Introductory Science Text-Books

PHYSIOLOGICAL PSYCHOLOGY

INTRODUCTION

TO

PHYSIOLOGICAL PSYCHOLOGY

BY

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AUTHOR'S PREFACE.

THE present work originated in lectures on physiological psychology that I have delivered at this university for several years. The doctrines herein presented deviate essentially from Wundt's theory, now dominant in Germany, and conform closely to the English psychology of association. Only Münsterberg in Germany has recently raised objections from the standpoint of physiological psychology to the doctrine of apperception, characteristic of the school of Wundt. By introducing an especial auxiliary function, the so-called apperception, for the explanation of certain psychical processes, Wundt evades, it is true, numerous difficulties in demonstration. Wherever a psychical process that is difficult to explain appears, it is ascribed to this apperception. At the same time, however, all psycho-physiological explanation is abandoned. This book is intended to show that such an "auxiliary function" is superfluous, and that all psychological phenomena can be explained without it.

The work was originally designed for the psychiater, just as the study of morbid psychical phenomena gave the first impulse to the psychological studies of the author. But as the circle of hearers broadened, the character of the "Introduction" has changed. In its present form it is designed for the student of natural science, the same as for the physician. I have retained the extensive consideration of the psychical processes of the insane with good reason. Just as a caricature sets off a single trait of character more forcibly, so the mental disease reveals to us now this, now that feature of psychical life with especially instructive sharpness, and in a measure disentangled from the intrication of other psychical phenomena.

As regards the citations, I wish to observe that it is their purpose solely to serve as a guide to further study in suitable channels. It has not been my intention to refer to all the authorities upon which the statements of this work are based.

TH. ZIEHEN.

TRANSLATORS' PREFACE.

FOR several decades a new line of thought and research in the sphere of psychology has been developing in Germany. It received its impulse chiefly from the dominant tendencies that characterize the modern methods of natural science. Psychology, in endeavouring to maintain its position as a science among sciences, was brought in contact with the so-called natural sciences, and the result was inevitable. The close relation that exists between certain departments of psychology and the physiology of the nervous system, and the efforts that have been made since Herbart to apply the methods of natural science to the former, inevitably led to the investigation of psychology from a new point of view (viz. the physiological) and ultimately to the development of a new science, the science of physiological psychology.

Brief as the history of physiological psychology is, it has yet opened a great many new fields for investigation. The empirical data, however, which the science has thus far been able to establish, already receive a variety of interpretations that are far from being concordant. In fact, as the perusal of this work will show, two distinct interpretations that conflict in many of the most essential points, have become especially prominent. The one is held by Wundt and his school, the other by Münsterberg and Ziehen.

The latter, who is well known in Germany, both as University instructor and as a noteworthy investigator in the lines of physiological psychology and psychiatry, has produced the first work which gives a brief presentation of the field of physiological psychology in general, and of an interpretation based upon the English psychology of association in particular. For this reason the translators have thought it advisable to produce a translation of the work for English readers. The work, though small in comparison with that of Wundt's (" Grundzüge der physiologischen Psychologie"), or even with that of the American author, Ladd (" Elements of Physiological Psychology"), who has produced the only other English work upon the subject, embraces within a small compass the essentials of the science. It is therefore fitted to be an excellent introductory compendium to physiological psychology.

The reader will note that in the opening and closing chapters the author clearly and sharply defines the province of his science, and fixes the limits that separate it from other related sciences. Throughout the entire work it has been his aim to develop all explanations as far as possible from physical or physiological data, and to account for the presence of certain functions by an application of the laws of evolution. Hence the work can only be understood and correctly judged when regarded as treating of physiological psychology as a natural science.

Besides being fitted for the use of the alienist and the student of natural science, the work will undoubtedly be of service to the educator and teacher in so far as it is a guide to the understanding of the relations that exist between psychical states and processes on the one hand, and nervous, especially cerebral, processes on the other.

The terminology of the subject, which is already so highly developed in Germany, presents a series of difficulties for an English translation that are by no means easily overcome. The terminology of this translation, however, holds, so far as possible, to already established precedents, wherever they do not conflict with a correct rendering of the views of the author. Wherever the coinage of a term or phrase has been necessary, it will be found to be justified by the needs of the subject and the requirements of the original.

The index to subjects, authors, etc., has been added in the translation, as it was thought advisable to provide a ready reference to related subjects in different chapters to which the text constantly alludes. The explanatory list of symbols has also been added that the reader may find no difficulty in interpreting the same at once, whenever they occur.

C. C. VAN LIEW.
OTTO W. BEYER.

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LIST OF SYMBOLS FREQUENTLY USED IN THIS WORK, WHICH HAVE A CONSTANT SIGNIFICATION AS INDICATED BELOW.

C=cortex, centre.
c=cortical.
d=distinction, difference.
E=excitation, excitant (hence also stimulation, stimulus, irritation and irritant).
f=tone of feeling.
g=ganglion-cells, etc.
i=intensity and ideational.
I=idea.
l=latent.
M or *m* =motor, kinæsthetic, etc.
O or *o*=object.
p=peripheral.
q=quality.
R=retina.
S or =sensation, sensory, etc.
T or *t*=time.

(Introductory Science Text-books.)

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CHAPTER I.

THEME AND SYNOPSIS OF CONTENTS.

THE psychology which I shall present to you is not that old psychology which sought to investigate psychical phenomena in a more or less speculative way. That psychology has long been abandoned by those whose method of thought is that of the natural sciences, and empirical psychology has justly taken its place. Physiological psychology constitutes a part of empirical psychology. Let us start from an antithesis which has long been traditional in philosophy, and to which psychology in particular owes its existence as an independent science. This is the antithesis of material phenomena and psychical phenomena. We shall purposely avoid the terms *mind* and *matter*, since each introduces a new and at first purely hypothetical unit instead of the manifold data primarily furnished us. For the present also we shall not investigate whether the material and the psychical data are equally primary or not. It shall be reserved rather for the close of our researches to decide whether "the material" and "the psychical" are entirely independent of each other; or whether the former is a function of the latter as the spiritualistic philosopher assumes; or finally whether the latter is merely a function of the former as the materialist conversely assumes. For the present we accept the antithesis of psychical and material phenomena and reserve for a later stage the finding of a unity for the two contraries, based upon all our physiological and psychological researches. But we must here emphasize one proposition, which we can draw directly from physiology and which can serve as fundamental for the entire field of physiological psychology. There is without doubt a certain number of psychical phenomena or processes that do not occur independently of certain material phenomena and processes, and that are not only not foreign to the latter but stand in obvious correlation to them. More briefly stated,—certain concomitant material processes correspond to a certain series of psychical processes, so that the latter cannot occur without the former, nor the former without the latter. The physiology of the brain, for example, teaches us that sensations of sight only occur as long as the occipital lobe of the cerebrum remains intact. If we remove this from a dog with a knife or cautery and keep the animal alive, it will be blind for the future. Conversely it appears that sensations and perceptions of sight occur as long as certain material processes (the particulars of which are as yet quite unknown to us) take place in the uninjured occipital lobe of the cerebrum. Let us ask in general, What material processes can be clearly shown to be accompanied by concomitant psychical processes? Our first answer is, physiological processes, *i.e.* those material processes that properly belong to living matter; still more specifically expressed, the material processes of the central nervous system, especially of the brain. Later we shall have to investigate whether such material processes in the central nervous system accompany *all* psychical phenomena, and our answer will be decidedly negative. Physiological psychology, however, deals exclusively with those psychical phenomena to which concomitant physiological processes of the brain correspond. Hence its name. It ignores all psychical processes for which no corresponding physiological processes in the brain are conceivable. Hence physiological psychology is correlated to the physiology of the brain, just as psychical processes are correlated to cerebral excitations. Wherever the physiology of the brain does not yet offer sufficient knowledge, physiological psychology may be allowed to investigate the bare psychical phenomena—as purely psychical—provided it is always guided by the thought that, even for these psychical phenomena, at least the *possibility* of concomitant cerebral processes must be shown.

Formerly it was doubted whether there could be an exact natural science of psychology at all. Even Kant shared this doubt. One of his chief arguments is as follows: The psychical phenomena are incommensurable because they are not quantitively comprehensible. Therefore they can never be subjected to mathematical treatment. It is not necessary for *us* to deduce from the conception of psychical life the possibility of applying mathematical computation to that field of science, for Kant has already been refuted by the history of psychology. Less than forty years after Kant had given this judgment, Herbart had already applied mathematics to psychology in the most fruitful way. One may agree with his results or not; at all events the *possibility* of a mathematical treatment of psychology was demonstrated by the works of Herbart as early as 1822. Furthermore, physiological psychology has now established important propositions capable of exact mathematical statement. This department of physiological psychology commonly receives the special designation of psycho-physics. It was Fechner, the psychologist of Leipsic, recently deceased, who first treated certain departments of physiological psychology mathematically with positive success. We shall become acquainted with a series of such psycho-physical laws; psycho-physics will therefore be a component fact of our science. The following scheme will make clear to us the position of our science:

1. Speculative Psychology.
2. Empirical Psychology.
   a) Transcendental Psychology: psychical processes *not* contingent on cerebral function.
   b) Physiological Psychology: psychical processes *contingent* on cerebral function (integral part: *metric* physiological psychology = psycho-physics).

In repairing to the great world of psychical phenomena, our first task will be that of every empirical science, viz., the critical investigation of data, which we must first gather empirically that we may then study their connection. Here we encounter the question at once, how do we recognise psychical phenomena? What will help us to a trustworthy diagnosis of such phenomena? The criterion can only be worded thus,—*All* and *only* the phenomena which are imparted to our *consciousness* are psychical. That which is without us in space and time, which we assign as the cause of our sensations, is material. The tree, whose existence we accept as external to us when we have the visual sensation of a tree, is material. The sensation of sight itself is psychical in so far as it concerns our consciousness. Here at the beginning of our investigations we find psychical and conscious to be wholly identical, for we can form no idea at all of what an unconscious sensation or idea might be. We know sensations and ideas *only* as far as we are conscious of them. Later we shall see that many investigators have also assumed unconscious sensations and ideas. Let us suppose that we pass a friend, and, being absorbed in thought, fail to see him; but after a few steps further it suddenly occurs to us that our friend has just passed and we then greet him. In this case it seems rational to assume that an unconscious seeing of the friend preceded the conscious seeing, that an unconscious sensation of sight was prior to the conscious sensation. On closer investigation, however, this assumption is seen to be wholly arbitrary. When the friend passed, the retina and optic nerve were irritated, and the latter conducted the excitation farther to the occipital lobe of the cerebrum, the so-called visual centre. We know that this excitation is a material, a chemical process. At first no psychical process at all corresponded to the material process. Other more intense ideas, *i.e.* more intense excitations of other parts of the brain, absorbed our thoughts. To express the fact briefly, we may say, Concomitant psychical processes took place for the time being only in other portions of the brain. Therefore we did not see the friend, and passed without recognising him. Then, after a few steps, we were aroused from our meditations, and the ideas that had just been occupying our attention diminished in intensity and retired. Now, for the first time, a concomitant psychical process appears in response to the material excitation of the occipital lobe, which has remained persistent and gradually taken effect. Now for the first time it occurs to us that we have seen the friend. Thus we perceive that it is by no means necessary to assume an unconscious sensation as antecedent to the conscious. The assumption that primarily only a physical excitation existed, which subsequently led to psychical processes, *i.e.* entered into the consciousness, is just as simple and decidedly more legitimate, since it introduces no new and wholly unintelligible conception. Let us repeat it: *"psychical" and "conscious" are for us, at least at the beginning of our investigations, identical.*[1] The latter, as it were, is the shibboleth for the former. From the outstart the conception, "unconscious psychical processes," is for us an empty conception. We shall meet with it again farther on as a hypothesis, though one to be regarded from the beginning with great scepticism.

Without proceeding from a definite classification into three mental faculties, or from any other hypothesis whatever, let us now seek the psychical phenomena wherever we find them in connection with the processes of the nervous system. It is

[1] Innumerable controversies have been spun out concerning the question as to whether there are unconscious psychical conditions or not. A good synopsis of these discussions is to be found in the work of G. CESCA, "Ueber die Existenz von unbewussten psychischen Zuständen" (*Vierteljahrschr. f. wiss. Philosophie,* 1885, Bd. IX.). The conclusion at which Mr. Cesca arrives is undoubtedly wholly false. Among those treating the question exhaustively are especially HAMILTON, "Lectures on Metaphysics and Logic," 1882; J. MILL, "Analysis of the Phenomena of the Human Mind," 1878; LEWES, "Problems of Life and Mind," 1879; and MAUDSLEY, "Physiology of Mind." In the case of the passing friend, already cited, however, the process is also frequently the following. The excitation of the visual centre by the image of the friend may, indeed, be accompanied by a sensation, which, however, in consequence of the predominance of other ideas, is not sufficiently intense at first to prompt any further thought, least of all the recognition of the friend.

obvious that the first beginnings of a nervous process are to be sought where animal anatomy first meets with a nervous apparatus in the ascending scale of animal life. Animal anatomy, however, is far from having brought its investigations in this line to a close. We find the first unquestionable rudiments of a nervous system in the Medusæ, on the free margin of whose swimming umbrella Romanes has found numerous nerve-ends and conductive filaments, which penetrate the umbrella. Irritation at any point of the umbrella causes a contraction of the lining sheet of muscular tissue resulting in locomotion. The contraction appears to begin at some definite point of the umbrella, and eventually to become universal. A certain capacity for nervous processes might properly be recognised in the motor activity of even the simplest Amœbæ. Let us imagine a monad to be placed before us, and a grain to be brought in contact with it. Protoplasmic masses, the so-called pseudopodia, stretch themselves out, envelop the grain, and contract again with it to the main mass. In this process, those features are already present that we shall recognise in the future as the essentials of nervous function, viz.: (1) a stimulation (later we shall say a sensible stimulation); and as a response to this stimulation, (2) a reaction, in fact a motor effect, that is by no means easily explicable by merely physical laws. Hence, wherever we find contractile substance, the conditions of nerve-life are already present. In the protista, one and the same cell, as a whole, is still the seat of the reception of the stimulus, and of the motor reaction. In a very interesting way this is changed in the Cœlenterata. In the Hydra we find the so-called neuro-muscular cells or epithelial muscular cells. They are less distinctively developed also even in many Flagellata (Poteriodendron). In these cases the stimulation is received by the cell only at *s* (fig. 1), and the motor reaction takes place only at the points *m* and *m'*, so that a separation of the sensory and motory parts has already been effected. In the Medusæ we find still further development, the gradual accomplishment of which we must conceive of as follows. Let us suppose an animal body composed of many cells, to be brought in contact with any given stimulus. The latter is constantly transmitted as an excitation within the animal along the path offering the least resistance. Thus the excitations will come to be transmitted only along fixed paths, the so-called paths of conduction. According to a fundamental law of biology, the constant execution of definite functions also gradually effects certain structural modifications. Accordingly these paths of conduction become anatomically differentiated from their surroundings and the nerves develop into independent anatomical tissues. Even in the Medusæ we find this degree of development. In these animals, in fact, a mediating organ has already been introduced, in the form of a so-called ganglion cell, between the sensory conductor receiving the stimulation and the

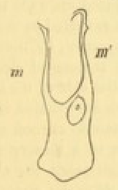


FIG. 1.

motor conductor imparting contraction. That which we find in the complete nervous system of the Medusæ has only been developed from the imperfect capacities which were already pretypified in the lowest Protista, but which did not yet appear to be anatomically differentiated. When, as in the case of the Medusæ, a stimulus acting upon the nerve-end *s* (fig. 1) reaches a ganglion-cell, and is transmitted by the latter along a new nerve-path to contractile masses, so as to impart motion, the entire process is designated as *reflex action*. Reflex action is the simplest nervous process of which we have knowledge. After the above statements there can be no objection to designating the numerous movements of the protista, caused by the mechanical stimuli of light (recently described anew by Verworn) as reflex action, although nerve-paths can in no wise be shown to exist in these animals. Among these reflex actions are the withdrawal of the Pseudopodium[1] when pricked, in the case of the Actinosphærium, or the movements of the Flagellata in darting back by means of the movements of their own cilia.

Let us pass at once from the Medusæ to the highest classes of animals, and seek reflex action in the latter. Here it appears that that which we learned from the Medusæ, is to be met with again, scarcely altered, in the highest animals. We understand by reflex action in higher animals, a motion imparted by a stimulus which acts upon a sensible periphery. Think of the well-known reflex action produced upon the sole of the foot. A prick on the sole of the foot is answered by the withdrawal of the foot, by flexion, and, to some extent, by the contraction of the toes. In this case the essential anatomical elements of the process are thoroughly known. In the sole of the foot are the terminations of sensory nerves. These are irritated and conduct the stimulus, or, as we shall call the stimulus as soon as it has been received by the nerves, the *excitation* to a sensory ganglion-cell *S* (fig. 2) in the spinal cord. This cell sends the excitation received along the inter-central path *S M* to the motor ganglion-cell *M*, which in turn transmits the impulse again toward the periphery, *i.e.* centrifugally, and generates muscular activity. There is a large number of such reflex motions. They are also designated as lower or simple reflex motions. Now, does a concomitant psychical process correspond to this nervous process with which we have just become acquainted as simple reflex action? Our consciousness, as shown above, is alone able to decide the question: it undoubtedly answers No. If our foot is but pricked unawares, it is only after the movement has been executed that we are in-

[1] Even here, in the cases of the simplest reflex action, "fitness," *i.e.* adaptation to a definite purpose, becomes very apparent; for nearly all the reflex movements of the protista, resulting from mechanical irritation, cause the withdrawal of the organism from the irritant (negative thigmotropism).

formed of what has taken place by a new sensation—the sensation of motion. A further argument for the non-psychical character of reflex action is supplied by objective investigation. Individuals whose psychical life has been totally extinguished, who are therefore unconscious, can still execute perfect, or even intensified reflex, plantar motions. A similar line of thought may be applied to all the lower reflex motions in as far as they can be subsumed under the above scheme. It is likewise valid when several sensory fibres act upon several sensory cells, and the latter again upon several motor cells. In fact this is already the case with reflex action in the sole of the foot. When the sole of the

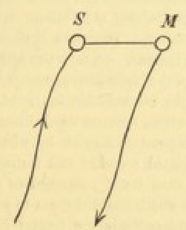


FIG. 2.

foot is touched, not *one* but *many* terminations of the sensory nerves are irritated, and hence also many sensory and motory ganglion-cells are excited. In the same way, not *one* muscular fibre, but a large number of fibres belonging to one muscle, or very frequently to several muscles, are made to contract by their respective nerve-fibres. The following characteristic, however, is common to all these lower reflex actions: the sensible stimulus may change, we may graze, prick, or tickle the sole of the foot, or singe it with a flame, we may apply the irritant now at this point, now at that, but in all cases the motor effect, the responding reflex action remains the same with stubborn monotony.

The vigour with which the toes are contracted or the foot is withdrawn may change, but the same groups of muscles are always innerved, and always execute the same movements. The peculiarities of the stimulus have no influence upon the motor reaction. At this point let us call attention also to another distinguishing feature of these lower reflex motions. Notwithstanding their constancy, they are generally fitting, *i.e.* adapted to a purpose. Here, above all, we must guard against the idea, too easily formed in connection with the idea of reflex action, that the fitness of a nervous process demonstrates its psychical nature. The colour of the bird's plumage, the structure of the hand, and countless phenomena of the vegetable world, in which we first meet with expediency and organization, are fitting; in no other sense is lower reflex action fitting. Therefore it is no more psychical[1] than the colour of a feather. In fact, the fitness of this reflex action, and the fitness of the bird's plumage were developed in a very similar manner, viz. by transmission or heredity, and by natural selection. Animals whose nervous mechanism was so constructed that they did not respond to a prick by withdrawing, but rather by extending the irritated member still further, were much more exposed to injuries than those possessed of a nervous capacity, primarily accidental, which enabled them to withdraw in response to the irritation. Accordingly the former developed with less vigour, did not live so long, propagated less rapidly, and consequently transmitted their unfitting mechanism to a constantly decreasing number of offspring. The constant operation of this natural selection effected the final extinction of all animals having an unfitting reflex mechanism. Only those animals prevailed in which a fitting mechanism existed, as at the present time.

Moreover the fitness of reflex action by no means demonstrates that psychical processes accompany the reflex motions. Accordingly Pflüger was wrong in assuming a special soul for the spinal cord upon the ground of this fitness of spinal reflex action. In

[1] LEWES has defended the theory of the "omnipresence" of consciousness in all reflex centres to the extreme, but upon quite insufficient grounds.

support of his theory, Pflüger made use of the following well-known experiment. A frog is decapitated, and its left leg amputated; as soon as a spot on the left side of the body is moistened with acid, it is immediately wiped off with the right leg. But this experiment offers no proof whatever of his theory of a special soul in the spinal cord: (1) because this same reflex act takes place elsewhere as a normal phenomenon, and is sometimes diagonally executed[1]; (2) because even the greatest fitness is conceivable without psychical processes.

From the above explanation we shall soon be able to understand still another point. These lower reflex movements are *generally* fitting, *i.e.* they verify their fitness in the great majority of cases; but there are cases also in which they may be directly unfitting and injurious. In such cases the characteristic constancy, that has been inherited through many centuries by all reflex action, is an obstacle. The reflex motion of the foot, for example, is executed in just the same manner when a second sharper needle is placed *above* the instep, the skin being thereby exposed to a much severer injury upon withdrawing the foot. The lower reflex motions are absolutely, and hence blindly, constant; they are therefore only *generally* fitting.

Whether these reflex acts, in which all psychical concomitant is wanting, have originated from acts originally psychical, that is from nervous processes having a psychical correlative (for example, voluntary acts), is a question that cannot affect our conception of them. We shall see later what degree of probability can be granted this assumption. At first we are only acquainted with lower reflex action as we *now* find it; we know *nothing* of any psychical correlate for *this reflex* process.

