [25]

On the other hand, such bodily orientations are not an absolute prerequisite for correct delayed responses. Where the cue is more complex it may offer other means of identification and the animal does not need to maintain a posture in order to make the proper selection after a delay. [14] In another experiment a cat was restrained in a cage while the experimenter walked across the room with a plate of food and out one of two doors. After thirty seconds the cat was released and made a correct choice of doors in 68 per cent of the trials. The cat did not maintain a rigid posture pointing toward the correct door during this interval.

[7] In still another experiment the reward was placed under one of three cups in the presence of a child and the child could make a correct selection after a considerable interval with no maintenance of posture during the interval. [27]

An actual movement in the direction of the correct response enables the animal to delay his final reaction even longer than is possible if he maintains a postural orientation or pointing. It would seem that an incipient movement functions as a means of partial identification and helps the animal to make the correct choice when he is free to make a complete response. [22]

The efficiency of a delayed response depends upon a clear identification of the choice to be made. After it is clear what should be done at some later time, the interval may be filled with rest or other activity. If the only identifying factor is an object in a certain location, the only successful way of delaying, and then making a correct response, is to maintain a bodily orientation with respect to the correct object. If the correct object can be identified by some other characteristic than its position, the animal need not maintain a bodily posture during the waiting interval. Fairly complicated problems can be solved by monkeys if the setting is so arranged that the animal can utilize some cue to identify the correct response. [60] In human beings the use of language makes possible more accurate identification and a much more prolonged delay than is possible in an animal, which cannot use language.

These experiments with delayed reactions in human beings and animals show fairly decisively that, if an individual is to withhold his response to a certain problem, he must have some sort of device which will guide him at the time he does respond. Becoming aware of some identifying cue is a form of preliminary set or incipient response which is not consummated because of some restraining influence. With the animal, it is a cage that restrains him; in human thinking, caution is probably the restraining force—a fear of error from precipitate or hasty reactions. At any rate, the preliminary response creates a "set," or readiness, to consummate a specific reaction when the time is ripe to do so. In some of the lower forms of animal life, and if the situation offers no cue except a spatial one, the animal may be forced to use a posture, or pointing attitude, to keep himself oriented to the

problem. When other cues are present the animal can forgo the postural set and utilize some other cue for identifying the correct response. The ideal cue to use is a verbal one and this is the type used by human beings in most situations calling for delayed reactions.

Multiple choice. Choosing between possible alternatives certainly is a prominent feature of problem solving. While this is so, a choice may be a quite different act depending upon other circumstances than the act of choosing itself. Choices may be classified in different ways:

1. Choices may be random or rational. If the alternatives are so nearly alike to the observer that he has no grounds for making a selection, his choice must be as purely random as the tossing of a coin or the throwing of dice. At the other extreme are selections based on complete knowledge of the factors involved so that the person making the choice is practically certain of the outcome of his choice. Most of the choices made in problem situations involve some degree of uncertainty.

2. Choices may be final or tentative. The chooser may in some instances reserve the right to retrace his steps and make another selection after he has examined some of the results of his choice. In other instances, an act may be irrevocable.

3. Choices may be real or imaginary. In some cases the thinker may imagine what the outcome would be were he to choose the different alternatives, in others no such imaginary speculations are possible. Imaginary choices are prominent in certain kinds of reasoning, where the thinker withholds a final act while speculating as to the possible results of various selections he might make.

4. Choices may involve two or more alternatives. In some instances there are only two possible alternatives from which to choose, in others there may be a great number. One of the obstacles in the way of clear thinking is the tendency to devote exclusive attention to the most obvious alternatives and thus fail to discern others. The individual in the problem situation becomes so engrossed in trying to decide whether to make selection A or B (both of which could be wrong choices) that he fails to note the possibility of the correct alternative C, D, or X.

If problem solving is to be efficient, an individual must dis-

cover rational bases for choice, with the consequent diminution and elimination of chance selections. Were this not so, it would be just as sensible for a person to carry with him a coin, a die, or numbered chips to use whenever alternatives presented themselves. If there were only two, the flip of a coin could be used to determine the selection. If there were six possibilities, one could throw the die. If there were more, he could shake up the chips, using one for each possibility. Students have been observed answering true-false examinations by flipping a coin, but it is hardly conceivable that one could make a successful journey through life using no other methods than these chance throws.

A problem that has been uppermost in the minds of experimenters in multiple-choice problems, using animals and human beings as subjects, has been to discover how progress is made from purely random selection to selection by rational cues. In such experiments, the subject is presented with a number of choices (from two to eleven have been used) offering no clue as to which one is correct. The subject must make some choice by chance. If it is the wrong one, he is not rewarded and may be punished. He may then make other selections and is informed that he has made the correct choice by the absence of punishment or by receiving a reward.

The problem to be solved is arranged arbitrarily by the experimenter and the subject of the experiment is given the task of discovering the solution. For example, the correct selection may always be the object at the left of all the others, the object at the right of all the others, the second object from the left, the second from the right and the second from the left alternately. [68]

One type of apparatus for testing multiple choice behavior consists of a room into which the subject is admitted by a one way door and from which he can depart only by selecting one of four exactly similar doors, equidistant from his point of entry (see Fig. 166). These doors may be opened outwardly by a push upon them except when they are fastened by a catch that is not visible to the subject entering the compartment. The problem confronting the subject is to select the door that has been left unfastened. This he can ascertain only by actually pushing against the doors. He must search for the only unlocked door

until he finds it. If the first one he tries is locked, he may go to another. Various problems can be set by means of such a device. A typical one required that the subject learn that he could not gain exit by means of the door which had been unlocked on the preceding trial. The experimenter had a schedule, determined by chance, by means of which he determined which door to keep unlocked for each trial. [16]

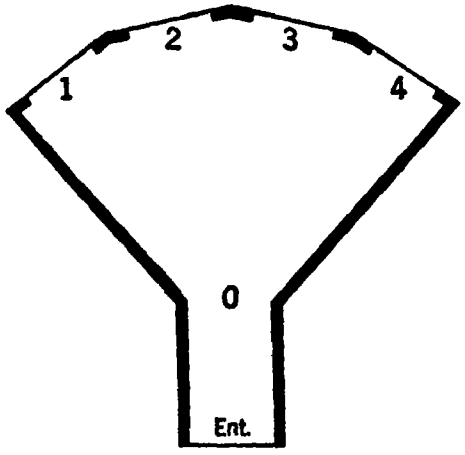


FIG. 166.—Diagram of a multiple-choice apparatus. The subject, animal or human, is equidistant from each of the four exit doors after he has entered the apparatus and reached the point O. The experimenter determines in advance which exit is correct at any one trial, and it is the task of the subject to determine what is the basis for the selection of the correct exit.

The poorest type of reaction to such a choice problem is where the subject seems to profit little from his failure. For example, he may try a door, leave it, and then return and try it again without having tried any other door. Or, he may try repeatedly two or three of the doors without trying all of them. In other words, the subject does not seem to grasp the principle that, if an act fails, it may pay to try a different one instead of repeating the identical act which brought failure. A little higher, or more intelligent, type of response is where the animal returns to a door he had previously tried before having explored all the doors. For example, he might try the sequence, 4, 1, 4, 3, 4, 1, 4, 2. A still better type of response is to adopt a pattern of trying all the doors from left to right, or from right to left, regardless of the results of preceding trials. Still better is the method of trying each door only once but in irregular order.

The best type of reaction for this particular problem is where the subject learns to avoid the door that had been left open on the preceding trial and to try each of the three other doors only

once and in irregular order. This highest type of selection was possible only for human beings above eight years of age. Animals never advanced above the more random types of choice. [16] These results may be interpreted as indicating that the animal cannot learn a temporal sequence; whereas in problems involving spatial factors the animals are able to learn the solution and make the correct choices.

The method of gradual correction. An uncritical observer is much inclined to credit an animal with "human" cleverness or with "reasoning power" when the animal demonstrates his ability to do such acts as to open a gate, to ring a doorbell, or to pull the cover off a table in order to get food that was on the table beyond his reach. The earliest workers in animal psychology argued against such an explanation and attempted to demonstrate that the ingenuity of animals in solving puzzles could be explained on a simpler basis than by attributing human intelligence to them. [45]

One of these investigators reported an experiment in teaching a dog a practical problem in mechanics. The ordinary dog usually has learned to pick up a stick in his mouth by grasping it near the middle. The stick is thus balanced and is easily carried without undue strain or dragging on the ground. In this experiment, the stick had a heavy ball on one end. To carry such a stick by grasping it midway between the two ends would result in an unbalanced and awkward act. When this stick was thrown, the dog, who had learned to carry sticks in the ordinary way, ran to retrieve it and, of course, took the middle of the stick in his mouth as he had been accustomed to do. Again and again, the stick was thrown to be retrieved, and gradually the dog learned to seize the stick nearer and nearer to the heavy end until, after an hour or two of practice, he had learned to carry it in a well-balanced manner. [45]

The early writers called such learning "trial-and-error" learning, contending that the dog learned to carry the stick correctly by making errors which were finally eliminated by chance. Probably a better name for the process would have been learning by gradual correction. This is actually what these experimenters had in mind, because, when they went on to explain what they meant by trial-and-error learning, they described it as a method

whereby the performance became more and more perfect owing to the gradual discovery of the best way of doing the act. The dog, for example, gradually found the most comfortable way of carrying the stick and then adopted that method.

This method of solving a problem is illustrated also by the parlor games commonly known as "hot and cold" and "tom-tom." In either game the subject is sent from the room and the other members of the party decide upon some act to be performed by him. Suppose he is to get on his knees before a certain girl. When he comes in he is told that he is getting hotter or colder (or the tom-tom is beaten more or less violently) according as he is approaching the required objective. As he walks toward the girl he gets his cue and continues; as he moves away he is told he is getting colder (or the tom-tom is beaten less loudly). He thus learns that he must stay at a certain spot but also knows that he must do something else. He may try various acts until finally, by permitting himself to vary his activity and at the same time correlate it with the signals, he does the right act.

Solving a problem by the method of gradual correction depends upon three factors:

1. *Variability of performance.* Learning by gradual correction certainly depends upon the fact that the learner does not perform in exactly the same manner each time. If performances were identical, there would be no basis for judging the relative value of one act as compared with another. For example, if the dog always grasped the stick at exactly the same place and in exactly the same manner each time he performed he would never learn to improve his technique. At the end of a thousand trials he would still be grasping the stick in the exact center. The fact that changes in performance occur is often due to extraneous influences. The dog may have had the carrying of ordinary sticks pretty well mastered and might have kept on in his accustomed manner were it not for the fact that a new type of stick was presented to him. The new element in any situation makes the old performance faulty. It is the changes in the challenging situations themselves that provide the need for solving problems. Variability of performance is absolutely essential because life itself is continually changing, because the old behavior does not fit.

'2. *Comparison of performances.* Problem solution depends upon some discernment of the relative merits of different acts. In many situations a person does not know what to do and his activities are purely random so far as progress toward any goal is concerned. If each of these random acts appeared to be as significant as any other act, the problem might be solved by accident, but each succeeding solution would also be accidental. When a series of variable acts is followed by a successful solution of the problem, the subject tends to make comparisons of his various acts and to interpret some acts as more related to the correct solution than were others. For example, if a cat in a pen effects his release when he has been clawing at a particular part of his cage, he will tend to stress pawing in the same general region rather than in some remote region. He has discerned some differential in value between different parts of the cage. After he has learned to favor a certain corner, he can then begin to compare the various acts which he does in that corner, and thus select one act in preference to those which are apparently unrelated to success. For example, if an animal raises his paw against a lever and gains food, whereas he gains nothing when he lowers his paw against the same lever, raising the paw against the lever will have preferential value.

It should not be assumed that an animal makes a deliberate comparison and choice in his solution of such problems. Even many adult human beings do not weigh two alternate acts and choose after deliberate comparison. If gold is found more often in California than in the Ozarks, men will devote more energy to searching in California than in Arkansas although none of them can give any reason why there should be more gold in one place than in the other. In short, as a result of the fact that, while varying his performances, an individual observes that some acts are more often followed by nearness to an objective than are others, he comes to favor those performances which make his actions quicker, easier, more comfortable, or more successful; and he comes to avoid those which make his performance more unsatisfactory.

3. *The formulation of some principle or rule as a guide for future action.* A rule based upon this method is faulty unless it is pursued further and is modified in such a manner that some

reason for the effectiveness of the behavior is discerned. This is done by isolating all the component acts in a situation, holding all constant, or making them ineffective, while varying one and observing its relation to success or failure. This is the analytical procedure of the scientist, but it is seldom carried out by the majority of individuals, rarely by children, and probably never by animals. The ordinary individual accepts his majority experiences as rules for further guidance and ignores the exceptions. The scientist knows that the exception to the general expectation probably signifies some new or unusual factor and tracing its effect makes possible the formulation of rules that are more accurate than the "rule of thumb" which results from repetition of experiences with no attempt at critical analysis or interpretation.

In other words, the method of gradual correction through repeated trials is merely the exploratory stage of problem solving. It is used primarily when situations are so strange that analytical procedures are impossible.

PROBLEM SOLVING BY HUMAN ADULTS

The experiments on problem solving in animals have demonstrated clearly that there is no one way for solving problems in general. The challenged individual must let himself be guided by the problem in hand and adapt his reactions to the situation. This same principle holds with human problem solving. There are some general principles which will help in understanding some of the procedures that may be used, but we cannot expect to find any rigid form of thinking which holds for all situations. Thinking involves variability from fixed habits. The person who acts according to fixed patterns is not thinking. A number of experiments have been performed to illustrate this fact.

Principles of puzzle solving by human adults. One experimenter used a large number of puzzles in an attempt to discover the procedures that human adults used in solving them. He kept time records and took elaborate notes on the comments of those individuals who were subjects in the experiments. [54] Some of the conditions affecting solutions are as follows:

Solution depends clearly upon variations in method. Such variations may be made unconsciously but those adopted consciously are most effective. The ease with which a subject is able

to vary his method depends strikingly upon his attitudes and upon his ability to avoid explicit assumptions.

1. Certain attitudes may interfere with problem solving. The two attitudes which are most detrimental to puzzle solving are sensitivity to the approval or disapproval of observers, and self-attentiveness. In the case of the attitude of sensitivity to observation, the solver is more interested in watching the observer than in the puzzle. In the self-attentive attitude, the subject is more interested in himself than in the puzzle. The subject with such an attitude becomes self-conscious, thinks he is on trial, and has his attention centered upon his own ineptness and ignorance. When success comes to such an individual, he is so elated that he fails to profit from it; when he does not succeed, he is so chagrined that he fails to study the significance of such a failure. It has been clearly demonstrated by experiment that problem solving depends upon the substitution of an objective attitude for the self-attentive attitude. Consciousness of the problem must be placed before self-consciousness.

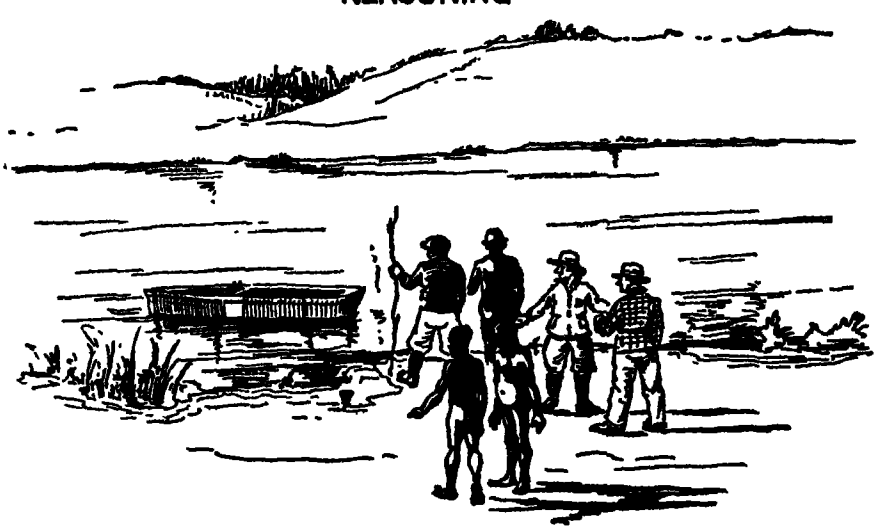
2. Assumptions may inhibit variation in method. In many instances the first glance at a puzzle may result in some assumption which may be clearly formulated or may be a mere



FIG. 167.—A six-piece cross puzzle. A, the component pieces; B, the cross after the pieces are correctly assembled.

vague attitude. No matter how it originates, such an assumption often tends to be maintained in spite of evidence that it is erroneous. The individual may begin to work on the wrong part of the puzzle, may turn it in the wrong direction; but the interesting part of the whole performance is the persistence with which the error is maintained.

Solution is often the result of accident rather than of analysis. In puzzle solution, success is more often the result of random activity than of straightaway thinking and the consequent formulation of a thoroughgoing plan of action. Regardless of whether success comes as the result of anticipatory analysis, of pure accident, or of a combination of both, subjects are able to benefit from such success. They often, for example, notice the final position of the parts of the puzzle just before the solution is



We have here 3 white men and 3 cannibals who are to cross this stream in the boat which carries only 2 passengers at a time. At no time must the white men be out-numbered by cannibals. How do they all get across?

FIG. 168.—Picture to be used for problem solving.

(From M. Metfessel and H. Musgrave, *Instructor's Guide for Demonstrations of Psychological Experiments.* By permission of McGraw-Hill Book Co., New York.)

attained, and by profiting from this observation, they can eliminate many useless movements. Success points the way, no matter by what means the success is achieved.

Solution is often aided by conscious analysis of the problem resulting from repeated successes or failures. By analytical procedures, (a) it is possible for subjects to develop hypotheses bearing on the problem; (b) to render these hypotheses more explicit with succeeding attempts and, at the same time, keep them flexible; (c) to keep up an active search for new points of view and to escape the tendency to be governed by fixed assumptions;

(d) to adopt some form of registration, such as naming or numbering, to avoid mere repetition; and (e) to evaluate different possibilities and to test the selected ones with a critical comparison of the results.

Effects of success and failure upon solution of puzzles. Near-success interferes with the ready acceptance of evidence of failure in a new situation. This is illustrated in experiments with reaching for objects with sticks. If the object is just beyond the reach of the animal when he is using the shorter of two sticks, the fact that he has *almost* solved the problem will tempt him to persist in his present activities rather than stimulate him to discard it for the other, longer, stick or to utilize the short stick to get the longer stick. A complete failure leads to a quicker change to other methods than does a near-success. Puzzles invariably incorporate this principle. They can almost be solved by some wrong method and this approximation to success tempts the solver to continue the wrong method. Since he is almost there, a little persistence should get him to the goal, he feels.

Many experiments indicate that sheer persistence is not a valuable adjunct in problem solving. The person who cannot admit defeat is a poor problem solver because such an admission is the first step toward changing methods or looking for some novel approach. However, the admission of defeat must be a challenging element and, instead of leading to the abandonment of the problem, must incite to further effort. The clever thinker admits that he has been wrong in the past, but refuses to stay wrong.

Insight. Other experiments show that a subject, whether an animal or a human being, acts differently when he has become aware of the nature of the trick involved in a puzzle. His activity becomes quicker and smoother. Besides, when confronted with a similar situation, he may hesitate before making any overt response, and then attack the problem in the correct manner. The onlooker, whether he is a psychologist or a layman, is certain that the subject knows what he is about. This knowing the solution has been called insight. It is indicated in the solution of mechanical puzzles in human beings (a) by a sudden drop in the learning curve, (b) by regularity of performance, and (c) by the report of the subjects that they knew how to work the puzzle. [54]

The term "insight" has been used at times as the sudden apprehension of meaning without reference to previous experience, but this exclusion of previous experience as a step toward insight is gratuitous. [34]

THE SOLUTION OF PRACTICAL PROBLEMS

When a human adult is given certain materials and is assigned the task of accomplishing a specific result with those mate

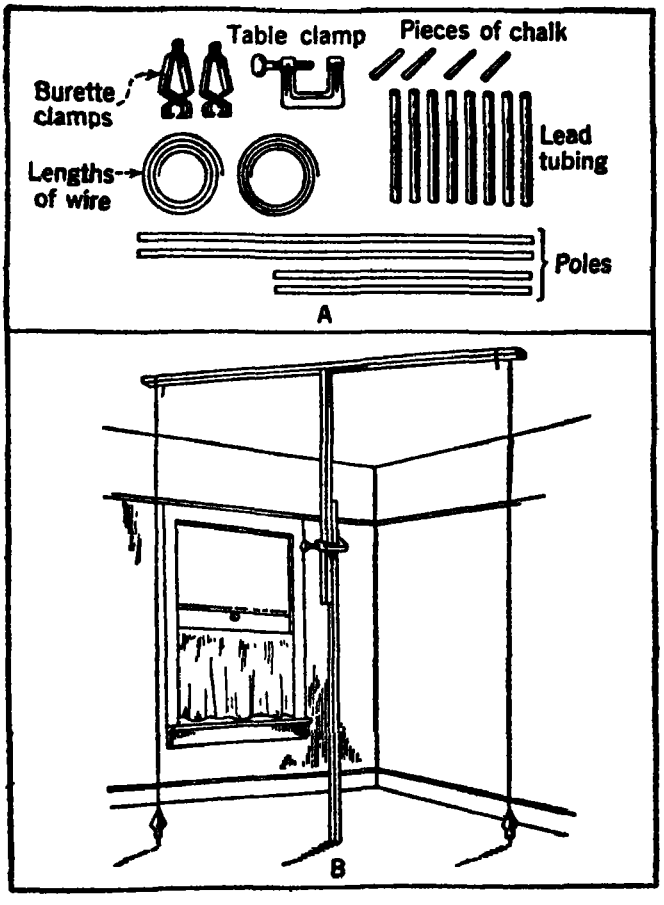


FIG. 169.—The pendulum problem. Diagram A shows the materials available to the subject. Diagram B illustrates the correct solution. The problem is to arrange the materials in such a manner as to construct two pendulums which would make chalk marks at specified points on the floor.

(From L. W. Crafts, *et al.*, *Recent Experiments in Psychology* New York: McGraw-Hill Book Co., 1938.)

rials, how does he go about his task? Some ingenious problems have been used in experiments to study the essential steps in working out practical solutions with familiar elements. [42]

The pendulum problem. The subject is given: two burette clamps, one table clamp, four pieces of chalk, two pieces of wire, eight pieces of lead tubing, and four poles. He is asked to construct with these materials two pendulums which can be swung so as to make chalk marks at specified points on the laboratory floor. The correct solution (as shown in the illustration in Fig. 169) is as follows: The two pieces of wire are attached to the opposite ends of the poles. To the free end of each wire a piece of chalk is fastened by means of a burette clamp. The other two poles are clamped together with the table clamp so as to make a pole of the right length to stand on the floor and hold the single pole against the ceiling in the form of a T. The position of the pole on the ceiling and the length of each pendulum are then adjusted so that one piece of chalk touches each of the marks on the floor.

This problem was used in an experiment to determine the significance of preliminary instructions in problem solving. In order to accomplish this purpose the instructions that might be given were outlined and different groups were given different combinations of these directions. The directions were as follows: (a) A demonstration showing how to make a plumb line out of a cord, a clamp, and a pencil. (b) A demonstration showing how to make a long rod out of two short rods and a clamp. (c) A demonstration showing how to hold a bar against the vertical edge of a doorway by wedging against the bar's mid-point another bar which reached to the opposite vertical side of the door. (d) A direct hint for solving the problem as follows: "I should like to have you appreciate how simple this problem would be if we could just hang the pendulums from a nail in the ceiling. Of course, that is not a possible solution, but I just want you to appreciate how simple the problem would be if that were possible."