The numerous more complicated reflex acts, with which we are at present acquainted, are to be distinguished from these simplest reflex acts as regards the motor part of the process. The

[1] The experiments of AUERBACH (*Zeitschr. f. klin. Med.*, IV, 4) and SANDERS-EZN (Arbeiten aus d. physiol Anst. z. Leipzig, 1867) also demonstrate only reflex—hardly automatic—activity of the spinal cord.

sensible stimulus, at least so far as quality is concerned, remains the same; but the motor response becomes more complicated in proportion as the growing intensity of the irritation sets a greater number of muscles in action. Finally, the thrust of the needle having become sufficiently intense, not only the one leg, but also the arm on the same side, then even the other leg and arm and the muscles of the face will be set in motion. But otherwise the motion retains its monotonous character. The withdrawal of the suckers of the starfish also furnishes a good illustration of the gradual propagation of reflex motion as the stimulus is increased. The movements of the Crinoidea, culminating in actual flight, offer another example. The following experiment furnished by Goltz is also interesting.[1]

If, after having removed the cerebrum of a frog, we touch the cornea of the brainless animal with a couching-needle, the first reflex motion is the closing of its eyelid. If we repeat or intensify the stimulation, the animal will strike the needle aside with the corresponding front foot. A still further increase causes the head and trunk to be turned away from the irritant. Finally, upon constantly increasing both the frequency and intensity of the irritation, the animal will retire to some other place. Vulpian has made a more accurate study of these more complicated reflex motions.

Furthermore, the conditions of reflex action, the sensible stimuli, may not only become more intense, but also more numerous and complicated. Auerbach has observed that a decapitated frog, the skin of whose breast has been cauterized at some point, executes a variety of movements according to the position of its limbs and the location of the cauterized spot. Hence, so-called "co-ordination" is also characteristic of reflex action to a great extent. And yet we have no ground whatever for assuming that these higher or more complicated reflex acts are accompanied by psychical processes.

[1] GOLTZ, "Beiträge zur Lehre von den Functionen der Nervencentren des Frosches," Berlin, 1869, S. 59.

Let us now leave reflex action and pass on to the next stage. A frog, whose cerebrum, *including* the optic thalamus, has been extirpated, still leaps away when pinched; but in so doing it stumbles against all obstructions. Let us next observe a frog more closely in which the cerebrum, *exclusive* of the optic thalamus, has been removed. All reflex action is retained. A prick on its foot easily causes it to leap off. If we place an obstacle in the path of its retreat, it avoids the obstruction, or, in rare cases, clears it with a well estimated bound.[1] The mere act of leaping away may possibly, in case of necessity, be regarded as a complicated reflex act; but the fact that the frog avoids the obstacle while retreating shows at once that quite another process is concerned. This process we shall analyze. A sensible stimulation (the pricking) imparts a complicated motor reaction (the movements in leaping), which thus far may be considered as reflex. While the latter is taking place, another *intercurrent* stimulus appears, viz. the obstruction which we place in the way and which irritates the terminations of the optic nerve. Such an intercurrent stimulus has no influence at all upon reflex action, or at the most its influence is but quantitative. If we prick the sole of one's foot and at the same time apply any other form of stimulation by permitting, for example, the brightest light to be flashed, or the loudest noise to be made, the motor reaction will at most prove to be somewhat weaker or stronger, but the same muscles will be affected. So far as quality is concerned, the reflex motion of the sole is constant. But that complicated process, involved in the movements of the brainless frog while making its escape, is very different. The intercurrent visual irritant modifies the action, and *the animal avoids the obstruction.* Therefore in this case, motor reactions of quite another kind are concerned. Those motor reactions that are not the invariable result of a definite stimulus, as are the reflex acts, but that are modified while in progress by the action of new intercurrent

[1] Goltz, "Beiträge zur Lehre von den Functionen der Nervencentren des Frosches," Berlin, 1869, S. 65.

stimuli, we shall call *automatic*[1] *acts* or *reactions*, in the more restricted sense of the words. We find such automatic acts innumerable. Call to mind the pianist who executes an often practised piece of music while his thoughts are wandering elsewhere. Despite his absence of mind, his fingers glide over the right keys in proper succession. In this case also an automatic act is concerned. The visual image of the notes and the sensations of touch, imparted by contact with the keys, act without interruption upon the execution of the movements of the fingers. Or, to cite another example, we often descend a flight of stairs while deeply absorbed in thought. In this case also, as in that of the experiment with a frog, the action of the cerebrum upon the motions of the body has in a certain sense been removed. And yet we are able to place one foot after the other safely. This is another example in which a motion in progress is modified by constantly intercurrent stimuli. These examples also show us that we are unconscious of such automatic processes, and that the latter are not psychical; in fact, our consciousness is employed elsewhere. All warrantable foundation for the assumption of concomitant pyschical processes[2] is wanting. Self-observation, which is alone able to demonstrate conclusively the existence of a psychical process, testifies to the contrary. Therefore the automatic acts share with the reflex acts the characteristic absence of concomitant, psychical, or conscious phenomena. Goltz has termed the automatic movements "response-movements." He also emphasizes as essential the fact that they are adapted to a definite purpose and are able to overcome opposing

[1] Unfortunately the word "automatic" is used with a great variety of significations. We are especially wont to designate as automatic also those rhythmic reflex movements which are the result of internal stimuli,—for example, the pulsations of the heart. This sense will be entirely excluded here.

[2] GOLTZ, to whom we are indebted for the first knowledge of these motor reactions, has assumed such a process, though of course *without* consciousness. In this particular he is opposed to Lotze, but his theory is based upon insufficient grounds.

obstacles. By this he also understands essentially the capacity, already emphasized, for regulating and modifying the reactionary movement by intercurrent stimuli.

It is difficult to state just where we first meet with automatic motions in the animal series. At all events they are to be found in an advanced stage of development in the Echinodermata. Tiedemann, Romanes, and others[1] have described, that star-fish when crawling off are able to avoid obstacles by stretching their tentacles, armed with eyes, forward and upward. Especially the Ophiuræ know how to overcome obstructions readily, for example, a line of upright pins closely encircling them. One can easily remove this capacity for automatic movements by completely severing a single ray from the central disk of the star-fish. The ray thus severed from the central nerve-ring is still capable of locomotion, but it moves quite aimlessly; it no longer avoids obstacles. The movements of the star-fish in turning over, as also those of the frog, laid upon its back, in returning to the position upon the abdomen, are still to be regarded as very complicated reflex acts. The completely severed ray of a star-fish succeeds in turning itself over, though of course very irregularly and with extreme slowness; the frog, deprived of its brain, and possessing only the medulla oblongata besides the spinal chord, is able when laid on its back to resume the natural position upon the abdomen. Preyer observed ophiuræ, on a single arm of which he had drawn a very impeditive sheath of caoutchouc, shove off the sheath by jerks of the two neighbouring arms. In opposition to Preyer, we must still designate this also as an automatic act. In the protista we find no *positive* automatic motions in the sense in which we understand the latter. They do not avoid obstacles, although a single observation of Engel-

[1] PREYER, "Ueber die Bewegungen der Seesterne." Mittheilungen aus d. Zoolog. St. z. Neapel, VII. 1 and 2; TIEDEMANN, Deutsches Archiv f. d. Physiologie, 1815; VULPIAN, Compt. rend. Soc. Biolog., 61, 62; ROMANES and EWART, "Observations of the Locomotor System of Echinodermata," Philosoph. Transact., 1881.

mann's,[1] who saw a vorticel-bud suddenly change its course and swim after a large vorticella with which it had come in contact, would demonstrate the occurrence of reactions in these animals, if it is correct.

At all events we can claim that the first automatic movements to be met with in the animal series, developed from reflex action through the agency of "natural selection." If we wish to illustrate the process of this natural selection, in a rough sketch, much more simply than it has actually taken place, we may present the following:—

Originally the amphibians that regularly avoided an obstacle suddenly placed in the way, thereby modifying their locomotor course, were just as numerous as those that did not. In the struggle for existence, however, the former had a decided advantage, for mechanisms situated below the cortex relieved the cerebrum of work and other deeper nervous centres fittingly performed its functions. This fitting peculiarity was inherited and constantly bred by transmission, while those animals gradually died out that were less favourably constituted. You will therefore understand also why automatic and reflex acts cannot always be distinguished from each other with absolute accuracy; there are numerous easy transitions from reflex action to automatic action.

But automatic acts are not alone the product of a progressive development from reflex acts. By a sort of retrogressive development, they may be the result of the so-called conscious or voluntary acts. Call to mind once more the above-cited example of the pianist, who plays a well-practised piece while his thoughts, his consciousness wander elsewhere. We designate this playing as automatic, although it was not automatic originally. Before the piece can be executed automatically, the player must practise it for hours with the application of all his energy and attention, and many such conscious voluntary acts must take place. Hence automatic action may be acquired by *practice, i.e.* by the frequent

[1] PFLÜGER'S Archiv, Bd. 2.

repetition of the so-called voluntary acts. These acts, executed at first *with* the constant co-operation of mental images, gradually lose their psychical concomitant and become automatic. For this reason, transitions from one stage to the other also characterize this form of the development of automatic action. This transformation will be fully understood as soon as we have together investigated the nature of the so-called conscious voluntary acts. We find that automatic acts subdivide into two large groups according to their development; (1) those which have developed from reflex acts in the course of long ages and many generations, *i.e.* phylogenetically; (2) those which are the product of voluntary acts during the life of a single individual, *i.e.* that have developed ontogenetically. It is very doubtful whether automatic acts of the second class are ever directly inherited. By committing a poem to memory during many generations, thereby rendering the voluntary repetition of it automatic, it is possible for all of the physical conditions of speech to be gradually perfected, but no single act itself will ever be inherited. All automatic acts of the second class are distinguished from those of the first class by being far too specific and complicated to be inherited.[1] This is a further distinction between the two kinds of automatic action. The conduct of the young pointer on the scent of the game during his first hunt, as described by Darwin, illustrates one of the most complicated, inherited, automatic acts. —The acts prompted by so-called instinct are also to be regarded as very complicated reflex acts that likewise occur without consciousness. At a certain time in its life the bird builds a nest; the developing genital organs have imparted the requisite external irritant. This act, however complicated, must still be considered reflex. Inherited ideas do not guide the bird in building its nest, but without the intervention of any idea whatever, the stimulus

[1] MEYNERT overestimates the importance of the automatic acts of the first class in that he derives *all* voluntary motions from them ("Psychiatrie," Wien, 1889); MÜNSTERBERG underestimates their value in that he derives automatic acts almost exclusively from acts of the will.

originating in the genital organs simply arouses the action of a reflex mechanism that is inherited. Only after the bird has begun to build its nest does it become aware to some extent of what it is about. Therefore these instinctive acts are undoubtedly performed unconsciously; they do not belong to the voluntary acts with which we shall become acquainted later. Of course, however, many of these acts lose their purely reflex character and resemble the automatic acts. When a frog whose foot has been crushed leaps away, its movements may possibly be regarded as purely reflex. We can conceive that, even though the frog while hopping should not receive new sensations of touch every time it came in contact with the floor, or new sensations of position every time it moved its legs, the motions thus executed would still occur in the manner in which they actually do take place, *i.e.* as purely reflex action. The frog performs an automatic act only when it *avoids an obstruction* lying in the way of its progress. So the motions of the bird while building its nest are at least affected by intercurrent sensations. The first motory stimulus originates in the genital organs, but the resulting motions are determined and modified by innumerable intercurrent stimuli. The bird perceives a straw, seizes it and carries it to a tree. He espies a flock of wool, and this intercurrent visual stimulus causes him to seize the flock. In this way the series of motor processes is modified and complicated. Therefore many instinctive acts are to be regarded as automatic and not reflex. On the other hand no instinctive act is a voluntary act.

While the reflex acts are essentially constant, the automatic acts are characterized by great diversities. The motions executed in deviating from a definite course vary according to the character and position of the intercurrent stimulus that causes the deviation. By reason of this infinitely greater variability, the automatic acts or reactions resemble the conscious or voluntary acts. On the other hand the automatic acts are quite like the reflex acts in that they have no psychical concomitant. We have already set forth above that there is no ground whatever for the assumption of concomitant psychical processes, and the example of the pianist illustrates best that no such conscious processes accompany the automatic acts. Hence reflex and automatic actions do not belong properly to the sphere of physiological psychology. Our consideration of the acts of will in the next chapter will introduce that subject for the first time. The reflex and automatic acts present merely the physiological, not psychological, antecedents of voluntary acts.

CHAPTER II.

SENSATION, ASSOCIATION, ACTION.

WE have become acquainted with "constancy" as characteristic of reflex action, at least as regards quality. As a criterion of automatic acts, we fixed on "the modification of a motion by external intercurrent stimuli." Let us recall to mind the frog, deprived of its cerebrum, that is still able to avoid an obstruction. Neither reflex nor automatic acts have a psychical correlative; in other words, both are performed unconsciously. At least we found no authority for the assumption of concomitant psychical processes. Let us now analyze a simple *conscious* action resulting from an external stimulus. We see a friend, for example, and greet him. In this case the visual sensation, or the image of the friend, is the external stimulus; the salutation with the hand is the resulting action, or, as it has been termed, reaction. What was it that co-operated in the production of just this motion? It is obvious that a sufficient cause is not to be found in the external stimulus alone, for if it had been some other person not our friend, the salutation would not have taken place. It is plain that the memory of having already seen this same person occurs to us. A mental image stored up in some manner in the brain, the image of our friend as it is carried with us in memory, has influenced or modified the motor process. If it had been our enemy, we might possible have turned away or looked elsewhere. But the memory tells us that it *is* our friend; we recognise him as such and the salutation follows. In this case, therefore, the course of the reaction is influenced by intercurrent *mental images*, which have been called forth from their state of latency by the sensation itself. We shall designate the mental image by *I* (idea) (Fig. 3), and indicate the modification of the reaction at first simply by a series of lines connecting *I* with the tract *SM*. The contrast with automatic acts becomes at once very obvious. The latter are characterized by the modification of motion through the agency of external intercurrent stimuli; "action" is characterized by the modification of motion through the agency of intercurrent mental images. The automatic acts are unconsciously performed; "action" takes place consciously. We therefore designate the latter as "conscious," or sometimes as "voluntary action"; but

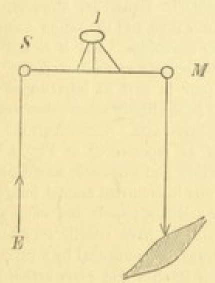


FIG. 3.

we must always keep in mind that these expressions are simply synonyms for "motion that is modified by intercurrent mental images," or, "motion accompanied by psychical processes."

The above is also a typical case of all psychical processes. There is no psychical process having a physiological correlative, *i.e.* no psycho-physiological process, that the above-described process does not comprehend. A survey of its single elements furnishes us at once with the best classification and summary of our science. The external stimulus *E* (excitant), with which we shall begin, is a purely physiological element. By irritating the extremities of the sensory nerves, this external stimulation becomes a nerve-excitation. This nerve-excitation is another physiological process, that may also be properly regarded as physical or chemical. This physiological process of excitation is transmitted toward the centre along the path of the centripetal nerves, and finally produces an excitation in the cerebral cortex at *S* (sensation). The first psychical element, the *sensation*, corresponds to this cerebral excitation. Therefore, the first part of physiological psychology treats of the theory of sensation. In the above case we have assumed *one* sensation as the starting-point of the "action." Generally, however, many sensations take effect at the same time, and the action occurs as the resultant of several or many sensations. But it is not always necessary that these sensations operate *at the same time*. On the contrary, they may also appear in part as intercurrent factors while the mental images that have already taken effect are still active, as in the case of the automatic acts. Accordingly the scheme of simple action will appear as represented in Fig. 3. The difference between simple action and automatic action consists only in the fact that in the former intercurrent mental images, in addition to the intercurrent sensations, appear and modify the motion. In the above statement we have silently accepted the hypothesis that "action" is always accompanied by a psychical process. In fact, self-observation teaches that every action *is* attended by a psychical process; but this connection is not absolutely necessary. It is possible to conceive that all our actions, even the most complicated, abstractly considered, have a purely mechanical or material cause. Ordinarily we imagine that all the complicated actions of human life are more easily explained by introducing the help of psychical processes. The opposite is correct; all actions, even the fittest and most complicated, can be understood as the effect of the material processes of the brain. But, on the contrary, there is something wonderful and inexplicable in the fact that only a certain part of these cerebral processes, certain processes of the cerebral cortex called "actions," are accompanied by psychical processes, and are therefore connected with a new series of phenomena that can only be known through the consciousness. Considered as purely material, the process of "action" is as follows: A certain stimulus imparts a cortical excitation; the latter, however, is not transmitted directly to a muscle along a centrifugal path until after it has been essentially modified by the action of the residue of former cortical excitations imparted by former stimuli. The cortical excitation corresponds to the sensation, *S*; the residua of former cortical excitations correspond to the mental images or idea, *I*. By natural selection, this mechanism of the brain has been so developed that the residua of former excitations can be utilized in the most complicated manner.[1] Therefore every action can be conceived of as a purely physico-chemical process. It is only through self-observation that we know our actions are accompanied by psychical processes. Hence we are justified in ascribing concomitant psychical processes to all those animal actions that cannot be accounted for without assuming the co-operation of ideas (*i.e.* the residua of former cortical excitations occurring in the life of the individual), although our conclusion is drawn merely from probabilities.

The statement, made above, that one simple sensation rarely operates alone, requires still further confirmation. Let us consider a well known experiment of physiological optics. Suppose a point of homogeneous red light to flash upon the dark field of vision. Suppose, furthermore, that this point, on account of its infinitesimal magnitude, can irritate but a single sensitive element of the retina. In this case it might seem as if but *one* simple sensation were really active. But think of the innumerable sensations of touch, constantly produced by our clothing and the surrounding air, which is never quite calm. That many sensations would still be present, in this case, is obvious. If we consider further what an exceptional case is assumed in the above-mentioned experiment, it becomes clear to us at once that many sensations are constantly taking effect. Sensations which

[1] MÜNSTERBERG, "Willenshandlung," S. 55.

are incapable of further analysis in consciousness, we call simple sensations. Let us call attention expressly to the fact that the external stimuli may be very numerous and yet the sensation may remain simple, as in the case of a tone struck on the piano. With the exception of individuals that are musically very gifted, most persons have a simple sensation, although six or more "overtones,"[1] besides the fundamental tone, are produced by the vibrating cord, and each tone is furthermore composed of a large number of single vibrations. It is also worthy of notice here that the same external stimulus, or the same group of external stimuli may be perceived differently by different individuals. One may perceive a simple, another a complex sensation. In fact, even during the life of the same individual, a simple sensation may become complex, or a complex sensation may become simple. At first, when C' is struck on the piano, we hear but a single composite sound. Despite the consonant overtones the sensation is simple. By practice, however, we can also cultivate the ability to distinguish the overtones in the composite sound from the fundamental tone C'; thus the simple sensation will have become complex. On the other hand, several sensations that often enter consciousness together may blend to a single sensation. For example, the taste of an apricot is composed of innumerable sensations; yet we experience but one sensation of taste when we eat the fruit.

As soon as the sensation is associated with the ideas, the *play* of *motives* (deliberation) commences. With a view to future considerations, this play of motives, or deliberation, may be termed more properly the activity of ASSOCIATION. This name shall designate the sum of all psychical processes that are induced by sensation and that result in action, *i.e.* all intercentral processes occurring between *S* and *M* (fig. 3). Association makes use of the sensations received at *S* (including those that may appear later as intercurrent) and the mental images that have originated in former sensations. The latter are briefly designated

[1] Also called "partial tones" or "harmonics."—*T'r.*

as *ideas*; the sensations themselves, in so far as they enter into the function of association, are termed *perceptions*. In the literature of psychology a remarkable confusion prevails as regards the conceptions "sensation," "perception," and "idea." For this reason let us be sure to remember that perception and sensation are to be understood as referring essentially to the same phenomenon. In a certain sense, sensation is the unused raw material; perception is this same material in use. We shall make no distinction between mental image and idea. Such images exist without doubt. The sensation of sight, imparted by a rose that we once beheld, is not totally lost after the flower has disappeared. If we see the rose again, it does not appear wholly new and strange as at first; but we recognise it as one that we have seen before. We can, in fact, reproduce its image in thought by the help of the imagination without its reappearance before our eyes. The existence of images of memory is therefore indisputable. It is supposed that they are deposited in the cells that presumably constitute the fixed points of rest in the confused interlacing of cortical fibres. This conception, at least in its native simplicity, is not correct. We will therefore postpone the question concerning the material basis of these mental images—where and how they are deposited—until we come to the *second* part of our science, which treats especially of *ideas*.

The theory of association, by far the most interesting and most important one of our subjects, constitutes the *third* part; the theory of action resulting from association, constitutes the *fourth* part. With reference to the last, let us guard against a certain erroneous idea from the beginning. Action itself, as motion of the muscles, has no psychical correlative, and is therefore a purely physiological process. During a conscious or voluntary motion, *i.e.* a motion which is neither automatic nor reflex, there are but two psychical phenomena of which we are conscious. Let us take, for example, the intentional movement executed with the right arm in trying to grasp an object lying before us and acting as an incentive. In this case the only conscious phenomena are as follows :—

1. The idea of the motion required in grasping the object. This idea of a motion that we have often executed is the purpose or motive of which we are conscious in the first moment. Such mental images are termed "ideas of motion."

2. The sensations by means of which we become aware that the motion has been executed. We *see* the arm moving, we *feel* the object seized, and finally the sensory nerves in the interior of the right arm inform us that the muscle has contracted. This last most important sensation is designated as a "kinæsthetic sensation" or a "sensation of motion" in the narrower sense.

That no conscious factor is inserted between the idea of the desired motion and the sensation of the executed motion, is a fact that can be easily confirmed by the test of introspection. *No psychical* process intercedes between the idea of motion and the sensation of motion. At one moment we have the idea, at the next the sensation of motion. Thus we see that when action is subjected to analysis, it is reduced to two psychical elements, the idea and the sensation. Besides these there is no other psychical element that is characteristic of action. The fact that we have experienced a sensation leads us constantly to assign some stimulus as the cause of our sensation. We conclude that a contraction of the muscles and a movement of the arm have taken place only when we have a sensation of motion, which is confirmed by sensations of touch and sight.

We have found that the motor scheme begins on the one hand with external stimulation and sensation and closes on the other hand also with sensation and external stimulation. The entire psycho-physical process is brought in as an accessory current. Through this psychological view, the antithesis of sensory and motory elements loses a great deal of its significance. Motor elements, in the strict sense, do not participate in the psychical life; all conscious phenomena are either sensations or ideas. A third psychical factor does not exist, unless we wish to consider the *association* of sensations and ideas as such.

The investigation of the important general and, in part, philosophical deductions, that may be drawn from the above discussion, is foreign to our present purpose. At present we wish to demonstrate that all psycho-physical processes are included in the above scheme. There is no psychical process whatever that is produced by the operation of other elements than those named above; nor is there any psychical process that does not make use of these two elements by means of the association of ideas. It is true, however, that many of our psychical processes are shorter than the process just described. In the first place, it is not necessary that the association of ideas, caused by sensation, should always result in motion. The influence of the ideas may moderate and finally arrest the motor process. Conduction having been thus checked in the internuncial paths, the intercentral incitation caused by the sensation either awakens no idea of motion at all, or only an idea that is not sufficiently intense to impart the motion. Let us take the example of a rose. The external stimulus, the rose in the garden of a stranger, imparts a visual sensation or perception. We see the rose. Instantly numerous mental images or ideas become active. We remember the fragrance of the rose and fancy our room decorated by it. These are all ideas that urge us to act, to perform the motions of seizing and plucking the flower; hence, as we shall say, their effect is positive. But other ideas also occur to us; we remember that the garden is the property of another, and that a penalty awaits us if we take what does not belong to us. These ideas have a negative effect; they tend to restrain our hand and arrest the act. This may lead to a genuine conflict between sensations and ideas, or between opposing ideas. The play of motives (deliberation) becomes a struggle between motives (hesitation). The action is the product of the stronger motives, and may therefore often remain wholly unexecuted. Hence the final element of the pyschical process may be suppressed. The process ceases with perception and deliberation and no motion ensues. Furthermore, it should be expressly emphasized that, also in case of introspection, we often overlook the action because it is very slight. Thus Lange has shown that the simple mention of the word "tower," for example, or our own voluntary reproduction of the idea of a tower, generally causes motions of the eyes that correspond to the contour of the object; the acoustic stimulus of the spoken word still causes certain slight motions. One reason that motion does not always ensue may be found in the relative weakness of the stimulus. Every sensation, indeed, has a motor tendency—it tends to generate muscular action; but different sensations have this tendency in very different degrees. The sensation must have a certain intensity in order to overcome the resistance to conduction in the intercentral paths and to produce a motor effect. The association of ideas may either increase or diminish the resistance to conduction. A very singular position is occupied by those actions in which the motion is not confined to the one occupying the mind, but is accompanied by other motions that are seemingly superfluous. The person who is about to strike a blow, clinches his teeth; often before the blow is given there is an almost universal tension of the entire muscular system, such as is characteristic of animals while crouching in "intense" expectation. Scarcely perceptible tensions of the frontal muscle very frequently accompany our actions, especially where strong emotions are present at the same time. Such actions as these we are especially inclined to designate as *voluntary* actions, κατ' ἐξοχήν. This tendency, assisted by the fancy that we act from choice in the association of ideas, has led to the assumption of a special faculty of will. But that which we call will, on strict analysis, is reduced essentially to the sensations of tension accompanying the association of ideas and the action. The feeling that we exercise a free choice in the association of ideas and in action, is easily explained by the fact that, in distinction from automatic acts, association and action are not only determined by external stimuli, but are also influenced by ideas, the sum total of which we may designate as our empirical "Ego." A definite action must follow certain external stimuli and certain ideas according to an inevitable law of causation, just as a stone detached from its support *must* fall in a certain direction with a certain velocity. Accordingly, physiological psychology acknowledges no freedom of the will. Since Spinoza, our great philosophers have been agreed in this point. But we believe that we exercise a free choice because, (1) we ourselves are conscious[1] participants in the active association of ideas; and (2) although the result of this association or, in other words, the result of the play of motives, is not distinctly foreseen, it is nevertheless anticipated; (3) because the decision is also finally made by a part of the Ego, *i.e.* the prevailing ideas.

We shall always speak simply of *actions*; we may add the term "conscious" and speak of conscious actions, but we must always keep in mind that *every* action, in distinction from reflex and automatic acts, has a psychical correlative, and is therefore psychical or conscious. The action is also frequently designated as a *voluntary action* or *action of the will.* But this is also a pleonasm. Every action, as such, is a voluntary action or an act of the will. We may make use of this combination of terms also, but we must not associate with it the false idea that actions are produced by a special faculty, the will. There is no such special faculty of the will. The expressions "action of the will," "voluntary action," and "conscious action" signify no more to us than the simple term "action."

We have seen above that the psychical process as traced by us consists of three chief factors, (1) the *sensation* or *perception*, (2) the *play of motives* or *association of ideas*, and (3) the *action*. It has already been emphasized that the result of the play of motives is often negative; the action prompted by the association of certain ideas is not performed because other ideas, more numerous and energetic, arrest it. Let us consider another very striking example of this fact. While hearing a play in the theatre innumerable visual and acoustic stimuli affect us. Numberless ideas are constantly being associated with the perceptions that have thus arisen. A certain character in the play is killed. Many ideas urge us to the aid of the imperilled individual, but they subside before the far stronger recollection that it is all only

[1] Consciousness is merely an abstraction. The association of ideas, with its accompanying sensations and images, *is* consciousness itself.

semblance, and that we should make ourselves ridiculous if we attempted to rescue. Therefore we remain quietly seated; no action takes place. We have already seen above, however, that the motor action is often simply overlooked because it is so slight! Who has not at times noticed an almost imperceptible quivering of his limbs while witnessing such a scene as the one just described? The omission of the final motor stage of such psychical processes is remarkably frequent, when the processes have originated in weak sensations or in sensations that have but a slight motor tendency.

One would suppose that in very rare cases both the second *and* the third stages—the association of ideas or the deliberation following the perception, and the motion—may possibly be omitted. In this case we should speak of pure perception or the simple apprehension of sensations. But if we consider that the essence of the psychical process consists in the activity of ideas, we shall doubt whether these pure perceptions are psychical processes at all.

For the same reason the middle stage of the psychical process, the association of ideas, can never be entirely omitted. It can only be very much shortened. For example, a person suddenly receives a blow and almost instantly returns it. How few hasty ideas flash through the mind in the moment intervening between the reception of the blow and retaliation! In this case the counter-attack occurs almost automatically; the reproduction of ideas may finally be almost entirely excluded. We are acquainted with a mental disease, mania, in which, from pathological causes, the association of ideas occurring between sensation and action has become regularly and excessively shortened.

The first stage of the psychical process, the sensation, can likewise never be entirely omitted. In fact, there is no psychical process that cannot be traced to an external stimulus and the sensation imparted by it.

But stimulation and sensation are often so remote or so weak that the second and third stages seem to be independent of their influence. Let us suppose, for example, that we have chanced to see a friend. Now, this *one* perception is followed by the recollection of numerous ideas; with these we constantly associate new lines of thought that ultimately have no connection whatever with the friend. These lines of thought, if they have a motor tendency, may produce action; or, as we have seen, the action may be entirely arrested. In the first case the action seems to be the immediate result of the reproduction of ideas without external stimulation, and is then commonly designated as spontaneous. The second case is exemplified by so-called simple *reflection* or *thought*; the primary stimulus of sensation is so remote and the motor tendency is at the same time so slight that action cannot take place.

It is also difficult to determine where action (a nervous process undoubtedly accompanied by a psychical process) is first met with in the animal series. It does not appear that such a process has been demonstrated with absolute certainty even in the Echinodermata.

Let us now briefly review all of the functions connected with the life of the nervous system. We have classified as follows:—

1. Reflex action: Motion constant and generally fitting; results from one or more external stimuli; no psychical correlative.
2. Reaction (automatic acts): Motion modified by one or more intercurrent stimuli; generally fitting; no psychical correlative.
3. Ideational Actions or Acts (conscious or voluntary actions or acts of the will): Motion results directly or indirectly from one or more external stimuli; modified by the association of intercurrent sensations and ideas; generally fitting; with psychical correlative.

Since action furnishes us with an outline of the psychical process, we have at the same time learned the psychical elements of action.

1. Sensation or perception.
2. Image of memory, or idea.

There is no ground for the assumption of any other elements in the psychical process. This process itself is divided into three stages :—

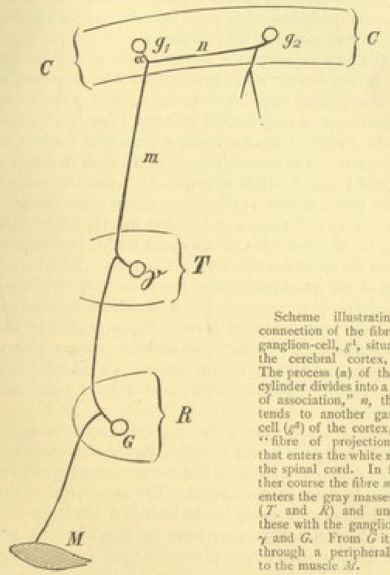
1. Sensation or perception ;
2. Association of ideas or Ideation (also called the play of motives or deliberation) ;
3. Action, *sensu stricto* ; the resulting idea of motion precipitates the act.

The omission of the third stage and the disappearance of the first stage give rise to subordinate forms of psychical function that are of especial importance. Among these forms are simple reflection or thought.

We will now briefly attempt to form a conception also of the anatomical localization of the three nervous processes—reflex action, automatic action, and voluntary action. The brain of vertebrates consists of gray and white masses, the ganglion-cells being the most essential constituents of the gray masses. The white mass consists chiefly of nerve-fibres. Besides the protoplasmic processes, that do not interest us here, every ganglion-cell probably has at least *one* so-called axis-cylinder. This divides, some of its terminal ramifications entering the white mass and becoming part of its constituent nerve-fibres, some passing on and uniting with the terminal ramifications of neighbouring ganglion-cells. The gray masses are distributed between the white, so that a fibre that originates in a ganglion-cell of the most centrally located part of the gray mass, or cerebral cortex, passes through a portion of the white mass and finally reaches a second aggregation of gray substance, where it unites with one of its ganglion-cells.[1] It may also leave this cell again and penetrate still other white and gray masses, until it finally quits the last gray mass in the spinal cord, and passes on with the peripheral

[1] Compare the latest researches of GOLGI, FOREL, and especially FLECHSIG. The outline given above is based upon the researches of Flechsig. Since the sensory fibres ramify more and more as they approach the centre, their connection would seem to deviate from this outline ; the last ramifications appear simply to interlace with the ramifications of the sensory ganglion-cells, instead of joining them directly.

nerve to a muscle or an organ of sense (*e.g.* the skin). This connection is still better explained by the accompanying sketch.



Scheme illustrating the connection of the fibres of a ganglion-cell, g^1, situated in the cerebral cortex, *C–C*. The process (*a*) of the axis-cylinder divides into a "fibre of association," *n*, that extends to another ganglion-cell (g^2) of the cortex, and a "fibre of projection," *m*, that enters the white mass of the spinal cord. In its further course the fibre *m* twice enters the gray masses again (*T* and *R*) and unites in these with the ganglion-cells γ and *G*. From *G* it passes through a peripheral nerve to the muscle *M*.

FIG. 4.

The most important gray masses that are of interest to us are the following :—

1. The *cerebral cortex*, which covers the spherical mass of the cerebrum like a thin rind;

2. The large ganglia situated in the interior of the cerebrum, especially the *thalamus opticus* (optic thalamus) and behind this the corpora quadrigemina (in some animals, corpora bigemina);

3. The gray masses of the *cerebellum*;

4. The gray masses of the spinal cord—the so-called *anterior* and *posterior horns*. These gray masses are connected by innumerable paths. Some of these are sensory paths that enter the spinal cord by the so-called posterior roots and conduct toward the centre. Others are motor paths that conduct toward the periphery. The most important motor path is the so-called "pyramidal tract," which originates in a definite part of the cerebral cortex known as the motor region (zone of Rolando), passes the optic thalamus, and is first interrupted by ganglion-cells in the anterior horns of the spinal cord. From these cells it leaves the spinal cord by the anterior roots. Both in the gray masses of the spinal cord and of the optic thalamus, cerebellum and cerebrum, the sensory ganglion-cells are connected with motor cells by internuncial fibres. Hence a sensible stimulus can be transferred to motor elements at various places, and impart motion. One gray mass produces chiefly reflex action, a second chiefly automatic action, and a third only conscious action.

Now physiology teaches that the *reflex action* of vertebrates generally originates in the spinal cord, although in the case of the frog the corpora bigemina and the cerebellum are also chiefly involved in the reflex mechanism. The movements of the frog when it wipes off the skin on the back that has been moistened with acid, when it hops away after its foot has been pinched, when it recovers the natural position upon the abdomen after having been placed on its back, when it balances itself while sitting upon a hand that is revolving, are all reflex acts that can be shown to depend upon the spinal cord, the cerebellum, the so-called medulla oblongata, and the corpora bigemina. We have not yet been able to localise these motor functions in higher animals so exactly, although in these the chief organ of reflex action is also the spinal cord.

In the case of the frog, *reactions* or *automatic acts* only occur when at least the optic thalamus, corpora bigemina, cerebellum and spinal cord are retained. We have already seen that a frog in this condition avoids an obstruction that has been placed in the path of its progress, showing that it is able to react automatically. It is also probable that the optic thalamus is the chief centre of automatic action in the higher orders of animals, including man.

Voluntary actions were characterised by the intercurrence of ideas. Experimental physiology indicates with the greatest probability that ideas are deposited only in the cerebral cortex, and that therefore actions originate only in the cortex. If the cortex of the occipital lobe of a dog be removed, the animal loses all visual sensations and ideas, *i.e.* also all the images of former sensations of sight.[1] Corresponding results have been obtained for all the senses. Therefore the cerebral cortex is the seat of that nervous process, which alone, as we have shown, is certainly accompanied by a psychical process; it is therefore the seat of all psychical processes, sensation or perception, the association of ideas and voluntary action. This view also agrees very well with the anatomical fact, that the pyramidal tract, through which, as we have shown, our voluntary motor impulses are conducted to the muscles, extends *uninterruptedly* from the cerebral cortex through the deeper ganglia until it reaches the spinal cord. In the same way that the reflex acts depend upon the spinal cord, and the automatic acts upon the optic thalamus, the voluntary actions depend exclusively upon the cerebral cortex. Still

[1] MUNK was the first experimenter who showed that an animal in this condition no longer has visual sensations or ideas. It has not yet been experimentally determined with certainty whether the movements of a dog or rabbit that has been deprived of the cerebral cortex, are still influenced by visual stimuli, *i.e.* whether in the dog or rabbit, the same as in the frog, the optic thalamus is sufficient for the production of automatic action (for example, the avoidance of an obstruction).

another fact agrees with this statement. Animals in which all of the cerebrum except the optic thalamus has been extirpated, are characterised by great restriction of the so-called spontaneous motions, *i.e.* motions that are not the immediate result of external stimuli. These spontaneous motions are chiefly acts that result directly from ideas whose primary external stimulus is very remote. Like all actions, they also depend upon the cerebral cortex, and must disappear when the latter is destroyed. However, a few spontaneous motions still take place, as in the case of a pigeon from which the brain has been removed. This is explained by the fact that internal stimuli (hunger, thirst, etc.) still continue to produce reflex motions which we are accustomed to designate as spontaneous,[1] because these *internal* stimuli are invisible. In such cases the circulation of the blood carries the excitation imparting motion to the centre, thus taking the place of excitation through the centripetal nerves.

In the course of the phylogenetic development of the animal series, many a function will have changed its location. The cerebellum of the frog without the corpora quadrigemina, for example, is still able to impart the reflex motions of hopping, while the rabbit requires at least the anterior and posterior corpora quadrigemina, in addition to the cerebellum. In no respect, however, has the phylogenetic development changed the chief facts of localization, as above stated.

The localisation of reflex action, automatic action, and conscious action in the invertebrates, is far less certain. So little has been established, especially concerning the voluntary actions of these lower animals, that attempts at localization have thus far been too hasty. Our future investigations will therefore be confined to vertebrates, particularly to man. The latter is alone able to give us any information concerning his psychical processes; for, to repeat it, we only know that phenomena are psychical when we ourselves are conscious of them.

[1] PREYER designates them as *impulsive*, BAIN as *automatic* motions.

CHAPTER III.

STIMULUS—SENSATION.

In this lecture we begin the discussion of the single elements of the psychical process with the first element—sensation. As we have seen, the external stimulus first imparts the sensation. Only motion, in the broadest sense, acts as stimulus upon the peripheral organs of sense. But not every motion can produce an excitation of the terminal ramifications of our sensory nerves that will be conducted toward the centre, and finally generate a similar excitation in the cerebral cortex and, as a correlate of the latter, a sensation. Let us first briefly review the various kinds of motion to be met with in nature, that can act upon the peripheral organs of sense. They are as follows:—

1. *Molar motions:* This class-name designates all those motions that may be regarded as the projection or impact of elastic or inelastic bodies. In this case a definite motion is executed in a definite direction by a material body, *i.e.* by an entire complex of numberless molecules. To this class belong all the stimuli of touch and pressure. The latter we can conceive of as projectile motions having the approximate velocity of O.

2. *Atomic* and *molecular motions:* These motions result in chemical changes within and among the molecules. Besides the stimuli of taste and smell, many visceral stimuli also probably belong to this class.

3. The *motions of ether:* Physiological psychology must accept the hypothesis of physics, that particles of ether pervade the space between the molecules of matter, and that the vibrations of this ether, according to their velocity, produce the phenomena that

are designated as "light," and "radiant heat," and probably also those of "magnetism" and "electricity."

The *acoustic stimuli* and the *thermal stimuli*, in so far as the *conduction* of heat is concerned, are to be classed under projectile motions. As yet we know but little of the special characteristics of thermal stimuli. In distinction from other projectile motions, acoustic stimuli are characterised by the fact that the projectile motions of the single molecules of the vibrating body, produce a wave of motion in a definite direction, which is immediately followed by a recurrent wave in the opposite direction.

The number of stimuli that produce direct excitation of the nerve-ends, and that are therefore to be considered by physiological psychology may be still further reduced. We know that those motions of ether that produce light do not act directly on the retinal terminations of the optic nerve, but produce chemical changes, or, as we may also say, atomic motions, in the retina. It is only these chemical processes that act as stimulus upon the ends of the optic nerve.

Therefore only two chief groups of sensible stimuli remain; they may be designated as chemical stimuli and mechanical stimuli. To these we may add the electric stimuli of sensation as a third group, not ignoring the fact, however, that the electric stimuli may also first produce chemical changes in the fluids of the tissues which envelop the nerve-ends, and that these chemical processes would then be the immediate irritants.

As yet we are too little acquainted with the physical characteristics of radiant heat to be able to determine whether it acts directly upon the nerve-ends, or through the mediation of chemical changes. It is also questionable whether radiant heat, as such, acts directly upon the nerves as a stimulus at all; or whether it must not first be converted into conducted heat.[1] It is at least probable that the sensation of heat in the hand, when near a glowing stove, is produced in the following manner:—

[1] But the question is still undecided as to whether the epidermis is diathermous or not; MASJE claims that it is, GOLDSCHEIDER that it is not.

The surface of the hand next the stove is first warmed by radiant heat; the heat thus produced in the surface of the skin is then *conducted* inward to the nerve-ends.

Finally, the irritation of the nerve-ends by magnetism has never been observed with certainty. On the contrary, Hermann's[1] experiments seem to demonstrate the inability of magnetism to act as a nerve-irritant; he placed both animals and parts of animals within the magnetic field of a large electro-magnet, and observed no effect whatever.

Hence two forms of the motions of nature, magnetism and radiant heat, in the light of our present knowledge, seem to be excluded from the list of nerve-irritants; even the other forms of motion are effective only within certain limits. For example, motion that produces sound must have not less than sixteen nor more than 40,000 vibrations per second; otherwise no irritation of the nerve-ends seems to be produced. Similar limitations are found in the case of ultra-red and ultra-violet rays of light. It is already probable that the non-nervous elements of the sense-organ that first receives the external stimulus, act like a sieve, arresting certain qualities of the irritating motions and permitting certain other qualities to pass on and irritate the nerve-ends. Thus, to a certain extent, the organs of sense have a power to select which is doubtlessly a natural fitness, brought about by the struggle for existence. There is no ground whatever for referring the exercise of this selection to the activity of cerebral centres. It is much more probable that the selection, which is apparent in the exclusion of ultra-red and ultra-violet rays of light and of sound-waves, having too great or too little velocity, is accomplished at once in the peripheral organ of sense. Therefore we may assume that certain mechanical and chemical motions produce no nervous excitation whatever. This peripheral selection is essentially determined by the *quality* of the stimulating motions; we shall presently learn of another form of selection that is accomplished in the *central* nerve-organs and which is determined

[1] Pflüger's Archiv, Bd. 43.

by the *intensity of stimulation.* It has often been claimed that the power of qualitative selection is exercised by the nerve-ends to a still greater extent. For example, it has been supposed that the terminations of the optic nerve are only sensitive to chemical stimuli produced by the vibration of ether, and the terminations of the auditory nerve only to acoustic stimuli. This question is closely related to the theory of the so-called specific energy of the sensory nerves.

The latter has often been attacked recently, and in consequence the theory has had to be greatly modified. The following statements, taken from the theory of the specific energy, are of fundamental importance to our future considerations.[1]

According to the above statements it is very doubtful whether any kind of stimulus whatever is capable of irritating the ends of any nerve, *i.e.* whether the nerves are characterized by receptive indifference.

The selection exercised by the non-nervous elements of the sense-organ is followed by another in the nerve-ends. Every sensory nerve has its specific or adequate stimulus.

On the other hand, however, wholly disparate or inadequate stimuli may also sometimes cause irritation of the nerve-ends. If the retina be twitched, for example, this mechanical irritation produces a glimmer of light. Particularly the mechanical and electrical stimuli seem to be nowhere wholly excluded from reception as irritants of the nerve-ends.[2]

But an excitation produced by some inadequate stimulus in the nerve ends, in being conducted to the central organs of sensation, will traverse paths and reach terminal centres that have been fitted by transmission and exercise for the reception of very different excitations. This excitation, therefore, will not harmonize well with the nervous elements upon which it has been

[1] WUNDT, "Physiolog. Psychologie," I, S. 332 and ff. MUNK, Sitzungsber. d. Königl. Pr. Ak. d. Wiss., 1889.