This experiment showed clearly that preliminary instructions certainly help in problem solving. The amazing part was that only one person in sixty-two who were not given *all* the instructions outlined above could solve the problem. Furthermore, only about a third of those who were given all the instructions suc-

ceeded. Demonstrations of similar processes were not enough, nor were direct hints on how the problem might be solved. It was necessary to give demonstrations and instructions. [8]

The two-cord problem. The two-cord problem has been

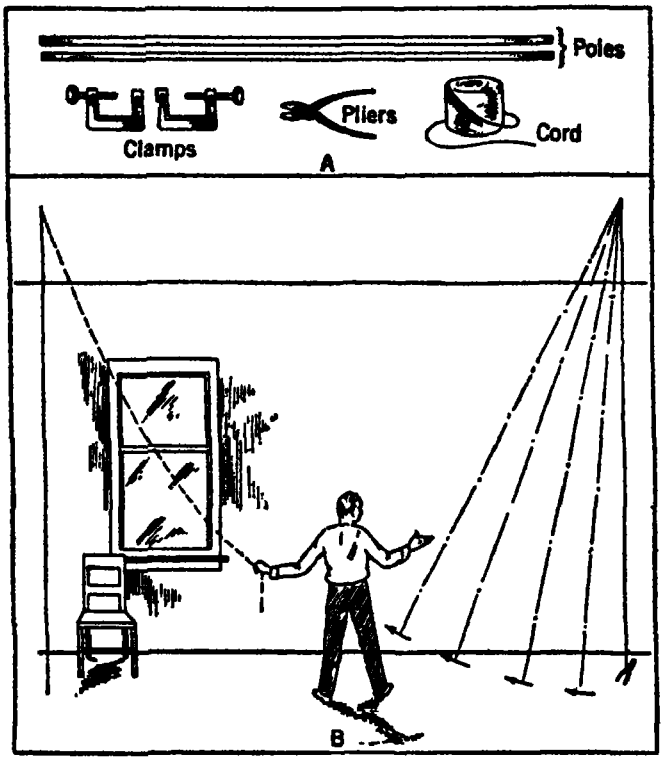


FIG. 170.—The two-cord problem. Diagram A shows the materials available to the subject. Diagram B illustrates the correct solution. The problem is to tie together the free ends of the two cords as they hang from the ceiling.

(From L. W. Crafts, *et al.*, *Recent Experiments in Psychology*. New York: McGraw-Hill Book Co., 1938.)

used to determine what part indirect hints may play in problem solving. A subject is supplied with the following materials in this problem: two cords hanging from the ceiling in such a manner that, if one cord was held in the hand, it was not long enough to enable the subject to reach the other cord; two table clamps, two poles, a chair, some extra cord and a pair of pliers (see Fig. 170).

The subject was required to tie together the free ends of the two cords as they hung from the ceiling. Several solutions to this problem are possible: (1) One cord may be lengthened. (2) One cord may be tied to the chair and pulled over toward the other cord so that the subject can reach it when holding the second cord. (3) One cord may be pulled with a pole while the other cord is held. (4) The pliers or clamp may be tied to one cord and the cord swung as a pendulum, enabling the subject to hold the other cord and catch the pendulum as it swings toward him.

The experimenter decided in his own mind that only the fourth solution would be "correct." If the subject solved it by any of the first three methods, he was told to look for another solution.

In this experiment the subject was given ten minutes in which to solve the problem in the approved fashion by making one cord into a pendulum. If he failed, he was given the following hint: The experimenter brushed against one cord, thereby imparting to it a swinging motion. If the subject did not take this hint within a reasonable time, another hint was given: The experimenter gave the subject the pair of pliers and told him that with the aid of that tool alone the problem could be solved.

The hints were effective in aiding the subjects to solve the problem. In many instances, the subject was not conscious that a hint was given, even denying afterward that he had received any hint, although he had obviously profited from it. When the solution did come to the subject, it was the same sort of quick transformation that takes place when the hidden figure in a puzzle picture becomes apparent. [8]

Unwarranted assumptions interfere with problem solving. Whenever a new problem is presented, there is a tendency to get clues as to possible procedures from past experiences. This, of course, is absolutely essential and, in many instances, of value. In other situations the new problem has a similarity to previous problems; which fact merely detracts the attention of the solver from the essential element in the new problem. The similarity to some past problem leads the solver to make unnecessary and unwarranted assumptions, which keep him from getting the proper solution. [3]

An instance of this tendency to be misled by unwarranted assumptions is this problem: Being given nine dots arranged in the form of a square, as in Fig. 171, the problem is to draw four straight lines without removing the pencil from the paper in such a manner that each dot will be included one or more times in these lines. Without being told, the solver naturally assumes that his

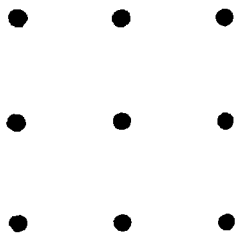


FIG. 171.—The nine-dot problem. The problem is to draw four straight lines without removing the pencil from the paper in such a manner that each dot will be included one or more times in these lines.

lines must be kept within the area included by the outer dots. He cannot solve the problem until he rids himself of this restriction and lets his lines extend beyond the area of the figure, as shown in Fig. 174 on page 495. [42]

Another illustration of this tendency is this problem: Being given six matches, make four equilateral triangles using all the matches and have none left over. The solver is not told that they should all be in the same plane but tends to work on the problem with that assumption. It can be done by erecting a tent with three matches on a triangular base made with the other three.

The limitations placed upon our thinking by such unwarranted assumptions are the most potent source of failure in problem solving. Having tried a few of the procedures which suggest themselves to us, we assume that we have tried all the possibilities. Instead, failure should stimulate us to look beyond our limitations. [19]

The cross problem. In this problem the subjects were given the task of solving five separate puzzles in succession, each solution consisting of making a square of a given set of blocks. [12] The blocks used for each of these puzzles are illustrated in Fig. 172. After solving these five puzzles the subject was given a rest period and then told that he was being given quite a different puzzle, that he was to take the blocks shown in Fig. 173

and arrange them so as to make a large eight-pointed cross. The purpose was to determine whether the solving of the preliminary

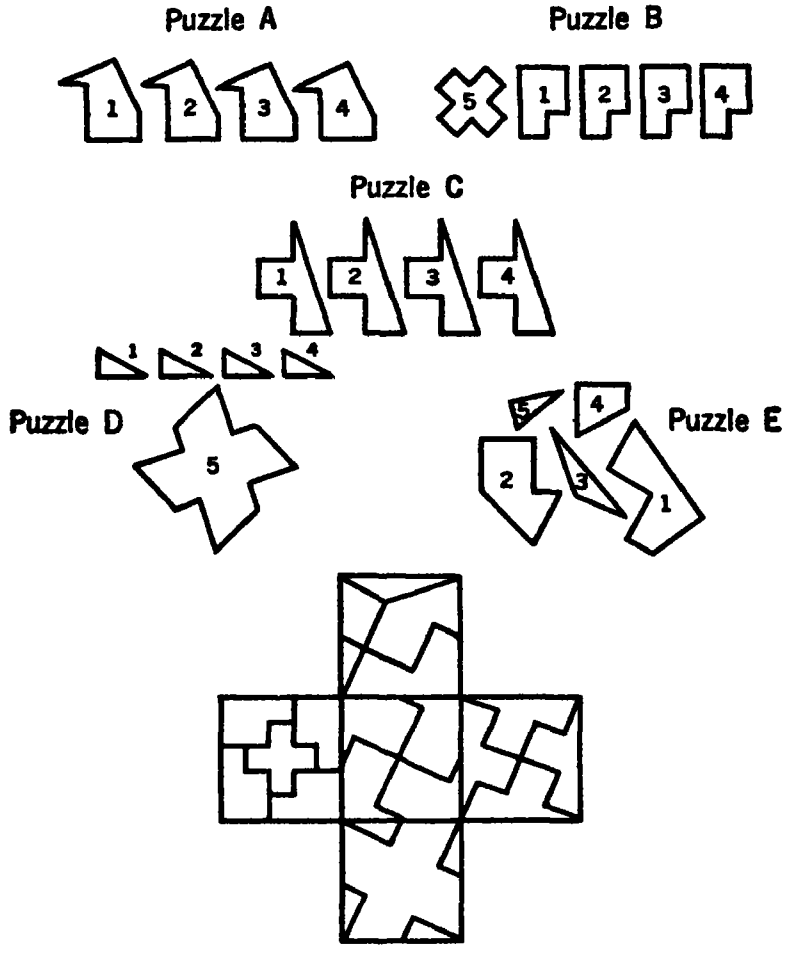


FIG. 172.—The cross problem. Puzzles A, B, C, D, and E were first presented as separate puzzles; the problem being to make a square from each set given. After this preliminary training the component blocks were presented as in Fig. 173, with instructions to make a large eight-pointed cross. The solution is the large cross in the lower part of the figure. Puzzle A forms the central part, puzzle B the left, puzzle C the right, puzzle D the bottom, and puzzle E the top.

puzzles contributed to the solution of the final cross puzzle. The subjects were also instructed to think aloud as they worked so that the experimenter could study their methods.

It was found that solvers without the experience of solving the preliminary five puzzles could solve the final puzzle but that those who had the preliminary training arrived at their solution

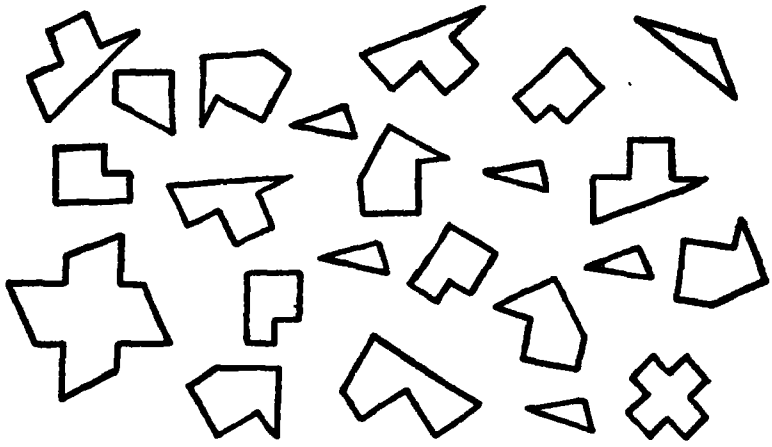


FIG. 173.—The blocks of all five puzzles of Fig. 172 as scrambled to test for benefit of previous training with the five puzzles.

by a different procedure. They would usually discern that the blocks in this new puzzle were the same as those used in the previous puzzles and then, after some floundering or hesitation,

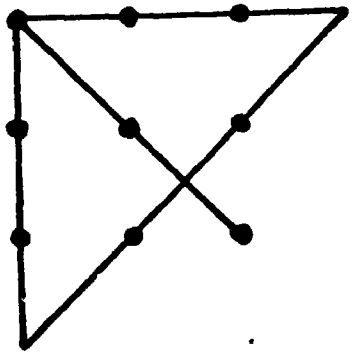


FIG. 174.—Solution of problem given in Fig. 171.

would suddenly realize that a large eight-pointed cross is essentially composed of five squares. With such realization the solution of the sixth puzzle was easy. Those who had no preliminary training were not likely to analyze the problem in this manner and, consequently, had to use much more random behavior and consumed much more time in their solutions.

In such a problem the general relation of previous experience to the present situation was easily discernible and the subjects took quick profit from this connection. In many problems such a quick association is not apparent and the benefit of previous experience is not so obvious. Even so, it should be clear that the person with a rich background of experience has a fuller storehouse from which to get suggestions for the solution of problems.

MAZE LEARNING

A maze is a device consisting of a system of pathways, with turns, branches, and blind alleys, through which the subject must

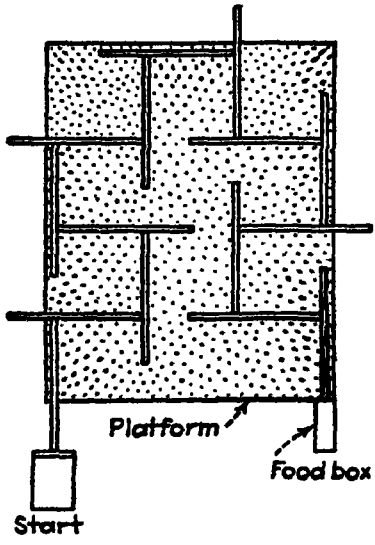


FIG. 175.—Diagram of plan of elevated maze for use with animals. The parallel lines represent elevated runways along which the animal must travel from the starting box to the food box. The whole maze can be turned so that the animal cannot use objects in the room to guide his movements.

(Adapted from Honzik, C. H., "The Sensory Basis of Maze Learning in Rats," *Comp. Psychol. Monogr.*, 1936, 13, No. 64.)

find his way from the starting point to the goal. In most mazes there is but one correct pathway, although some offer alternate routes. The kinds of paths vary with different mazes. In the enclosed-alley maze the pathways are between walls so that the subject cannot see any of the maze except the small portion in which he happens to be. In the elevated or open animal maze the passages are strips supported from beneath at such a height that the animal will not jump down and far enough apart to prevent jumping from one passage to another. In the elevated maze vision is unobstructed.

Any maze resolves itself into a series of choice points. The subject starts from the entrance and comes to branching pathways

between which he must choose. If he makes the wrong choice he finds himself in a blind alley and must retrace his steps to the point where he made the wrong choice.

Different methods are used to indicate when a maze is learned and to measure progress in learning. The most widely accepted criterion for successful mastery of a maze is the standard of three successive perfect runs. Sometimes the standard is nine perfect runs in a sequence of ten runs; or the experimenter may set his own arbitrary standard. Measures of progress may be the total number of errors committed (that is, the number of entrances into blind alleys) before reaching the criterion of mastery, the total time consumed in attaining mastery, the total time or errors in a specified number of trials, or the errors per trial. The two latter methods enable the experimenter to construct a learning curve.

Sensory cues used by animals in maze running. Much experimentation has been done in the attempt to determine which sensory cues an animal uses in learning a maze. One method has been to make the different senses inoperative in turn to discover the effect of such deprivation on learning the maze. By such methods it has been found that blind animals, anosmic animals (that is, those deprived of the sense of smell), deafened animals, animals with their vibrissae removed, animals whose feet were anesthetized [63], and animals whose kinesthetic sensitivity was eliminated [37], could learn a maze about as readily as a normal animal. [31] In other words, each sense has been excluded without producing a marked disturbance of the ability to learn the maze. The conclusion that follows from this work is that maze learning is not dependent upon any one set of sensory cues, although the animal must have some sensory cues in order to learn the maze. [64] The animal uses what sensory apparatus he has.

This conclusion was checked by a different type of experiment, in which it was found that if a rat has learned a maze by the aid of visual cues and is then transferred to another maze of the same pattern, but one in which visual cues cannot function, the animal has to learn the maze all over again. Blind rats are at a disadvantage in mazes which depend primarily on vision but are not handicapped by blindness when placed in the enclosed type

of maze where they can use other sensory cues than vision. These experiments confirm the previous conclusion; namely, that no one sense furnishes any indispensable cues. The animal uses the cues which he is most accustomed to use and if these are not permitted to function he does the best he can by utilizing cues from another sensory field. [65, p. 129]

Importance of goal in maze learning. There are a number of experiments which indicate that the paramount problem for the animal is to get from the starting point to the goal. The experimenter may see the animal *learning the maze* but from the point of view of the animal he is learning to reach the goal as expeditiously as possible. He is hungry and wants the food

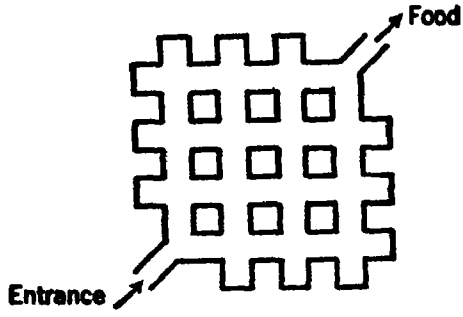


FIG. 176.—A maze permitting progress from entrance to food by a number of equally short pathways.

he has learned to expect; or he is confined and desires to get the freedom he has secured on previous runs. It is the goal that orients him to the maze problem. [10]

The following facts support this emphasis upon the need for becoming oriented to the goal in maze running:

1. Until the animal gains orientation he is likely to spend considerable time roving around and leisurely exploring the maze. Any experimenter in an animal laboratory has had the tiring experience of waiting for a rat to become alive to his need for getting to the food box or of getting out of the maze.

2. The animal is not concerned with following a fixed pathway to the goal. He may do this after practice has shown him that it is the best way; but under certain circumstances he will vary his path or will discard a learned route in favor of a more expeditious one when it is presented. If the wire cover of a maze is removed, some rats will take advantage of the opportunity thus presented and run along the tops of the partitions

of the maze directly to the food box, a procedure which necessitates following an entirely new route. [36, p. 137] In experiments where equally good paths to the food box are offered to the animals, as shown in Fig. 176, they often vary their routes,

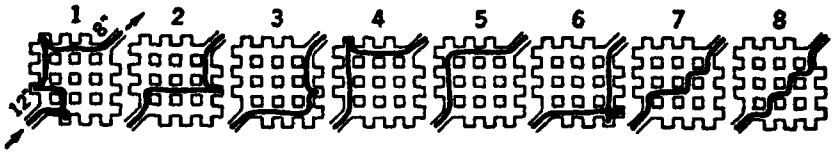


FIG. 177.—Variation in performance. The tracings are records of the first eight runs made by a rat in the maze illustrated in Fig. 176. (From J. F. Dashiell, *Comp. Psychol. Monogr.*, 1930, 7, No. 32.)

as illustrated in Fig. 177. Their concern is apparently to get the food rather than to get it in any stereotyped manner. [9]

3. An animal will favor alleys which lead in the general direction of the goal. For example, in Fig. 178 is illustrated a maze with the goal to the right of the starting box. When this

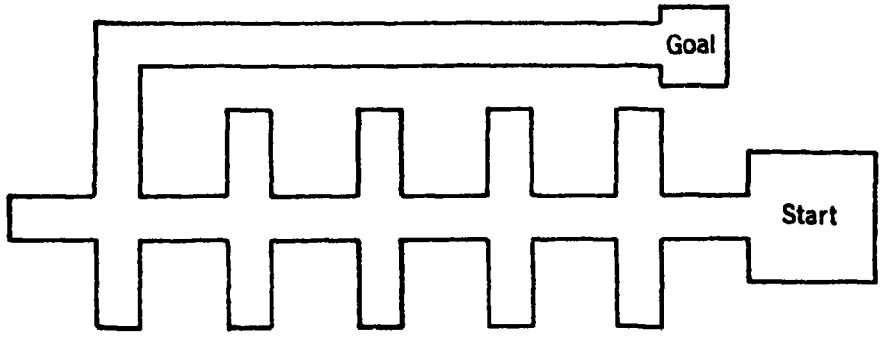


FIG. 178.—Diagram of maze used to demonstrate tendency of animal to take pathways leading in general direction of goal. The blind alleys leading in the general direction of the goal were entered more often than those pointing away from the goal.

maze was used with rats, it was found that the goal-pointing alleys (the ones leading to the right) were entered three times as often as the alleys leading away from the goal (toward the left). This predilection for the goal-pointing blind alleys appeared early in the training process and developed quickly, reaching its maximum at the fourth trial. [56]

4. When the animal becomes confused in learning the maze he hunts for landmarks from which he can secure reorientation in respect to the goal. If an animal is blocked and forced to go around an obstacle, he tends to resume the original direction after detouring the barrier. [10] In some instances a confused animal will return to the starting point in order to regain his bearings.

5. An animal may learn to traverse a maze in one manner to gain food and to traverse the same maze in another manner to gain water. If food is placed in one part of the maze and water in another, the animal will go to the food if he is hungry and to the water if he is thirsty. [38] If the rewards are placed in the same part of the maze and the animal is required to take one path to get food and another path to get water, he finds the task somewhat harder, but he can learn to accomplish it. [23]

The conclusion from these experiments seems to be that animals learn maze problems not by mastering certain fixed motor acts or certain sequences of acts, but by spatial and directional cues. Such cues are in the nature of guides toward some goal. When the cues are clearly apparent, learning is easy for the animal; when they are absent, the animal cannot learn; and when they are confused, the animal has difficulty. Spatial and directional factors make maze learning possible for animals. If solution depends upon temporal sequences or upon verbal cues, the animal finds himself unable to solve the problem.

Explanations of animal maze learning. Various theories have been advanced to explain animal maze learning. One writer suggests that the animal puts together in one act what has been learned at different times. [41] Another writer argues that the animal forms hypotheses in his early trials and then discards or corrects these hypotheses on the basis of further trials. [35] Another believes that the choices in a maze are reactions to cues which are essentially symbolic substitutes for the postural pointing reactions which animals show in delayed reaction (see page 477) experiments. [25] These are all probably partial truths; they are correct as far as they go but they do not explain adequately the whole procedure of mastering the maze.

There are probably three processes in learning a maze: (1) getting acquainted with the maze in a general way, including

the recognition that the problem required is to proceed from the starting box to the goal; (2) learning a path within the multiplicity of paths offered which will enable the animal to reach the goal; and (3) developing some skill in following this pathway efficiently, with the elimination of errors that might have been present in the earlier runs. [65, p. 137]

These steps correspond roughly with what is observed in any form of problem solving. There is (a) a general orientation to the problem in hand; (b) the working out of some sort of

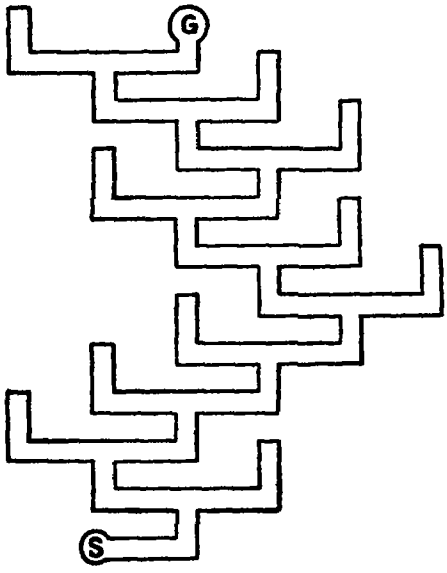


FIG. 179.—A typical stylus maze.
(From J. C. Warden, *J. exper. Psychol.*, 1924, 7, 101.)

crude solution; and (c) the improvement of this solution by the elimination of irrelevant factors on the basis of repeated trials.

A comparison of human maze learning with animal maze learning. Human beings have been given the problem of solving mazes which are quite similar to animal mazes. Some human mazes are merely enlargements of the enclosed-alley type. Other human mazes, such as the one illustrated in Fig. 179, have depressions which are covered and which must be traversed by a stylus held in the hand of the subject. The finger maze illustrated in Fig. 180 has elevated ridges along the top of which the subject moves his finger. In some human mazes the major portion of the maze is hidden from view, in some the subject

is blindfolded, while in others (as in Fig. 181) the subject is permitted to see the entire maze.

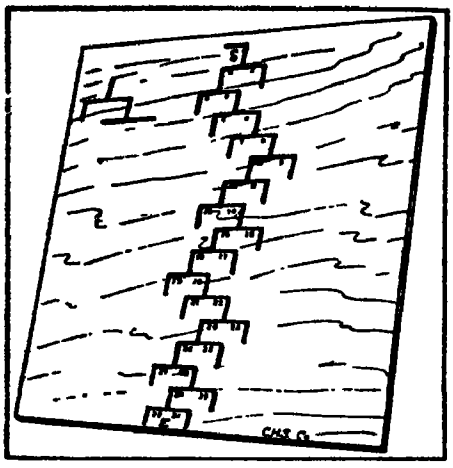


FIG. 180.—A typical finger maze.

Some valuable principles have been secured by comparing human and animal maze learning. Human beings profit more quickly from errors, they adopt superior modes of attack, they orient themselves to new problems more quickly and accurately, and they are able to maintain interest on the essential problem more persistently.