[2] GOLDSCHEIDER assumes, it is true, that whenever they appear as inadequate stimuli, they act directly upon the nerve-fibres instead of upon the end-organs of sense themselves.

forced. Despite the fact that they are not fitted for the reception of different stimuli, however, the elements of the path and terminal centre, will at least endeavour to harmonize to some extent with the inadequate excitation, E, coming from the periphery, and to receive and transmit it. But they will be able to actually receive and transmit only a small part of E. All that is specifically characteristic of E is therefore lost; there will remain but a very vague excitation as the residue of E, and even this will have been transformed so as to render it capable of affecting a path and centre that have been trained for the reception of other specific excitations. We can pull the optic nerve in any way we please, but we always produce the same sensation of light. It is uncertain whether this adaptation of nervous elements to inadequate stimuli is accomplished chiefly in the nerve-path or in the nervous centre; probably in the latter. The most important fact is that such an adaptation is effected, both in the non-nervous elements of the peripheral organ and in the nerve-ends, nerve-path, and, finally, especially the nervous centre. In this sense the theory of specific energy is properly to be understood. To deny the validity of the theory, as thus understood, would be to contradict all the fundamental principles of evolution, which assert that every function determines the character of its organ, or, in a certain sense, trains its organ for its own use. Therefore we must reject Wundt's assumption that all paths and centres are functionally indifferent, and that the processes generated in the central cells are only different because the stimuli are different, and because the irritation is transmitted to the nerve-paths in all its native individuality.

As yet we have no sure knowledge as to the nature of the excitation while being conducted through the nerves. We were formerly inclined to assume conducting currents of electricity, while more recent views more correctly regard conduction in the nerves as a chemical process. In connection with the latter hypothesis, the theory of specific energy may still assume that the excitation is conducted through the nerves in different ways, according to the difference in stimuli. That each nerve-path, including peripheral terminations and centre, is not only fitted for a single quality of excitation, but also for a series of similar qualities, agrees very well with the above theory. Hence it follows that the constitution of the nervous system is an essential factor in determining the quality of sensation. This fact reveals the obvious error of former centuries, first refuted by Locke, though still shared by naive thought to-day, that the objects about us themselves are coloured, warm, cold, etc. As external to our consciousness, we can only assume matter, vibrating with molecular motion and permeated by vibrating particles of ether. The nerve-apparatus select only certain motions of matter or of ether, which they transform into that form of nerve-excitation with which they are familiar. It is only this nerve-excitation that we perceive as red, warm, or hard.

The following table gives a comprehensive review of the different forms of irritation :—

Stimuli.	Intermediate Process in the Peripheral Apparatus.	Organ.
Vibrations of ether; 400–900 billion (Eng. num.) vibrations per second.	Transformation into intra-molecular atomic motion.	Eye.
Intra-molecular (chemical) motions.	Wanting.	Organs of Taste, Smell, and General Sensibility.
Mechanical stimuli (projection, impact, pressure).	Wanting.	All Organs of Sense.
Heat.	Wanting.	Organs of General Sensibility.
Electricity.	Possibly, transformation into atomic motion.	All Organs of Sense.
Molecular motions of sound; sub-contra C–c_8; 16–24,000 vibrations per second.	Wanting.	Ear.

We have now reached one of the chief results of these investigations for physiological psychology. A given stimulus, *E* (excitant), generates an excitation in the peripheral ramifications of the nerves, which we shall designate as *Ep* (peripheral excitation). This *Ep*, which has already become different from *E*, ultimately reaches the cerebral cortex by way of the appropriate nerve-path and, during conduction, undergoes still further, final modifications. We shall designate that which *Ep* has become when it has reached the centre in the cerebral cortex, as *Ec* (cortical excitation). In a given case we can determine *E* exactly as to quantity and quality, though often with difficulty. *Ep* and *Ec* are almost entirely withdrawn from our observation. Now *Ec* is that material process of the cortex to which the sensation *S* corresponds as a correlated psychical process. Of course the exact *physical* or *physiological* measurement of this *S* is likewise impossible; but the *S* is a fact of consciousness, and as such is directly known by us through consciousness. Now what properties do we perceive in our sensation, or by what characteristics are our sensations to be distinguished from one another? We are acquainted with three such distinguishing features; as the first of these we shall mention the *quality* of sensations. The sensations of red and of green, of the tone *C*, and of the taste of sugar are different in quality. A further distinguishing feature of sensations is their *intensity*. If the tone *C* is sounded louder and louder, or if the tongue is moistened with a more and more concentrated solution of sugar, the intensity of the sensation varies without a change of quality. It would be wholly false to reduce differences in intensity to differences in quality; it is always possible for the intensity of a sensation to be gradually reduced to zero, but not for the quality. A third and last characteristic we designate as the accompanying *tone of feeling*. Introspection teaches that every sensation is accompanied by a feeling of pleasure or pain (displeasure). This emotional emphasis of sensations may diminish to zero; as a rule, however, it is present. In every sensation, therefore, we distinguish the quality (*q*), the intensity (*i*) and the tone of feeling (*f*), and indicate them by placing q, i, and f as the indices of S,—$Sqif$. Later we shall become acquainted with two other characteristics of sensations in connection with another subject,—their *localization* and their *duration*.

Let us now consider the intensity of sensations. We at once encounter the question: If the intensity of the stimulus E be known, what is the i of the accompanying sensation S? We have no means whatever for the exact measurement of the intensity of our sensations. If we allow two sources of light to act upon the eye, we can easily estimate the intensity of each by *comparison*; but this estimation is only possible *as* a comparison, and even then is capable of but very inexact numerical expression. At first, therefore, we shall do better to express the problem as follows: Given two stimuli, E_1 and E_2, E_2 being by a definite ratio greater than E_1 (for example, E_2 is twice E_1); in what relation do the two intensities of the accompanying sensation stand to each other? As the simplest solution one might at first suppose that S_2 is also twice as intense as S_1, since E_2 has twice the intensity of E_1; in this case S would simply be proportional to E. To illustrate this relation graphically, one might protract the stimuli upon an axis of abscissas (fig. 5), and the intensities of the sensations perpendicular to this axis as ordinates. By simple proportion the series of intensities of sensation would then produce a straight line (a–e).

If ab (fig. 5) represent the magnitude of the stimulus E_1 and ac the magnitude of the stimulus E_2, ac being equal to $2\ ab$, then ec (the intensity of S_2) is twice as great as db (the intensity of S_1). Closer consideration, however, causes such a simple proportion, assumed before the application of any experimental test whatever, to appear improbable. We have already seen that E is received as Ep, and finally reaches the cortex of the cerebrum as Ec; hence E is subject to a long series of modifications before the correlative process S is imparted. It will be strange, indeed, if these modifications are shown to be so exact for all the different magnitudes of E, that Ep always remains proportional to E, and Ec proportional to Ep. To begin with, it is much more probable that the exact relation between S and E is far more complicated, even though S increase in general with the augmenting E. Of course a definite decision can only be furnished by experiment. However, before we enter into a discussion of the numerous experiments that have been employed since Fechner to ascertain the connection between S and E, we must briefly discuss the meaning of S and E. By our own experience we know directly what is meant by "intensity of the sensation"; but what is to be understood by the "magnitude of the stimulus"? Obviously the quantity of living force contained in the stimulus. It is self-evident that the measurement of this force is in many cases like-

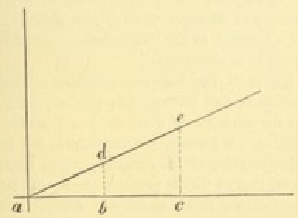


FIG. 5.

wise difficult or impossible. For example, who could determine exactly the kinetic energy of a source of light? Only very recently have we been furnished with exact results in this department of scientific research through the investigations of Thomsen and Tumlirz. But here again we must have recourse to the *comparison* of two stimuli. By permitting the same source of light, for example, to act first at a definite distance a, and then at the distance $2a$, we have an intensity of light in the second case, at least, whose relation to the first intensity can be easily estimated.

We shall begin our experimental investigations with the following simple test. We place ourselves at a distance of 10 m. from a trumpet which is blowing with a uniform intensity, and then recede from it gradually until we reach a point where we can just hear the sound, and then one where we just fail to hear it any more. Suppose the latter point to be about 120 m. from the trumpet. At this distance the sound-waves still reach our ear, it is true, but whether they produce an excitation in the nerve-ends (*Ep*) or not is doubtful; it is still more doubtful whether an *Ec* takes place; but beyond all doubt no *S* is produced. It follows that there are stimuli which produce sensations, the sensible intensity of which is equal to *O*. The stimulus must first reach a definite intensity before it can impart a sensation, *i.e.* we must approach to 119 m. from the trumpet before we hear it. Therefore, that intensity of stimulus which is just sufficient to impart a sensation we designate as the "minimum of stimulation" (*Reizschwelle*=threshold of excitation).

We now approach the trumpet gradually; accordingly the acoustic stimulation, and likewise the intensity of the sensation increase. At the distance of 8 m. the sound already imparts a piercing sensation. We continue to approach, but can now perceive no further increase of the sensation, or, in other words, the sound is so loud that we do not perceive any further augmentation. We have reached the point where our sensation is no longer capable of further increase; hence that intensity of stimulus, which imparts a sensation incapable of further augmentation, is designated as the "maximum of stimulation" (*Reizhöhe*=height of excitation). In the unlimited series of intensities of stimulus rising from 0 to ∞, the first section imparts no sensation whatever; in the second section the intensity of the sensations increases with the stimulus; in the third and last section of the scale of stimulus, the sensation remains constant at a maximum of intensity, despite the further increase of the intensity of the stimulation. The graphic expression for this is presented in fig. 6. The curve of sensations only rises above the axis of abscissas, representing the various intensities of the stimulus, at a definite distance (the "threshold," or minimum of excitation) from the zero point; it then gradually ascends, as the stimulus increases, to a certain

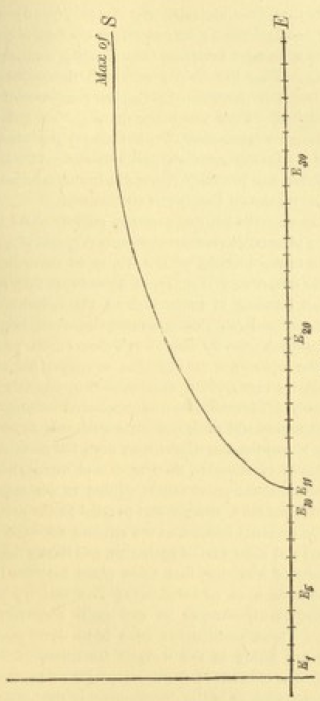


FIG. 6.

height, and finally, at a definite distance from the zero point (the "height" or maximum of excitation), ceases to rise, and extends as a constant parallel to the axis. E_1, E_2, etc., (fig. 6) to E_{10}, are too weak to produce an S; only at E_{11} is the first S perceived; E_{12} produces a stronger sensation than E_{11}, E_{13} a stronger sensation than E_{12}. Thus the S's augment with the increase of the E's, until a sensation generated by E_{30}, the maximum of stimulus, has been reached. Then the following E_{31} does not impart a stronger S than the preceding E's, but simply the same S_{30} imparted by E_{30}. In the same way, all subsequent E's are unable to raise S above the intensity S_{30}. E_{11} is the minimum (threshold), E_{30} the maximum (height) of stimulation.

In this case we have left the question entirely open as to how the intensities of sensation increase between E_{10} and E_{30}: whether in proportion to the increase of the E's, or in some other ratio. A very simple experiment is sufficient to show us that the sensation does not increase in proportion to the stimulus. Let us together observe a light, that gradually becomes brighter the nearer we approach it. By careful self-observation we perceive that at first the intensity of the light (*i.e.* as regards our sensation) seems to augment very rapidly, while later it apparently increases but very slowly. Therefore, in the graphic illustration, the intensities of sensation will present a curve that rises at first swiftly and abruptly above the axis of abscissas from the point representing the minimum of stimulus, then more and more slowly, until it finally vanishes at the point corresponding to the maximum of stimulus, and becomes a straight line parallel to the axis.

These three essential features of the sentient life—the presence of a minimum and maximum of excitation, and finally the increase of the intensity of sensation, that takes place between the minimum and maximum of stimulation, at first rapidly, and then gradually more slowly—are, as we can easily conceive, exceedingly fitting. These peculiarities have been developed simply *because* they are fitting in the struggle for existence. Natural selection is just as efficient in the development of psycho-physiological characteristics, as in the development of the purely physiological. The existence of a minimum of excitation protects us from an inundation of small stimuli, that would flood the consciousness by their very superabundance, and prevent the employment of the greater, more important stimuli. The existence of a maximum limit of excitation prevents a superabundance of too powerful stimuli, and secures the medium stimuli and their concomitant sensations from being overshadowed and overlooked. Both the distracting preponderance of many insignificant stimuli and the partiality and tyranny of one or a few too potent stimuli are avoided by this restriction of the sentient life to a range lying between a maximum and minimum of stimulation. But the third peculiarity of our "curve of sensation" (its ascent at first abrupt, then gradually slower) is also generally fitting. In consequence of this peculiarity (1) we are very sensitive to those small stimuli that are just sufficient to produce sensation, in fact, we are very liable to over estimate them; (2) we estimate the medium stimuli very accurately, since here the curve approaches a straight line; and (3) we begin to lose the ability to distinguish the difference in the intensity of only those stimuli that approach the maximum limit.

The attempt has frequently been made to find an exact mathematical expression for the increase in the intensity of sensation in its relation to the increase of stimulus, or, in other words, to determine the path of the curve more exactly. Ernst Heinrich Weber first employed experiments that seemed to present a fixed law for the relation between stimulus and sensation. If we stretch forth the hand and let small weights—at first, for example, one decimilligr.—be laid upon it, we feel nothing at all. We lay greater weights upon the hand, to the amount of $1\frac{1}{2}$ mg. and still perceive nothing. These stimuli are evidently too small; they lie below the minimum of stimulus necessary to produce excitation. Only when we have laid 2 mg. upon the hand do we have a slight sensation. Therefore the minimum of stimulus sufficient to produce the sensation of pressure upon the palm is, apparently, 2 mg. Weber now proceeded with the following experiment. The hand is loaded with a weight of 1 lb., *i.e.* a weight far above the minimum of stimulus. Now if we add 2 mg. more to the 1 lb., the sensation remains unchanged. We lay more and more upon the hand, but the sensation does not change until we have added $\frac{1}{3}$ lb., or about 160 g., to the 1 lb.; then we perceive a change, an increase of the sensation. This increase of stimulus, that is just sufficient to produce a change of sensation, we shall designate as the "absolute threshold of distinction," the change of sensation itself, as *d S.* Therefore when $\frac{1}{3}$ lb. is added to the 1 lb. we distinguish or feel no greater *increase* than before, when 2 mg. were laid upon the empty hand. We now load the hand with 2lbs., and add $\frac{1}{3}$ lb. to that; but the addition of $\frac{1}{3}$ lb. produces no distinguishable increase in sensation, and we find that we must now add $\frac{2}{3}$ lb. in order to obtain any change of sensation whatever. We take 3 lbs., and as a result, find that an addition of $\frac{3}{3}$ lb. is necessary to produce a barely noticeable change of sensation. The addition of $\frac{3}{3}$ lb. to the previous weight of 3 lb., of $\frac{2}{3}$ lb. to the previous weight of 2 lb., of $\frac{1}{3}$ lb. to one lb., and the laying of 2 mg. upon the unweighted hand, all produce in the same manner the sensation of difference, or, more correctly, a barely noticeable change of sensation, *d S.* Now let us consider whether the nerves of the hand, which was empty before the 2 mg. were laid upon it, were really free from the effects of stimulation by pressure? Certainly not. Both skin and air already pressed upon the nerves of the skin. The reason that this pressure is not perceived is probably to be sought in the fact that the pressure of the skin and air has existed constantly since birth, and that, as we shall presently learn, we generally only perceive *changes* in stimulation, and not stimuli that have long remained the same. This is, for example, the reason that we have no sensations from the visceral organs, despite the abundance of their nerves. The fact that we must consider here, however, is that the constant stimulation by the air and skin may still be increased some 2 mg. without the appearance of a sensation. But our experiments also teach that not every change of stimulus produces a sensation; the latter appears only when the change of stimulus has reached a certain limit or magnitude, but this magnitude is determined by the *relative* change; the *absolute* change of stimulus is of no importance whatever. The law embodying this fact we designate as the "Law of Weber." In the above experiments the stimulus must always be increased one-third, in order to produce a change in the sensation. We saw first that a change in sensation, dS, was produced by a weight of 2 mg. Next, Fechner, going beyond the limits of Weber's law, assumed that exactly the same sensation dS is produced when $\frac{1}{3}$ lb. is added to 1 lb., or $\frac{2}{3}$ lb. to 2 lb. and that, therefore, this dS is constant, although it corresponds to very different absolute increases in stimulation. At first we shall adopt this hypothesis as assumed by Fechner, the father of psycho-physics, although, as will appear later, it needs correction. Accordingly the stimulus must always increase one-third, or reach four-thirds of its original magnitude, in order to produce dS. If we designate the number $\frac{1}{3}$, the ratio of the barely perceptible increase of stimulus to the original stimulus, as the "relative threshold of distinction," the Law of Weber may be formulated thus: The "relative threshold of distinction" is constant. Therefore, beginning with the minimum of stimulus 2 mg., we can construct a complete scale of stimuli, in which each successive member is $\frac{4}{3}$ of the preceding, and in which the difference between any two adjacent members always produces the increase of sensation dS, which, according to Fechner's assumption, is always constant.

This series, therefore, is as follows:—

$$\underbrace{2 - 2(\tfrac{4}{3})}_{dS}\underbrace{- 2(\tfrac{4}{3})^2}_{dS}\underbrace{- 2(\tfrac{4}{3})^3}_{dS}\underbrace{- 2(\tfrac{4}{3})^4}_{dS}, \text{ etc.}$$ [1]

Hence the stimuli increase in geometrical, the sensations in arithmetical progression. Any stimulus E may accordingly be expressed as 2 times a given power of $\frac{4}{3}$. Thus for example:

$$E_x = 2 \times (\tfrac{4}{3})^x$$
$$E_y = 2 \times (\tfrac{4}{3})^y.$$

[1] We shall for the present disregard the fact that the Law of Weber is not exactly valid for very slight stimuli.

Then the sensation S_x, produced by E_x, is obviously equal to $x \times dS$ and S_y is equal to $y \times dS$. Therefore:

$$\frac{S_x}{S_y} = \frac{x \times dS}{y \times dS} \text{ or } \frac{x}{y}.$$

Now we can easily compute the value of x in the above comparison logarithmically. If

$$E_x = 2 \times (\tfrac{4}{3})^x, \text{ then}$$
$$\log. E_x = \log. 2 + x \log. \tfrac{4}{3},$$
$$x = \frac{\log. E_x - \log. 2}{\log. \frac{4}{3}},$$
$$y = \frac{\log. E_y - \log. 2}{\log. \frac{4}{3}};$$

Therefore,

$$\frac{S_x}{S_y} = \frac{\log. E_x - \log. 2}{\log. E_y - \log. 2}.$$

Observing, further, that log. 2 (milligr.) is almost infinitesimal, and may therefore be disregarded, we then obtain briefly,

$$\frac{S_x}{S_y} = \frac{\log. E_x}{\log. E_y}.$$

Therefore two sensations are in the same ratio as the logarithms of their stimuli, or *the sensation is proportional to the logarithm of its stimulus.* This remarkable proposition was designated by Fechner[1] as the "fundamental formula" of Psycho-physics. As already mentioned, it is only a result of the law of Weber when one admits the assumption that dS, the barely noticeable sensation, is always constant. We designate it therefore as the "Formula of Fechner" in distinction from the "Law of Weber," which expresses only the constancy of the "relative threshold of distinction." Others, in fact, have rejected the formula: dS is constant, and have substituted instead: dS is proportional to S, or $\frac{dS}{S}$ is constant; among those who make use of the latter are

[1] FECHNER, "Elemente der Psychophysik," and "Revision der Hauptpunkte der Psychophysik."

Plateau and Brentano. In this case the sensation does not depend upon a logarithmic ratio, but upon the formula $S = E^k$, c and k being constants. Retaining the formula of Fechner until we shall have examined it more closely later, let us next ask: Does it correspond to the above-established characteristics of the curve of sensation? We answer in the affirmative. In fact, the *logarithmic* curve also belongs to the many curves that are characterized by ascending, as the magnitude of the abscissas increases, at first rapidly, then more slowly, becoming constantly flatter, and finally vanishing in a parallel to the axis.

The experiments intended to demonstrate either the so-called Law of Weber itself or the Formula of Fechner, have been often repeated since they were first applied, but the original results have only been partially corroborated. Many, besides us, have found the existence of such a simple algebraic relation between material stimuli and psychical sensations too strange. A great many sagacious methods have been devised to establish this relation with empirical exactness. We shall become acquainted with some of these when we come to discuss the qualities of sensation separately. In general the most reliable recent investigations demonstrate that the Law of Weber itself is strictly valid only within certain limits; that in the case of very strong or very slight stimuli, it has but an approximate validity. Whether the Formula of *Fechner* necessarily follows from the Law of *Weber*, even if the *strict* validity of the latter be granted, is a question that requires another special discussion. In place of the former, Helmholtz and others have sought to substitute a more complicated formula that should conform more closely to experimental results, but without success.

A still more spirited controversy has been associated with the interesting question as to what this connection, expressed by the law of Weber and Fechner, means. There have been investigators who thought they could solve one of the great problems of the world by this law. Among these also was Fechner, the founder of psycho-physics, the one whom we have to thank for the most thorough investigations and discussions in this field.

He assumed that the law is directly valid as expressing the relation of the psychical phenomena to the physical. We remember that the stimulus *E* becomes first *Ep* and finally *Ec*. Fechner assumed that the material cortical excitation *Ec* remains proportional to the acting stimulus itself (*E*) and that only the sensation *S* following the *Ec* in the cerebral cortex bears that remarkable logarithmic relation to *Ec*, and hence also to *E*. As we see, a sort of bridge would thus span the chasm between the physical and the psychical life; at least the quantitative connection between the two would be established. However, we must reject this bold interpretation. To assume that the excitation changes in so simple a manner during the process of conduction that the ultimate *Ec* still remains proportional to *Ep* is wholly arbitrary and improbable. This, Fechner's, interpretation of the law may be called the *psycho-physical* interpretation.

On the contrary, the *physiological* interpretation assumes that the excitation is transmuted in the very path leading from the peripheral surface of sense to the nervous centre according to the logarithmic formula of Fechner's Law. Hence *Ec* would be proportional to the log. of *E*, but the sensation *S* proportional to the *Ec* itself. Very naturally we know nothing whatever yet as to how the peripheral excitation is changed on the way to the cerebral cortex, or by what ratio the cortical excitation augments with the increase in stimulation. The botanist Pfeffer[1] has, in fact, shown by some interesting experiments that the logarithmic relation expressed by the Law of Weber is likewise valid in a very different sphere where only a physiological interpretation can be concerned. For example, if the zoösperms of the fern are placed in solutions of malic acid, the latter attract the former with a certain force. It appears that the force of this reaction is proportional to the log. of the stimulus, the latter being a given concentration of the solution of malic acid. Here we have an analogy, even though remote, to the relations existing between stimulus and sensation. In fact, Pfeffer has placed his experi-

[1] Untersuch. a. d. botan. Inst. z. Tübingen, Bd. I, H. 3, 1884.

ments on the scales in favour of the physiological interpretation of Weber's Law. Empirical data, however, that would tend to substantiate such a physiological interpretation are still too limited, although the latter has the undoubted advantage of being able to explain or account for Fechner's Formula entirely in accordance with the spirit of the natural sciences, and without a new hypothesis. From the standpoint of the above theory, of course, only an approximate validity of the logarithmic relation can be granted; for we would not be justified in assuming that in all cases this simple and exact relation is preserved, despite the various, complicated modifications which the excitation must undergo while being conducted to the cerebral cortex.

A third interpretation, whose chief representative is Wundt, is designated as the *psychological.* Wundt regards the Law of Weber as only a special case of the universal law of relativity applicable to our psychical processes in general. In accordance with this law, consciousness is only able to measure the intensity of its present conditions by a relative standard, not by an absolute standard. Hence "apperception" measures every mental condition by some other, and we become aware of a definite difference only when the increase of one sensation has reached a certain constant fractional part of another sensation that either preceded or accompanied it. This interpretation, as we see, introduces a wholly new and hypothetical mental faculty that is an important factor in Wundt's psychology. It is to a certain extent an "over-soul," the so-called "apperception," which notes, estimates, compares and combines the lower psychical processes. As we shall endeavour to show at some length in the future, there is no demonstration whatever that can be found to prove the existence of this apperception. The sensation is there, and of a definite intensity; it does not need to be estimated first. Therefore we shall reject this arbitrary assumption including Wundt's interpretation of the Law of Weber.

In our interpretation of the Law of Weber we prefer to start from the simple fact that a central process of excitation (Ec) in the cerebral cortex, produced by a sensible stimulus (E), must, the same as *E*, have a certain living force or energy in order to produce any psychical process or sensation whatever. Now the cerebral cortex is never a complete "tabula rasa"; it is never entirely without excitations resulting from certain sensible stimuli; the first excitation was present as soon as the first nerve had developed. Therefore some *Ec* is always at hand. Now the Law of Weber states: If no sensation is yet present, one will only appear when *Ec* or *E* has reached a certain magnitude, namely, the minimum of excitation. Furthermore, if a sensation, corresponding to an *E* or *Ec* above the minimum excitation, is already present, in order to produce a change of sensation, there must be a change of stimulus, whose absolute magnitude is in general irrelevant, but which always constitutes a definite fractional part of *E*. This rule is valid, however, only in the most favourable case, when all other sensations and ideas then occupying the attention are reduced to a minimum, leaving but *one* simple sensation in the consciousness. We make use of this most favourable case when we test the Law of Weber in the usual manner; we then direct our entire attention to the anticipated sensation, *i.e.* we make ourselves as free as possible from other disturbing ideas. Let us recollect our experiences with the tooth-ache; how often an interesting conversation can cause us to forget the pain for a moment! What happens in such a case as this? We often answer falsely,—the sensation has not come into consciousness. But *un*conscious sensations do not exist; the real process in such a case is as follows: The stimulus continues to act, but although its intensity is unchanged, it generates no sensation because of other more intense sensations and ideas, *i.e.* more intense *Ec*'s. For this relation, Hering has formulated the following fundamental law: "The purity, distinctness or clearness of any sensation or idea depends upon the relation in which the weight of the same (*i.e.* the magnitude of the corresponding psycho-physical process) is to the collective weight of all simultaneously present sensations and ideas, *i.e.* to the sum of the magnitudes of all corresponding psycho-physical processes." Therefore, whether a stimulus generates a sensation or not, and what the strength of the imparted sensation is, depends upon the total strength of the other *Ec*'s, in part merely material, in part accompanied by sensations and ideas that are present in the cerebral cortex at the same time.[1] Now the Law of Weber is only valid for the special case in which one sensation, similar to another one about to be experienced, occupies the consciousness to the exclusion of almost all others, and is therefore also essentially greater than the supervenient sensation. The greater the *Ec* or the *S*, already present, just so much greater must the supervening *dEc* be in order to impart a *dS*, or change of sensation. The Law of Weber is a law of association. The *dEc* must have a certain magnitude, not for the purpose of being "apperceived" by some hypothetical faculty of "apperception," but in order that the material process *dEc* may produce a corresponding psychical process, *dS*. What is meant in general by the comparison of two *Ec*'s? They may occur either successively in the same cells of the cerebral cortex, or in entirely different cells, or in cells that are partly different and partly coincident. We generally regard this process of comparison as a very elementary and frequent phenomenon. Close introspection, however, teaches the contrary. As a rule, we merely pass from sensation to sensation; our sensations, successive as well as simultaneous, are different, although we do not always become especially cognizant of this difference. Most of the operations of sentient life, as a rule, have no time to stop for the purpose of making comparisons. But what does take place when, for some reason or other, we really compare? This "comparing" is no inborn capacity, no metaphysical faculty belonging to mankind; it is rather an accomplishment, a power of association, laboriously acquired by practice. As children we learn to construct very slowly and laboriously the idea of "greater"; this idea, the same

[1] In the discussion of the theory of attention we shall return to the question as to whether the decrease in the intensity of sensation with the decrease in the intensity of the stimulus and the decrease in the intensity of sensation with the diversion of the attention are psychologically identical.

as every image of memory, is deposited and retained as a verbal idea in a definite portion of the cerebral cortex. All our sensations, in so far as their intensity and their relations to space and time are concerned, when two or more appear either simultaneously or one after the other and the circumstances are favourable for association, may act upon this idea of "greater," and tend to rouse it into action. Now during childhood the idea of "greater" is so deposited in the brain that it always responds to the stronger excitation imparted by the more intense of two homogeneous sensations acting upon it. It is, therefore, always associated with the stronger sensation. Then we are wont to say, "this sensation is greater." If both sensations are alike, their influence upon the idea "greater" is destroyed in a certain sense by interference. But also very slight differences in magnitude are insufficient to excite and reproduce the dormant idea "greater." Generally the discipline of this capacity, as of every other, is inexact; cases of false comparison occur besides those of correct comparison. Where *large* differences between the stimuli occur, the *absolute* difference in stimulation is the essential determinative factor in comparison. Hering observes very correctly,[1] that if we place a weight of 100 g. in the left hand and 1,000 g. in the right, and then add 100 g. to the former and 1,000 g. to the latter, despite the uniformity in the *relative* increase of the two stimuli, the increase of sensation perceived in the right hand is considerably greater than the increase perceived in the left. Only when the difference, representing the amount by which the first stimulus is increased, is less than the first stimulus can the relative difference be, in fact, the essential determinative factor as set forth by the Law of Weber. Now if two but slightly different stimuli take effect, it is very possible that the consequent excitation of the idea "greater," to which the brain has been especially trained, corresponds to the *relative* difference between the stimuli. We can also understand, as shown above, that such discipline of the brain

[1] Sitzungsber. d. Wiener Acad. d. W., 1875, S. 323.

is fitting. Every estimation and comparison of sensations, therefore, already involves associative activity. Hence, in the strict sense, we should not speak of *sensations* of "larger" or "smaller," but only of such *ideas*. Of course the sensations themselves are already different in intensity, but we only acquire an idea of this difference by association. The child when very young already has *sensations* of different intensity, but as yet no *idea* of their different intensity. The latter is not grasped at once by the consciousness at all; we only acquire the ability to compare by slow degrees.

Hence the Law of Weber proves to be explicable, in fact, within certain limits. The conclusions that Fechner on the one hand and Plateau on the other have drawn from this fact, all proceed from the false hypothesis that the intensity of sensation can be ascertained by mathematical computation the same as other natural phenomena, that also in this case, for example, $S+S=2S$. But this is wholly undemonstrated. On the contrary, accurate introspection shows that it is not the case. Wundt proposed[1] to decide the controversy concerning the interpretation of Weber's Law by the so-called "method of average gradations," and the attempt was made accordingly by Delbœuf and Merkel. Thus, for example, the attempt is made to select that stimulus which produces a sensation, the intensity of which is just the mean between the sensations imparted by two stimuli of very different intensity. This mean is

$$Sm=\frac{S_1+S_2}{2}.$$

However, this search for the mean sensation is quite impossible, as one quickly perceives by the embarrassment in which he finds himself on attempting to carry out the experiment. We have only acquired our estimation of about where the mean is to be sought by experience and that which affects our judgment chiefly

[1] Before this, also Plateau, "Über die Messung psychischer Empfindungen und das Gesetz, welches die Stärke dieser Empfindungen mit der Stärke erregenden Ursache verknüpft." (Pogg. Ann., 1873, S. 466.)

is just this experience as to the magnitude of stimuli. Accordingly the results of Merkel's experiments showed that the medium stimulus, thus experimentally determined, corresponds neither to the arithmetical mean, as required by Plateau's theory, nor to the geometrical mean, as required by Fechner's theory, but lies between the two. Mathematics is not at once applicable to psychical intensities as it is to the various intensities of an electric current.

Let us now review the outcome of our experiments and deliberations. We have obtained two chief laws:

(1) The sensation increases considerably slower than the stimulus.

(2) The increase of stimulus sufficient to impart a barely perceptible growth of sensation generally stands in an approximately constant relation to the original magnitude of the stimulus.

We shall learn of many limitations of the latter rule in detail. The numerous deviations from Weber's Law rest upon the fact that on the one hand the modification of the excitation, while being conducted to and in the cerebral cortex, probably varies in a very complicated way, according to its intensity; and that on the other hand the degree of perfection acquired by associative discipline varies.

CHAPTER IV.

SENSATIONS OF TASTE, SMELL, AND TOUCH.

WE have discussed the *intensity* of sensations at some length, especially in their relation to the original stimulus. The second property of every sensation is its *quality*; the sensations of red, of the tone *C*, of heat and of sweet are all different in quality. We shall now become acquainted with these qualities more exactly in detail. As regards quality, we generally distinguish, according to the organ receiving the stimulus, five chief groups of sensations[1] or modes of sensibility, sensations of smell, taste, feeling, hearing and sight. We shall presently learn, however, that the sensations of feeling undoubtedly require a still further classification; that the surface of the skin contains several quite different organs, capable of imparting sensations that are very different in quality. Sensations of feeling and hearing are more closely related in so far as they are caused by mechanical stimuli, while sensations of taste, smell, and sight, are produced by chemical stimuli. On the other hand, sensations of feeling and light are capable of very exact localization; hence they are intimately concerned in our perception of space. We see and feel in space, but how inexactly we localize a sound, taste, or smell! In general, we hear, taste, and smell, without localizing at all, while feeling and sight are pre-eminently the senses that refer to space.[2]

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[1] Helmholtz designates those differences in quality, so essential that no transition whatever from one to another is conceivable, as "modalities," *i.e.* modes of sensibility.

[2] The term *feeling*, as used in this chapter, is to be understood only in its more restricted sense as one of the five senses, whose organ consists of the so-

We shall first discuss the *sensations of taste.* Separate organs of taste are not yet developed in the Echinodermata, and they have not yet been shown to exist in the insects. In vertebrates they consist of the so-called gustatory bulbs [1] which are scattered with comparative irregularity over the tongue, palate and epiglottis, and are only clustered more thickly in the so-called papillæ circumvallatæ and foliatæ. Only fluids can be tasted, solids and gases must first be reduced to a liquid state before they can be tasted. Only four qualities of taste are to be distinguished with certainty : *sour*, *sweet*, *salt*, and *bitter*. Without sufficient grounds,[2] some writers add *alkaline* and *metallic* to this list as special qualities of taste. We might cite, in opposition to so limited a list as that given above, the multitude of tastes that we distinguish in our food, but to infer that these are pure sensations of taste is incorrect. What we designate as taste, aside from these four or six qualities, is smell, for some of the food is vapourized in the back part of the cavity of the mouth and thence reaches the cavity of the nose where it is smelled. The sense of taste, therefore, has but an extraordinarily limited variety of qualities. The numberless acids of chemistry all excite but *one* sensation of taste, which varies only in intensity. Likewise the distinction of different bitter substances in solution is rendered impossible by the choice of suitable degrees of concentration ; for example, a solution of quinine in the proportion of 1:100000 cannot be distinguished from a solution of morphine in the proportion of 1:3000. The terminations of the gustatory nerves are probably only sensitive to chemical irritation ; stimulation by pressure is very doubtful. The sour or metallic sensation of taste that is produced when a galvanic current is passed through the tongue does not necessarily depend directly on stimulation of the nerve-ends by electricity, but may be caused by the products of the electrolysis,

called *general* nerves of sensation. In this sense *feeling* includes *touch*, the latter being the more specific term, the former the more generic.—*T's.*

[1] Also gustatory *knobs* or *flasks*.—*T's.*

[2] LINNÉ distinguished even ten qualities.

produced by the galvanic current. The central terminations of the gustatory fibres are probably to be sought in the Gyrus hippocampi of the cerebral cortex. It is not probable that all four qualities of taste are received and conducted to the cerebrum by all the nerve-fibres in a like degree, for the base of the tongue is chiefly sensitive to bitter tastes, the point and lateral parts of the tongue to the other qualities. Oehrwall[1] has also found that on stimulating single papillæ fungiformes, some of the papillæ are sensitive only to acids and not to sugar or quinine; he has therefore assumed specifically different terminal apparatus for the different qualities of taste. Even the new-born babe probably distinguishes all four qualities of taste with comparative certainty, if the solution to be tasted is sufficiently concentrated.

Frequent attempts have been made to prove the validity of Weber's Law for the sense of taste. A method has been used for this purpose, that has frequently found application in testing the Law of Weber. This method is designated as the "method of the correct and false (mistaken) cases." We shall become acquainted with its characteristic features later in the discussion of sensations of pressure. The application of this method resulted in demonstrating only the approximate validity of the Law of Weber for sensations of taste. The minimum of stimulus for sugar may be expressed in the ratio of 1:83; for quinine, 1:33000; for saccharine, 1:200000; for strychnine, 1:2000000 (Venables).

The important question as to how the sensation changes when the same stimulus affects many adjacent nerve-fibres, is one that will constantly occupy our attention. Is the intensity, quality, or any other property changed? In the case of seeing and feeling the answer can be given at once; the functions of the adjacent nerve-fibres are in general identical. If the stimulation affects a large number of nerve-fibres, at the same time, the sensation receives the spatial character of a surface. In the case of the sense of hearing we shall find that very many quite identical nerve-fibres probably do not exist, but that almost every fibre transmits

[1] Skandinav. Arch. f. Physiol., ii, 1, 1890.

a different quality of sensation. Neither of these characteristics appear in the senses of taste and smell. Aside from the above-mentioned four qualities of taste, the numberless gustatory fibres are all functionally identical; but if the stimulus is distributed over a large surface of the tongue, we do not receive the image of a tasting surface, but merely notice an increase in the intensity of the sensation of taste. The sense of taste has no reference to the relations of space, as have the senses of touch and sight; the sensation is made stronger, or, as we may say, more distinct by the superficial extension of the stimulus, but otherwise it remains unchanged.[1] This explains our inability to localize sensations of taste accurately; We should perhaps be wholly unable to do so, if sensations of taste were not also always accompanied by sensations of touch imparted by the tasted body.

Let us pass on to *sensations of smell.* The sense of smell seems to have become differentiated from a common sensory surface in much lower forms of animal life than the sense of taste. At any rate, it is already well developed in the Echinodermata. A blinded star-fish, even at some distance, can scent the crab which serves as its food. In how far certain apparatus in the feelers of insects are to be regarded as organs of smell is doubtful. May[2] has shown that certain organs of smell exist in the outer branches of the antennules of many crabs. In vertebrates we find the organs of smell in the regio olfactoria of the nose. They consist of so-called neuro-epithelial cells, whose external processes are elongated into cilia, upon the surface of the mucous membrane. Exner considers that the olfactory nerve is connected with all the epithelial cells of the regio olfactoria; in fact W. Krause has found *very* fine hairs also in the common epithelial cells; Lustig has likewise confirmed the results obtained by Exner.

The number of qualities of smell is exceedingly large. As the

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[1] Compare CAMERER, Ztschr. f. Biologie, xxi, Tab. 8, S. 580.

[2] MAY, C., Diss., Kiel, 1887. Compare also DAHL, "Versuch einer Darstellung der psychischen Vorgänge in den Spinnen." Vierteljahrsch. f. wiss. Philos., 1885.

sensations of taste unite readily with those of smell and touch, so also the sensations of smell unite readily with those of taste and touch. Many of the simple qualities of smell are very often produced by the co-operative stimulation of the senses of touch, taste, and smell. It is impossible to classify the different qualities of smell, or to arrange them in definite series, as can be easily accomplished in the case of the higher senses of sight and hearing. The irritation of the ends of the olfactory nerve is only possible by means of a chemical process, but since only gases smell, solid bodies and fluids must first evaporate in order to produce any effect upon the olfactory nerve-ends. It is very doubtful whether mechanical stimuli are effective, but galvanic stimuli[1] have recently been shown to be capable of irritating the olfactory nerves. This fact was tested as follows: The nose was filled with a solution of chloride of sodium, one electrode placed in the nose and the other upon the forehead, whereupon many persons on whom the experiment was tried perceived sensations of smell. This experiment, however, does not exclude the possibility of electrolytic action. The central terminations of the olfactory fibres are also probably to be sought in the Gyrus hippocampi of the temporal lobes.[2] In animals, below man, the Gyrus marginalis and the olfactory bulb, which is often developed into an independent lobe, are also probably to be designated as the cortical centre of the olfactory fibres.

No attempt has yet been made to establish, experimentally, the validity of Weber's Law for the sensations of smell. The minimum of stimulus for many substances is extraordinarily small; for example, $\frac{1}{460000000}$ mg. mercaptan is sufficient to produce a sensation of smell.[3] The localization of our sensations of smell is, if possible, still more inexact than the localization of sensations of taste, for the former receive no assistance from accompanying

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[1] ARONSOHN, Centralblatt f. d. med. Wiss., 1888.

[2] Compare Brain, 1889, Oct., and ZUCKERKANDL, "Ueber d. Riechcentrum," Stuttgart, 1887.

[3] FISCHER and PENZOLDT, LIEBIG's Annal., Bd. 231.

sensations of touch. Experience has taught us to seek the cause of a sensation of taste in the cavity of the mouth, the cause of a sensation of smell in the air that enters the nose; more exact localization than this is impossible. All fibres of the olfactory nerve are probably identical in function; each one can transmit every sensation of smell, but the sensations transmitted by adjacent nerves do not arrange themselves into an image of surface.

The so-called *sensations of feeling* in the *skin* and *mucous membrane* must occupy our attention considerably longer. The sensibility of the skin is the first sense that appears, and the one from which all others have probably developed by a gradual process of differentiation and selection. Sensibility exists wherever animal life is to be found, long before any separate nervous system, the presence of which can be demonstrated, has developed. The moner, that changes its form when touched, already possesses sensibility in this sense. The anatomical apparatus that receive the stimulus are the so-called "tactile corpuscles" and "end-bulbs," which appear in the most varied forms. Besides these, free ends of the sensory nerves are also to be found in the tissues. Mechanical, electric, and caloric stimuli are the chief excitants of the sensory apparatus of the skin. The chief form of mechanical stimulus is impact; even the slightest touch is impact. Uniform statical pressure is also apparently effective, though much more seldom than one would at first assume. When a weight simply lies at rest upon the hand, it seems as if all dynamic pressure is excluded; but this is not the case. The hand does not remain immovable; its involuntary motions and the pulsation of the blood constantly impel the surface of the skin against the weight resting upon it. For this reason we shall not be able to separate the sensations of static pressure from those of touch or dynamic pressure. Cold and heat themselves do not act directly as caloric stimuli, but only indirectly by warming and cooling the skin beyond its so-called physiological zero-point. The number of qualities of sensation imparted by the sensibility of the skin is comparatively limited.

We recognise only sensations of heat, cold, and touch as *positively* different qualities of sensation received by the sense of feeling. The differences in the local extension, intensity, and duration of these qualities of sensation are probably the conditions that determine those fine nuances of tactual sensation which we designate as *smooth*, *rough*, *slippery*, *sticky*, *velvety*, etc. But we must also consider that after frequently appearing simultaneously, sensations of touch may blend with one another or with those of temperature into a sensation that, to the conscious individual, has but a *single* quality.