Maze learning is easier for those individuals who profit most quickly from their errors. An experiment was conducted by making an enlargement of a maze that had been used for animals. Blindfolded adults and children were taught to run this maze and their performance compared with that of rats. It took all three groups (the blindfolded adults, children, and rats) practically the same number of trials to learn the maze, but adult human beings excelled in speed and made many fewer errors. In the first trial the rats averaged seven entrances to each blind alley, the children averaged four, and the blindfolded human adults averaged only one. There is a striking difference in the quickness with which the different groups profited from their mistakes. This is apparently an important factor in problem solving. The most intelligent individual quickly profits from false moves and erroneous cues. The child, the animal, or the dull adult has to repeat an error more frequently before he discovers its significance and is able to eliminate it. [20]

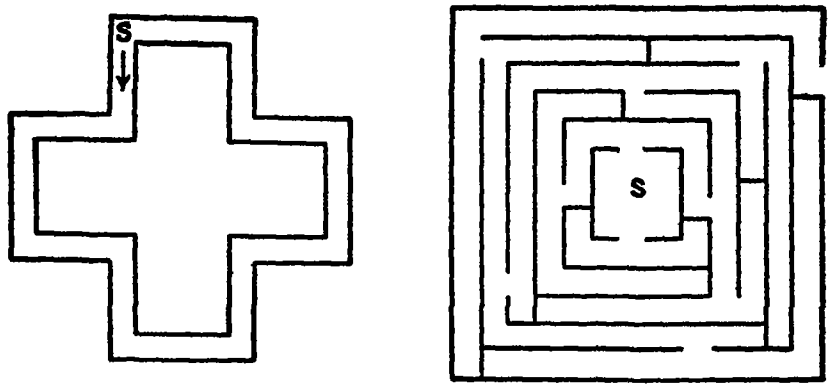


FIG. 181.—Pencil mazes. The subject is permitted to see the whole maze as he threads his way from S with a pencil.

Success is definitely related to the mode of attack upon the problem. Human individuals show marked differences in their approach to maze problems. [46] Furthermore, the same individual will show a greater tendency to change his method during an attempt than will an animal. This variability of performance is an asset; it enables the individual to compare methods and to select those most suitable for the problem at hand. [29]

When naïve human subjects were permitted to choose their own methods for running a maze their methods fell roughly into three main groups: (1) the word reaction method, in which the subject named his turns left-right; (2) the visual imagery method, in which the subject attempted to visualize the maze pattern; and (3) the motor method, where the subject permitted himself to be guided by motor cues. [62]

While the majority of subjects used more than one method in the course of their trials, most of them favored one method or the other. [30] The greater number (42 per cent) favored the word reaction method, the fewest (28 per cent) the motor method, while the visual imagery method stood between the two (30 per cent). [62] The most efficient method was the word reaction method. It required less than one-quarter as many trials as did the motor reaction method, and about one-half as many trials as the imagery method. Human subjects vary their pro-

cedure during the course of their work, and the more alert ones tend to select the more efficient methods.

Quick and accurate orientation to a problem helps in its solution. When human subjects were given the task of going blindfolded through a large outdoor maze, they quickly oriented themselves, usually during the first trial. They learned the relation of the entrance to the exit, the general course of the true path, and became familiar with certain of the paths so as to get specific cues. [2]

There seems little doubt that an important element in solving any kind of problem is the ability to discern clearly just what the problem is. If an individual waits for someone to explain exactly what should be done, it is apparent that someone else has previously solved the problem. The sagacious individual does not wait to be told what a problem is; he discerns it himself from the nature of the situation; and while his less astute comrade is still groping, he is on his way toward solving it.

Attention to the central problem should overshadow interest in irrelevant details, distractions, and failure. This ability to maintain the central problem in spite of changes in certain aspects of the problem was demonstrated in an experiment in which human subjects were made to solve various forms of mazes.

After the blindfolded subjects had learned their way through the large maze, they were given the following problems while still blindfolded: (a) they were required to trace their way with a stylus through a small maze of the same pattern; (b) the maze was rotated through 90° and 180°; (c) they were required to retrace their pathway from the exit to the entrance; (d) they were required to trace it with their left hands after they had done it with their right hands. [38] The subjects adjusted themselves to all these changes with surprising rapidity, showing that they had the ability to maintain the central problem and to utilize that knowledge to solve what might otherwise have been a relatively new problem. [46]

It is an essential element in problem solving to get the proper balance between this ability to avoid irrelevant distractions or to follow circumscribed channels and, at the same time, to grasp any tiny cue that relates to the problem at hand. Poor thinkers may make an error in either direction: (a) they may

be so eager to let no clue slip that they become lost in a confusion of details or (b) they may be so anxious to retain the central problem that they fail to see the means of solution even though these should be clearly apparent.

Procedures involved in finding the principle of a maze. The derivation of rules, principles, or laws from a series of concrete experiences (the process of induction) is an important element in human thinking and reasoning. Human maze learning has been used to study the procedures by means of which such generalizations are effected.

The importance of language cues to assist an individual is demonstrated clearly in the solving of a temporal maze, where spatial factors are entirely eliminated. In the temporal maze the alleys are changed with succeeding runs so that the animal may be required to make a right turn at a certain point on one run and then to make a left turn at the same point on a later run. Where the animal has to depend upon the sequence of his movements instead of spatial orientation, he has trouble. [33]

The temporal maze is built upon the principle of a double square (see Fig. 182) with gates that can easily be changed from trial to trial in such a manner that the animal cannot tell how they are arranged until he has completed a run through an alley involving two turns. For example, in the first trial he may be required to go to the left to get food but on the next trial the gate at the end of the alley to the left is closed and he finds he should have gone to the right. He must learn the sequence and orientation in spatial terms does no good. All the choices are made at the same point, whereas in the ordinary maze the choices are made at different places. The rat has great difficulty in learning such a simple sequence as right, left, right, left (RLRL), and finds it almost impossible to learn the sequence RRLL. [28] In contrast with this difficulty in the lower animals, children and human adults find such a maze relatively easy. They soon catch on to the nature of the problem, even though they have been given no verbal instructions, and formulate their solution in words: right, left, right, left; or twice to the right and twice to the left; or three times to the right and twice to the left. With verbal interpretations the cues become very simple. [15]

The verbal analysis of a maze greatly facilitates its learning. The way in which this may operate can be seen by examining the ways in which a human being might go about solving such a maze as the one illustrated in Fig. 183. At the very beginning a human being is not much better off than an animal, that is, he must use purely random responses at first. For example, as

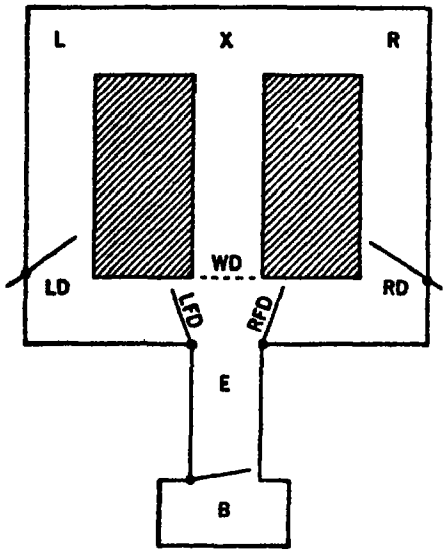


FIG. 182.—Diagram showing operation of a temporal maze. Animal is released from starting box B and enters the maze through the alley E. As he enters, both front doors (LFD and RFD) are closed and the wire door (WD) is open. Hence, the only way he can proceed is toward X. When he passes WD, the door is closed so that he cannot retrace his steps. At X he has the choice of turning to the left (L) or right (R). After he makes his choice, the experimenter opens one of the two doors LD or RD according to a plan which he has arranged in advance. If the animal turns to the right and RD is the door that is opened he is rewarded. If his choice does not correspond with the experimenter's schedule, he is not rewarded.

(From L. W. Gellerman, *J. genet. Psychol.*, 1931, 39, 50–72.)

he enters the maze at P he has two alternatives: he may turn left into the blind alley N or he may turn right into the correct alley V. When he gets to the opening at I, he again has nothing to guide him and must choose at random, turning at I or continuing into the L alley. These random selections at each point in the maze where a choice is possible continue until he reaches the goal. Should he make any false turns, he must retrace his steps to the point where he made his error.

On the first run he can make certain observations which will provide him with a general orientation and make his next run easier. For example, he may note that the alleys are circular and that the home compartment is near the center of the circular area. Such an observation would make it seem wise always to go through any doorway leading in the general direction of the center. After several runs, he might observe that if he stays in the lower left quadrant of the maze he gets along expeditiously; whereas, if he gets out of this quadrant he gets into a blind alley. Still another generalization might be that after entering a door

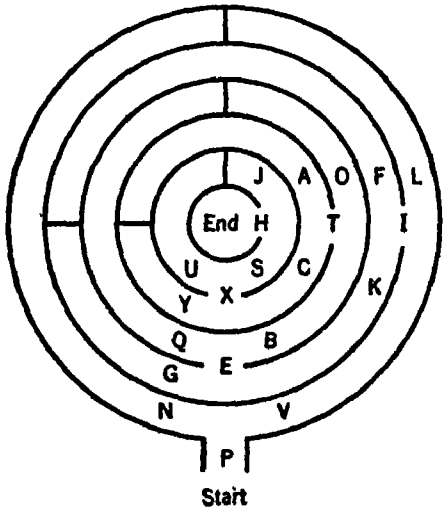


FIG. 183.—Circular maze. This maze has been used to study the use of generalization in maze running. Various levels of generalization are discussed in the text.

taking him nearer the center of the circular area, the correct turn is always in the direction opposite to that taken on a previous passage through such a door. At P he turns right; at I he turns left; at E he turns right; at T he turns left; at X he turns right; and at H he turns left. Finally, he might formulate what he has learned in a verbal expression: right, left, right, left, right. The rule: alternate the direction at each choice point.

With less insight the subject might make a poor generalization, which would enable him to get out of the maze but in an inefficient manner. For example, he might discover that if he kept in contact continuously with the wall on either side of him he would eventually get out. Such a course is depicted in Fig. 184. Should such a learner measure his performance by the sole

criterion of success he would never improve. It can be seen how fallacious it would be for him to argue: "I have succeeded; therefore, my method must have been right." Instead, the sagacious solver is continually saying: "I have succeeded, but couldn't I do it next time more expeditiously?" In short, the fact that one can make a correct generalization does not prove that another generalization might not be better.

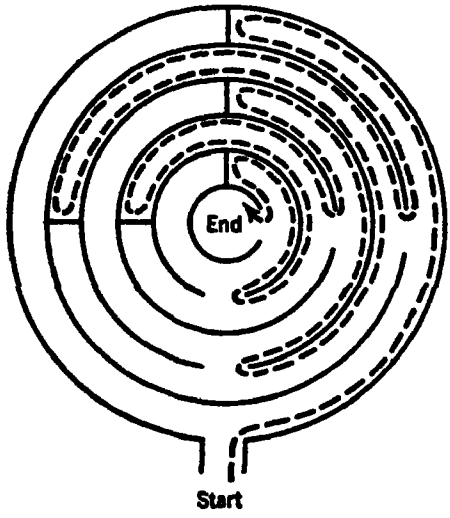


FIG. 184.—A poor but successful solution of the circular maze. The subject gets through the maze by following the wall to his right throughout the maze. Such a solution requires nearly four times as long a run as the best solution.

INDUCTIVE REASONING

We now have the task of considering in more detail those forms of problem solving where the great proportion of work is internal and the results of which manifest themselves in a final act that is precise and correct.

The use of language in problem solving. We have already seen how the use of words can be of assistance in problem solving. In working on a temporal maze, the solver can formulate the succession of turns as right, right, left, left, right, right, left, left, etc. In multiple-choice problems, he can formulate the problem in words such as: "Always take the smaller door." "Never select the door which led to food on the previous trial." In solving more intricate problems, work is facilitated if accurate meanings and definitions can be formulated to guide the thinker.

Abstractions. An abstract quality is some attribute which is found to be common to a series of experiences. For example,

by observing iron, copper, and silver it may be observed that they all have the common quality of hardness. Hardness may then be considered without reference to any of the other characteristics of the three separate substances in which it was observed; it can be thought of as a separate entity although it has never been observed in isolation. A clear-cut abstraction helps to guide us in our behavior. For example, we treat hard objects differently from the manner in which we treat soft objects.

Formulation of definitions. Clear thinking depends upon definitions which are so clear that they prevent misunderstanding between persons who use them, so precise that they enable users to be consistent, so fixed that they prevent changes in their meaning during the process of thinking.

The ability to define varies with intellectual maturation. [57] The very young child defines with increasing skill, passing through the following stages: (1) by pointing to an object; (2) by repeating the name of an object ("A chair is a chair"); (3) by giving the use of the object ("A chair is to sit on"); (4) by describing the object in some detail as to its form, size, color, or appearance; and finally (5) by telling to what class the object belongs or its relation to other classes of objects.

Formulating a mature definition consists of showing the relation of a less inclusive group of objects (called the species) to a more inclusive group of objects (called the genus). In the simplest type of definition the mere relation of genus and species may be accepted as satisfactory. For example, it may be stated that man is an animal. This definition leaves something to be desired for it does not differentiate between man and the other species of animals. A good definition requires not merely the statement of a more inclusive group into which the word to be defined may be placed, but it requires as well some distinguishing characteristics (differentia) between the object to be defined and other members of the genus into which it is placed by definition. Thus, a man is an animal, but in addition, a man is an animal belonging to the class of primates, and distinguished in behavior by language, civilization, and the elaborate use of tools.

In order to be considered a first-class definition, the following requirements should be fulfilled: (1) the definition should be more than a mere synonym of the word defined. (2) The defi-

nition should not be in terms less familiar than the term defined. (3) The differentia should clearly distinguish the term defined from all other species of the same genus. (4) The definition should be in positive terms, that is, it should indicate what the word is, not merely what it is not.

Inductive and deductive reasoning. Induction, or generalizing, is the process of reasoning from particular to general. It is the development of a hypothesis, theory, principle, or law after discerning certain uniformities or common factors in successive situations. Inductive reasoning is often contrasted with deductive reasoning, which is reasoning from general premises or propositions to more concrete and specific applications of the general rule.

The distinction between induction and deduction lies largely in the nature of the problems to be solved. In an inductive problem the given factors are specimens, and from these individual specimens of objects, acts, or situations the thinker endeavors to formulate a definition, some working principle, or some rule to guide him in dealing with those specimens. For example, a child may have learned that whenever he has put his hand on a hot stove he has been burned. From these experiences he derives the general rule that a hot stove will burn one's hand. Such a rule is of service to him; for he refrains from touching hot stoves, and does not burn his hand.

Deductive reasoning, on the other hand, attempts to discover the implications of certain given propositions. For example: If Bill is at the right of Paul, and if Paul is at the right of Sam, what can be said as to the relative positions of Bill and Sam?

In actual thinking processes, induction and deduction are utilized in conjunction, the one tending to reinforce and support the other.

The development of class concepts. The general plan of experiments directed toward an understanding of the development of class concepts is to present the subject with a number of specific examples of a class, giving him the name of the concept at the same time; after which he is asked either to define the concept or to recognize whether other succeeding illustrations should or should not be included in that same class.

For example, suppose a *dax* is a circle with two dots, the

one dot being inside the circle and the other dot outside the circle. The experimenter shows (Fig. 185) various illustrations of the class *dax* and after the subject has examined them he is asked to tell what a dax is. If he cannot define the concept correctly he is shown further illustrations of *dax* interspersed with others which are *not dax*.

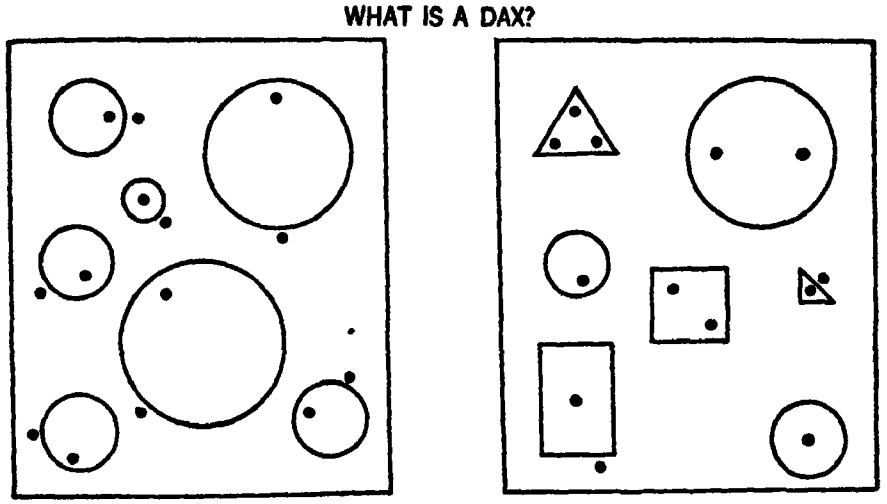


FIG. 185.—Diagram to illustrate how class concepts are formed. At the left are seven illustrations of DAX; at the right are seven illustrations of figures which are not DAX. Try to formulate a definition of DAX before reading the text.

With a number of concepts studied in this manner, it has been found: (a) Individuals may learn concepts with sufficient accuracy to identify them and to distinguish them from objects which should not be included in the class and still not be able to define the concept with accuracy. (b) The process of concept formation involves grouping of objects. Sometimes the basis for such grouping is vague even though it may correspond closely with the definitions arbitrarily given by the examiner but not revealed to the subject. (c) The clearing up of a vague concept involves a tentative definition and the corroboration, rejection, or correction of that tentative definition with succeeding experiences. [13, 55]

Concept formation involves not only the statement of essential qualities but the exclusion of irrelevant qualities. This is brought out in a test of concept formation conducted about as follows: [17]

The subject has spread before him 22 blocks. Each block has a name but the names are turned down so that the subject cannot see them. (a) There are six flat blocks with relatively large top surfaces of varied shapes and colors, and these are named *bik*. (b) There are six flat blocks with relative small top surfaces of varied shapes and colors, and these are named *cev*. (c) There are five tall blocks with relatively large top surfaces of varied shapes and colors, and these are named *lag*. (d) There are five tall blocks with relatively small top surfaces of varied shapes and colors, and these are named *mur*.

The subject is told that there are four different *kinds* of blocks, each with a distinctive name, and he is to sort them out into four different groups according to these four *kinds*. His task is to discover that the bases of distinction are height and top-surface area and that shape and color are irrelevant.

In an experiment where the class concept was a grouping of lines buried in other lines so as to give the subject the impression that he was looking at a Chinese character, it was found that the subjects experienced great difficulty in discerning the common element involved. They would experience a vague feeling of familiarity, discern some family resemblance, but could not identify the specific lines upon which this resemblance was based. [24]

When confronted with a novel object, two general methods are used in classifying that object. One method is to assimilate it to some class of objects with which one is already familiar. The second is to analyze the new object into parts and then to fit the parts into separate categories. The first is the method of everyday experience; it is quicker and not so accurate in its results. The latter analytical method is more dependable and is the method which scientific thinkers attempt to use. [5]

Classification, then, depends primarily upon a clear delineation of the essential qualities which distinguish a class of objects, with an exclusion of those qualities which are irrelevant. In addition, classification should adhere to the following rules:

(a) Some controlling principle should be followed in a system of classification. For example, it is faulty to classify books into quartos, octavos, duodecimos, and paper covered. (b) The species into which the genus is divided must not overlap but must be mutually exclusive. For example, men cannot be divided into good and bad because goodness and badness are not mutually exclusive and men overlap in the possession of these traits. (c) The constituent species in a classification must, taken together, exhaust the genus; no part of the genus must be omitted in the classification. If all the members of the genus cannot be named specifically, there can be created a miscellaneous group. [4]

It should be apparent from the study of concept formation and the rules for correct classification that the primary need is to strive continually for greater precision in meaning. It is failure in this respect that leads to much fuzzy thinking.

The process of formulating a principle. Usually, in the first contact with a problem whose solution is sought, the puzzled individual does not even know in what area the solution lies. It takes more than one contact to formulate any generalization whatsoever. Succeeding experiences are different but are not totally new; they combine some new elements with elements which have been present in preceding experiences. As life rolls on, the animal or human being uses the familiar aspects of his environment as cues to guide him. For example, after an animal has learned to escape from a puzzle box by turning a certain button, he will restrict his activities to the location of the button in succeeding attempts and not scratch at all parts of the box indiscriminately. He has isolated a certain part of the box for his activities. Furthermore, after he has learned to escape from one box by turning a button, he will tend to isolate a button for his attention when placed in a new puzzle box, provided there is a button for him to manipulate. If the solution of this new puzzle involves the manipulation of the button, his past experience may help him even though he may have to do something different with the button in this new box. If, on the other hand, the new box must be solved by raising a latch in a different part of the box, his past experience will prove a handicap. He will take the button as a cue, but it will be a false one. In some cases generalization may help in solving problems; in others it may

interfere. The puzzled individual may profit from generalizing from past experiences, but he cannot take his generalizations too rigidly or he may be acting upon some irrelevant or misleading factor. If it is a puzzle, he manipulates it in his search for a clue; if it is a definition, he searches for identical elements in a series of experiences; if it is a rule, he searches for essential sequences.

One experimenter studied the method of deriving a general principle by means of a game played with matches. Seven matches are presented and the rules of the game are stated about as follows: Each player is to take, alternately, either one or two matches and to manipulate his plays so that he will always take the last match. Sometimes a subject can learn to win at this game without being able to formulate any law or principle which enables him to win. If he watches his plays he may be able to formulate the rule, which is: *To win always draw enough matches to leave your opponent a number that is a multiple of three.* If your opponent is left with three matches, he may draw one and leave two, in which case you may take them and win; or he may draw two and leave one, in which case you take the one and win. When only seven matches are used, a learner may formulate the partial rule that it is always desirable to leave your opponent with the last three matches, but when given a larger number to begin with—say ten or thirteen—he may find that he cannot manipulate matters so as to accomplish this end unless the formulated rule is applied early in the series of plays. In order to help him learn the rule, the game may be varied by using ten, eleven, thirteen, or any number of matches which is not a multiple of three. [48]

Such a generalization may be reached in various ways: (a) One may be told the rule as the reader has here been told. All he needs to do is to verify it. (b) It may come as a sort of guess, which is found to hold upon experimentation. (c) It may come partially and be corrected with succeeding trials. (d) It may come as the result of analysis and comparison of one trial with another, the learner varying his procedure and studying the effects of such variation. Individuals vary greatly in their insight into the significance of the generalization or the ability to state it

clearly. Some learners become proficient in learning to play the game but are unable to state the rule.

Imperfect generalizations. The greatest enemy to a wholesome use of the inductive method is the temptation to make hasty generalizations. A hasty generalization is the fallacy of assuming that a result has wider or more dependable application than is justified from the information or experiences at hand. Hasty generalizations take various forms:

False analogy. A belief should not be accepted upon the basis of some superficial resemblance between the situation in question and some known principle. Many superstitions are based on false analogies. For example, when the moon is waxing the crops should grow likewise. We judge a man to be tenacious because he has a broad jaw like a bulldog. One striking illustration will convince the ordinary man of a proposition in spite of a great amount of definite evidence that the proposition is false.

When this method is applied to our judgment of individuals, it has been called the "halo" effect. When we like a man because he has favored us, this fact is likely to color our estimate of his intelligence, his honesty, or even his sanity.

When you wish to convince a person, use illustrations and analogies; when you wish to ascertain the truth, avoid them.

Giving weight to accidental concomitance. Because the stop light always turns red when your car is approaching it is no evidence that the approach of your car causes the light to change, as some disgruntled souls have been heard to complain. Nevertheless, there are devices to cause the light to change to green when a car approaches an intersection. How can one tell whether his approach is really a factor in the change of the light or an accidental circumstance? If he observed the light over a long period of time and noticed that it never changed unless a car approached and that it always did change whenever a car approached, he might assume that there was some connection. Because the street lights come on in a city exactly ten minutes after sunset is no reason to assume that the movement of the sun turns on the lights.

Extending the reach of generalizations. Suppose that one, by prolonged observation, came to the conclusion that a go light

came on upon the approach of a car. He could make the generalization that that particular light responded to the approach of a car, but he would not be warranted in assuming that all go lights were operated by oncoming cars. It is told that when the king of Siam heard a Dutch traveler tell how the water in Holland became so hard that people could walk across it, he exclaimed: "Now I know you are lying." A law may be general in one set of circumstances and still not hold in others. Can you imagine the comment of a man a hundred years ago were he told that a man would be able to sit in his study and talk in a whisper and yet be heard by millions of people at distances ranging up to thousands of miles?

The tendency to generalize instances because of their number alone. The acceptance of testimonials is evidence of this fallacy. It is all too common to find the tendency to generalize on insufficient evidence, even from a single instance. In escaping from this tendency it is easy to fall into the related error of thinking that the accumulation of illustrations provides sound evidence for the truth of a proposition. A million persons might testify that after anointing with bear grease the knife by means of which they cut themselves, the wound healed. Would this prove, or be the slightest evidence, that the anointing of the knife was directly related with the healing of the wound? Even though the million testimonials included those of intelligent and famous men, the generalization would still be invalid.

Reasons for imperfect generalizations. A great many factors enter into the tendency to maintain false generalizations. To mention a few of them briefly: (a) We dislike to remain in suspense. Once having found some satisfactory way of meeting one situation, we tend to utilize it quickly rather than remain in suspense while hunting something better. (b) Once we have accepted a position, personal pride makes us tend to retain it even though we may have severe doubts as to the wisdom of so doing. (c) A firmly established emotional prejudice will tend to crush any factors which might make this prejudice doubtful. (d) Hero worship of others who maintain a position may make us slow to accept evidence which runs counter to their views. (e) Mental laziness or inertia. [4]

DEDUCTIVE REASONING

Deductive reasoning should normally take the form of a syllogism; although this form is often hidden in language in such a way as to disguise it.

Form of the syllogism. The syllogism consists of three propositions, two of which are premises and one of which is the conclusion. Each of these three propositions contains two terms connected by a copula—*is* or *are*. In the whole syllogism there can be only three terms. The conclusion must contain one term from each of the premises and must omit the term common to each of the premises. This term which is present in each of the premises and is absent from the conclusion is called the middle term. This middle term is the link between the two premises and must be used in strictly the same sense in both premises, otherwise the conclusion will not be valid.

An illustration of a syllogism is the following:

All books are made of paper. (first premise)
The Bible is a book. (second premise)
The Bible is made of paper. (conclusion)

While the logic in this syllogism is valid, the conclusion is not true necessarily because one of the premises is not true; not all books are made of paper. The logical soundness of a syllogism may be correct, but, if the premises are not true, the conclusion may not be true. Each premise should be considered as an *if* proposition. *If* all books are made of paper; and *if* the Bible is a book; *then*, but only under the conditions stated in the premises, the Bible is made of paper. When this qualifying *if* is kept in mind, the thinker will be reminded that his conclusion is also a qualified statement. A conclusion can be considered true only when the premises are true and the reasoning valid.

Significance of relationships. The deductions made in syllogistic reasoning depend upon relationships. When we know the relationship of term A to a middle term and, at the same time, the relationship of term B to the same middle term, what do these facts tell us (if anything) about the relationship between terms A and B? The best way to think clearly is to reduce the propositions in any syllogism to some diagram which clearly indicates the relationships involved.

Linear relationships. Some syllogisms can be reduced to simple linear relationships. [6]

For example:

> If Bob is heavier than Fred; and
> if Dick is lighter than Fred; then
> is Dick heavier or lighter than Bob?

Weight can be represented in linear terms. If we conceive the lightest to be on top and the heaviest to be on the bottom, we have the following arrangement:

> Dick—lighter than Fred
> Fred—middle term
> Bob—heavier than Fred

The conclusion (Dick is lighter than Bob) is clearly seen from inspection of the arrangement of the three. Any propositions that can be reduced to a straight-line relationship could be handled in a similar manner. East-west, right-left, inner-outer, and earlier-later can all be represented in this manner and propositions based on such relationships clearly tested.

Suppose we have the two propositions:

> If Bob is heavier than Fred; and
> if Dick is heavier than Fred; then
> is Dick heavier or lighter than Bob?

An attempt to reduce these propositions to a diagram will show that nothing can be deduced because both terms (Dick and Bob) vary in the same direction from the middle term (Fred), and nothing is said to indicate which varies more.

Relations of inclusion and exclusion. Relations of inclusion and exclusion are best symbolized by circles to represent the terms of the propositions. If we let X equal one term and Y equal another, it is possible to have them related in the different ways represented in Fig. 186.

By reference to the diagrams in Fig. 186, any proposition depending upon the relation of inclusion and exclusion may be reduced to graphic form. Such a representation of the syllogism usually reveals immediately which conclusions are valid and which are invalid.

Errors caused by attitudes of reasoner. As a result of careful experiments with different kinds of syllogisms, it has been found that when a person is presented with a set of propositions that can be reduced to syllogistic form he tends to get a "global" impression from the way in which the propositions are stated. This global impression determines his attitude toward various possible conclusions and leads him often to error. The rule seems to be that when both premises are alike, that is, when they are

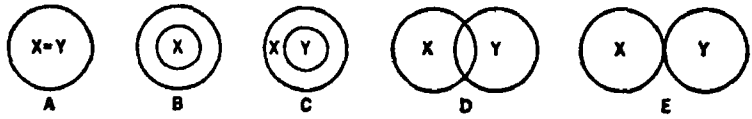


FIG. 186.—Diagrams to represent relationships of inclusion and exclusion. Let one circle represent the area included by the term X and another circle represent the area included by the term Y. In A, the area of X corresponds with the area of Y—the two coincide; which condition is represented by such statements as: X equals Y, or Y equals X. In B, the whole area of X is included in Y, but not all the area of Y is included in X; which condition is represented by such a statement as: All X's are Y. In C, the whole area of Y is included in X, but not all the area of X is included in Y; which condition is represented by such a statement as: All Y's are X. In D, the area of X overlaps with the area of Y; which condition is represented by such statements as: Some X's are Y's, or Some Y's are X's. In E, the areas of X and Y are mutually exclusive; which condition is represented by such statements as: No X's are Y, or No Y's are X.

both the same kind of proposition, the accepted conclusion tends to be a proposition of a similar sort. [66]

Such an experiment indicates that it is necessary to examine critically the construction of a proposition if one is to reason clearly. Logicians have divided all propositions into four kinds:

Universal-affirmative propositions (called A propositions or *all-yes* propositions. Example: All strangers are welcome.

Universal-negative propositions (called E propositions) or *all-no* propositions. Example: No strangers are unwelcome.

Particular-affirmative propositions (called I propositions) or *some-yes* propositions. Example: Some welcome people are strangers.

Particular-negative propositions (called O propositions) or *some-no* propositions. Example: Some welcome people are not strangers.

An examination of syllogisms which contain premises representing these different kinds of propositions will show how little justification there is for this common tendency to accept a conclusion because it is stated in the same kind of proposition as the premises. [66]

1. When the premises are both universal-affirmative propositions, a valid conclusion may be also a universal-affirmative proposition under certain circumstances; but under other conditions such a conclusion is not valid. This makes such a syllogism particularly tricky. The two illustrations given here demonstrate this.

For example:

If: All X's are Y's; and
All Y's are Z's; then
How many X's are Z's?

This syllogism may be reduced to the diagram shown in Fig. 187. An inspection of this diagram shows that all X's are



FIG. 187.—Diagram representing the syllogism: If all X's are Y's and if all Y's are Z's, then all X's are Z's.

Z's. The premises are universal-affirmative propositions and the conclusion is also a universal-affirmative proposition.

Another example:

If: All X's are Y's; and
All X's are Z's; then
How many Y's are Z's?

There are two possible conclusions, either of which would satisfy these premises, as shown in Fig. 188. All Y's may be Z, as shown in A in the figure; or some Y's may be Z, as shown in B. Yet, when syllogisms of this order were given to subjects, it was found that 78 per cent said that all Y's are Z. They tended to favor a universal-affirmative conclusion when the premises were universal-affirmative propositions.



FIG. 188.—Diagram to show that no one answer may be given to the following question: If all X's are Y's, and if all X's are Z's, how many Y's are Z's? Either of these two diagrams will satisfy the premises. (1) Diagram A shows that all Y's may be Z, and the premises be satisfied. (2) Diagram B shows that some Y's may be Z and some Y's not be Z, and the premises be satisfied.

2. When the premises are both universal-negative propositions, no conclusions can be drawn about the relation of X to Z. For example:

If: No X's are Y's; and
No Y's are Z's; then
How many X's are Z's?

An inspection of Fig. 189 will show that three different drawings all satisfy the premises: X and Z may be mutually exclusive, X and Z may overlap, or X and Z may be identical. Hence, no conclusion can be drawn about the relationship of X to Z. Notwithstanding this obvious fact, 67 per cent of those tested with such syllogisms gave the conclusion: No X's are Z's.

3. When the premises are both particular-affirmative propositions, no conclusions can be drawn about the relation of X to Z. For example:

If: Some X's are Y's; and
Some Y's are Z's; then
How many X's are Z's?

There are three possible diagrams all of which satisfy the premises, as shown in Fig. 190. Since the syllogism cannot be reduced to a diagram showing the relationship between X and Z, no valid conclusion about their degree of overlapping can be drawn. Nevertheless, 90 per cent of subjects tested replied: Some X's are Z's.

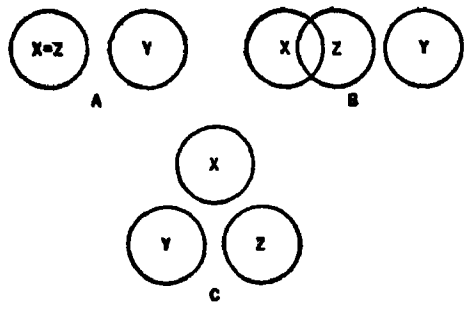
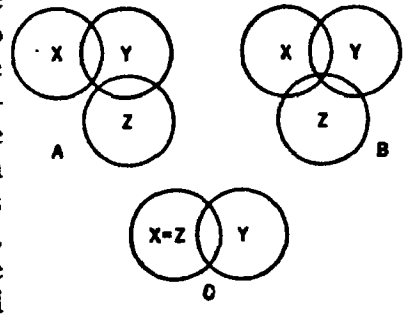


FIG. 189.—Diagram to show that when both premises of a syllogism are universal-negative propositions, no conclusion can be drawn. Any one of the three diagrams will fully satisfy the two premises: No X's are Y's; no Y's are Z's. In A, X and Z may be coextensive and the premises satisfied; in B, X and Z may overlap and the premises be satisfied; while in C, Y and Z may be mutually exclusive and the premises satisfied.

FIG. 190.—Diagram to show that when both premises of a syllogism are particular-affirmative propositions, no conclusion can be drawn. Any one of the three diagrams will fully satisfy the two premises: Some X's are Y and some Y's are Z. As shown in A, no X's are Z's, and the premises are satisfied; in B, some X's are Z's, and the premises are satisfied; while in C, X and Z are coextensive, and the premises are satisfied.



4. When the premises are both particular-negative propositions, no conclusion can be drawn about the relation of X and Z.

For example:

If: Some X's are not Y's; and
Some Y's are not Z's; then
How many X's are Z's?

This syllogism may be represented equally well by the same three diagrams shown in Fig. 190. Nevertheless, 70 per cent of those tested gave the conclusion: Some X's are not Z's.

A great deal that passes for reasoning is not reasoning at all, but merely a foreknowledge that a conclusion is wrong or right.

For example:

If: Some men are liars; and
Some women are liars: then
How many men are women?

Everybody would quickly answer: No men are women. However, this is not the result of his reasoning. The premises are both particular-affirmative propositions, which, when reduced to abstract terms, were answered in a way equivalent to saying that "some men are women" by 90 per cent of the individuals tested. As shown in Fig. 190, it is no more logical to say that "no men are women" than to say that "some men are women."

It seems apparent from these experiments that accurate syllogistic reasoning demands some method for escaping from atmosphere effects and extraneous influences.

1. Where the material is couched in ambiguous language, it must be reduced to terms which can be rigidly defined and these definitions must be maintained throughout the logical processes.

2. The propositions should be clearly stated and should be reduced to syllogistic form. If the premises are not true, no conclusions deduced from them can be valid.

3. The syllogism should never contain more than three terms.

4. The relations involved should be clearly recognized. This is best accomplished by means of symbolic diagrams.

QUESTIONS FOR REVIEW

1. What are the essential characteristics of a problem situation?
2. Outline the variations that may characterize problems.
3. Describe the function of random activity in problem solving.
4. In what way should the following statement be qualified: "Past experiences are useful in problem solving"?
5. What is meant by orientation to a problem?
6. How do incentives affect problem solving?
7. Enumerate the advantages of language in problem solving?
8. What are the characteristics of puzzles which make them useful instruments for research in problem solving?
9. Outline the steps involved in the learning to escape from a puzzle box by an animal.

10. How do experiments with string pulling illustrate the operation of chance success in problem solving?
11. Explain the function that guidance may perform in learning as demonstrated in the stick-reaching problem.
12. What do detour problems demonstrate?
13. How do box-stacking problems indicate that learning of a simple problem contributes to the solution of a more difficult one?
14. What is meant by a delayed reaction?
15. Explain why the use of language assists in extending the range of delayed reactions.
16. In what four different ways may choices be classified?
17. Show how multiple-choice problems can be arranged in an order of increasing difficulty.
18. What is the significance of learning by gradual correction?
19. Upon what factors does learning by gradual correction depend?
20. In the light of experimental research, how must insight be explained?
21. What part do success and failure play in problem solving?
22. Outline the principles of problem solving by human adults.
23. Explain how certain attitudes and assumptions interfere with problem solving.
24. Give evidence to show the value of preliminary instruction in problem solving by human beings.
25. Describe an experiment which indicates that hints may be accepted by a problem solver without his being aware of it.
26. How do unwarranted assumptions interfere with problem solving?
27. Explain how the solving of one problem may carry over to other problems?
28. What conclusion has been reached about the sensory cues used by animals in maze running?
29. What three steps are involved in maze learning by animals?
30. Give the evidence that points to the importance of becoming oriented toward a goal in maze running by animals.
31. What four characteristics of human activity make their maze learning superior to the maze learning of animals?
32. In what way do temporal mazes indicate man's superiority in problem solving?
33. Explain the use of verbal analysis in maze learning.
34. Show how a successful solution may be a poor one.
35. What is an abstraction?

36. Through what developmental stages does a child pass in the formulation of definitions?
37. What are the requirements for a good definition?
38. Distinguish between inductive and deductive reasoning.
39. Of what importance is a definition in the formulation of clear concepts?
40. Show why a clear concept involves the exclusion of irrelevant qualities as well as the inclusion of essential qualities.
41. Distinguish between classification by assimilation and by analysis.
42. Give three rules for correct classification.
43. Describe the process of formulating a principle.
44. Describe four types of imperfect generalization.
45. Name some factors which make it easy for persons to generalize incorrectly.
46. What is a syllogism?
47. Give illustrations of syllogisms based on linear relationships.
48. What is meant by the relationship of inclusion and exclusion?
49. From arguments which you have heard formulate syllogisms and reduce them to graphic form.
50. Describe four kinds of proposition.
51. Build syllogisms containing the different kinds of proposition; have your friends give their opinions as to the conclusion that follows from the premises; then check their conclusions by the construction of diagrams.
52. State four rules that will provide safeguards against inaccurate syllogistic reasoning.

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Chapter XVII

THE PSYCHOLOGICAL INDIVIDUAL

UP TO this point our study has been analytical. We have isolated successively different aspects of the psychological individual and studied each feature to the exclusion of others. Now we plan to study the individual as a whole.

COMPLEXITY OF THE PSYCHOLOGICAL INDIVIDUAL

We are immediately struck with the difficulties involved in undertaking the study of the entire individual. No two persons are exactly alike and the same person changes from day to day. Shall we study the areas in which some similarity exists between individuals and ignore the points of difference? Shall we hunt for the more stable factors and ignore the changing ones? Or shall we go to the opposite extreme and take cognizance only of each individual as an entity and stress his unique and changing characteristics? We might venture the statement that the pure scientist would prefer to hunt for common elements and the pure artist would prefer to stress individual differences or unique characteristics. On the other hand, no one is either a pure scientist or a pure artist; each student will have his own preferences. These personality preferences in those who have studied human nature have kept the study of psychology from becoming stereotyped.

This diversity of interest with its consequent multiplicity of approaches does no damage so long as the student realizes that he is driven by his own interests rather than by objective facts. Everyone likes to consider himself a "student of human nature." Let anyone study who cares to do so; but let each

beware of the temptation to believe he has the last word. Each one is almost sure to emphasize one particular aspect, to favor some particular method, and to give too much weight to congenial conclusions.

METHODS FOR STUDYING INDIVIDUALITY

This diversity of interests in people is well illustrated when one begins to outline the different ways in which people may be studied. One author lists fifty definitions for personality, and has listed fifty-two methods for studying personality. [1] Another author, in a fairly comprehensive outline for personality study, lists for investigation 11 main items or areas of study, 79 subitems under these 11 main ones, 304 subsubitems, and 486 subsubsubitems: 880 in all. No one man would be competent to secure all the information contained in this outline for any one individual. [14]

The complexity of our study will be apparent by a reading of the following list of methods, all of which have been seriously utilized to study individuality: [1]

1. Influence upon the individual of the cultural setting in which he lives. For example, two young men may join the Communist party. Superficially, it is the same act by both; but the unique significance of each man's act may only appear when it is learned that one man is the son of a wealthy banker, while the other is the son of a disgruntled laborer.

2. Language analysis. Individual analysis may be sought by a study of the language preferences of the person, or by the size of his vocabulary. General analyses may be made by a study of the words in a language which are used to describe personal traits, by a study of proverbs, by an analysis of the figures of speech, or the like. It has been assumed that if the language of a people contains a word descriptive of individuality there must be some trait to correspond to that word. One study of the English language found 17,953 terms descriptive of personality or behavior.

3. Hereditary background.

4. Family situations in which individual was raised. These include the study of the interaction with the personalities of parents, sibljngs, and other persons in the home.

5. Biochemical factors. These include psychogalvanic re-

flexes, circulatory peculiarities, blood composition, brain waves, and endocrine make-up.

6. Constitutional factors. Such characteristics as weight, skin texture, coloring, bodily proportions, and the like play a part in individual development.

7. Socioeconomic status.

8. Play history.

9. Work habits. These include jobs held, length of tenure, and circumstances surrounding changes.

10. School history.

11. Response to other people. Very important are the reactions of a person to others when he has been irritated, thwarted, punished, rewarded, cheated, or loved by them.

12. Response to difficulties. Comparisons of responses to social, economic, physical, moral, or romantic problems are often illuminating.

13. Diaries. Whether or not a person enjoys keeping a diary may be significant, as would be an analysis of the contents of a diary.

14. Analysis of correspondence.

15. Analysis of written or oral themes.

16. Analysis of expressive behavior of the individual. Individual study may be approached by an analysis of facial expression, mannerisms, dress, drawings, speech, writing, emotional behavior, postures, and the like.

17. Rating scales. Hosts of rating scales have been devised. These include ratings of character, conduct, good citizenship, executive ability, teaching ability, leadership, and a host of other so-called personality traits.

18. Psychograph methods. Various traits may be isolated, and the person scored by some means on each of these traits. The psychograph is a graphic representation of these scores.

19. Tests. In recent years much effort has been devoted to the development of a great variety of personality tests.

20. Questionnaires.

21. Behavior scales.

22. Attitude scales.

23. Statistical analysis. The most recent of these is the method of factor analysis.

24. Taking time samples of an individual's life.

25. Behavior in a miniature representation of a real life situation.

26. Trap situations. On the theory that an individual will reveal his true characteristics better when in a challenging situation than when he is in complete control of himself, many experiments have been conducted where the unexpected happens or the subject finds himself confronted by an apparent danger. This method has been used, for example, in studying such characteristics as honesty and loyalty.

27. Psychoanalysis.

28. Dream interpretation. This would include interpretation of both night and day dreams.

29. Analyzing the significance of slips of speech, forgetting, losing objects, and the like.

30. Free association.

31. Study of involuntary movements.

32. Hypnosis.

33. Interviews.

34. Biographies.

35. Complete case studies.

Having read this array of methods, the student should be thoroughly bewildered at the complexity of the problem of individual analysis. This is as it should be. Any satisfyingly simple procedure is sure to tempt one to accept it, and this outline has been given to make clear the absurdity of any claim for the adequacy of a simple system.

The student should also be on his guard against the opposite error; namely, that of saying that he has an intuitive understanding of "human nature" which he does not wish to mar by any analysis of the components of individuality. A good artist is never injured by a study of techniques, whereas a potentially good one may remain a dauber if he refrains from detailed study. Psychology is the scientific study of the individual; the artistic study of the individual may involve the application of all that psychology has to teach. There is a place for the abstract scientist; there is a place for the artist; but there is little place for the individual who tries to take a short cut and to make personality analyses with no basis for his work. [16]

HISTORICAL SURVEY OF THE SEARCH FOR COMMON FACTORS

The study of individuality has a long and interesting history. A review of its course will reveal an incessant search for common factors. There is an admission by all that the differences between persons are extremely striking; but it does not satisfy the inquiring mind to stop with the assertion that no two persons are alike. People are different, but there must be common factors. One group of students will seem to work out certain common elements and classify people on those bases; the next group will show that the classification is untenable and propose a new classification. Historically, we have a sequence of fads in personality analysis and the present era is no exception. [1]

The doctrine of humors. The oldest classification of personalities of which we have any record comes from the Greeks. It ascribed the peculiarities of temperament to the "humors," or fluids, in the body. Persons were classified according to the predominance of these fluids. A person with a large supply of blood was sanguine; one with a large supply of black bile was melancholic; one with a large supply of yellow bile was choleric; while one with a large amount of phlegm was phlegmatic. We still use the descriptive names to designate certain temperaments; but the relation of these to the original "humors" is thoroughly discredited. According to present-day usage, a sanguine person is one who is confident, lighthearted, vivacious, and enthusiastic. A melancholy person is one who is habitually low-spirited, downcast, and dejected. A choleric person is irascible, fiery, high-tempered, and easily provoked to anger. A phlegmatic person is cool, calm, composed, and emotionally indifferent.

The theory of body types. Men have long thought that general body build was related in some way to mental characteristics. The fat man was supposed to be happy, successful, and aggressive. The lean man was unhappy, dissatisfied, and dangerous.

Rather recently, attempts have been made to construct a rather comprehensive classification on the basis of body build. People are divided into four groups: [16]

1. *The asthenic* (or tall, slender, and weak person) is temperamentally shut-in, idealistic, romantic, silent, unhappy; a retir-

ing person who tends to retreat into his own emotions instead of meeting life in an objective or heroic manner.

2. *The pyknic* (or short, heavy, small-boned, and corpulent individual) is likely to be genial, easy to meet, happy, good-natured, objective, and realistic.

3. *The athletic* (or tall, muscular individual) is active, fond of physical activity, but less happy about his adjustments than the pyknic individual.

4. *The dysplastic* (or physically deformed person) tends to be odd, peculiar in disposition, with a freakish temperament which often is appropriate to his deformity.

While it may be possible arbitrarily to classify people into these four types, extensive studies of the relationship between these physical characteristics and the personality ascribed to them have shown that such a classification is purely conjectural. Where differences in personality are found connected with physical types, these may be explained on the basis of differences in experiences which go naturally with physical build. For example, boys who have solid and substantial physiques (whether pyknic or athletic) tend to develop personalities that are aggressive and realistic, partly because such a physique disposes them to act in an aggressive manner.

Personality classifications based on endocrine factors. The most clear-cut classification of this sort is into sexes: male and female. We are all familiar with the so-called secondary sex characteristics, such as the pitch of the voice, the distribution of hair, the bony structure, and the like. That these characteristics are directly related to the sex glands has been demonstrated by extirpation and transplantation experiments in animals.

However, some of the traits that we recognize as being different in men and women are not clearly and arbitrarily dependent upon the endocrine glands. Many recognized sexual traits depend upon differences in social treatment. With no social influence it would be hard to imagine that most boys would prefer to play baseball and marbles instead of choosing to knit and to play with dolls.