Since the experiments of Magnus Blix,[1] it has become very doubtful whether each nerve-fibre can receive and transmit to the brain all qualities of sensation of feeling (*i.e.* touch, including pressure, heat, and cold) in the same degree. This experimenter has shown on the contrary that upon one spot on the skin only cold is perceived, upon another only heat, and upon a third only touch. We can easily convince ourselves of this fact by applying a cold point of steel here and there upon the fore-arm; by this means we easily discover regions on the skin having an area of about one square centimeter that receive no sensation of cold from the point of steel, although sensations of heat or touch appear at once if we apply the proper stimulus. But close beside the spot thus tested we find points that are intensely sensitive to cold, though no sensations of warmth or touch can be perceived there. There are therefore separate spots for heat, cold, and touch, and each nerve-fibre transmits but *one* sensation. A spot for either heat, cold, or touch evidently corresponds to each termination of the nerve-fibres. The stronger stimuli of pressure, however, impart slight sensations also outside of the so-called "pressure-spots"; but we may justly assume in this case that the mechanical stimulus is transmitted to the next neighbouring "pressure-spots." Goldscheider,[2] to whom we are

[1] MAGNUS BLIX, "Exper. Beitr. z. Lösung der Frage über die spec. Energie d. Hautnerven." *Ztschr. f. Biologie*, 20 and 21.
[2] Archiv. f. Physiolog., 1885.

indebted for some excellent investigations in this field, assumes another diffused *general sense of feeling* as operating between the different points of pressure. His hypothesis does not seem to be well grounded. Electrical stimulation, especially that of faradic electricity, acts upon all points of sensation, whether of temperature or pressure; but it imparts only sensations of cold at the "cold-spots," only sensations of heat at the "heat-spots," and only sensations of touch at other points. According to Goldscheider, a *strong* mechanical stimulus applied to the spots for temperature imparts a corresponding feeling of temperature. It must also be mentioned that there is still considerable doubt as to what the real, active element is in the case of caloric stimuli. E. H. Weber thinks that irritation is produced by the rise and fall of the temperature of the skin; Vierordt thinks it is produced by the direction of the current of heat passing through the skin; Hering ascribes it to the absolute deviation of the temperature of the cutaneous nerve-apparatus itself from a physiological zero-point of temperature at which neither warm nor cold is perceived. It has not yet been determined as to where the central terminations of the sensory fibres of feeling are to be found. At one time the Gyrus fornicatus was designated as the cortical centre for sensations of feeling; then it was thought that this cortical centre coincides with the so-called motor region in which the path for the conduction of voluntary motor impulses originates.

But the skin is not the only organ containing sensory nerve-ends. We find them also scattered through all the organs of the human body. These so-called "organic sensations" are distinguished by great indefiniteness and slight intensity under normal conditions. Only *one* more group of the more deeply seated sensory nerves deserves mention as being of special importance; it is that group of nerves whose terminations have been shown to penetrate the synovial duplicatures of the joints, the ligaments, tendons, and muscles. By means of the sensory nerves of the ligaments and muscles, for example, we perceive the condition of the muscles, their contraction and relaxation.

The sensory nerves of the joints transmit to us those peculiar sensations which appear when the ends of the bones forming the joint are pressed against each other or when their surfaces glide over each other during motion. Considered apart from their connection with the functions of the body, these sensations have but slight importance; taken together, however, they constitute those complex sensations by which we perceive the position of our limbs, and which we therefore call "*sensations of position*." If we close our eyes, for example, and direct our attention to the position of the closed right hand, the nerves in the joints inform us as to how far their surfaces touch each other; the nerves of the tendons inform us that the extensors of the fingers are relaxed, the flexors contracted and shortened. Sensations of touch upon the skin also assist very considerably in producing these sensations of position, for in the case just cited the sensory nerves of the skin inform us that the tips of the fingers touch the palm of the hand. Let us now imagine a continuous series of these sensations of position, gradually passing from one to the other. Accordingly let the closed hand open by slow degrees; the sensations of position that follow in regular succession inform us as to the movement of the hand. In this manner "*the sensations of motion*"[1] are produced. We distinguish *passive* and *active* sensations of motion according to whether our fingers are moved by another person or by ourselves. Goldscheider's more recent investigations, furthermore, have made it probable that the sensation of passive motion depends less upon the successive sensations imparted by different positions of the limb at rest, than upon sensations of pressure or friction in the joints, directly imparted by the motion itself. According to this the sensibility of the joints would be almost the only essential factor in the production of sensations of passive motion; while in the production of the sensations of active motion the sensations of position are also of

[1] A much less familiar, but very fitting synonym for "motor sensation" is "kinæsthetic sensation." Kinæsthesis is the perception attendant upon the movements of the muscles only. "Kinæsthetic sensation" is therefore less comprehensive than "motor sensation" in its general application.—*T's.*

very great importance. Introspection shows that there is still another difference, apart from the sensation of touch produced by contact with the skin of another person during passive motion. In the process of thought, the ideas that cause the active motion precede the sensations of active motion, while such ideas do not precede the sensations of passive motion. There is no immediate reason[1] for assuming special "sensations of innervation" that instruct us during an active motion as to the amount of innervation employed. The capacity for sensations of position and motion has been expressed by the collective term "*muscular sense.*" The term is not very well chosen, for the sensibility of the muscles is of the least importance in the production of such sensations. The combination of sensations of motion with sensations of touch received from the same object is of special importance. By moving the hand over the surfaces of an object, we inform ourselves as to its form. This succession of combined sensations of touch and motion is designated as sensation of *active*[2] touch.

The number of such complex sensations is exceedingly large, as may be easily realized by calling to mind the peculiar complexes of sensation produced by lifting weights or by colliding with some obstruction. However, the most important classes of these sensations of feeling are the four just described :—

1. Sensations of position.
2. Sensations of active motion.
3. Sensations of passive motion.
4. Sensations of active touch.

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[1] The lively sensations which cripples claim still to perceive in the maimed parts of the body when they try to move them gave special occasion for the assumption of particular sensations of innervation. We shall return to this question later.

[2] *Active* touch is to be distinguished from *passive* touch in the same way that active motion is distinguished from passive motion, viz. by the precedence of motor ideas. In fact, there is a motor element in active touch ; in this sense only are the two expressions to be distinguished in this work. As soon as a motor element appears in thought the sensation becomes one of active touch (*Tastempfindung*).—*Tr.*

According to more recent pathological experiences, we may probably locate the central terminations of the sensory paths communicating with the tendons, muscles, and joints, in the cortex of the upper parietal lobe.

It was while investigating the sensibility of the skin, in fact, that E. H. Weber first discovered the fundamental relation expressed in the Law of Weber. Since then these experiments have been often repeated. The minimum of stimulus proves to be very different for separate regions of the skin, in the case of common sensations of touch or pressure. On the forehead, the pressure of even a weight of 0·002 g. is perceived, but on the abdomen, only that of a weight of 0·005 g. According to the greater or smaller area touched by the same weight, still other differences also appear. The "discriminative sensibility"[1] in the case of stimuli of pressure, has been investigated since E. H. Weber's time by Biedermann and Löwit, and by Dohrn and Merkel.[2] The barely noticeable difference, according to the investigations of Merkel, for example, for a previous weight of—

1 g.	=	0·32 g.
5 „	=	0·96 „
10 „	=	1·40 „
20 „	=	2·04 „
100 „	=	7·4 „
500 „	=	38·9 „
1000 „	=	81· „
4000 „	=	156· „

Therefore if a weight of 4,000 g. press[3] upon a finger of the hand while resting upon a support, fully 156 g. must be added to it in order that any difference in weight whatever can be perceived. We shall now test these numbers more exactly and see if they

[1] Unterschiedsempfindlichkeit—*Tr.*
[2] Philosoph. Stud., V, S. 2.
[3] The constant area of contact in this particular series of experiments amounted to 1 sq. mm. With a greater area of contact the discriminative sensibility is more limited.

agree with the Law of Weber. The latter states that not the absolute but the relative differences of stimuli are determinative, *i.e.* the increase of stimulus requisite to effect a perceptible difference in sensation is always the same fractional part of the original stimulus. If the original stimulus is E and the increase of stimulus dE, then $\frac{dE}{E}$ is constant without regard to the magnitude of E. Let us determine this fraction for each of the above pairs of numbers.

0·32	:	1 = 0·32
0·96	:	5 = 0·19
1·40	:	10 = 0·14
2·04	:	20 = 0·10
7·4	:	100 = 0·07
38·9	:	500 = 0·08
81·	:	1000 = 0·08
156·	:	4000 = 0·04

Thus we see that the above-mentioned fraction remains approximately constant only when the original weights lie between 100 g. and 1000 g. Only within these limits must the increase of stimulus reach the same fractional part of the primary stimulus in order to be just observable. Therefore Weber's Law is valid only when the stimuli are of medium intensity; the relative sensibility to difference is smaller in the case of very small stimuli and greater in the case of very large stimuli than the Law of Weber requires. This fact is designated as the "upper and lower deviation" of Weber's Law. The discriminative sensibility, therefore, increases in proportion as intensity of stimulation is greater.

The discriminative sensibility proves to be essentially greater when the weights are not placed upon the hand at rest, but when we execute the motions of lifting the weights while they lie on the hand. In the latter case, of course, the sensation is much more complicated; sensations of position and motion are associated with those of pressure. We are also assisted by being able to compare the sensible effects of the same stimulus in different positions. In investigating the discriminative sensibility in the case of lifted weights, Fechner applied a special method designated as the "method of correct and false (mistaken) cases." The nature of the method is made clear by the following example. We shut our eyes and a friend lays first a weight of 300 g. and then one of 312 g. upon our hand. We must now state which of the two weights is the heavier. The additional weight of 12 g. more than the original 300 g. is so small that the difference is not constantly perceived with certainty. However we state the difference more often correctly in favour of the second weight than falsely in favour of the first weight; sometimes we also remain undecided. Thus, for example, Fechner found that in one hundred such trials as the one described above, in which of course sometimes the lighter, sometimes the heavier weight was first laid upon the hand, the answer was given correctly sixty times. Therefore the number of correct cases amounted to 60 %. Now a second series of trials is made, the beginning weight being 600 g., the additional weight remaining at first 12 g. It then soon appears that the number of false estimations has greatly increased; the number of correct cases, perhaps, amounts to but 40 %. We next take a larger additional weight and compare, for example, 600 g. and 620 g. in a new series of trials. It now appears that the number of correct cases has considerably increased, although the old number of 60 % has not yet been reached. In order to attain 60 % of correct cases again, as in the trials with 300 g. and 312 g., we must raise the additional weight to 24 g., the beginning weight being 600 g. Therefore, although the additional weights are imperceptible, their magnitude still had some influence upon the *probability* of a correct estimation of the sensation; in fact, as we have just seen, not the absolute difference but the relative difference is determinative. If the beginning weight (E) is doubled, the additional weight (dE) must also be doubled in order that the probability of a correct discrimination between the two remain constant. This fact is quite in accord with the spirit of Weber's Law: the difference between any two stimuli is estimated as being the same, and the probability of a correct judgment or discrimination of this difference is constant if the *ratio* of the stimuli remains unchanged. These are the essential features of Fechner's interesting method; in its practical application and the employment of the numbers, of course, many difficulties and doubts still arise that complicate one's procedure.[1] In the most favourable case a relative difference of $\frac{1}{40}$ is still perceptible. Also in the case of sensations of pressure, therefore, the Law of Weber is verifiable only within certain limits of stimulation.

Goldscheider has also recently determined the minimum of stimulation, at least in the case of single sensations of passive motion. It appears, for example, that a swing of the arm amounting to 0·22°—0·42° is sensibly perceived in the shoulder joint. Experiments were also made for the purpose of establishing the minimum velocity necessary to cause sensations of passive motion. This minimum velocity for the shoulder joint amounts to 0·3°–0·35° in a second of time. It is conceivable that a minimum velocity of stimulation can be determined also for sensations of passive motion, for they are not imparted by sensations of static pressure, but chiefly by slight sensations of dynamic pressure within the joints; and velocity, of course, is an essential factor in the sensible effects produced by impact.

It is remarkable that in the case of a swing executed by some member of the body, the minimum of excitation is but very little smaller for the sensations of *active* motion than for sensations of *passive* motion.

Finally, there remain the sensations of heat and cold. In how far the Law of Weber is valid for these sensations has not yet been established with certainty. Under the most favourable circumstances the threshold of distinction appears to amount to 0·2° C. It is possible[2] that the minimum of stimulus for sensations of warmth lies somewhat higher than for sensations of cold.

[1] Besides FECHNER ("Elemente der Psychophysik" and "Revision einiger Hauptpunkte der Psychophysik") compare especially G. E. MÜLLER, "Zur Grundlegung der Psychophysik."

[2] According to GOLDSCHEIDER, contrary to EULENBURG.

Experiments are rendered more difficult by the constant change in the temperature of the skin itself, to which the physiological zero-point of the skin seems also to adapt itself.[1]

We should here call attention to the fact, still further, that certain sensations can be misjudged. If the skin on the nape of the neck is first lightly touched with a small brush, then warmed by a match that has been lighted near it, we are often unable to distinguish whether heat or touch acts upon the skin. Obviously the quality of very weak sensations is often too indistinct or insufficiently pronounced to recall the ideas and words that were previously associated with the pronounced sensation. It is also interesting to note that cold weights appear to be heavier than warm weights of the same value.

Let us now consider the question once more as to how those sensations of pressure and temperature vary that are produced by the separate irritation of different nerve-fibres or by the simultaneous irritation of many nerve-fibres. The answer for sensations of heat and cold is in part similar to that for sensations of taste. If the same caloric stimulus irritates a large number of nerve-ends, *i.e.* if the stimulus spreads over a large area of the skin, neither the quality of the sensation changes, nor does its superficial character[2] become essentially more pronounced; but the intensity of the sensations of heat and cold augments. It is different in the case of sensations of pressure. If the *same* stimulus of pressure act first upon a certain spot on the skin of the thigh and then upon a certain spot of the same size on the skin of the cheek, by the exercise of sufficient attention we can observe a slight difference in quality that is independent of the difference in localization, despite the identity of the external stimulus in each case.

It is hardly to be assumed that the nerve-fibres which receive the stimulus in the skin of the forehead are essentially different from those in the skin of the abdomen; but the external stimulus

[1] HERING, Sitzungsber. d. Wiener Ak., LXXV., III. Abth.
[2] Further investigations by GOLDSCHEIDER have also determined the capacity for localising sensations of temperature: Archiv f. Physiol., 1885.

does not reach the nerve-ends directly. It is variously modified by the structure of the skin (including its hairs) which intervenes between the nerve-ends and the acting stimulus. The same external stimulus will therefore be modified on the way to the terminations of the nerves according to the locality of the skin upon which it acts, and will hence prove to be everywhere somewhat different. The constitution of the nerve-ends receiving the stimulus may also change somewhat according to the *extent* of the nerve-tracts. Hence the structure of both skin and nerve-ends gives the sensations of pressure their so-called "local stamp." Let us cite one of the rougher, but most striking, examples of this fact. If we touch the skin of the cheek, the sensation of pressure has a very characteristic stamp which is especially conditioned by the absence of a firm substructure, the flaccidity of the skin, and the insertion in the skin of the muscular fibres. By means of these characteristics we are able to distinguish the sensation of pressure on the skin of the cheek in quality from similar sensations of pressure on other parts of the body. In accordance with Lotze's precedent these "*local stamps*," characteristic of sensations of pressure, are also designated as "*local signs.*" In fact these "local signs" materially facilitate the localization of sensations of pressure. Hence if the same stimulus of pressure act upon different nerve-fibres separately, some difference in quality, though small in fact, is already perceptible. But independent of these local signs, we are also able to localize at once, and with comparative certainty, any sensation of touch whatever. In so doing, of course, we commit a certain so-called "error in localization" which has a constant value for each region of the skin. This error is very great, for example, when we attempt to localize sensations felt in the leg and toes. Certain individuals possessed of healthy nerves, but unpractised in self-observation, have been known to mistake the second toe for the third, or the third for the fourth in attempting to localize sensations of touch. But whence arises this faculty of localization? How do we know instantly that in one case the leg, in another case the foot is touched, although *exactly the same* stimulus acts upon both and produces sensations that are but little different in quality? The sensation itself does not furnish this localization; it only assists us somewhat to localize by means of its local sign. The localization is rather an achievement of association. The sensation of touch in the foot is associated with numerous ideas of the foot, especially with ideas of sight, motion and speech. This process of association takes place in a manner which we shall discuss more thoroughly in the future. If the foot is touched these ideas are awakened with the speed of lightning; the form and motions of the foot and the word "foot" occur to us and these images of memory also guide the hand in pointing out the region touched when we are requested to do so. Especially this motion executed in indicating the spot touched is closely associated by practice with the sensation of touch in each region of the skin. The usual localization of the sensations of pressure does not consist at all in the projection of the sensations into abstract space, but rather in their association with definite ideas of sight, motion and speech. Hence we can understand more readily why localization in general becomes more accurate as the intensity of the stimulus increases. The so-called "eccentric projection" is also only to be understood as the result of these associations. By "eccentric projection" we understand the fact that a sensation produced by the stimulation of the nerve-*trunk* instead of the nerve-*ends* is regularly attributed to irritation of the peripheral ramifications of the nerve. It is known, for example, that persons who have lost a foot may still feel pains in the amputated member. In this case the old, familiar associations have not yet received sufficient correction, rendered necessary by the amputation. We shall return to this subject in connection with the theory of the so-called "intuition of space."

The first part of our question is now answered. How do the sensations of pressure differ when the stimulus acts upon different nerve-ends separately? The second part of the question remains to be answered. If the same stimulus reaches many adjacent nerve-ends at the same time, thus acting upon a larger area of the skin, what is the sum of the sensations thus imparted? In general we find neither an increase in the intensity of sensation (*i.e.* an actual summation), nor a change in its quality, but the many sensations arrange themselves into a form or image with which we are not yet familiar. This image is a form of spatial extension known as surface. Here we confront one of the greatest puzzles of psychology. Let us present clearly to mind the peculiar aspect of the facts in hand. Suppose that 1,000 excitations, proceeding from 1,000 nerve-ends in a given area of the skin that has been touched, reach the cerebral cortex and impart 1,000 sensations. Two questions now arise: (1) How are two sensations that were produced by the excitation of *neighbouring* nerve-ends combined into an image of space? (2) How can we account for the origin of this remarkable arrangement at all? The second question cannot be answered at all by physiological psychology. We here confront one of those psychological facts that are as yet incomprehensible in the light of physiological psychology, and that will perhaps always remain so. A great deal of pains has often been taken to explain the development of our intuition of space in a purely genetic way, either by the local signs or by the combination of ideas of pressure with those of motion. We shall not trouble ourselves with these attempts at explanation, which have, in fact, been fruitless. We project all our sensations into space, even the tone heard and the taste received upon the tongue. Physiological psychology must accept this fact without being able to explain it. At first this projection is quite indefinite; the senses of hearing, taste, and smell still illustrate this first stage of space-perception, in which the localization is quite indistinct. The sensibility of the skin shows us the next higher stage of space-perception; the localization is already more definite. For example, if we close the eyes and let a very small piece of board of unknown dimensions be placed upon the hand by another person, we are able to tell about what place upon the hand is touched, and also to state approximately the boundaries of the surface thus touched. If we compare the capacity of the sense of touch for localization with that of the sense of sight, the deficiency of the former becomes clearly apparent; on the other hand the localization of the visual sense appears unique to us because, in fact, we can make no comparison with another sense in which the ability to localize is still more highly developed. Let us consider the process of this superficial localization in the case of the sensibility of the skin somewhat more exactly (fig. 7). *H* and *H'* represent the cross-section of some area of the skin,—on the hand, for example; *a*, *b*, *c*, and *d* are nerve-ends. Tracing the nerve-fibres along their entire course to their cerebral cortex, we find them terminating in the ganglion-cells *a'*, *b'*, *c'*, *d'*, which are all probably connected with one another. It is furthermore

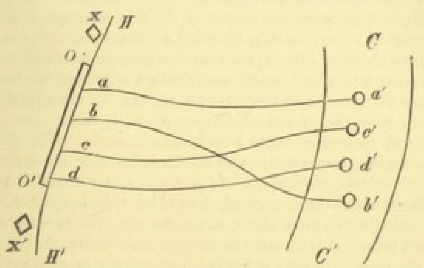

Fig 7.

possible, though improbable, that the succession of the nerve-fibres at their peripheral terminations is retained undisturbed during their long course through the spinal chord and cerebellum, despite frequent intervenient interruption in the ganglion-cells, and that thus exactly the same order recurs in the cortex of the cerebrum. In the illustration, therefore, it is assumed that the succession has been altered; *d'* is now adjacent to *b'* which terminates the series. Now let a homogeneous object, which we shall at first conceive of as having only length, touch the skin and irritate the four terminations of the nerves. Four excitations, almost absolutely identical in quality, will then be transmitted to the brain; here like excitations will occur in the four ganglion cells and impart four like sensations of pressure. At first we are not conscious of anything more than these sensations, which, if there is any definite succession at all, are given in the order a', c', d', b'. We furthermore accept, as a fact, the projection of the four sensations into space. But now what causes us to correct the order of the series to a certain extent, and to so project the four sensations a', c', d', b' into space that their order becomes a', b', c', d', thus corresponding to the order of the nerve-ends touched, and of the points on the stimulating object? The cause lies in the ideas of motion which are associated with each one of the ganglion-cells. For example, if we move the surface of the skin represented in the illustration a short distance, the point a is first brought in contact with an object at x (fig. 7); a somewhat greater movement brings the point b to x, and so on until finally the greatest movement places the point d in contact with x. On the other hand, we might have placed the object also at x', in which case the slightest movement would have produced contact with d, the greatest movement contact with a. In either case the order of the nerve-ends, whether a, b, c, d or d, c, b, a, is constant in so far as the extent of the motions requisite to bring the four nerve-ends in contact with a given object, is concerned.[1] The experience as above described is repeated numberless times during the lifetime of the individual, until it finally becomes fixed in memory. A memory or idea of a motion having a definite magnitude is associated with the sensation received from each nerve-end. For example, let us suppose this idea of motion to be $1m$ for a, $2m$ for b, $3m$ for c, and $4m$ for d. Now if an object touch a, b, c and d at the same time, the sensation produced by the excitation a–a' unites with the idea of motion $1\,m$;

the sensation bb' with the idea of motion $2m$;
" " cc' " " " " " $3m$;
" " dd' " " " " " $4\,m$.

[1] The importance of conceiving of the elements, by means of which we perceive space, as a series, and the possibility of inverting its order, were first emphasized by Herbart ("Psychologie als Wissenschaft").

Thus this scale of intensities representing the concomitant ideas of motion, determines the order in which the sensations are localized in space. The sensations are not arranged according to the order of their position in the cerebral cortex, but according to the scale of the accompanying ideas of motion. What we have thus demonstrated in the imaginary case of linear contact, may also be applied somewhat more minutely to superficial contact, and to the taction of solid bodies. In this case also we first project the sensations of touch into space without regard to order; only the accompanying ideas of motion that we acquire, cause us to project the sensations received from the surfaces bounding an object in just the same spatial order in which the points are really arranged on the surfaces of the external object. It is furthermore obvious that ideas of motion may also be acquired indirectly, not when the hand is moved along the object x, but when the object x is moved over the hand under our eyes.