Endocrine factors and physical make-up probably do have some influence upon personality characteristics; but a classification

based solely upon such factors is certainly hopelessly incomplete. [1]

Phrenology. Although the attempt to localize functions at various areas of the brain was begun by scientists, the idea of such localization struck a popular note which led to an exploitation of the belief in phrenology. In spite of its manifest absurdity, this belief still creeps up in modern life. According to this system, the mental life of the individual may be subdivided into specific traits which actually have no existence: inhabitativeness, alimentiveness, ideality, sublimity, form, weight, color, time, tune, and the like. To these they add others which are loosely descriptive of human beings but hard to define: destructiveness, acquisitiveness, amativeness, mirthfulness, and the like.

The phrenologists have listed forty-two of these "faculties" and have plotted them on the cortex of the brain. They are supposed to have the seat of their functioning at these areas. Furthermore, it is assumed that as these traits develop they cause increases in brain mass at these points which in turn push out the skull located above such areas. Character can thus be read by studying the bumps on an individual's skull. These views have been totally discredited.

Stigmata of degeneracy. This theory maintained that the presence of certain bodily peculiarities, which were called stigmata of degeneracy, indicates a tendency toward traits of instability and degeneracy. Some of the stigmata that have been named are: woolly hair; peculiarities in the shape of the skull; scanty eyebrows; absence of body framework of the nose; extremely large or thick ears; wrinkled, pale, or sallow skin; deeply cleft lips; peculiarities in the formation of the teeth. This theory has been thoroughly discredited.

Physiognomy. Physiognomic systems attempt to interpret human characteristics from the form of the face and other outward appearances of the individual. Some of these systems have been based upon hypotheses of reputable scientists. Physiognomy has been shown to be erroneous but has, nevertheless, been exploited by uncritical individuals and widely publicized. One physiognomist, for example, divided the human personality into three types: the mental, the motor, and the vital. The mental type was supposedly indicated by an elongated or triangular face with

the base across the top of the head, and the apex pointed downward at the chin. The motor type could be recognized from a square head and face. The vital type had a round, flabby countenance.

Numerous studies have shown that there is no relationship between such physical characteristics and temperament. In spite of this negative evidence, the belief in such relationships is persistent. It has been found, for example, that the unlettered individual incorrectly and with no sound reason believes that certain physical traits are connected with distinctive personality traits: Thick bushy eyebrows, to these persons, suggest sternness. A receding chin suggests vacillation and lack of initiative. Small eyes suggest greed. Small bones they believe to mean high ideals and delicate feelings. Fine hair indicates fine temperament. Coarse hair suggests toughness, meanness, and low ideals. Small ears suggest thrift. Big ears suggest eloquence and excellence of speech. A thin sharp nose suggests shrewdness in business. Thick lips suggest passion, strong feelings, and impulsiveness. A high forehead suggests great intellect. A receding forehead suggests low intelligence and criminal tendencies. A square jaw, to these people, suggests stubbornness. [16]

Regardless of where these superstitions originated, and in spite of their unsoundness, some people believe that they can judge by such characteristics. The important consideration is not to guard against judging others by these methods but to counteract the tendency of others to judge us according to some such physical trait. The logical procedure is to get rid of characteristics which produce unfavorable impressions or, if they cannot be eliminated, to counterbalance such impressions by exaggerating our manifestation of counterbalancing physical traits.

Contemporary attempts to classify personalities. Modern investigators have endeavored to avoid the mistakes which this historical sketch of personality study has revealed. Of those methods listed on pages 531 to 533, they have found the following to be the most valuable: clinical studies, rating scales, questionnaires and inventories, tests, experiments, and statistical analyses. These are not mutually exclusive and some of them depend upon or presuppose the others. We shall deal with these in

greater detail presently, although we shall not take them up in regular order. [24]

THE GROWTH OF THE PSYCHOLOGICAL INDIVIDUAL

Whereas the individual is complex and defies classification into any limited set of categories, he still has a coherence and a unity which mark him off from every other individual. Even identical twins are separate, unique personalities in spite of the fact that one may be mistaken, at times, for the other.

Individual unity is, nevertheless, not a static entity. Some persons are more unified than others. Some easily fall apart physically, emotionally, and intellectually. Some resist the most violent disrupting influences.

Furthermore, there are changes in the degree of unity as life proceeds. The thread of unity runing through a single life is a somewhat elusive thing. A person is born, goes through his life, and dies; we consider that he is the same person all the way along and, in a sense, he is. On the other hand, the infant John Jones is not the same John Jones whom we see in grade school, in high school, as a mature businessman, or as an irascible man of eighty-five who cannot remember at ten o'clock what he had for breakfast.

People differ in their reactions to this phenomenon of changing personality. Complacent, self-satisfied persons tend to dislike the notion of change. They would like to remain as they are because they believe they have "arrived." Ambitious persons, who are still dissatisfied with themselves, like to believe that there are better things ahead for them: so they stress the changing factors in life. In other words, whether one wants change depends upon where he thinks he is in relation to the top or the bottom. If one is at the bottom of the social ladder, any change is more likely to be up than down; if one is at the top, any change is more likely to be down than up. The psychologist should not permit such personal considerations to enter into his study of individuality.

How can continuity of individuality be reconciled with the fact that a person is continually changing? The answer probably lies in the fact that the degree of change at any one time is small in relation to the whole individual. When changes become

too great there is disruption or death. The slow, continuous nature of development is clearly manifest when one attempts to divide a life into periods. It is almost impossible to indicate exactly where infancy passes into childhood, childhood into adolescence, adolescence into maturity, and maturity into senility.

Interaction between environmental and hereditary factors. Each individual is a product of hereditary processes and of the experiences through which he passes after conception. A man's structure is certainly the result of hereditary factors. Hereditary accounts for such facts as that he is a human being and not a goat, that he has two feet and not six, that he can live in air rather than in water, and that his larynx, tongue, lips, and lungs are adapted to speaking. Certain activities also are determined by such inherited structures. A man walks as he does because of his structure, he breathes air instead of water not from choice but from necessity. He talks partly because he has the organic structures which he has. However, what he says does not depend upon heredity. Perhaps a safe generalization would be that there is more dependence upon heredity in those characteristics which are relatively closely tied to the structure of the individual, and more dependence upon experience in those traits which are not closely linked with structure.

The way in which heredity and environment are related to each other has often erroneously been regarded as a summation effect. A certain percentage is presumed to come from heredity and another percentage from environment; the sum of the two must be 100 per cent. The two are not added in any such fashion. The relationship is better expressed by multiplication than by addition. The individual is the product of heredity times environment. With such an equation, if either factor is reduced to zero the product is zero. With no environment, heredity cannot produce an individual. Without heredity, environment is just as powerless.

The relative weight that should be given to each factor is certainly not a constant. It probably varies with individuals, and in the same individual it varies in different situations. This being the case, it is futile to attempt to assign relative weights to each, and statements which presume to do so are probably in error.

Relative value of maturation and learning. Those who stress hereditary factors encounter a striking difficulty when they study the development of the human infant. The equipment of the human infant is certainly meager and he is exceedingly incompetent. If most of his ability comes through inheritance, where is it during infancy? The concept of maturation was conceived to escape this difficulty. According to this theory, there is a ripening of innate behavioral tendencies in the absence of any training and experience. The infant is incompetent, but ripening makes up for his deficiencies without the benefit of teaching or experience.

As we have shown in a previous chapter (page 46), there is little reason to reject the concept of maturation or ripening as a factor in physiological development. One cannot learn to use an arm until the arm has reached a stage of development that will permit its use. An individual cannot become a parent before adolescence. No amount of training can teach a person to perform an act unless the structural mechanism for its performance is present.

On the other hand, there is no justification for reasoning from analogy and contending that elusive personality traits await personality maturation. There is reason for thinking that such characteristics as deceitfulness, neatness, humility, aggressiveness, or fidelity are dependent more upon learning than upon the ripening of some innate mechanism.

This does not carry with it the implication that innate structure, or structure acquired by maturation or even by accident, is not effective in the direction of intricate traits. One might easily expect that a weak, sickly child is more likely to be dependent, shy, and fond of the mother who nursed him incessantly than is the robust child who has had less need for his mother's care.

Learning should be viewed in its broadest sense when we are considering the part it plays in individual development. It may be unintentional learning; it may be that the child was "taught" one thing but learned something entirely different; it may be that some violent shock was more effective than long periods of training; a vague attitude may be the result of learning as much as is the ability to hit a target with an arrow.

The role of conflict in the growth of individuality. In our study of emotional adjustments we found that when a person was confronted with some emergency situation, he mobilized his energies and reacted in a more violent way or in some new manner. We discussed the adequacy of such different responses. There is another aspect to emotional situations; namely, the permanent or semilasting effect they have upon the one who experiences them. The traits which we class as personality traits are more likely to be based upon emotional experiences than upon routine events. To state the issue in another way: Personality traits contain a large proportion of emotional habits.

One can imagine situations which, when repeated with a child, could develop various so-called traits, to wit:

Suggestibility might be taught to a child if he found solutions for his difficulties by taking the suggestions of others; a nonsuggestible child might be developed by seeing to it that he gained nothing but more trouble by taking suggestions.

See to it that a child is happier when he daydreams than when engaged in objective and active pursuits, and it should be possible to develop in him the tendency to daydream.

See that a child repeatedly gains his ends by stealing and that he is caught and suffers infrequently; and he may thereby learn to be a sneak thief.

Qualities of the mature individual. If we accept the developmental conception of individuality, we should interpret the changes which we see in the growing person as pointing toward



FIG. 191.—A cycloid curve. The imaginary representation of an undisturbed life cycle.

a condition of ripeness or maturity. Ripeness, however, is never static; rather, it carries with it the implication of retrogression, deterioration, and decay. The curve of an individual life has never been precisely determined, but we can imagine it to be in the form of a cycloid. A cycloid is represented in Fig. 191. Such an imaginary representation of a life cycle is, doubtless, an oversimplification.

Maturation is not definitely related to chronological age.

Some individuals reach the highest level of development earlier in life than others; some continue to grow longer than others; some are cut off, so that the curve may make an abrupt drop from any conceivable point.

Furthermore, growth and maturity are the product of a number of different factors. An individual may be relatively mature in some respects and infantile in others. Such infantilism may never be overcome, or it may be followed by a period of rapid development.

All these qualifications indicate clearly that the idea of individual maturity is a vague and unmeasurable concept. In spite of this, clinical studies have shown that the following aspects of individual maturation are of some significance.

The mature individual should be well rounded. By this is meant that he should have a normal amount of development in all aspects of his individuality. Such an individual is equipped to compete on an even basis with other individuals. A case can be made, nevertheless, for the lopsided individual—the freak or the genius who has some quality lacking, or some trait present in a grossly exaggerated form. An extreme oddity may give him a decided advantage in a competitive society. For example, the late boy giant of Alton, Illinois, who was over eight feet tall, had a decided advantage in playing forward on a basketball team. He merely stood under the basket, received the ball from his teammates, and dropped it into the basket.

The mature individual should have achieved a fair amount of objectivity. He should be well adjusted to his environment. Such maturity shows itself in the preference for dealing with the actual world rather than for solitary daydreaming, in the variety of interests shown in objective life, in the ability to become absorbed in work, in play, in civic activities, and in the ability to meet a challenging situation by cool analysis.

Such an objective adjustment can be accompanied by a desire to change situations and does not involve docile acceptance of unfavorable aspects of living. There should be an active planning for the betterment of conditions instead of the more infantile reaction of whining, complaining, or solitary retreat.

The mature individual should have insight. Insight is essentially knowledge of oneself; it is freedom from self-decep-

tion. It is not unusual to see a child boasting loudly about his prowess while, at the same time, he is failing completely. He lacks the self-criticism which a mature individual should possess. Insight is more likely to be accompanied by a modest appraisal of oneself than by exaggerated statements of ability.

Insight is manifest also in the willingness of an individual to take the responsibility for his own acts when these are not so excellent. One lacking insight takes the credit for his successes and blames others for his failures. Maturity brings a reversal of this process.

A genuine sense of humor about oneself is a good index of insight. The young child usually lacks such humor. He laughs readily at the misfortunes of others, but seldom sees a joke on himself as really funny. He takes himself so seriously that his failures cannot amuse him. It is seldom that a man admits that he has no sense of humor; and probably all men have some. It is the direction that his humor takes which indicates his degree of maturation. The mature man genuinely enjoys a good joke on himself more than he does a joke on others.

The mature person is socially adjusted. Probably no other quality measures the maturity of an individual more than the degree to which he has developed a consistently mature type of social philosophy. Perhaps the significance of this characteristic can be made clear by drawing some contrasts between the individual who is still infantile in his social adjustments and one who is relatively mature:

1. The social infant needs others; the socially matured person helps those who need him.

2. The social infant tries to impress others with his virtues; the socially matured person appreciates the good points in others.

3. The social infant is fortunate if he is able to get along with one person—his mother; the socially matured person understands individual differences and gets along well with persons of widely different types.

4. The social infant wants to be understood; the socially matured person wants to understand others.

5. The social infant wants others to contribute to his hap-

piness; the socially matured person gains his greatest happiness by contributing to the happiness of others.

6. The social infant wants others to like him; the socially matured person is so busy liking others that he has no time to consider whether they like him or not.

7. The social infant takes; the socially adolescent person gives and takes; the socially matured person gives.

UNIFYING FACTORS IN THE INDIVIDUAL

Even while subjecting the human individual to the process of psychological dissection, it is apparent all along that there are numerous integrating or unifying factors. It may be of value to summarize these factors briefly.

Each cell in an individual contains the same essential pattern of chromosomes. In the early stages of growth, each division of a cell leaves the daughter cells with the same pattern as the parent cells because reproduction is by division. Even when cells become highly specialized this pattern remains the same. However, in the adult individual, identical chromosome pattern is not so essential as might be imagined for continued unity. For example, the individuality of a person is not much affected by having a part grafted to him from another person or even from an animal.

Specialization of parts of the individual does not destroy unity. In the analysis of early development, it was found that the individual was, at first, a mass of cells which acted as a whole, and that development proceeded by the process of individuation. One part of the body learned to do some specialized act; there was the emergence of a specific and local activity out of general mass activity. Instead of being a breakdown of the original unity of the individual, as it might seem to be at first glance, individuation is essentially the beginning of a unity of a higher order. It enables the growing organism to deal with a local situation effectively while still free to attend to other matters. Individuation proceeds, however, only so far as the welfare of the individual is served. Instead of differentiation of function leading to civil strife and disunity, it makes for increasing efficiency.

Unity is accentuated by teamwork. Orderly performance requires that each contributor (or actor) not only becomes

individually efficient, but that he knows when to join with other contributors, when to sit back and wait, and just what degree of assistance or restraint to exercise. In other words, unity of function requires accurate timing. This is illustrated well in skilled motor acts, but it also appears in every function where specialized individual contributions are made. Parts of the body have to learn cues as to when they should come in; and the study of conditioned reflexes showed us how such learning takes place. There must be profiting by mistakes, which involves memory; there must be proper co-ordination, which comes with practice; and there must be a unifying objective at any one moment, which requires consistent motivation.

Unity requires the avoidance of dangerous excesses. In times of stress, we found that various parts of the body changed their function to maintain what has been called homeostasis. If there was an approach to the danger line away from balance in such essential conditions as water content, salt content, temperature, and the like, there was a mobilization of energy to bring the organism back to safety. It would do no good for a hand to continue practicing some motor trick when the total individual was threatened by death from loss of blood. The hand would be forced to stop its specialized performance so that all available energy might be utilized to meet the emergency.

The nervous system is a unifying instrument. By means of the nervous system, every part of the body has a line, or lines, of communication with every other part. All these connections, moreover, are effected through central connections of a complex order. The brain is the essential switching center and co-ordinator of activity in such a complex organism as an individual. Simple reflex patterns can operate without the co-operation of the brain, but the solution of a difficult intellectual problem requires more than local reflexes. It requires a mechanism to mobilize all the energies of the individual, all his past experience, all aspects of the present, and the possibility of making tentative responses to test the validity of possible solutions.

Different parts of the body are more important than others; but the brain outranks them all. One can live when large parts of the brain are not functioning (as in sleeping sickness), but not

effectively. The arm might go on a strike (because of a motor paralysis) and efficiency might be somewhat reduced; but the individual could get along much better than if the brain went on strike.

Unity is helped by shifts of interest. When an individual is bombarded at one time with a number of problems demanding solution, an attempt to deal with them all simultaneously could end only in disruption. The ordinary procedure is to give complete attention to one at a time. This leads to the phenomenon commonly known as a shift of attention. When this process does not function adequately, various forms of individual disruption may occur. Extreme efforts to deal with all issues at once leads to "jitteriness." If too much attention is given to one problem and the others are completely ignored, so that they do not get their attention in turn, there may be dissociation owing to a memory blocking. The individual forgets instead of delaying action. In an extreme form of this type of behavior there may appear a complete dissociation of the personality. The individual forgets who he is. He starts life afresh because he does not remember who he was or what problems he had. Shifts of attention, with successive attention to different problems, is an important aspect of psychological unity.

Every person evolves individual codes for living. Although these may be difficult for a person to formulate, each individual is continually building up a body of principles or points of reference for the regulation of his own behavior. Various names have been suggested for such life codes: philosophy of life, world outlook, ideology, creed, belief, point of view, way of thinking, or confession of faith.

Probably in most instances an individual is unable to formulate in words what his own set of rules for living are. He may state one rule and live another. He may have evolved his own, or he may have accepted them from others.

Normally, every experience modifies them continually in some manner, although a person may believe that he is living consistently by the same rules through a period of years. They may contain many inconsistencies, or may be fairly well integrated. It might be safe to say that, in most instances, the guid-

ing rules are not those verbally enunciated by an individual, but a set of attitudes or emotional habits which come to the foreground especially in times of crisis.

THE MEASUREMENT OF TRAITS

A trait may be defined as a distinctive mode of behavior. It is purely a descriptive term, an index of an outsider's interpretation of the behavior of another. We observe the indications of a trait in another person; we infer the presence of a trait if those indicators are consistent with our definition of the trait in question. The measuring of a trait is the process of determining the degree to which a person fits such an arbitrary definition.

Suppose a boy has been guilty of an act which he has been told was bad and that he is reasonably certain that his father does not know he did it. Suppose, further, that this father approaches the boy with anger written all over him, and screams at him, "Did you do that?" The boy knows if he says "yes," he will be whipped. If he says "no," he has reasonable assurance that he will not. Consequently, if he says "no," he is making an intelligent response. Does this make him a liar? He certainly should not be classified along with the pathological liar who tells lies in all sorts of circumstances, who prefers a lie to the truth, and who can always be counted upon to tell a lie if it is at all possible to do so.

Suppose we wish to measure to what degree a certain person tends to tell falsehoods. Whether he told the truth or told a lie would depend upon: (a) The amount of pressure put upon him to tell a lie. (b) The number of equally promising methods of adjustment apparent to him. The observer might see other ways of adjusting, but the important consideration is whether the subject sees them. (c) The strength of the habit of telling lies without waiting to look for other reactions or considering them if they were present; that is, the degree to which he has specialized in lying. (d) The attitude of the subject toward the particular lie in question. [12]

In no psychological experiment designed to measure traits have all the variables been controlled or measured. Hence, the student should be warned that the status of trait measurement

is unsatisfactory. We shall, nevertheless, review some of the methods that have been used.[1]

Ratings of others. In a rating scale the individual under consideration is assigned a score, rank, mark, or position on the trait under consideration.

Requirements for a valid rating scale. In order for a rating scale to be valid certain basic requirements should be met. The neglect of these has made many ratings of little or no value.

1. The rater should have a clear conception of the trait he is judging. If the trait cannot be clearly defined, it is futile to attempt to rate any person on it.

It has been found that definitions in terms of what a man does, or the effect that the man has on the persons or things with which he comes in contact, are much more valuable than descriptions in terms of so-called traits or personality characteristics.

2. The rater should know the person he is rating. The rater should have observed the one he is rating over a long enough

[1] Some representative personality inventories and adjustment questionnaires are as follows:

Allport, G. W., & F. H. A scale for measuring ascendance-submission. Boston: Houghton Mifflin Co.

Allport, G. W., & Vernon, P. E. A study of values. Boston: Houghton Mifflin Co.

Bernreuter, R. G. Personality inventory. Stanford, Cal.: Stanford Univ. Press.

Conklin, E. S. Introversion-extroversion in terms of interest. Eugene, Ore.: Univ. Oregon Press.

Heidbreder, Edna. Personal traits rating scale. Chicago: C. H. Stoelting.

House, S. D. Mental hygiene inventory. Chicago: C. H. Stoelting.

Humm, D. G., & Wadsworth, G. W. J. The Humm-Wadsworth temperament scale. *Amer. J. Psychiat.*, 1935, 92, 163–200.

Laird, D. Colgate mental hygiene tests. Hamilton, N. Y.: Hamilton *Republican*.

Marston, L. R. Introversion-extroversion in young children. Chicago: C. H. Stoelting.

Mathews, E. Revision of the Woodworth personal data sheet. Chicago: C. H. Stoelting.

Neymann, A. & Kohlstedt, K. D. A diagnostic test for introversion-extroversion. Chicago: C. H. Stoelting.

Pressey, S. L. X-O tests for investigating the emotions. Chicago: C. H. Stoelting.

Rogers, C. R. A test of personality adjustment. New York: Association Press, 347 Madison Avenue.

Thurstone, L. L. & T. G. Personality schedule. Chicago: Univ. Chicago Press.

period of time and in diverse situations, so that he has some solid basis for rating.

3. Allowance should be made for the halo effect. The halo effect is the tendency (to which any rater is subject) to be influenced, in rating one trait, by an estimate of some other trait or by a general estimate of the person. A teacher, for example, would be inclined to rate a boy high in studiousness if he is attentive to her or if she liked him.

4. The ratings of several judges should always be considered. If there is little or no consistency among them, the ratings are worthless.

5. The selection of judges from different areas of contact with the subject is important. It might be possible, for example, for all the teachers in a school to rate low in desirable traits a boy who had the reputation of being bad; on the contrary, other persons who knew him under different circumstances might give him an entirely different rating. Prejudiced ratings can be cumulative.

6. Attempts should be made to determine the competence of each rater. It has been found there are wide individual differences in ability to judge the significance of behavior in others. Some persons are so low in this ability that their ratings are worse than useless. There is no easy way to judge a person's rating ability. One method has been to compare the ratings of each rater with the composite score of the other raters. The one who disagreed most with this composite score was judged the poorest rater. This may not always hold. A trained psychologist might disagree with a host of gossipmongers in a community as to the rating of a boy in that community in some trait, and yet the psychologist might be the only one who was even close to a correct judgment.

Self-rating methods. Self-rating is the attempt made by an individual to evaluate himself in some characteristic. There are obvious limitations in this method. [24]

Errors in direct self-ratings. The most apparent error arises from the fact that it is easy for a person to lie in the estimate he renders, provided he knows the significance of the trait he is rating. On the other hand, even if a person attempts to be honest in rating himself, it has been found that he tends to make consistent errors which tend to make self-ratings unreliable.

A person tends to overestimate himself on desirable traits and to minimize the undesirable ones. However, this tendency is not always in conformity with the social standards of his community. If a person believes a trait to be desirable, and the community believes it to be undesirable, the person will rate himself high on the traits he prefers rather than on those the community prefers. In other words, he manifests his overestimation of himself even in his judgment of the significance of traits. About all that can be told from direct self-ratings, then, is how conceited a person is by comparing his estimate of himself with the estimate of his peers.

Indirect self-rating methods. Various means have been devised for disguising the significance of a person's rating of himself.

1. Comparison with an imaginary person. In one test for children, the subject is required to make a direct comparison between himself and some imaginary character with certain characteristics.

For example, the child is told that "Peter is a big, strong boy who can beat any of the other boys in a fight." The child is then asked to indicate on a graphic rating scale the degree to which he thinks he is just like Peter. After this comparison has been made, he is asked to indicate on another graphic scale the degree to which he wishes to be just like Peter. Other hypothetical characters are given (each with a different name and with girls' names when the subject is a girl) and the same procedure repeated for each. Some of the characters are:

George likes to read. He has read all the books he can get about cowboys.

Ed is the best ball player in school.

Sam gets good marks on all his schoolwork.

Allan has make-believe friends and a make-believe world which is much nicer than the real world. He sits and dreams of all sorts of make-believe adventures with these make-believe friends.

Joe is a leader. All the fellows do what he tells them to do.

2. The "guess who" test. Another method for getting a child to compare himself with others is incorporated in the guess-

who test. For example, the child is told: "Here is the class athlete. He can play baseball, basketball, and tennis, can swim as well as any and is a good sport. See if you can guess who it is. It may be one person or several or it may be you. Think over your classmates, and write the names of any boys or girls who may fit the person described."

3. How I feel—how others feel—how I ought to feel. In still another test, various situations are described, such as: having other folks praise me, reciting in class at school, washing dishes, and the like. Three scales are arranged as follows and the subject required to indicate a point on each scale for each situation described. [12, p. 284.]

Having other folks praise me:

(a) How I feel:

dislike	rather not	don't care	like some	like a lot

(b) How most boys feel:

dislike	rather not	don't care	like some	like a lot

(c) How I think I ought to feel:

dislike	rather not	don't care	like some	like a lot

This test is scored on several different counts:

(a) Score for self-criticism. This score is found by counting the number of times the "ought to feel" response is different from the "how I feel" response. The more the boy tends to depreciate himself the higher this score will be.

(b) Score for criticism of the average boy. This is found by counting the number of times the "most boys feel" response is different from the "ought to feel" response. The more the boy tends to be critical of others the higher will be this score.

(c) Feeling of difference from the average boy. This is found by counting the number of times the "most boys feel" response differs from the "how I feel" response. The higher this

score the greater the indication that the boy feels different from others.

(d) Feeling of superiority. A feeling of superiority is indicated when the "how I feel" rating is nearer to the "ought to feel" position than is the "most boys feel" rating.

(e) Feeling of inferiority. A feeling of inferiority is indicated when the "how I feel" rating is farther from the "ought to feel" position than is the "most boys feel" rating.

(f) Deviation from the accepted idea of the right. The items which most raters indicate as "ought to feel" are determined. When the rater to be investigated marks a large number of items "ought to feel" which other boys do not mark in this manner, or fails to mark "ought to feel" those which the others do mark in this manner, it indicates a deviation from the accepted idea.

(g) Social insight. High social insight is indicated when the "most boys feel" ratings agree with a tabulation of what other boys actually indicate as to how they feel.

The psychological questionnaire. A questionnaire consists of a group of questions submitted to a number of individuals with the request that they give an answer to each item. There are certain characteristics which distinguish a questionnaire from a test. In a test the issue is whether the person *can answer* the question; in a questionnaire the issue is whether he *will answer* the questions *truthfully*. In a test a person's score is determined by his ability and the test is made difficult in order to offer a challenge to ability. A questionnaire is made as easy and as simple as possible, and the person given as much time as he desires to answer it. Tests are designed to find out what a person can do, while questionnaires are designed to find out what a person has done, will do, or how he thinks, feels, or believes. While the questionnaire method may be used to discover facts, the psychological questionnaire is designed primarily to learn about reactions of the individual who answers it, such as beliefs, preferences, likes and dislikes, wishes, judgments, and choices.

Two main kinds of questionnaires have been used in attempts to study individuality: the adjustment inventory and the expression of wishes. [21]

1. *Adjustment inventories.* It happens to be a delicate

matter to inquire directly into the adjustment problems of an individual. Since a questionnaire may be answered truthfully or untruthfully, with or without bias, and may include any degree of distortion; its use to study psychological adjustments is particularly difficult. In order to surmount these difficulties it is customary to have a relatively large number of questions in the questionnaire (or inventory, as it is euphemistically called), ranging from highly significant ones to jokers which have no significance. It is assumed that the one who answers will not be able to distinguish all the significant items and thus will probably reveal his maladjustments by the number of such items he answers in a manner characteristic of the maladjusted person.

This method has been grossly overworked. It was developed in order to meet an emergency, in 1917. A widely publicized form was later developed because a psychologist was assigned the task of examining a large incoming college class in order to select those who might be in need of psychiatric assistance. Those who developed the method have pointed out its crude nature, but others have tried to use it as though it were a psychological micrometer. With ordinary common sense a person can answer such a questionnaire in a manner that would indicate that he needed help or in a manner that would make him well balanced. What it reveals, then, is whether the one who takes it wants sympathy and attention or wants to be let alone. If he is a neurotic of the complaining variety he will give a large number of "neurotic" answers.

Other workers have evolved much more elaborate lists, but have not improved much on the original ones, for the simple reason that the basic flaws are intrinsic in the method and cannot be removed by increased complexity of formation. Inventories have been designed to measure the following: various kinds of psychotic tendencies, such as tendencies toward hysteria, neurasthenia, psychasthenia, paranoia, schizophrenia and the like; introversion and extroversion; family relationships, such as relationships with parents, siblings, and wife or husband; love affairs; vocational adjustments; general emotional stability; school and social adjustments; ascendance-submission; negativism and suggestability.

2. *Expression of wishes.* The expression of a wish is not frowned upon violently even when the wish is nonconven-

tional. Consequently, the expression of wishes has been used to secure an index of personal adjustment. For example, children have been asked to state three wishes, the examiner then attempting to interpret the significance of the replies.

A more formal use of the wish is to be found in a test of personality adjustment,[2] as follows:

(a) ——— a housewife
(b) ——— a teacher
(c) ——— a movie star
(d) ——— a stenographer
(e) ——— a storekeeper
(f) ——— a cowboy
(g) ——— a businessman
(h) ——— a businesswoman
(i) ——— a princess
(j) ——— an inventor
(k) ——— a policeman
(l) ——— an aviator
(m) ——— a captain
(n) ——— a fireman
(o) ——— a poet
(p) ——— a detective
(q) ——— a doctor
(r) ——— a nurse
(s) ——— an engineer
(t) ——— an actress
(u) ——— a prize fighter
(v) ——— a king
(w) ——— a singer
(x) ——— a lawyer
(y) ——— a salesman
(z) ——— an artist

The choice of such an item as c, i, t, u, or v indicates that the child making the selection tends to daydream or to indulge in fantasy.

Another test is:

"Suppose you could have just three of the wishes below, which would you want to come true?"

(a) ——— to be stronger than I am now.
(b) ——— to have the boys and girls like me better.
(c) ——— to get along better with my father and mother.
(d) ——— to be brighter than I am now.
(e) ——— to play games better.
(f) ——— to have a different father and mother.
(g) ——— to be a girl (if a boy) or to be a boy (if a girl).
(h) ——— to be bigger than I am now.
(i) ——— to have more money to spend.
(j) ——— to be grown up and get away from home.
(k) ——— to have more friends.
(l) ——— to be better looking.
(m) ——— to have my father and mother love me more.

[2] The Rogers Test. See footnote on page 548.

The choice of such an item as a, d, h, i, or l by boys and a, d, g, i, l, or m by girls, indicates a feeling of personal inferiority.

The selection of such an item as b, e, j, or k indicates a feeling of social inferiority.

The selection of such an item as c, f, or m indicates a family maladjustment of some sort.

Objective tests of personality. A test has a definite advantage over a rating scale or a questionnaire. Instead of basing judgment on crude opinion or on an answer that may be biased or may be a downright lie, in a test the individual's score is determined by what he does in the test situation.

Many ingenious tests have been devised to measure personal traits. As an illustration of a typical test approach to this field of study we shall describe some tests devised to measure honesty and trustworthiness. [10, 11, 12]

The duplicating test technique. Two tests of equal difficulty are made. One test is given under conditions in which cheating is impossible; while in the other test ample opportunity for cheating is given. If there is a difference in favor of the one taken where cheating is possible (a larger difference than might be expected by chance), the presumption is that cheating took place.

The self-scoring technique. A test is given and the student then permitted to score his own paper. Various devices have been used to detect any changes made while the student scores his own paper. One is to secure a paraffin impression of all markings made on the original performance. Another more laborious method is to collect the papers and make a duplicate copy of the answers, then to return the papers and permit each student to score his own paper.

Another type of self-scoring can be used with tests of motor skill or strength. Students are put in competition with each other in such performances as strength of grip, lung capacity, chinning, and broad jump. Motivation is secured by offering prizes of various sorts. Each contestant is given three trials, which are scored and records kept by the examiner. Then each child is permitted to make five additional trials in which he scores himself. Since practice effects are small, a marked increase in

grade when the child scores himself is presumptive evidence that he cheated when permitted to keep his own record.

The improbable achievement technique. Subjects are given tasks impossible of accomplishment to determine whether they will cheat in order to achieve success.

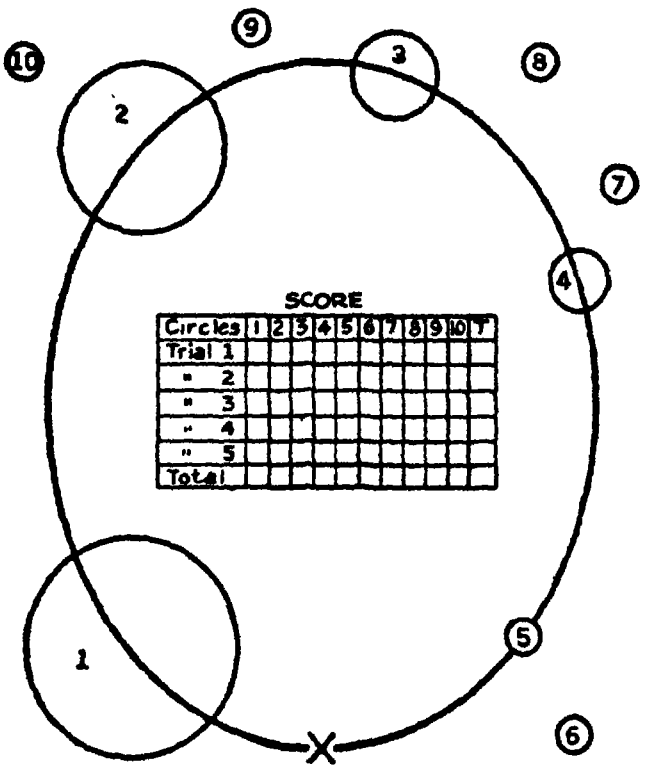


FIG. 192.—Circles test for honesty. The subject is required to keep his eyes closed while putting digits in order in circles as indicated. He makes five trials and records his own scores. It is impossible to accomplish this task without the help of vision. A high score is presumptive evidence of cheating.

For example, the subjects may be required to perform a motor task which can be done successfully only with the aid of vision, with the requirement that they keep their eyes closed. A successful performance indicates peeping. The circles test, shown in Fig. 192, requires that the subject with closed eyes make marks in irregularly placed circles of decreasing size, a

task which no subject has ever been able to accomplish with eyes closed. Another is to trace a pencil maze with eyes closed without touching the sides.

Still more ingenious is the weight test. Seven boxes, each one varying from the other by one tenth of a gram, are marked correctly on the bottom with numbers one to seven. The subject is asked to arrange the boxes according to weight. He is then to turn the boxes over and mark the numbers on a score sheet, being told at the same time that the correct order is 1, 2, 3, 4, 5, 6, 7. Then he is told to turn the numbers down and arrange them again. Success in succeeding trials is an indication of peeping.

Overstatement techniques. A typical example of this technique is found in the "Books Read Test." The test consists of a number of book titles, some of which are fictitious. The subject is asked to check those he has read. The subject may check titles of books which do not exist.

Another is to give the subject a list of questions with the requirement that he check all questions to which he knows the answer. Such questions as the following are given: Who discovered America? Who saved the life of Captain John Smith? Where are the pyramids? After fifty such questions have been examined (or have been asked orally) the subject is given a chance to give the actual answers. His overstatement is found by comparing those he actually knows with those he claimed to know.

Cheating in games. Various games are played with opportunities for cheating.

Stealing tests. Various opportunities are given for stealing coins or other objects under circumstances where the subject is made to feel that he will be able to steal without detection.

The Character Education Inquiry used thirty-two tests similar to those just described to make an extremely comprehensive study of cheating, lying, and stealing. The interesting part of their work is the revelation that there is so little relation between the results of the different tests that it makes any such trait as honesty a dubious entity. Instead, each test indicates what the subject will do in that particular situation and gives little basis for predicting what he will do in another specific situa-

tion, supposed to measure another aspect of honesty. A single test of deceit has little value as an index of deceit in general. The child does not respond to honesty in the abstract, but to such concrete things as the teacher, paper, pencil, school marks, coins, the urge to succeed, imminence of detection, ease of cheating, and the like.

The implication from these studies is that most of the traits about which we talk so glibly are merely abstractions based on outside observation. What we do depends upon the needs of the moment and is not determined by any abstract traits in us.

THE MEASUREMENT OF ADJUSTMENT

The futility of attempts to measure abstract traits in individuals has pointed toward the need for emphasis on adjustment processes. Instead of attempting to find whether a person is honest or dishonest, aggressive or retiring, conceited or modest, more interest is being devoted to the significance of what a person does when he is confronted with some difficult problem. [22]

Any individual's life can be looked upon as a succession of problems which must be solved in one way or another. There is little uniformity in the pattern of these problems. They come in no regular sequence; they manifest little equality or uniform intensity; the periods between them may be long or short; and the degree of success in one may have no relation to the relative success in another. Furthermore, each problem carries with it the seeds for new problems whether one makes a satisfactory adjustment or not. As long as a person lives he must adjust, adjust again, then readjust, ad infinitum. Death is the only final adjustment. It is nonsense for a living person to speak of being adjusted.

Dual effect of adjusting. Now, there are two ways of looking at an adjustment process. The first is to judge the whole sequence of actions in terms of how well the individual solved his problem. Did the person win or lose? How efficient were his methods? Could he have done better? How does his solution compare with the solution of others? What is the effect of his solution on other problems? Such are the questions that the observer is likely to ask when objective accomplishment is made the issue. Even most psychological studies of human adjustment

tend to stress the adjustment process in terms of its merits in meeting the actual problem presented.

The second method of viewing adjustment processes is that of attempting to discover the effect of the whole situation on the individuality of the one who makes the adjustment. Every problem a person solves, or fails to solve, leaves him a different individual from what he was before. The curious and fascinating part of this residual effect is that it is not dependent upon the degree of success as judged by objective standards. The important consideration for the psychologist should be: What did this experience do to the person involved?

Furthermore, the only way in which we can determine the effect that previous adjustments have had upon the individual is by what he does and says *now*. This is not easy. A response at the moment is partly determined by the needs of the moment, by the tendencies in an individual based on habitual adjustments in the past, by the need for concealing some motives, by the necessity of making a good impression upon observers, by other problems which exist simultaneously with the one that appears momentarily dominant, and other factors that might be listed. Consequently, it is not possible to observe a person make a single adjustment reaction and, on the basis of that one situation, arrive at any pronouncement as to the kind of person he is.

Circumstances under which dominant trends are revealed. Certain situations tend to bring out habitual trends in an individual more readily than do other situations. [9]

Emergencies. It has been found that the way a person behaves when everything is moving smoothly is not so likely to be indicative of his customary trends as is his behavior when he is confronted with some emergency. This is one of the reasons why clinical methods have been so valuable in the study of individuality. The clinician is called upon to examine a person after he has been more or less shattered by unusual circumstances and he thus has the opportunity to study how the patient behaved when he was hard pressed.

The frequency with which a trend is used. Other things being equal, if a person is given frequent opportunities to make a number of responses and tends to choose a single one repeatedly,

it may be inferred that the preference thus demonstrated indicates a personality trend.

Trend manifested when individual is free from social restraint. A third method is to compare the behavior of an individual when he believes he is being observed with his behavior when he is reasonably sure he is not being watched.

In short, a person's habitual trends are manifested by the way in which he behaves in an emergency, the preference he shows for one type of response when he has the freedom of choice, and the way in which he behaves when free from any of the inhibitions arising from being observed by others.

Unwholesome effect of excessive use of a single trend. Because these tendencies are so easily and clearly observed when the person gets into some adjustment difficulty, they have been called defense mechanisms. This is merely another way of saying that anyone uses his favorite means of adjustment when pressed the hardest. The use of this term is likely to obscure the real significance of the tendency thus manifested. It gives the impression that such behavior is abnormal and that it should be avoided. This is not so. Some habitual methods of solving problems are desirable and some are undesirable in and of themselves. Some good ones can be overworked and some poor ones should be used on occasion.

The ideal person, from the adjustment standpoint, is the one who has a vast number of ways of reacting to life's problems and has the facility for choosing the one best suited to each problem as it arises. The most undesirable person is the one who has but one device, which he tends to use on every occasion whether it is suitable or not. Most of us fall somewhere between those two extremes.

According to this analysis, the poorly adjusted person is the one who has specialized in a few types of adjustment behavior to the exclusion of others and, further, that the types of behavior he has chosen are those which have a bad residual effect upon his general personal structure. The best type of person is no specialist in the use of any one adjustment pattern. He adjusts his behavior to the needs of the present situation. In other words, he is more likely to be guided by objective circumstances than by his individual habits. This conception of traits is a dynamic one

and is in marked contrast to that conception which looks for some fixed abstract quality in the individual.

CLASSIFICATION OF ADJUSTMENT TENDENCIES

Many abnormal individuals are characterized by the fact that they have a relatively small group of characteristics developed to an unusual degree. Such exaggerations really provide an excellent opportunity to study these characteristics. [19]

Nevertheless, in giving a classification of behavior tendencies, or adjustment mechanisms, there is no implication that each kind stands for a type of person. Any one person may use a combination of a great number. Some do not fit together so well as others and are not so likely to come in combination; others fall together very easily. The grouping, then, is in terms of habit patterns and not in terms of personality types.

Responses which are primarily objective. From the point of view of making the best adjustment to any situation, it is better to be objective about the problem than to let personal bias influence one. The best synonym for objectivity in this sense is rationality. The rational approach to a problem involves interest in the problem itself, the study of all factors that can be observed, the making of tentative reactions while observing their effect upon some hypothesis that has been formulated, the realization that the situation is unique, and the recognition that a successful response at one moment may not be the successful one at the next moment.

Such complete objectivity and rationality of behavior is the exception and represents an ideal. Some individuals come nearer to it than do others. There are persons who are more objective than subjective in their attack upon life, but who, at the same time, are not so ideally rational in the way they go about meeting the objective situation. These less perfect objectivists may be grouped as follows:

Objective perseveration. Perseveration is the tendency to continue a type of response once it has been used. It is a relatively nonintelligent type of behavior. Of course, one may persist in a type of response without regard for the objective world at all. Objective perseveration implies that the subject made his first response in relation to the objective situation and then continues

to use it rather than to attempt some new reaction when he discovers that his is inadequate. As an illustration, a woman asked for help in breaking her child of the habit of sucking his thumb. She asserted that she had tied his hands up in tin cuffs for six years and that it did no good. When it was suggested that she discard this practice, she seemed surprised. Here was a woman who admitted that she had done the same thing 2,190 times, who recognized that it was futile, and who yet insisted that she must continue to do it.

Overactivity. Sometimes it is advisable to try a little harder before giving up an attempted solution. If a door sticks, it may open if it is pushed a little more vigorously. There are times when this simple procedure is inadequate. It might be better to observe some peculiarity in the sticking, whether at the top, at the bottom, or at the lock. Even on a football field, there are times when some indirect attack is better than an attempted drive through center.

Distinctively habitual responses. Some defense reactions are effective because they influence others to respond favorably. Tears are a good example. A child soon learns that he can produce results with his mother in a great diversity of situations if he makes the proper use of tears. Some of the habitual reactions, which a person tends to use primarily because he has acquired the habit of so doing, are:

Playing upon the sympathy of others. Here the attention is not directed toward the actual problem at hand but at the reactions of those whose help is sought. It is a form of parasitism. The individual expects someone else to solve his problems and his main concern is to manipulate them effectively. There are hundreds of ways of eliciting the sympathy and help of others. These vary in subtlety, in the extent to which society tolerates them, in the ease with which they may be applied, as well as in the effect their continued use has upon an individual.

1. Getting ill. Children learn this easily because they are treated with more consideration when ill than when well. Many adults continue to exploit others by this means.

2. Display of affection. The little boy who has been naughty softens his punishment by a vigorous demonstration of affection for his mother. The man who has been out half the

night playing poker softens the jolt by bringing home a gift to his outraged wife.

3. Working on the other person's self-esteem. This is found effective and is utilized by great numbers of persons. It takes a multitude of forms: (a) A direct "build-up" is effective more often than one might suppose. (b) Indirect compliments are usually effective; that is, tell A how fine a person B is on the theory that A will tell B what you said and thus make B take a favorable attitude toward you. (c) Let the other fellow think he is the boss while you are getting your own way by some indirect process. (d) Let the other fellow win the argument while you get your way. (e) Being an attentive listener does wonders. (f) Showing interest in the hobbies or fads of the other person makes him proud of his choice of occupations.

Children learn all these tricks. The amazing part is the way their effectiveness persists through the older years.

4. Making some problem into a moral issue in order to enlist the help of others. It is much easier to get people on your side if you are espousing a cause than if you want direct personal help. Most "moral issues" are disguised personal aims.

Distracting devices. Many a problem is solved if one can get the attention of others centered on some irrelevant factor in the environment so that the real issue is hidden. One can easily get in the habit of stirring up the mud instead of trying to see a problem clearly. Rationalization, that is, pretending to argue the question out by excessive talking, is a good illustration. This habit can be initiated easily by a parent who has the theory that he should "reason" things out with his child. Such a process often is not reasoning in any real sense but a contest to determine who can talk the longest. Much of our so-called reasoning in adult life is merely a continuation of these talking contests.

Blaming others. The habit of blaming others for our misfortunes and failures may begin as a form of distraction. There is no better way to distract the teacher's attention from the essential problem than for all the students to engage in the mutual game of blaming the other person. By the time the guilt of all concerned has been evaluated, it is spread out so thinly that no one gets much punishment.

Conventionality. A person may easily learn that the ob-

servance of conventions can be a means of gaining ends that are otherwise elusive. Here is an illustration where the method did not work: A little girl brought in two apples which her mother had told her to share with her brother. One apple was large and one small. She wanted the large apple but had been taught to be unselfish. How could she get it? She put the two on a plate and holding them both out asked her brother to take an apple. He (being unconventional) took the big one. Whereupon the girl complained that he was selfish for taking the big apple. He asked her which one she would have taken had he presented them both to her. "The smaller one," was her moralistic answer. "Well," her brother replied, "you have it, so why do you crab at me?"

Revolutionary behavior. Children learn that they often gain their ends by making a scene—starting a revolution. Older persons carry out the same type of behavior. A revolutionist has nothing to lose and he may gain something. Hence, when you don't like what is going on, start something and try to grab off what you want in the turmoil.

Exploitation. Because of the spoiling by doting parents or, conversely, because a child has been neglected, the habit of exploiting others by fair means or foul, with little regard for their feelings, may be learned. Persons thus develop the attitude that the world owes them a living and set out to collect, feeling injured if anyone stands in their way or if they are called to task for their lack of conformity to law and order.

Compromise adjustments. Compromise adjustments are the rule rather than the exception. Few individuals actually reach the goal they set for themselves, and most of us must be satisfied with some sort of compromise. These compromises take a multitude of forms.

The sweet-lemon outlook. This is a form of consolation in which the loser tells himself that he gained more in other ways than if he had received the prize.

Sour grapes. After losing, one tries to convince himself that the prize was not worth having anyway.

Hero worship. When a person knows he cannot achieve some objective, he worships someone who does, thus getting some

vicarious satisfaction through the activity of one who is more successful than himself.

Sublimation. When a person is thwarted, another goal may be substituted in place of the lost one. Thus, a woman whose desire to become a mother has been unfulfilled, may mother other children as a substitute form of satisfaction.

Daydreaming. Building air castles is a common way of adjusting to failure.

Compensation. Compensation is the process of covering up, or making up for, deficiency in some particular by excellence in another. For example, the girl with the unattractive features may compensate by developing exceptional excellence in social graces. The boy with the weak physique may compensate by superiority in his studies.

Withdrawal reactions. Withdrawal may, at times, be a sensible reaction. When it becomes habitual it may make failure certain. It takes various forms.