Hence a perception of the world as it exists in space may be developed within us entirely without the help of the visual sense, although, of course, it remains more or less incomplete. The well-known Chesseldens,[1] who was born blind, and later in life received the power of sight by an operation, only discovered after the operation that all things are solids; before he had only known of coloured surfaces. On the other hand, Franz[2] related that a certain individual, who had been born blind, was unable to form any idea of a square, even upon seeing it after his sight had been acquired by an operation, until he began to perceive a sensation in the tips of his fingers as though he was really engaged in touching the object at which he was only looking. The patient had constant recourse to his sense of touch, just as the normal man resorts to his sense of sight in the recognition of objects. When we come to consider the theory of visual sensations, we shall have to return to these cases, which are of extraordinary importance for physiological psychology, and to the

[1] Philosoph. Transact., 1728.
[2] Philosoph. Transact. R.S., 1841.

entire subject of space-intuition in general. At present only one more conclusion is to be mentioned as a direct result of the preceding. The ability to distinguish two sensations that arise in neighbouring nerve-ends, can be considerably cultivated by practice, since it is also chiefly dependent on accompanying ideas of motion. If we place the two points of a compass upon the thigh at a distance of 6 cm. from each other, we generally perceive but *one* touch; we are able to perceive two touches only when the distance between the points of the compass amounts to 7 cm. This smallest distance within which two sensations may still be distinguished from each other is designated as the "minimum of space"[1] that can be perceived or the "just perceivable amount of space," and the region of the skin within which we still feel two sensations as *one* is designated as the "sensation-circle" in accordance with the precedent established by E. H. Weber. Within the area of a single "sensation-circle," therefore, the local signs and the associated ideas of motion are not sufficient to render two sensations distinguishable when they are caused by like stimuli. Thus we can also easily understand why the "sensation-circles" are very large in those regions of the skin which have very few nerves and are little used in active touch, as the trunk, thigh, etc. It is a fact of great importance that two points of contact may be also felt as *one* when both are at pressure-spots separated by one or more other pressure-spots. It appears therefore that the distribution of pressure-spots is by no means the only factor determining the ability for localization, but that the local signs and particularly the accompanying ideas of motion exert the chief influence. The partition of the sensibility of the skin into pressure-spots only renders possible the separate appearance of two like cortical excitations in different cortical elements; but the distinction of two sensations does not depend on this simple fact of anatomical separation. We may here make the paradoxical statement that if all the nerves of the skin and their cortical terminations were anatomically quite

[1] Germ. *Raumschwelle* = space-threshold.—*Tr.*

identical, and if all were irritated by the same stimulus at the same time, only a single sensation would appear. The distinction of neighbouring sensations from one another is only possible by means of local signs and ideas of motion. That the sensation-circle becomes smaller when just two *pressure*-spots are touched may be partly explained by the fact that the intensity of the sensations is greater on the pressure-spots than elsewhere; and within certain limits at least, the distinction of sensation becomes easier, the greater the intensity of the sensation.

A further explanation may be sought in the fact that a single, isolated "local stamp" or "coloring" and a single, isolated complex of motor ideas appear only on irritation of a pressure-spot; if a point *between* two pressure-spots be irritated, the stimulus acts upon several such spots; the sensation is therefore associated with *several* local signs and complexes of motor ideas, and the differences between sensations are thus directly obliterated. In regions that possess an abundance of nerves the sensation-circles are smaller. A greater abundance of nerves renders possible a greater variety and speedier change of the local signs and a more extensive association with separate complexes of motor ideas.

In conclusion one fact must seem remarkable to us. We have succeeded in explaining how the separate sensations of pressure are discretely projected into space in a definite order; in so doing, however, we have simply obtained a regular contiguity of numberless *discrete* sensations. But whence arises the continuity of the impression produced by an object touching the skin? We do not feel numberless points, but a continuous surface. This fact may be explained as follows: It is true that the pressure-spots are discrete; but we have already demonstrated at some length that, strictly considered, the same stimulus acting upon different neighbouring pressure-spots, can impart but a *single* diffused sensation, the localization of which is quite indefinite, somewhat as in the case of sound. Our sensations of touch are only separated spatially and arranged so as to produce a surface by their association with local signs and ideas of motion. But the local signs and ideas of motion are regularly graded and therefore form a continuous series. Hence we can easily understand also that the separation of the tactual sensations and their arrangement in a surface has this continuous character. When the continuous gradation of the local signs and ideas of motion is wanting, the sensations do not blend into an image of surface. If we place three needle-points, for example, at a distance of 2 cm. from each other upon the hand, the three sensations will never blend into an image of surface.

We have now finished the discussion of that mode of sensibility from which all the other senses have probably developed, the sensibility in the narrower sense of the term. We shall next turn to the highest senses, hearing and sight.

CHAPTER V.

SENSATIONS OF HEARING.

We have now come to the discussion of acoustic sensations. The external stimulus producing these sensations is, in fact, very exactly known. It consists exclusively of longitudinal periodic vibrations of the molecules of air. Thus if *A* (fig. 8) designate a source of sound which sends out waves of sound in all directions, a particle of air at *M* will first move to the point *N*, then

Fig. 8.

return to *M* and pass on to *L*, finally returning to *M* again. The motion along the entire path *M N M L M* is called a vibration, and is executed in a single straight line. The latter is somewhat altered in the figure in order to illustrate visibly the reversal of the path, hence the particle of air does not appear to have returned to the exact starting point. In illustrating a series of vibrations it is best to depart still further from a straight line and represent the path of the particle as a wave. This may be accomplished most advantageously by letting the abscissas (fig. 9) indicate the time that has elapsed since the beginning of the motion, while the ordinates indicate the vibration that has taken place. These vibrations are periodic in that they are continuously repeated. A definite number of vibrations takes place in a second of time. These periodic vibrations may be regular, *i.e.* the form and number of the vibrations remain constant. Such vibrations impart sensations of musical sound; the accompanying external stimulus is designated as a *musical sound.* On the other hand, the periodic vibrations may be irregular;[1] form and duration of the vibration change. In this case sensations of noise are produced and the accompanying external stimulus is designated as a *noise.*

Fig. 9 I, represents the wave-line of a tone;[2] fig. 9 II, the wave-line of a noise.

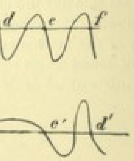

FIG. 9.

A single wave reaches from *a* to *b* (fig. 9 I). This distance corresponds to the length of time required for the vibration of one particle. The curves, *ab*, *bc*, *cd*, etc. (fig. 9 I), all represent a single vibration of the particle of air; likewise *a′b′*, *b′c′*, *c′d′*, in the second curve (fig. 9 II). The greatest breadth of displacement of a vibrating particle is called the amplitude of vibration. The lengths of the straight lines *ab*, *a′b′*, *bc*, *b′c′*, etc., represent the duration of each vibration. We see at once that in the first curved line both the form and duration of the single vibrations is always

[1] Throughout the entire chapter the reader should bear in mind that the author here makes a peculiar, but important, distinction between *regularly* periodic and *irregularly* periodic vibrations.—*T's.*

[2] In this chapter the term "tone," when used without modification, is to be understood in its restricted sense as designating only a "simple tone," not a "composite tone" or "musical sound."—*T's.*

the same. This is characteristic of the tone. On the contrary the form and duration of the vibrations in the second curved line are constantly changing, as is characteristic of a noise. The rustling of the leaves is a noise; if we strike the key of a piano, we produce a musical sound; both are complex products, as we shall soon see. Both *musical sounds* and *noises* may be reduced to simple acoustic elements, or tones, by mathematical computation (construction) or by the use of special instruments, the so-called "resonators." Both noise and musical sound consist of a series of simple tones. The wave-line of both the noise and musical sound may be graphically represented as the product of several wave-lines of especial simplicity, viz. the so-called "sinusoids" or

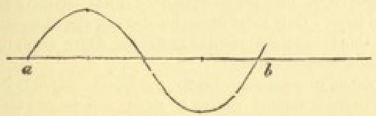

FIG. 10.

"curves of sines." Expressed in the language of physics, all the regular, periodic motions of musical sound and all the irregular periodic motions of noise may be reduced to a certain number of regular periodic motions of exceeding simplicity. These component vibrations, to which both a musical sound and a noise may be reduced, all have the same general form of vibration, the sinusoid, as represented in fig. 10.

The vibrations are to be distinguished from one another merely by their duration, or, in other words, by the number of vibrations per second. We may therefore express this general proposition as follows: Each sound, whether musical sound or noise, may be reduced to a series of simple component tones, which, irrespective of their intensity, are to be distinguished from one another merely by the number of vibrations. Musical sound and noise are different in that the numbers of vibrations producing the component tones of the latter conform to no definite law of proportion, while the numbers of vibrations producing the various component tones of a musical sound stand in a very simple numerical relation to each other. For example, if that component tone (or partial tone) of a musical sound which has the smallest number of vibrations, possesses n vibrations per second, then all the other component tones of the same musical sound have a number of vibrations which is just sufficient to produce an exact multiple of n; the numbers of their vibrations therefore amounts to $2n$, $3n$, or $4n$, etc. Also when the lowest tone has a number of vibrations equal to $4n$, and the following tones have numbers equal to $5n$, $6n$, etc., the form of vibration still remains regularly periodic. It is only essential that the relations between the numbers of vibrations for each component tone are expressed by whole numbers that are not too large. Only tones whose numbers of vibrations stand in such a simple numerical relation as the one above cited, together compose a musical sound.

Therefore, to recapitulate briefly, the specific physical stimulus for the organ of hearing consists of simple sound-waves that unite sometimes as musical sound-waves sometimes as sound-waves of noise.

It is difficult to determine exactly where organs of hearing first appear in the animal series. Without doubt, however, such organs are already present in the Arthropoda. It is often particularly difficult to determine whether the so-called otoliths of the Ctenophora and other similar animals are organs of hearing or organs that serve to keep the body in balance. The organ of hearing has been developed into a very complicated structure. A peripheral apparatus, which includes the external meatus, the membrana tympani and the auditory bones, serves especially to keep back all stimuli from the nerve-terminations, except the adequate stimuli of sound. These latter they transmit to the nerve-ends in the most suitable form possible. The final terminations of the auditory nerve lie partly in the organ of Corti in the cochlea, partly in the ampullæ of the semicircular canals; in both they come in connection with the so-called "hair-cells." The part of the auditory nerve that ends in the cochlea is designated as the nervus cochlearis; the part which ends in the ampullæ, as the nervus vestibularis. In their course through the brain they separate again; the nervus vestibularis reaches the cerebellum, while the nervus cochlearis, which probably performs the chief part of the function of hearing, reaches the cortex of the temporo-sphenoidal lobe in the cerebrum. Now the left auditory nerve, in fact, terminates chiefly in the cortex of the right temporo-sphenoidal lobe, the right auditory nerve in the cortex of the left temporo-sphenoidal lobe. The auditory centre is therefore to be sought in the temporo-sphenoidal lobe. It has not yet been decided whether the ampullæ and the nervus vestibularis take any part in the functions of hearing whatever or whether they simply transmit those sensations which assist us in retaining our balance; the sensations of noise have also been ascribed to them. In the organ of Corti the nerve-terminations lie in an expanded membrane, the breadth of which is very different in different parts. Sounds that have a large number of vibrations will cause particularly the narrower parts of the membrane to vibrate sympathetically; sounds having a small number of vibrations, the broader parts. One can conceive of the entire membrane as composed of numerous transverse chords, gradually decreasing in length from one end to the other, each of which is tuned to a definite tone. If a musical sound or a noise reach the ear, it is analyzed into its component tones; *i.e.* the membrane is set in vibration at different points, each of which corresponds to a definite component tone.

Sound-waves act as stimuli upon the peripheral terminations of the auditory nerve. They constitute the specific adequate stimulus. Sensations of musical sound can also be produced by electric stimulation of the auditory nerve; in this case it is probable that the trunk of the nerve is chiefly irritated. Mechanical stimuli, such as the pressure of tumors on the auditory nerve, for example, also produce sensations of hearing. Those sensations of hearing that are not produced by adequate stimuli are always exceedingly simple and monotonous.

Thus far we have dealt with those certain or probable facts offered by physiology and anatomy. Let us now analyse the sensations of sound psychologically. We shall first seek their different *qualities*. From the beginning we may be allowed to exclude that large class of sensations known as noises; they compose an especial group of sensations that are hardly accessible to investigation. We shall occupy ourselves only with the simple sensations of tones and the sensations of musical sounds. We have already heard that the so-called tones of the piano are not simple, but complex; they may be more correctly designated as musical sounds. Simple tones are produced most easily by striking a tuning-fork; the flute also gives comparatively simple tones. The only difference in the quality of all *simple* tones lies in the *pitch*, to which the number of vibrations per second in the stimulating medium corresponds. We perceive a tone to be higher the greater the number of its vibrations. The lowest audible tone has sixteen vibrations,[1] the highest about 40,000 vibrations per second. But the various sensation of pitch are not irregularly distributed between sub-contra *c* and the eight-times-marked *c* (c^8), as is the case, for example, with the different qualities of the sense of smell; on the contrary, the sensations of pitch constitute a continuous series which corresponds to the constant increase in the number of vibrations, of the acoustic stimuli. Without the omission of one interval, we can ascend from sub-contra *c* to c^8 by a regular scale of simple tones. Strictly speaking, however, there are numberless tones between the lowest and highest tones. For reasons which we shall learn to understand more fully later, we distinguish only a very limited number of tone-pitches. For example, in the interval between the tone of 256 vibrations (c^1), and the tone of 1,024 vibrations (c^3), there are only 14 whole tones, including the lower tone c^1. The chief factors that determined the historical development of this scale were æsthetic. All those tones that directly or indirectly harmonized with c^1 were sought and the above-mentioned 14 tones were the result. A more thorough analysis of this development does not fall within the province of this discussion. Especi-

[1] Wundt claims to have heard even eight vibrations per second.

ally the tone having twice as many vibrations as c^1, or a tone of 512 vibrations per second, produces a very harmonious accord with c^1. Likewise tones that have three and four times as many vibrations, c^3, c^4, etc., harmonize with c^1 remarkably well. Between c^1 and c^2, c^2 and c^3, etc., are six intermediate tones of harmonious character. C^1 with the six following tones were embraced in one so-called octave,—likewise c^2 and the six following tones, etc. We have thus obtained a division of the long series of tone-sensations which was determined by æsthetic factors. The series of tones is divided into octaves, and each octave into seven notes. We are acquainted with the seven notes in their various octaves as *d*, *e*, *f*, *g*, *a*, *b*. Next the octave was completed by a series of intervening tones (*c* sharp, *d* sharp, *f* sharp, etc.), which were also determined by æsthetic reasons. Thus the scale of simple musical tones has been developed from the natural series of numberless simple tones. This classification of the sensations of pitch was first developed historically. For this reason the demarcation of the octaves and the number of tones within the octave long varied.

In calling to mind the musical scale, the thought readily occurs to us to test or establish our sensibility to differences of pitch. How does the sensation of the pitch of tones increase or, more properly, vary when the number of vibrations changes? This question has frequently been conceived of as a special case for the application of the Law of Weber. It is obvious that there are no grounds whatever to warrant such an application; the Law of Weber compares the *intensity* of stimulus with the *intensity* of sensation. We shall presently apply the Law of Weber to sensations of sound in answer to the question as to how the intensity of acoustic sensations increases in proportion to the increase of the acoustic stimulus, *i.e.* in proportion to the increase in the intensity of the sound. The question occupying us at present, however, is quite different:—How does the sensation of the pitch of a tone change when the *number* of its vibrations changes? Neither has the sensation of pitch anything to do with the intensity of the sensation, nor the number of vibrations anything to do with the intensity of the acoustic stimulus. On the contrary, a sensation of pitch depends merely upon the quality of sensation and the intensity of the acoustic stimulus upon the amplitude of vibration. Hence the Law of Weber has no direct connection with the question. In a former chapter we sought the true nature of Weber's Law in an act of association and the incitation of the idea "larger" or "smaller." The comparison of tones of different pitch with the incitation of the idea "higher" or "lower" is, of course, somewhat analogous to the above case. For this reason it is conceivable that if the Law of Weber is valid in the one case within certain limits, similar mathematical relations may also be valid in the other case. A large number of experimental investigations have been employed in this line, the most reliable of which were made by E. Luft.[1] The result of these investigations shows that the relative discriminative sensibility is not quite constant, as required by the Law of Weber. If we sound a tone of 120 vibrations and then one of 120$\frac{1}{6}$ vibrations per second, we can distinguish the pitch of both tones clearly. Hence, at a pitch of 120 vibrations, a difference of $\frac{1}{6}$ of vibration is required to render two tones distinguishable, or the barely perceptible difference amounts to $\frac{1}{6}$ of a vibration per second. If we now choose as the beginning tone one with four times the number of vibrations, *i.e.* with 480 vibrations per second, the barely noticeable difference, according to Weber's Law, should also be four times as great. Thus the two tones should only be distinguishable when we increase the number of vibrations by the addition of $4 \times \frac{1}{6}$ or $\frac{2}{3}$ of a vibration per second. This is not the fact however. On the contrary, experiment proves that the addition of only $\frac{1}{4}$ of a vibration is sufficient for the distinction of both tones. If we select another pitch twice as high as the last and begin with a tone produced by 960 vibrations, it appears that a tone of 960$\frac{1}{3}$ vibrations can be clearly distinguished from the first tone of 960 vibrations, while according to the Law of Weber an increase of pitch should only be

[1] Philosoph. Stud., Bd. IV, S. 4.

distinguished when the difference is $8 \times \frac{1}{8}$ or more than *one* vibration per second. Therefore the *relative* discriminative sensibility[1] is not constant, while, on the contrary, the *absolute* sensibility for medium pitches seems to deviate but little from a constant average magnitude. The threshold of distinction only varies from $\frac{1}{8}$ to $\frac{1}{4}$ vibration per second, but may be materially affected by practice and musical talent. Persons who are not naturally musical err in the judgment of pitch, even more than we should suppose. For example, Stumpf found that persons not at all musical were mistaken *once* out of four times when they attempted to tell which of two tones, separated by the interval of a third, was the higher. The ability to distinguish is very limited, especially when the tones are very low or very high,[2] for the individual is not assisted by the experiences of daily life. Still it is astounding to reflect how exceedingly sensitive the organ of hearing is in general. We even notice a change from 1,000 to $1{,}000\frac{1}{8}$ vibrations per second; at the latter limit the quality of sensation has already changed. Some persons have been pleased to speak of this facility as an "unconscious counting" of the vibrations, and have been astonished at the certainty and rapidity with which the soul accomplishes this enumeration. It is unnecessary for us to be shown that no such enumeration takes place. It is only necessary to conceive of the chemical combinations in the terminations of the fibres from the auditory nerve as extraordinarily complicated, in order that so slight a difference in the mechanical stimulus may produce a difference in the central chemical process sufficient to render the tone distinguishable as higher or lower. Here for the first time we meet with time as an essential factor in the analysis of sensations. The quality of the sensation of tone corresponds to the number of vibrations of the sound-wave per second; it is therefore dependent on the *duration* of the

[1] Expressed by the ratio, $\frac{E}{dE}$, while the *absolute* descriminative sensibility is expressed by the ratio, $\frac{1}{dE}$.

[2] above c^5.

single vibrations, every change of which is followed by a corresponding change in the sensation with remarkable precision.

But the qualities of the sense of hearing, however, are not exhausted with the simple tones, even though we exclude noises, as we have already done. Apart from the scale of comparatively simple tones, such as the flute produces, we further distinguish a large number of qualities that belong to sensations of sound. The c^1 of the piano sounds very different from the pure c^1 of the tuning fork or flute, despite the sameness of pitch; and the c^1 of the violin is distinguished from both of the others. Or, if the human voice sing a vowel at the pitch of c^1, we can distinguish this also from the c^1 of the tuning fork, piano, and violin. Furthermore, the human voice can sing the vowels *a, o, e, i, u,* etc., to the same note. All these differences in the quality of acoustic sensations that are distinguishable even when the pitch remains the same, are included under one conception,—*timbre* or colour-tone. The same tone upon each instrument and each vowel of the human voice has its special timbre. Helmholtz[1] first showed what physical differences in the stimulus condition this difference in the quality of the sensations of sound when the pitch remains the same. As already briefly mentioned, the so-called tones of the violin, piano, horn, and human voice are in fact not simple tones at all. At most, only the tones of the tuning fork and flute may be considered simple. The tones of all other instruments and of the human larynx are composed of several, often of numerous, simple tones. Since the numbers of vibrations producing the component tones stand in very simple relations to one another (they are in general multiples of the same number), their combined effect should therefore be designated more properly as a musical sound. Thus, for example, if we strike c^1 upon the piano, six more tones sound with it, c^2, g^2, c^3, e^3, etc. The musical sound c^1 on the piano is therefore composed of seven simple, component tones, or, as it is also expressed, of one fundamental tone and six overtones. The fundamental tone

[1] "Lehre von den Tonempfindungen."

is loudest, the intensity of the over-tones diminishes as the pitch increases. Let us now compare this with c^1 of the violin. In this case also over-tones sound in harmony with the fundamental tone; in fact, we find not only the over-tones c^2, g^2, c^3, e^3, etc., again, but also from four to five more than before. Hence the intensity of the higher over-tones on the violin is essentially greater than upon the piano; by this means the violin receives the peculiar timbre characteristic of all stringed instruments. The component tones of the human voice have likewise been recently determined by Helmholtz, Hermann, and others.

The physical basis for the differences in timbre, therefore, depends upon the difference in the number and intensity of the overtones blending with the fundamental tone of the musical sound. This analysis of the musical sounds of instruments into their composite tones can be accomplished by means of special resonators. But the musician, and after some practice even one who is not musical, is able to distinguish by the sense of hearing without resonators, at least the lower overtones of c^1, struck on the piano, from the fundamental tone. The theory of partial tones or overtones is of the greatest importance in musical æsthetics.

Among the various qualities of the sensations of noise, the most important are those that are produced by the consonants of the human voice. A physical analysis demonstrates that the consonants are essentially noises, *i.e.* they are composed of simple tones, the numbers of whose vibrations do not stand in simple numerical relations to one another.