Forgetting. After an individual discovers that genuine forgetting has the added effect of enabling him to avoid unpleasant obligations or to forget unpleasant events, he may cultivate convenient forgetting to such an extent that it becomes habitual. He may begin the habit of forgetting as a side issue in trivial situations but, once started, the habit may grow until large sections of his life may be lost.

Sleeping. Sleeping is the natural way in which an individual recovers from fatigue. At the same time, it may come as a welcome relief when a person has been hard pressed by difficult situations. In one sense, this is not an unwholesome type of withdrawal. It gives a person a temporary relief, and when he wakes he will probably be in better condition to face his difficulties than he was when tired. There have been a few cases where individuals learned to sleep as a chronic means of escape but, on the whole, sleeping over a problem is a useful procedure.

Procrastination. Delay, when used wisely, is a valuable device; when used habitually, with little regard for the nature of the difficulty to be met, it may be a mere way of avoiding an urgent responsibility.

Drug addiction. The use of drugs as an escape from unpleasant or difficult situations is, on the whole, a dangerous

and unwholesome procedure. In their place, drugs have value in helping an individual avoid pain. The use of anesthetics in surgical operations, the professional use of sedatives to bring relief from physical distress, and the administration of specific drugs to treat certain ailments are instances of wise application. The degeneration of what may be a beneficial treatment under professional guidance into habitual drug addiction constitutes one of the most unintelligent forms of evasion.

Worry. When a person is in the presence of a real danger, it pays him to be emotionally aroused and to use the energies thus set loose to attempt to reach some solution to his problem. Worry, on the other hand, is a form of ingrown emotion which turns the emotional energy away from the active pursuit of some solution to the nursing of one's own feelings and to self-pity. By becoming engrossed in worry the victim of this habit evades any active attempt at adjustment and settles down to chronic evasion.

Living in the past. The lasting value of any experience is the help it provides in meeting some new situation. We learn from both the successes and the mistakes we have made. Evaders escape a present problem situation by dwelling upon the failures of the past, becoming emotionally depressed, and arguing that there is no use in trying again; or they may evade a present challenge by continual prating about the victory they once achieved. Reminiscence is a form of consolation to be expected in an old person who has lived his life; it tends to reconcile him to the fact that there is little ahead for him. In a younger person who should be actively engaged in the challenging issues of the present, such premature old age is certainly an unwholesome escape device.

Extreme introversion If an individual pauses long enough in the process of living to take a good look at himself, to make a personal inventory so that he can be more sure of his personal assets and liabilities, he can doubtless profit thereby. The chronic introvert, on the other hand, might be compared with the businessman who has turned miser. He becomes so engrossed in the contemplation of himself that he ignores the environment in which he lives as well as the ways in which he might utilize his personal qualities. The ironical part of such a procedure is that the very

qualities that the introvert guards so jealously slip out of his grasp through decay, and atrophy from disuse.

Self-destruction. Most of the adjustments we have outlined to this point may have their bad features eliminated and the good elements cultivated as experience points out these qualities to the individual who uses them. Even though some may be inherently less wholesome than others, all can be changed and used more intelligently as life proceeds. The tragic part of self-destruction is that it is final. Once having exercised this method of retreat from the problems of life, there is no turning back.

Intelligent adjustment. Intelligent adjustment involves the use of that form of reaction which is most appropriate at the moment, the checking of the results of each trial adjustment, and the modification of the next reaction accordingly. Please note carefully: The essence of intelligent adjustment is variability of response—the selection of one of many possible reactions; it is not the blind repetition of one type of reaction merely because it was successful at one time. The specialization in one type of adjustment reaction is inefficient, nonintelligent, and may easily lead to a pathological condition. The mother who complains that her son is unpredictable, that he is continually getting into one unexpected situation after another, is really describing the adjustment behavior of an intelligent and forward-looking child. Pity the child whose mother can always depend upon him. He will become the cog in some machine that is controlled by his more intelligent comrades.

A trait is, then, essentially the habit of responding in a distinctive (or habitual) manner to a great number and variety of situations requiring adjustment. If a person has a definite personality trait, it means that his friends can count on a certain type of behavior which characterizes that trait.

Various social organizations laud certain traits and stress the importance of their development. In an army situation, blind obedience is held up as a virtue. In a fraternal group, loyalty is desirable. In a group of salesmen, aggressiveness is praised. The good referee is characterized by quickness of decision. The development of such a trait is more a convenience for the particular society than for the individual. Of course, if the person is to live in that group he needs to have the trait that the group

demands. When he joins himself to any group he tacitly or openly agrees to cultivate the traits which that group commends. Should he change his mind he should get out. For example, when a boy comes to college he tacitly agrees to attempt to develop the trait of studiousness. Having entered, he may assert his independence and revolt against concentrating on study, attempting to turn the college into a social club.

This brings us to a common performance by an individual who finds that he has become too specialized. Instead of reverting to the intelligent objective type of behavior, he picks some other type of defense behavior and begins to specialize in it. The boy who feels too dependent tries to become independent. Such independence tends to show itself in silly negativism or nonconformity in nonessentials. The overdisciplined two-year-old child often shows stubbornness. He shows he is a real man by refusing to eat his food, by refusing to lace his shoes, by refusing to fold his napkin. All you need do to get him to do a thing is to tell him to do the opposite of the act desired. The extreme of this sort of thing is found in a symptom in some pathological cases known as approximate answers. The patient knows the right answer but shows his independence by refusing to give it. Ask him how much twenty-five minus four is, and he will reply successively with the answers: twenty, twenty-two, nineteen, eighteen, twenty-three, seventeen, twenty-four, and the like.

The best adjusted man is the one who lets "traits" control settled issues, but who is versatile in his adjustment behavior in any problem situation. He uses intelligence to guide his behavior instead of relegating his decisions to habits.

QUESTIONS FOR REVIEW

1. What is the significance of the fact that so many methods have been used to study the psychological individual?
2. Show how personal preferences may play a major role in making a selection from these methods.
3. What is the doctrine of "humors"?
4. Criticize the theory of body types.
5. How may endocrine factors be overemphasized in the study of the psychological individual?
6. What is phrenology?
7. What is the theory of "stigmata of degeneracy"?

8. What is meant by physiognomy?
9. What directions are being taken in modern attempts to study individuality?
10. What is the most useful attitude to take toward the relative contributions made by hereditary and environmental factors to personality development?
11. What is the relative importance of maturation and learning in individual development?
12. What part does conflict play in individual development?
13. What are the essential characteristics of a mature individual?
14. What is the effect of specialization upon individual unity?
15. How does teamwork influence individuality?
16. Show how a danger may intensify individual unity.
17. Discuss the importance of the brain in individuality.
18. What is the significance of jitteriness?
19. Of what importance are individual codes for living?
20. Enumerate the requirements for a valid rating scale.
21. What errors are likely to appear in attempts to rate oneself?
22. Describe three methods designed to avoid the errors inherent in self-rating.
23. What are the limitations of adjustment inventories?
24. Describe tests based on the expression of wishes.
25. Describe tests to measure honesty.
26. What conclusions can be drawn from attempts to measure personality traits?
27. Why are attempts to study adjustment significant?
28. Why is the tendency to specialize in one adjustment mechanism an unwholesome practice?
29. What is meant by perseveration and what is its significance?
30. What are the advantages and the disadvantages of overactivity?
31. Outline different ways in which one may play upon the sympathy of others to gain his ends.
32. State the significance of the following habitual reaction tendencies, playing upon the sympathy of others, distraction devices, blaming others, conventionality, revolutionary behavior, and exploitation.
33. Describe the following compromise adjustments: the sweet-lemon outlook, sour grapes, hero worship, sublimation, daydreaming, and compensation.
34. Describe and give the relative significance of the following withdrawal reactions: forgetting, sleeping, procrastination, drug

addiction, worry, living in the past, extreme introversion, and self-destruction.

35. What is intelligent adjustment?

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GLOSSARY[1]

ability. What can be done by an individual with his present training and development.

abscissa. The horizontal axis of reference on a two-dimensional chart.

abstract. Characterizing aspects or qualities of objects or experiences rather than the objects or experiences themselves.

accommodation, visual. The adjustment of the curvature of the lens of the eye to changes in the distance from the eye of the objects fixated.

Achilles tendon. The tendon uniting the muscles in the calf of the leg with the bone of the heel.

achromatic. Without color.

action current. An electrical current which accompanies activity in a nerve or muscle.

adaptation, biological. Those changes in the form or functioning of an organism which better fit it for existence under the conditions of its environment.

adaptation, sensory. A change in the sensitivity of a sense organ by means of which the sense organ accommodates to changes in the stimuli affecting it. In vision, dark (scotopic) adaptation refers to the increased sensitivity of the retina to weak stimuli as a result of a continued decrease in general illumination; whereas light (photopic) adaptation refers to the decreased sensitivity of the retina to weak stimuli as a result of increased general illumination.

adequate stimulus. The type of stimulus which normally excites a given sense organ. For example, light is the adequate stimulus for the eye; it is an inadequate stimulus for the ear.

adrenal glands. A pair of endocrine glands lying on or near the upper pole of the kidneys. The inner part (or medulla) secretes a hormone, called adrenin, which reinforces visceral activity in emotional situations. The outer part (or cortex) se-

[1] The student may supplement this brief glossary by referring to the *Dictionary of Psychology*, edited by Howard C. Warren and published by Houghton Mifflin Co.

cretes a hormone, called cortin, which affects bodily tonus, blood pressure, and sex development.

affect. A general term used to denote any type of emotional experience.

aftersensation (or **afterimage**). The sensory experience which persists after the external stimulus has ceased to operate.

all-or-none law. The principle which states that a single nerve or muscle cell responds to a stimulus either with its full capacity or not at all.

alpha conditioned reaction. The type of conditioned reaction in which the acquired response is identical in quality and speed with the original response.

alpha movement. The type of apparent movement in which there is an illusory change in size caused by a change in the pattern of successively exposed stimuli.

alpha rhythms. The type of brain waves having the greatest amplitude and slowest frequency. The average frequency of alpha waves is 10 per second.

alpha tests. A set of mental tests used during the first World War in the United States army to measure the mental ability of recruits.

ambiguous figure. A picture in which certain parts are open to two interpretations. In one type of ambiguous figure the same part may be interpreted either as the essential figure or as part of the background. In another type the same element may be interpreted as nearer the observer or farther away than the adjacent elements.

analogies test. A type of mental test designed to measure the familiarity of the subject with certain relations, such as cause-effect, part-whole, genus-species, etc. Example: As fire is to heat, so ice is to — ·—.

analytic method. That method of investigation which proceeds by breaking down compounds, or intricate situations, into more elementary units.

apparent movement (or **motion**). The perception of movement experienced when stationary stimuli are exposed in brief succession. Five types have been differentiated: alpha, beta, gamma, delta, and epsilon.

appetite. An inborn or habitual desire or propensity for some personal gratification.

aptitude test. A test designed to measure the fitness of a subject

for undertaking a specific kind of activity, for example, music, mechanics, language study, etc.

aqueous humor. The transparent, watery fluid which fills the space in the front part of the eye between the cornea and the lens.

association. The establishment of functional relations between psychological activities following individual experience. For example, if A and B are associated, the appearance of either one at a later time will tend to be accompanied by the other.

association, controlled. A response or a series of associative responses conforming to some previously announced restriction. Example: words are presented to a subject, who is required to give the opposite of each.

association fiber. Nerve fibers which connect different nerve centers.

association, free. An associative response, or a series of such responses, which is unrestricted.

association tests. Tests designed to measure some aspect of response sequences. Example: a subject may be presented with a standard list of words to each of which we must give an associative response.

association time. The interval elapsing between the giving of a stimulus and the associative response made by the subject.

asthenia. A lack of general strength. Weakness.

ataxiameter. An apparatus that measures the swaying movements of a subject who is trying to stand motionless.

attention. A set, attitude, priming, posture, or adjustment which makes it easier for one to respond to a certain stimulus.

attitude. A muscular posture, mental set, or mood which influences in a general way a person's behavior in a variety of situations.

audiometer. An instrument for measuring the acuity of hearing.

automatograph. An instrument used to make a graphic record of unrestricted movements of a part of the body.

autonomic nervous system. The division of the nervous system which activates the smooth muscles of the body and certain glands. It functions predominantly in emotional behavior.

autoscope. A general term for any one of a number of devices by means of which imperceptible, involuntary muscular movements are intensified and thus become significant. Illustrations are the planchette, the divining rod, the ouija board, and tables for table tipping.

axon. The fiber of the neuron which conducts the nerve impulse away from the body of the cell. Contrasted with the dendrite, which is the fiber that carries the nerve impulse toward the cell body. The region where the axon transmits its impulse to the dendrite is called the synapse.

Babinski reflex. The name given to that type of response to the stroking of the sole of the foot which is characterized by an extension of the great toe (sometimes of the other toes as well), whereas the normal adult response to this stimulus is a flexion of all the toes.

ballistic movement. A rapid, thrown type of movement in which the force and direction are applied at the beginning; in contrast with slow, halting, and constantly redirected tense movements.

basal metabolic rate. The heat produced by (representing the energy expended in) the vital and vegetative functions of the body. It is expressed in terms of calories of heat generated per square meter of body surface, measured from 14 to 18 hours after eating, and when the individual has been resting for at least 30 minutes, but not sleeping.

basilar membrane. A membrane of the inner ear that supports the organ of Corti, the latter containing hair cells for the reception of sounds.

beat, auditory. A fluctuation in sound intensity that is dependent upon the combination of two sound waves of different periodicity.

behavior. A general term used by psychologists to designate all forms of muscular and glandular responses of an organism to stimulations of all sorts.

bel. The unit for comparing two different levels of sound energy. It is the common logarithm of the ratio between two sound intensities.

beta conditioned reactions. Those conditioned reactions which are different from the original responses, which are longer, and which are similar to deliberate and conscious responses.

beta movement. The type of apparent movement in which the observer has a perception of actual growth when two successive stimuli differ in size.

beta rhythms. The type of brain waves superimposed upon the slower alpha waves. The average frequency of beta waves is 25 per second.

beta tests. A set of mental tests used during the first World War

in the United States army which were designed especially for illiterates. The material used was largely pictorial in character and instructions were given by dramatic signs.

Binet-Simon test. A series of graded tests designed to rate the mental development of children. Devised about 1905 by Alfred Binet and Th. Simon.

binocular. Pertaining to the combined or associated functioning of the two eyes.

biological inheritance. See **inheritance, biological.**

blind spot. A small area in the retina of the eye which is insensitive to light. It contains neither rods nor cones. It is the place where the optic nerve leaves the eyeball.

brain. The mass of neural tissue within the skull and including the main co-ordinating centers of the skeletal (or cerebrospinal) nervous system.

brain waves. Rhythmic electrical impulses which arise almost continuously from the neural centers within the brain and the spinal cord.

brightness. Brightness is that quality of light (or radiant energy) which may be expressed on a scale ranging from white to black. The unit of brightness is the lambert.

brilliance. The sensory quality of visual sensations which corresponds most nearly to brightness.

CA. Abbreviation for chronological age.

cardiograph. An instrument which makes a graphic record of the action of the heart.

caudal. Pertaining to the tail, or rear portion of the body of an animal.

cell. The fundamental unit of structure of a living organism, consisting of a small mass of protoplasm, always containing a nucleus, and enclosed in a cell wall.

cephalocaudal axis. The axis of reference passing from head to tail of an animal. Synonymous with the vertical axis in man.

cerebellum. A large division of the brain situated in the back part of the skull cavity and below the cerebrum. It is believed to play a prominent part in muscular co-ordination.

cerebral cortex. The outer coating of the cerebral hemispheres, made up largely of gray neural tissue, and functioning as a unifying center for the most complex neural processes.

cerebrospinal nervous system. That part of the nervous system which includes the brain and the spinal cord.

cerebrum. The largest and most highly developed part of the brain.

choroid coat. The intermediate of the three coats of the eyeball, lying between the outer coat (the sclerotic) and the inner coat (the retina).

chromatin. That part of the protoplasm in the nucleus of a cell which stains with basic stains.

chromosome. A small threadlike structure composed of chromatin, found in the nucleus of cells during the process of reproduction, which bears or contains the genes (hereditary determiners).

chronaxie. The index of excitability of a tissue.

chronoscope. An instrument for measuring short time intervals.

circumstantial recall. A type of recall determined by, and following with some fidelity, the sequence of events in the original experience.

coats of the eyeball. The three layers which make up the wall of the eyeball. They are: (1) the sclerotic (outermost), (2) the choroid (intermediate), and (3) the retina (inner).

cochlea. The spiral canal (shaped like a snail shell) of the inner ear, which contains the receiving apparatus for hearing.

color. A property of visual sensation depending upon the effect of light of different wave lengths upon the retina, and characterized by brilliance, hue, and saturation.

color blindness. A defect of color vision marked by a reduction in the ability to discriminate certain hues.

combination tone. An additional tone which arises when two tones of different frequencies are sounded together. There are two types: the difference tone, whose frequency is the difference in frequencies of the generating tones, and the summation tone, whose frequency is the sum of the frequencies of the generating tones.

complementary colors. Any two colors which, when mixed by such a device as the color wheel, give a sensation of neutral gray.

conditioned reaction (or **response**). A response which may now be set off by a stimulus (the conditioned stimulus) which originally was inadequate to initiate it.

cone, retinal. A type of structure found in the retina of the eye, which functions as a receiving apparatus for color.

congenital. Existing in the individual at birth.

congruent points. A pair of points in the two retinas which,

when stimulated simultaneously, give rise to binocular fusion, or single vision.

contiguity. The state of being in intimate association or relation in time or space.

contrast. The enhancement of differences between sensory stimuli resulting from their presentation together or in close succession.

control group. A group of individuals used to make an experimental test of the truth of a hypothesis. Customarily, two groups are selected (an experimental group and a control group) which are alike in all respects. The two groups are then treated in ways differing in some measurable fashion and are subsequently compared. Resultant differences are presumably the result of the specifically different treatment.

convergence, visual. The turning of the two eyes toward each other so that both eyes may be fixated on the same object. Such a movement is necessary as the distance between the object and the individual decreases.

cornea. The transparent part of the coat of the eyeball lying in front of the iris and the pupil.

cortex. The outer layer or layers of an organ.

Corti, organ of. The structure, lying in the cochlea of the inner ear, which contains hair cells for the reception of sounds.

cortin. A hormone secreted by the outer layer (the cortex) of the adrenal glands. It affects muscular tonus and the development of secondary sexual characteristics.

co-twin control, method of. A method of experimentation in which one member of a pair of identical twins is treated in a specifically different manner from the other. A subsequent difference between the twins is presumed to indicate the effect of the difference in treatment.

critical fusion frequency (or **critical flicker frequency**). The lowest frequency of interruptions per second of rapidly intermittent visual stimuli at which all flicker just disappears.

cue. A seemingly minor or secondary element in the stimulating situation which an individual utilizes as a guide to his response.

cutaneous. Pertaining to the skin.

cycle. One complete course of operations or events, returning to the original state. In sound waves, a cycle is a complete pendular movement, from the zero axis to one side, back through the zero axis to the other, and then back to the zero axis again, as represented by the curve ~.

cycloramic illusion. The effect of continuous perspective pro-

duced by solid objects in the foreground merging with painted backgrounds.

dark (scotopic) adaptation. The increased sensitivity of the retina of the eye as a result of a continued decrease in general illumination.

decerebrate animal. An animal whose cerebrum has been removed for experimental purposes.

decibel. A unit used for comparing two different energies of tonal stimuli. It is ten times the common logarithm of the ratio of the two energies.

deduction. A type of reasoning that proceeds by inference from given premises or propositions to concrete and specific conclusions. Illustration: If John is taller than Bill, and if Bill is taller than Frank, then, by inference, John is taller than Frank.

defense reaction. A type of self-protective behavior. Often used to designate behavior tending to divert attention from some unacceptable aspect of the individual to another that is more praiseworthy.

delayed reaction experiment. An experiment designed to determine how long the response of a subject (usually a child or an animal) can be delayed after a signal is given without the occurrence of errors in response or a failure to respond at all.

delta movement. The type of apparent motion perceived when the second of two figures shown successively in adjacent areas is more impressive than the first (that is, larger, more intense, or more complex); the more impressive figure seems to move toward the less impressive, to unite with it, and then the united figure seems to move to the original position of the more impressive figure.

dendrite. The fiber of a neuron which conducts the nerve impulse toward the cell body. Contrasted with the axon, the fiber of a neuron which carries the nerve impulse away from the cell body. The region where the dendrite receives the impulses from the axons is called the synapse.

depth perception. The direct appreciation of the solidity of objects, or of the relative distance of parts of the same object or of different objects from the observer. This appreciation is dependent upon a number of factors, called depth criteria.

determiner. Often used as a synonym for gene, which is a factor in the germ cells involved in the production of a hereditary characteristic.

difference threshold (or difference limen). The smallest amount by which two stimuli must differ if their difference is to be perceived. It is the amount of difference between two stimuli necessary for them to be judged different in 50 per cent of the judgments made and to be judged the same in the other 50 per cent.

difference tone. An additional tone heard when two tones of different frequencies are sounded together, whose frequency is the difference in frequencies of the generating tones.

digit-span test. A memory test in which a series of digits is presented to a subject, who is required to attempt to reproduce them in the order in which they were given. The longest list reproduced correctly is taken as an index of the digit span of the subject.

discrete stimulus. A discontinuous stimulus that is separate and distinct from other stimuli.

disinhibition. The process of stopping an inhibitory process.

distribution. A descriptive term often applied to a table or a graph which organizes data into groups having successive values, and which shows the number of individual items, or measures, falling in each group.

disuse, law of. A generalization derived from learning experiments which states that a learned reaction deteriorates with disuse.

divergence, visual. The turning of the two eyes outward so that both eyes may remain fixated on the same object as it moves farther away from an individual, or the movement that occurs when the eyes change from fixation on a near object to fixation on a distant object.

dominant character. A biological term used in contrast to the term "recessive character." Each biological factor is presumed to have two aspects, one dominant and one recessive; the dominant always suppressing or preventing the appearance of the corresponding recessive character when two factors are associated.

drive. Any internal condition that stimulates an individual to perform in some manner.

dynamism. A term used as a synonym for defense mechanism. A form of conduct tending to guard some aspect of an individual's personality from scrutiny by others or by himself by calling into play some diverting act.

dynamometer. An instrument for measuring the strength of con-

traction of a muscle or group of muscles; for example, the strength of the grip.

effector. A general term to designate any organ of response. It may be a muscle or a gland.

electrocardiograph. An instrument that detects and records the electrical effects of the contractions of the heart muscles.

electroencephalogram. The graphic record of brain waves obtained by placing electrodes outside the skull at widely separated places.

electrogram. The graphic record of an electric action current obtained by placing electrodes directly in live tissue.

embryo. An organism in the early stages of development. In man, the embryonic period is restricted to the first five weeks of intrauterine life.

emotional behavior. Emotional behavior designates those forms of response which are relatively intense, random, unusual, disorganized, and indiscriminate. A person is emotional when he is in a stirred-up state.

empirical method. The scientific method which makes primary use of observation and experiment.

endocrine gland. A ductless gland. An organ of secretion, which forms a specific substance, known as a hormone, and discharges this substance directly into the blood or lymph; by means of which the hormone is transported to other parts of the body and produces effects upon other organs.

endolymph. The fluid which fills the membranous cavities of the inner ear.

environment. A general term that includes all the surrounding conditions, influences, or forces (physiological, biological, and social) which act upon organisms.

epsilon movement. That form of apparent movement resulting when a white line on a black ground is succeeded by a black line on a white ground (or vice versa), with a change in position.

equipotentiality theory of brain function. A theory which assumes that each part of the brain may take an equal part in each brain activity.

ergograph. An instrument for measuring and recording the work done by a single muscle or by a set of muscles.

esthesiometer. An instrument (essentially similar to a pair of dividers) used to determine the distance which must separate

two points so that, when applied to the skin, they are perceived as two points.

eugenics. The branch of biology that deals with the influences affecting the hereditary qualities of living organisms, especially of human beings. Practical eugenics is concerned with measures for race improvement.

Eustachian tube. A tube connecting the cavity of the middle ear with the pharynx.

exercise. The frequent repetition of an act, usually for the purpose of acquiring skill or increasing proficiency in performance.

experience. The actual living through an event or series of events.

experiment. A practical trial or test designed and performed for the purpose of confirming or disproving a hypothesis. In a scientific experiment, all factors either are kept constant or are varied by known amounts; and variations in conditions are made in a manner designed to have a bearing on the hypothesis being investigated.

experimental extinction. The unlearning of a conditioned reaction (under laboratory control) by means of the repeated presentation of the conditioned stimulus without the unconditioned stimulus.

extensor. A muscle that serves to extend or straighten a limb or part. Opposed to flexor.

extrovert. An individual who is characterized by such an attitude or type of personality that he manifests more interest in other persons and in objective events than in himself and his own experiences.

facilitation. An increased ease in performance as indicated by an improvement in speed, increased output, or greater smoothness of execution.

factor. One of the elements that contribute to produce a result. In mathematics it is any of the quantities which, when multiplied together, form a product.

factor analysis. A statistical technique by means of which the component factors in a group of test scores or other measures are resolved.

fad. A line of activity, a custom, or an amusement followed by an individual (or a number of individuals) for a time with exaggerated zeal.

fashion. The prevailing practice or convention, mode of living,

style of dress, etc., which, while not so stable and persistent as a custom, is more enduring than a fad.

fatigue. A condition of cells or muscles resulting from continued, and often excessive, activity, which shows itself in loss of power or efficiency and is often accompanied by subjective feelings of weariness.

fetus, human. The human individual during the period of development extending from the embryonic period (that is, about five weeks after conception) until birth.

fixation, binocular. The directing and focusing of both eyes upon the same point in space.

fixation, visual. The directing and focusing of the eye upon a point in space in such a manner that the image of this point falls upon the fovea.

flexor. A muscle that serves to bend a limb or part. Opposed to extensor.

flicker. The rapidly intermittent visual impression that corresponds with interruptions of the visual stimulus. When the frequency of interruptions passes a certain point (called the critical flicker frequency), flicker is replaced by fusion, and the stimulus is perceived as though it were uninterrupted.

folkways. The conventional or traditional patterns of conduct common to the members of a particular group, departure from which indicates a lack of refinement or of good taste.

forgetting, curve of. A curve that displays graphically the speed with which material, once learned, is forgotten during a period of no recall or review.

fovea. A small depression in the central region of the retina of the eye, which is the place of sharpest vision and the center of fixation.

fraternal twins. See **twins.**

free association. See **association, free.**

fundamental tone. The lowest tone in a compound tone.

fusion, binaural. The combination of the stimuli presented to the two ears into a single auditory impression.

fusion, binocular. The combination of the stimuli falling upon the two retinas into a single visual impression.

g factor (general factor). A common or general factor that is supposed to play a part in the performance of a great number of intelligence tests.

galvanic skin response. See **psychogalvanic reflex.**

gamma movement. The type of apparent movement that appears as the expansion or contraction within a single figure when the figure is suddenly exposed or withdrawn or when the illumination is suddenly increased or decreased.

gamma rhythms. The type of brain waves with frequencies from 35 to 50 per second.

ganglion. A cluster of nerve cells located outside the central nervous system.

gene. A factor in the germ cell, the essential determiner of a hereditary character.

generalization. The process of deriving a general principle or formulating a hypothesis from a limited number of particular facts.

global method. A method of memorizing in which large assignments are learned as units.

goal. An object or condition toward which an individual strives, the attainment of which is followed by a cessation or a reduction of goal-seeking activity.

gustation. The sense of taste, or the act of tasting.

habit. A well-learned pattern of activity (often restricted to a co-ordinated muscular movement) that is relatively invariable, easily elicited, and characterized by facility of performance.

habituation. The process of becoming adapted to a given stimulus or to a general environmental situation.

hallucination. A perceptual misinterpretation that may go so far that an individual is certain he is being guided by sense data from sense organs which are receiving no relevant stimulation.

harmonic motion. The kind of swinging movement made by a tuning fork or a pendulum.

hate. An attitude characterized by extreme aversion toward, frequently accompanied by a desire to inflict injury upon, some individual or object.

heredity. The transmission through the germ plasm of factors that determine certain physical characteristics of the offspring.

homeostasis. The tendency or capacity of an organism to maintain a balance in its physiological and chemical processes.

hormone. A specific organic substance formed by the cells of one organ and passed from that organ through the blood or lymph to other organs, upon which it produces characteristic effects.

hue. Color tone. The sensory quality that varies with the wave length of light.

hunger. The discomfort and drive to activity initiated by the periodic contractions of the stomach walls.

hybrid. The offspring of two parents belonging to different species.

hypnosis. A state resembling sleep in that the subject is unresponsive to the greater part of his environmental stimuli; but in which he can talk, walk, and execute various complex acts such as a person may perform in a sleepwalking experience, and in which he is unusually obedient to another person, called the hypnotist.

hypothesis. A preliminary and tentative presupposition, or principle, adopted to explain observed facts.

identical twins. See **twins.**

ideology. A system or systems of beliefs, attitudes; character tendencies, world views, or philosophies of life.

idiot. A feeble-minded person who manifests the lowest grade of mental ability, usually limited to an individual whose IQ lies between 0 and 25.

illusion. A misinterpretation of the sensory impressions upon which a perception is based.

image. An experience that continues, reproduces, or copies with varying degrees of fidelity a sensation or perception in the absence of the original sensory stimulation.

imagination. The reconstruction of components of past experiences into new combinations in such a manner that this artificial construct seems almost as vivid as a perception based on present objective stimulation of the sense organs.

imbecile. A feeble-minded person who manifests a medium grade of mental deficiency, usually limited to an individual whose IQ lies between 25 and 50.

immediate memory. The ability to reproduce material directly after one presentation.

inbreeding. The mating of closely related individuals.

incentive. A stimulus that sets off or directs the energy already stored in an individual.

incus (anvil). The second of the little bones (ossicles) in the middle ear, situated between the hammer (malleus) and the stirrup (stapes).

individuation. The splitting off of specific activity from general or mass activity.

induction. The act or process of reasoning from a part to a whole, or from particular instances to general statements.

inheritance, biological. The transmission of characteristics from parent to offspring by means of the process of reproduction. The characters thus transmitted.

inheritance, social. The items transmitted from parent to offspring, or from one generation to later generations, by other means than the process of reproduction; such as a name, a title, real estate, money, prestige, or education.

inhibition. The restraint or stoppage of one physiological activity by another.

insight. A depth of understanding or discernment that involves an interpretation of given circumstances.

integration. The formation of a whole from constituent parts..

intelligence. The capacity of an individual to meet a novel situation by improvising a novel adaptive response.

intelligence quotient. The figure obtained when the mental age is divided by the chronological age, and the ratio is multiplied by 100.

interest. The excitement or feeling accompanying special attention to some object.

introspection. The examination of one's own feelings, sensations, efforts, ideas, or imaginations.

introvert. An individual characterized by an attitude or type of personality that manifests more interest in himself and his own experiences than in other persons or in objective events.

IQ. Abbreviation for intelligence quotient.

iris. The colored diaphragm surrounding the pupil of the eye.

kinesthetic sensations. Sensations attending movements of any members of the body. Sensations arising from the muscles and joints.

knee jerk (patellar reflex). A kicking of the foot elicited by tapping the patellar tendon, just below the kneecap.

kymograph. An instrument for recording graphically the temporal variations of activities or events; consists of a drum revolving at a uniform speed, carrying on its surface a record sheet, upon which a marking device moves at right angles to the motion of the cylinder.

labyrinth, auditory. The inner ear.

labyrinthine sense. The static or equilibrium sense, the receiving apparatus for which is the semicircular canals in the innear ear.

lambert. A unit of brightness.

latent time (latency). The period of apparent inactivity between the moment of stimulation and the beginning of the response.

law. The statement of a fundamental uniformity in nature that has been demonstrated by extensive research.

learning. The improvement of efficiency of performance by means of practice, usually measured by some such criterion as speed, freedom from error, better co-ordination, economy of effort, or perfection of form.

learning curve. A graphic representation of improvement in ability with successive practice units, the units usually being equal intervals of time or equal accomplishment units.

lie detector. An instrument that makes a simultaneous graphic record of respiration, blood pressure, and heart rate. It is claimed by some individuals that the pattern of these curves changes significantly when a testee is guilty of lying.

light. See **radiant energy.**

light (photopic) adaptation. The decreased sensitivity of the retina of the eye as a result of a continued increase in general illumination.

limen. See **threshold.**

localization of sound, auditory localization. The estimation of the position of the source of a sound.

loudness. The intensity characteristic of sounds as experienced by an individual.

MA. Abbreviation for mental age.

macula lutea. See **yellow spot.**

malleus (hammer). The first of the little bones (ossicles) in the middle ear. It is attached to the eardrum and articulates with the second bone, the anvil (incus).

mammalia, mammals. The highest class of vertebrates (animals equipped with a backbone) including man and all other animals characterized by embryonic development in the uterus and nourishment after birth by secretions from the mammary gland.

mammary gland. The milk-secreting gland.

marsupial. A mammal having a pouch (mársupium) on the abdomen of the female in which the young, born comparatively undeveloped, are carried.

masking. The partial or complete obscuring of a given tone by the simultaneous presentation of a tone of different frequency.

maturation. The process of coming to full development.

maze. A network of confusing pathways, usually containing some

blind alleys, lying between a starting point and a goal, through which the subject (man or animal) must thread his way if he is to reach the goal.

mean. An intermediate value in a given series. Commonly used as synonymous with arithmetical mean or average, that is, the sum of all the values in the series divided by the number of items.

median. The mid-point in a series of values when these values are arranged in order of magnitude.

memorizing. The process of repeating material (usually verbal) in such a manner that it can be recalled more easily or more perfectly. The process of making an immediate experience effective so that it may be utilized at some future time.

memory span. The number of items of a certain kind that can be correctly reproduced in correct order immediately after their first presentation.

Mendel's law. A principle of hereditary transmission, discovered by Gregor Mendel, which states: When parents that are opposite in a particular genetic character are crossed, the progeny of the first generation will all be like one of the parents with respect to the character in question. When the hybrid offspring of this first generation are, in turn, crossed with each other at random, they will produce a mixed progeny, 25 per cent of which will be like one grandparent, 25 per cent like the other grandparent, and 50 per cent like the hybrid parents.

mental age. A score made in an intelligence test denoting a performance equivalent to that of the average child of corresponding chronological age.

metabolic rate. See **basal metabolic rate.**

metabolism. The chemical changes in living cells by which energy is provided for vital processes and activities, and new material is assimilated to repair waste.

micron. A unit of length equal to one-thousandth of a millimeter.

middle ear. The part of the ear lying between the eardrum and the inner ear. It is filled with air and contains the three auditory bones (ossicles): the hammer (malleus), the anvil (incus), and the stirrup (stapes).

millimicron. A unit of length equal to one-thousandth of a micron.

mirror drawing. The process of tracing a figure which can be seen only as it is reflected in a mirror.

mitosis. The type of reproduction of living tissue accomplished by the division of the cell into two parts.

mode. As used in statistics, the most common value in a given series.

monaural. Hearing with one ear alone.

monocular. Seeing with one eye alone.

mores. Those standards of conduct which have received the conscious approval of the group, departure from which is disapproved and frequently punished.

Moro reflex. The fear reaction of newborn infants to such a stimulus as a loud sound, a bright light, jarring, or a quick change in position. It is essentially a clasping movement of the arms and legs, but is usually associated with other random and violent movements.

moron. A feeble-minded individual whose intelligence quotient is between 50 and 70.

motive. A general term that includes all those driving forces which incite an individual to make a choice, to perform an act, or to continue in readiness to act.

Müller-Lyer illusion. A visual illusion in which two equal linear distances appear unequal, owing to the shortening or lengthening effect of lines, arrowheads, etc.

muscle sense. See **kinesthetic sensations.**

natural selection. The elimination, through competition, of those organisms least adapted to the environment, with a corresponding survival of the fittest.

negative adaptation. The gradual loss of potency of a stimulus through its repetition or continuation.

negativism. An attitude that manifests itself in strong resistance to suggestions from others.

neonate. The newborn child.

nerve. A cordlike bundle of nerve fibers.

nervous system. The entire system of neurons in the body of an organism. In the human organism it includes the cerebrospinal and autonomic nervous systems.

neuron. A neural element, consisting of a cell body with all its projecting fibers.

night blindness. A condition characterized by the inability of a person to adapt his vision to weak illumination.

noise. A relatively nonperiodic sound.

nonsense syllable. A combination of letters that can be pronounced but has no meaning. Nonsense syllables are used extensively in studying memory.

norm. An authoritative standard. In the realm of mental testing, norm is used to indicate the central tendency of the group of individuals used to standardize the test; as represented by the average, median, or modal score of that group.

nystagmus. Involuntary oscillatory movements of the eyes.

odor prism. A figure designed to show the mutual relations of the six primary odors.

olfactometer. An instrument used to measure olfactory (smell) sensations.

ontogeny. The origin and development of the individual. Contrasted with phylogeny, the origin and development of various animal species.

oral. Pertaining to the mouth.

ordinate. The vertical axis of reference on a two-dimensional chart.

organ of Corti. See **Corti, organ of.**

orientation, illusion of. Any misinterpretation by an individual of his environmental bearings; including errors in spatial relations, errors as to time relations, and errors in the recognition of persons or objects.

oscillograph. An instrument that produces a record of the forms of electrical fluctuations or waves.

ouija board. See **autoscope.**

oval window. See **window, oval.**

overtone. The tone produced by the vibration of a part of the sounding body that is also vibrating as a whole.

ovum. The female germ cell.

paired associates, method of. A procedure frequently used in memory experiments, in which the material is presented in pairs (such as, puer-boy). The efficiency of the memorizing is tested by presenting one member of the pair, the testee endeavoring to recall its associate.

paired comparison, method of. A method for ascertaining the relative value of the different items in a series. Each item is compared with each other item and the results of all these comparisons are consolidated. For example, if a series consists of items a, b, c, d, and e; a is compared with b, c, d, and e; b is compared with a, c, d, and e; and so on.

palpebral. Pertaining to the eyelids.

papilla. Any small nipplelike projection.

paradoxical cold. A sensation of cold in response to a typically warm stimulus.

paradoxical warmth. A sensation of warmth in response to a typically cold stimulus.

parallax. The apparent shift in relative position of two unequally distant objects with a change in position of the observer.

parasympathetic nervous system. The sacral and cranial segments of the autonomic nervous system conceived as functioning in opposition to the sympathetic system.

parathyroid glands. Four small glands located on the surface of the thyroid glands, which secrete a hormone that regulates blood calcium.

partial tone. One of the simple harmonic components of a compound tone. The first partial is the fundamental tone; the second partial is the first overtone; the third partial is the second overtone; and so on.

patella. The kneecap.

pendular motion. The motion made by a body so suspended from a fixed point that it can swing freely to and fro under the combined action of gravity and momentum.

perceiving. The process of becoming aware of external objects, qualities, and relations.

performance test. A type of mental test in which the factor of language is eliminated or greatly diminished.

perilymph. The fluid that fills the bony cavities of the inner ear.

phase. In simple circular motion (or simple harmonic motion), the point to which the rotation has advanced from its starting position.

phi phenomenon. A term sometimes used to designate apparent motion.

photopic vision. Color vision, that is, vision occurring when the illumination is sufficiently bright to permit color discrimination.

phylogeny. The origin and development of various animal species. Contrasted with ontogeny, the origin and development of the individual.

physiological limit. The limit of excellence of performance in a given motor act, which is determined by such factors as speed limitations, strength limitations, and the like.

pitch. That characteristic of a tone which makes it possible to differentiate it from others in terms of high and low, or acute and grave. It depends primarily (but not entirely) upon the frequency of the sound wave.

pituitary gland. A ductless gland situated at the base of the brain that secretes several hormones, some of which affect growth, sexual development, sexual activity, the production of fat, and the general tension of the body.

planchette. See **autoscope.**

plantar reflex. A reflex movement consisting of the flexion of the toes in response to the stroking of the sole of the foot.

plateau. A temporary halt in the progress of learning, which manifests itself as a flat portion of a learning curve and indicates a period of inability to increase speed or to decrease the number of errors.

plethysmograph. An instrument used to record changes in the size of a part of the body resulting from changes in blood supply.

pneumograph. An instrument used to record the rate and extent of breathing movements.

polygraph. An instrument that makes a simultaneous graphic record of several physiological processes, such as heartbeat, breathing, and muscular contractions.

premise. A proposition from which a conclusion is to be drawn.

prenatal. Before birth.

prestige suggestion. A suggestion that depends for its effectiveness upon the personal influence or reputation of the one who gives it.

problem solving. A type of adjustive behavior in which an individual is stimulated by some uncertainty in the situation to discover how to use some of the unknown elements, factors, or conditions in order to achieve some definite end.

protoplasm. The essential living substance of the cell.

psychogalvanic reflex. The change in resistance of the skin to the passage of electric current (presumably caused by physiological activity under control of the autonomic nervous system) which follows sensory stimulation or accompanies thinking processes.

psychology. The study of how people act and why they act as they do.

Purkinje phenomenon. A name used to designate the various changes in color values resulting from decreases in general illumination. As the spectrum is darkened, the long-wave end darkens more rapidly than the short-wave end.

radiant energy. Electromagnetic waves traveling through free space at a velocity of about 186,000 miles per second, those

wave lengths ranging from about 400 to 760 millimicrons being known as light.

rating scale. A method of securing and recording judgments by indicating where each judgment should fall on a prearranged set of values.

rationalization. The process of justifying an act or opinion by excuses displayed in the guise of reasons.

reaction time. The interval of time between a stimulus and the beginning of a response to that stimulus.

reasoning. A way of solving problems involving a departure from routine reactions and frequently making use of words or other symbolic devices.

recalling. The process of making use at a given time of what was memorized in the past.

receptor. A general name for sense organ.

recessive character. A biological term used in contrast to the term "dominant character." Each biological factor is presumed to have two aspects, one dominant and one recessive; the dominant always suppressing or preventing the appearance of the corresponding recessive character, when two factors are associated.

recognizing. The process of identifying an object or of locating it in the setting in which it occurred in some previous experience.

reflex. A simple form of response which involves a sense receptor, a central nervous connection, and a motor organ (or gland).

refractory phase, refractory period. A brief period of time, following the excitation of a nerve, during which it is inexcitable.

reminiscence. The tendency of an experience to become more firmly fixed, or more easily recalled, with the passage of time.

reproductive interference. The interference with what has just been learned, by intense activity following the learning.

resonance. The vibratory response of a body to a harmonic motion imposed upon it.

retained members, method of. A memorizing method in which the score is the proportion of material previously memorized that can now be reproduced.

retaining. The process of keeping intact what has been learned as evidenced by subsequent recall.

retina. The innermost of the three coats of the eyeball, which contains the essential receptors for light; namely, the rods and cones.

retinal rivalry. An experience that results when radically different

colors or figures are presented simultaneously to congruent areas of the two eyes, consisting of a fairly rapid alternation between the two stimuli—the individual sees first one and then the other instead of a fusion of the two.

rod, retinal. A rodlike structure found in the retina of the eye and functioning as a receiving apparatus for light.

round window. See **window, round.**

s factor (specific factor). A specific factor that is supposed to be distinct from a general intelligence factor, to play a part in the performance of individual intelligence tests, and to account for individual differences between those who have equal general ability.

saccadic movement. The sudden movement of the eyes from one fixation point to another.

sacral segment. That portion of the nervous system which is situated near the lower part of the human body and the tail end of animals.

saturation. The degree to which any color possessing a given hue differs from a gray of the same brightness.

sclerotic coat. The outermost of the three coats of the eyeball.

scotopic vision. Vision that occurs in faint illumination.

semicircular canals. Three canals in the inner ear lying at right angles to one another and serving as sense organs to detect changes in general position or balance of the body.

sensation. An experience resulting from the stimulation of a sense organ.

set. A posture, attitude, interest, or other condition of the individual which facilitates a certain type of activity.

sibling. One of two or more children of the same parents, regardless of sex.

size-weight illusion. An illusion based on the common tendency to judge objects of greater size as lighter in weight than smaller objects of the same actual weight.

smooth muscles. Muscle fibers which are smooth in appearance (i.e., not striated), are innervated by the autonomic nervous system, and operate the internal viscera. Their period of contraction and relaxation is much slower than that of striped muscles.

somesthesis. A general term used to designate all sensations from the skin and underlying tissues, as well as sensations from the internal organs of the body.

sound. The mechanical disturbance that is produced when harmonic motion affects some material substance capable of being moved by its pulsations or pistonlike movements.

spinal animal. An animal in which the entire head part of the nervous system has been severed from functional influence upon the spinal cord.

sphygmograph. An instrument for recording pulse movements.

stapes (stirrup). The third of the little bones (ossicles) in the middle ear; it is articulated with the incus (anvil) and fits into the oval window of the inner ear.

stereoscope. An optical instrument, consisting of a prism placed before each eye in such a manner that, while each eye is seeing a different picture, the two pictures are superimposed and combine with each other. When the two pictures are of the same objects and have been taken by two cameras separated by a distance equal to the distance between the two eyes, the observer has a perception of depth when he views them through the stereoscope.

stroboscope. An instrument for producing a static effect from a rapid series of periodic visual stimuli.

subliminal. Below the threshold.

suggestibility. The characteristic of an individual that shows itself in his tendency to be responsive or obedient to other persons.

syllogism. A pattern for a formal argument, consisting of (1) a major premise, (2) a minor premise, and (3) a conclusion. For example: (1) All men have heads, (2) Joe is a man, (3) therefore, Joe has a head.

symbol. An object, letter, character, sign, movement, or emblem used as a representative substitute for something other than itself.

sympathetic nervous system. The central portion of the autonomic nervous system, concerned primarily with emergency functions of the organism.

synapse. The region of functional contact between two or more neurons; usually the region where the branchings of the dendrites of some neurons are intermeshed with the axon branchings of other cells.

tambour. A device for making a graphic record of changes in air volume. It consists essentially of a small vessel, one side of which is covered with an elastic membrane to which a writing

lever is attached. It is connected with a tube through which changing impulses are communicated as changes in air volume.

taste tetrahedron. A figure designed to show the mutual relations of the four principal tastes.

tau effect. An illusion in which judgment of spatial intervals is influenced by the temporal intervals involved.

technique. The specific way or means of securing data or of working on an experimental problem.

threshold, difference. See **difference threshold.**

threshold, stimulus. That magnitude of a stimulus at which a transition occurs from no sensation to sensation.

thyroid gland. A ductless gland, located in the region of the neck, which secretes a hormone that regulates the basal metabolic rate of the body.

tone. An auditory sensation aroused by a periodic sound wave.

trial-and-error method. The name applied to a method of learning characterized by a series of rather blind and random attempts to solve a problem.

twilight vision. See **scotopic vision.**

twins. Offspring produced at one birth. Fraternal twins are those which develop from separate fertilized ova and have no more similarity in heredity than any other pair of siblings. Identical twins develop from a single fertilized ovum and thus have identical heredity.

tympanic membrane. The eardrum membrane.

unconditioned stimulus. The original, or adequate, stimulus which naturally initiates a certain response.

valence. The effective combining power of a chemical element. The term has been used by analogy by psychologists to designate the interacting attracting and repelling values of various objects or activities.

vascular system. The system of blood vessels in the body.

vertical axis. The axis of reference of the human body passing from head to feet.

viscera. The large internal organs of the body.

visual axis. A straight line passing through the external point of visual fixation and the nodal point of the eye to the fovea.

window, oval. An oval opening into the inner ear into which fits the stirrup, the innermost of the three bones (ossicles) of the middle ear.

window, round. A round opening between the middle and inner ear, just below the oval window, and closed by a flexible membrane.

yellow spot. A pigmented spot about 2 mm. in diameter in the central area of the human retina, in the center of which is the fovea, the point of clearest vision.

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