This finishes the consideration of the various *qualities* belonging to sound. It is obvious that the *intensity* of acoustic sensations increases with the strength of the sound. The latter may be subjected to a still more exact physical analysis. The intensity of a sound is in fact directly dependent on the amplitude of the vibrations produced in the sounding body. The proper formula is more exactly stated as follows: i is proportional to a^2n^2. Therefore the intensity (i) of the sound grows in proportion as the square of the amplitude (a), it being understood of course that the number of vibrations (n), or, in other words, the pitch, remains the same. Now is the Law of Weber valid in the case of sensations of sound? Is the absolute "threshold of distinction" in constant, direct proportion to the primary or beginning stimulus? In the investigations that were undertaken for the purpose of solving this question, great difficulty arose in producing any desirable gradation of the intensities of sound. Recently metal or ivory balls, that are allowed to fall upon an ebony or iron plate, have been applied with great advantage. In these experiments the timbre changes but very slightly[1] with the change in the height of falling and in the weight. On the other hand, the intensity of the sound is, within certain limits, proportional to the height of falling, the weight being constant, or to the weight, the height of falling being constant. Hence, by selecting balls of different weights or by altering the height of falling, one can vary the objective intensity of the sound at pleasure. The results have shown that Weber's Law is valid and comparatively exact for the intensity of acoustic sensations. A so-called "lower deviation" is met with in this case also, although it may possibly be caused by concomitant noises which are never wholly avoidable. The average relative threshold of distinction is about one-third. The minimum of stimulus, or the least amount of acoustic stimulus that imparts any sensation at all, has not yet been determined with sufficient precision.[2] The following series of experiments by Merkel is interesting. He permitted the person on whom he was experimenting to hear two stimuli of sound, alike in quality but different in intensity, and then requested him to determine an acoustic stimulus that should impart a sensation lying directly midway between the first two sensations. This "method of mean gradations" showed that the stimulus of sound which produced the mean sensation resulted in the approximate arithmetical, but not geometrical, mean between the two beginning

[1] STARKE, Philosoph. Stud., Bd. V, H. 1. MERKEL, Philosoph. Stud., Bd. V, H. 4.

[2] NÖRR's values appear to be too high (Zeitschr. f. Biologie, 1879).

stimuli. If Fechner's construction of Weber's Law is correct, *i.e.* if not only $\frac{dE}{E}$, but also dE, is constant, and if therefore S is also proportional to log. E, the geometric mean should be the result. In the case of sensations of sound, therefore, Fechner's formula is shown to be wholly invalid; the assumption of Plateau is more correct; $\frac{dS}{S}$ is constant. Let us here call to mind once more, however, that neither the geometrical nor the arithmetical mean results for other sensations; the actual outcome is a value between these two. We have already referred to the essential scruple that can be brought against the "method of mean gradations."

We shall now turn to the question also in reference to sensations of hearing, that has previously been asked concerning other sensations: How is the sensation modified if the same stimulus of sound act on several nerve-terminations? In the case of the sensibility of the skin it appeared that, aside from the three qualities manifest in sensations of pressure, cold and heat, all nerve-terminations are practically identical in function, and that when the stimulus spreads over a larger number of nerve-ends the numerous like sensations are so arranged with reference to each other as to produce an image of space. In the case of the sense of hearing the result is different. The number of qualities here is much larger; each pitch represents a special quality of sensation. We have already mentioned that the physiological structure of the organ of hearing renders it very probable that each nerve-end of the nervus cochlearis can only be irritated by one pitch, or at most only a very small number of pitches. One and the same stimulus of sound, therefore, cannot act at the same time upon many nerve-ends, as our question would imply, but simply upon one or at most a few neighbouring terminations. The qualitative adaptation or differentiation of the auditory fibres is so far developed that in general no two fibres [1] can partake of the same

[1] The membrane of Corti is set in vibration only at a definite place by a

kind of excitation. Accordingly a distinct spatial contiguity in the arrangement of several tones heard at the same time is never developed. All sensations of sound are different in quality; but the favourable condition for the development of the spatial character of our sensations is the simultaneous existence of several sensations *alike in quality*. Like all sensations, the sensations of hearing are projected out into space; but this projection is extraordinarily inexact. It is of especial importance that the sensations produced by the excitation of different nerve-ends may be projected to about one and the same place. For example, some one strikes a chord on the piano, in which perhaps eighteen simple tones are contained. At least eighteen different nerve-ends are irritated in each auditory nerve, and still we do not project the sensations produced by these excitations into space either separated or side by side, but altogether to about the place from which the tone seems to proceed. This fact cannot be sufficiently explained by the highly developed differentiation of the auditory fibres and their adaptation to the numerous qualities of sound; for the separate projection of the sensations into space is conceivable, even though they are wholly different in quality. In this connection we must consider that association with sensations and ideas of motion, which is so essential for the development of space-perception in the case of touch, is very incomplete in the case of the sense of hearing. We cannot let the ends of the auditory nerve glide over a sounding body, as our hands did over an object, nor construct [1] an image of space from the successive impressions received by sensations of increasing motion. We can, it is true, turn the head from or toward the sounding body; we can approach it or recede from it; but in so doing no other nerve-ends are brought in contact with the stimulus. On the contrary, the same nerve-ends are irritated, and only the intensity

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definite pitch; each nerve-fibre thus becomes to a certain extent accustomed and especially sensitive to a certain pitch.

[1] Otherwise the formation of an image of space from sensations of hearing is not quite inconceivable.

of the stimulus increases in the one case and decreases in the other. A person with one ear, and without the ability of moving from place to place or of turning the head, would project all tones into space quite indefinitely and without regard to the direction from which they came. Of course the localization of sensations of sound by the normal human being is somewhat more definite, since he is able to observe how the intensity of a sound varies on turning the head or moving from one place to another, and can therefore form some conclusion as to the direction of the sound. When the head is held at rest, we are often mistaken in judging of the direction of a sound, exchanging *before* for *behind*, *above* for *below*, etc.[1] Slight concomitant sensations of touch on the skin, appearing in different localities according to the direction of the sound, are produced by delicate sympathetic vibrations of the hairs in the concha, and possibly also by vibrations of the bones (cranio-tympanal conduction). These sensations often render at least an approximate judgment possible. Sounds coming from the right and left are also difficult to distinguish when the head is motionless. In this case we are aided in distinguishing the direction from which a sound proceeds by our knowledge of the fact that a sound coming from the right is physically compelled to produce a stronger excitation in the right ear than in the left. In this case, therefore, in view of the fact that most of the auditory fibres proceeding from one ear cross to the opposite side of the brain, the cortical excitation is also greater in the left temporo-sphenoidal lobe than in the right. Conversely, in response to a sound coming from the left, the cortical excitation is greater in the right temporo-sphenoidal lobe. This fact renders the distinction of direction possible, to a certain extent, for it is very probable that the acoustic fields of the two hemispheres have, for purposes of association, very different connections. But a slight turning of the head still remains the most important and

[1] PREYER (Arch. f. d. ges. Physiol., Bd. XL) has recently ascribed the function of localizing the acoustic impressions to the semi-circular canals, but apparently without sufficient grounds.

natural means for determining the direction of sound. Finally, the localization of our impressions of sound is quite uncertain as regards the distance to which we project sensations. The sensations of touch on the skin are referred directly to the surface of the skin because experience teaches that only mechanical stimuli produce sensations of touch by direct contact. As regards the sensations of sound, we likewise permit ourselves to be guided in general by experience ; weaker sensations of sound are projected to a point remote from us, stronger sensations to one nearer us. In such cases we are assisted by an experiential knowledge of the strength which the sounds of certain things have at a certain distance previously estimated by the eye ; hence after having acquired this experience we are also able to determine with closed eyes whether a distance is greater or less by the greater or less intensity of a sound.

We see that the localization of the sensations of hearing is determined in part at least by processes that are essentially associative and to some extent comparatively complicated. The acoustic sensations have no direct spatial relations such as we found for the sensations of touch or such as we shall find most highly developed for the sensations of sight which are presently to be considered. The sense of hearing is not, in fact, a sense that brings us in close relations with space. We may designate it briefly as a purely qualitative sense ; but by virtue of the extremely delicate gradation and the exceedingly rapid perception [1] of the qualities of stimulation, the sense of hearing is fitted to receive the best means of communication employed by mankind, the spoken language.

[1] Even eighteen vibrations are sufficient for the recognition of the pitch or quality of a tone.

CHAPTER VI.

THE SENSATIONS OF SIGHT.

THE adequate physical stimulus of the eye is furnished by the vibrations of the ether. We conceive that imponderable particles of so-called ether are distributed in infinite numbers between the atoms or molecules of matter. The physics of to-day teaches that light is diffused through space in all directions by the vibration of these particles of ether. These vibrations are not executed longitudinally, as are the vibrations of the molecules of a body conducting sound, but transversely; in other words, the direction of vibration is perpendicular to the direction in which the rays of light are transmitted. The vibrations of light may also be represented best as wave-lines, governed by laws very similar to those for waves of sound. The vibrations of light without exception are to be regarded as regular periodic vibrations. Not all velocities of ethereal vibration impart a sensation of light to the eye; the number of vibrations per second may be too large or too small to produce such a sensation. In general only more than 400 billion and less than 900 billion vibrations per second are capable of exciting visual sensations.

Let us now consider the organ that receives this stimulus—the eye. Even in the lowest animals, the Protozoans, we find spots in the protoplasm that are sensitive to light, and marked by the deposition of special pigments. They may therefore be designated as pigment-spots. Also in the eye of the most highly developed vertebrates the rays of light are conducted through many refracting media and finally reach a layer of the so-called retina containing pigment. This layer of the retina, which covers the inner surface of the posterior wall of the eye-ball, is designated as the "layer of rods and cones." Here numerous structures, part in the form of rods, part in the form of cones, are arranged mosaically, their bases turned toward the inner part of the eye. These rods and cones are connected with the terminations of the optical nerve, but it is not probable that a fibre of this nerve is allotted to each one of the rods and each one of the cones. The most familiar pigment of the retina is the "visual purple" discovered by Boll, which speedily bleaches when exposed to light. This visual purple, however, is only present in the rods. The cones, which are far more numerous in that part of the retina which is of service in sharp, steady sight, contain no visual purple. It is also entirely wanting, for example, in the eye of the snake. Besides the visual purple, the so-called pigment-epithelium of the retina should be taken into consideration, although we cannot undertake the explanation of its anatomical arrangement here. The process of an act of sight is as follows:—The vibrations of ether, having reached the retina, decompose its so-called photo-chemical or visual substances, which are sensitive to light. (There are numerous analogies to this decomposing action of light.) By means of this decomposition, the nerve-ends laden with visual substances are set in commotion. The fibres of the optic nerve then conduct this excitation to the occipital lobe of the cerebrum. On their way to the brain, part of the optical fibres of the two nerves cross, part remain on the same side. Hence all the impressions from the right half of the space viewed *also* reach the left hemisphere, all the impressions from the left half of the field of vision *also* reach the right hemisphere, so that all impressions are received by both hemispheres.

We may here at once observe that, besides the adequate stimulus furnished by the vibrations of ether, the universal nerve-stimuli (mechanical and electrical) can also impart sensations of light. If we press against the eyeball anywhere along the edge of the orbit, an impression of light is produced which is known as a "phosphene." The cause of this phenomenon is obviously mechanical stimulation. When, on account of being generally diseased, the eyeball is extirpated and the optic nerve severed, the patient on whom the operation is performed sees great masses of light during the moment in which the nerve is being cut. Volta was the first one to establish the electric excitability of the organ of sight. It has been observed that a flash of light appears both on opening and shutting the galvanic current; it is sufficient to place an electrode upon each temple.

After these preliminary observations we can now undertake the psychological analysis of the sensations of sight. We at once meet with numerous *qualities* of visual sensation, which we designate as colour in the broadest sense. There are no other qualities except those of colour; these we shall now consider more thoroughly in their relation to the physical stimulus. A long series of colour-sensations is directly produced by the so-called "colours of the spectrum," which include violet, blue, green, yellow, orange, and red. These sensations of colour corresponding to the spectral colours compose a series similar to that produced by the different sensations of pitch. Red, which has the least number of vibrations, would correspond to the lowest tones; violet, having the greatest number, would correspond to the highest tones. Below the following line the series of spectral colours is arranged in order.

Red—orange—yellow—green—blue—violet.

The red rays both have the greatest wave-length and are least refrangible.

Of course we at once observe a difference between the series of sensations of spectral colour and the series of tone-sensations. In considering the latter we discovered certain harmonious relations, the nature of which we shall investigate later. Guided by these relations and proceeding from any given tone, we found it possible to discover all those other tones which stand in certain harmonious relations to the first tone. In this manner we obtained a limited scale whose tones are separated by definite intervals, instead of an unlimited, uninterrupted series of tones. It is different with the series of sensations produced by the colours of the spectrum. In this case there are no such harmonious relations and hence there is no colour-scale. We can only select special colours that seem to us to be particularly striking, or that we find occurring very frequently, the intervals between them being thus determined quite arbitrarily. For this reason the designation of colours among the ancients was very indefinite. According to Helmholtz,[1] for example, the Greeks appear to have designated the entire series of colours from golden yellow to bluish green by the term "xanthos" (ξανθός). The colour of the sky derived its designation, cæruleus, or cerulean, from the term meaning sky, *cælum*. In a similar manner the German word "blau" (blue), related to the English word "blow" (Germ. *blasen*), was derived from the colour of the air, or that which moves when the wind blows. One can of course, construct a scale of colours, similar to the scale of tones, according to the relations which the numbers of vibrations bear to each other. This has been done by Newton, and later, especially by Drobisch.[2] The arrangement of the seven chief colours of the spectrum, still in use (violet, indigo, blue, green, yellow, orange, red), was first used by Newton simply in analogy to the musical scale.[3] But these are merely the theoretical figments of physics that have no foundation whatever in the sentient life. So far as sensation is concerned, the series of spectral colours is quite continuous; it is not divided into a scale of various shades of colour.

In our future considerations we shall notice many more differences between the sensations of pitch and those of colour. Let us next ask if there are not still other sensations that are not produced by the colours contained in the spectrum, besides those of

[1] "Physiologische Optik."
[2] POGGENDORF's Annalen, Bd. 88.
[3] Thus the breadth of the spectrum was divided in proportions analagous to the whole tones of an octave.

the seven spectral colours? To this question we answer, Yes. Brown,[1] with all its varieties, purple, black, grey in all its shades, and white are not contained in the spectrum. One might at first doubt whether black, with all its transitions through grey to white, ought to be included in the list at all. The objection may be offered that white is no definite colour, black simply the negation of colour, and that finally grey is merely a white of diminished intensity. As regards the facts of physics this is correct. According to physics, black is in fact the absence of all vibration of ether; but psychologically black is as genuine a sensation as any of the other sensations of sight. If we look straight ahead of us into an entirely dark space, we are still able to distinguish the dark field of vision before us from that which lies behind us, and which produces no sensation of sight at all.[2] In the same way it is possibly correct, according to physics, that white is not a definite colour. On the other hand, it is for psychology to gather all the qualities of *visual sensation*, and from this standpoint white is a quality or a colour, the same as green or yellow. Finally as to the different grades of grey between pure white and pure black, it is psychologically quite false to designate the sensations of grey as less intense sensations of white. According to this conception white would also be a more intense grey. In this case also one must guard against introducing physical propositions directly into psychology. In *physics* the proposition may be correct; the physical stimulus that imparts the sensation of grey may be less intense than that imparting the sensation of white, for a body is grey that reflects only the same *fractional part* of all the rays of light falling upon it. But in *psychology* the difference between white and grey is one of *quality* and not of *intensity*.

We must therefore regard brown, purple in all its varieties, grey in all its grades, white and black, as special qualities of visual sen-

[1] Brown is here chosen as an example only.

[2] In this connection it is also very convincing to note that in cases of hemianopsia and peripheral blindness of many years' standing, the sensation of darkness disappears.—WILBRAND, "Seelenblindheit," S. 82.

sation, the same as the sensations of the spectral colours. Now what physical stimulus produces these sensations?

Let us begin with the sensation of purple. The sensation of *purple* in its different grades is produced by mixing those simple colours that stand near the ends of the spectrum; especially by mixing red and violet, or also orange and blue. By a suitable choice of the proportions in which the elementary colours are mixed, a continuous graded series of purple colours may be produced between violet and red. Therefore, while the series of physical, spectral colours themselves is represented by a straight line, the series of corresponding colour-sensations may be represented as a circle by the addition of the sensation of purple (fig. 11).

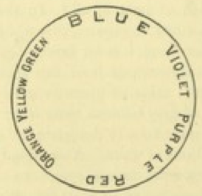

Fig. 11.

The question as to the physical stimulus for the *sensation of black* has already been answered above. In this case, vibrations of ether that come to the eye from without, and reach the terminations of the optic nerve, are wholly wanting. For this reason, the sensation of black must be produced by those chemical excitations which accompany rest, and the restoration of the previously decomposed visual substances, or the previously irritated terminations of the optic nerve. Therefore the sensation of black is just as positive as the sensation of any colour, and corresponds to the external stimulus, $E = O$. This fact constitutes a further important difference between sensations of sight and those of sound.

The *sensation of white* is always produced by the combined action of several spectral colours. It is produced,—

1. By the union of the rays of *all* the colours of the spectrum. This takes place, for example, when the colours of the spectrum, artificially produced by analysis, are again united by a prism.[1]

2. By the union of two definite spectral colours. Each colour of the spectrum, having a certain wave-length of vibration, when combined with only *one* other colour of the spectrum, produces the sensation of white. Thus, for example, red and greenish blue, yellow and indigo-blue,[2] etc., are colours which together give the sensation of white, and are therefore designated as "complementary colours." Considered strictly in the light of physics, two complementary colours have no especial relation to one another; they only become complementary in our sensations. There is no *simple spectral* colour which will give the sensation of white when combined with pure green. On the other hand, *purple* proves to be the complementary sensation for green. It would seem natural to compare white to a complex tone or to an accord. An essential difference exists between the two, however. By the sense of hearing we can distinguish the single tones of a chord with greater or less ease; the organ of hearing analyses it. On the contrary, the sensation of white contains nothing of the sensations of those colours which compose the physical stimulus of white in any given case. The physical stimulus of the sensation of white is complex; the sensation of white itself, however, is simple. We are accustomed to ascribe a special central position to the sensation of white, setting it in opposition to all other sensations of colour (fig. 12). This is justified by the fact that any two complementary colours together give the sensation of white. But in

[1] White-coloured objects are those which reflect all the rays of light, unabsorbed and undecomposed.

[2] The artist's formula, adopted by Goethe also, according to which yellow and *blue* mixed produce green, may be offered in opposition to this statement. It is, in fact, correct in the case of the artist's colours, but it can be easily proved that in mixing *material* colours an addition of coloured light, such as we desire, does not take place.

our estimation of the sensation of white, we are inclined to go still further and identify it directly with a hypothetical sensation of colourless light. We imagine that light in itself is white, white being therefore synonymous with lightness. In so doing, we are chiefly influenced by the fact that our most powerful source of light, the sun, imparts approximately white light. We then come to the further conclusion that white, as a sensation of light, is in itself the absolute and only antithesis of black, the sensation of the absence of all light. But, in fact, the above conclusions do not represent the true relations in the case. We perceive "lightness" in a room also that is lighted by the homogeneous yellow light of natrium. It may be dazzlingly bright in a room that does not contain a single *white* object, with only the blue sky before the window. Hence white and lightness are *not* identical. Lightness is an attribute of all sensations of light, the sensations of spectral colour, as well as the sensations of white or purple. White simply presents a mixture of spectral colours, especially important to mankind, In this connection it is particularly necessary to consider that the sun emits white light; coloured bodies are characterized by absorbing a part of the rays contained in the white light, and by reflecting only the remaining part to the eye. They are thus coloured, but weaker in light. Since the white bodies of our sun-lit surroundings in nature reflect all the rays of light, they are also always brightest, or strongest in light. Thus arises the error of supposing that white and lightness are identical.[1] But if a definite intensity of lightness belongs to each sensation of spectral colour as well as to the sensation of white, it is also false to regard the sensation of black merely as the opposite of the sensation of white. The

[1] One might also have recourse to the fact that, if the intensity of the light of the spectrum increase to a certain degree, all colours finally pass into white. If, however, the homogeneous light of natrium becomes so intense as to appear white, it may be demonstrated by the spectroscope that the originally yellow light has given place to a complete spectrum. Therefore the physical stimulus has also changed and not merely the sensation. We shall return to this subject presently.

sensation of black stands in just as much of an opposition to the sensations of all the other spectral colours. The sensation of black is characterized by an intensity of lightness equal to 0; or, in other words, the light-intensity of the stimulus causing the sensation of black, equals 0. By reducing the light-intensity of any spectral colour whatever, the corresponding sensation of colour finally changes to a sensation of black.

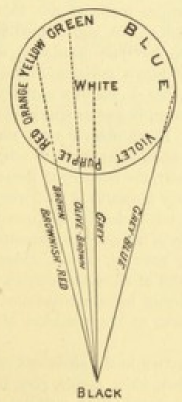

Fig. 12.

Let us consider these transitions somewhat more minutely. The physical stimulus of a red, weak in light, produces the sensation of reddish-brown; that of a yellow, weak in light, the sensation of brown; that of a weak green, the sensation of greenish-brown, or olive-green; that of a weak blue, the sensation of greyish-blue, etc. If the intensity of light is still further diminished, reddish-brown, brown, olive-green, and greyish-blue, all finally pass into black. We can produce a graphic representation of these transitions, by uniting (fig. 12) by straight lines a point representing black, situated in the axis of the circle of spectral colours, with the different points of the circle drawn above it. These connecting lines then represent the different transitions of the single colours of the spectrum to black, on reducing the intensity of light. It is well worthy of notice, in connection with the colour-sense, that a decrease of the intensity of the physical stimulus produces not *only* a decrease of the *intensity* of the sensation, but also a modification of its *quality*. This agrees with the fact just mentioned, that the intensity of light, 0, does not produce a sensation of the intensity 0; that is, no sensation at all, but a positive sensation, the sensation of black, which, moreover, is just as positive psychologically as the sensation of white. If we observe a red surface at a constantly increasing distance, or, in other words, in a light that is constantly diminishing in intensity, the intensity of the sensation also changes in fact, but the change of quality is particularly noticeable. There is no true scale of intensities for the sensations of light, corresponding to the scale of intensities for sensations of sound. This transition to black, however, is not characteristic of spectral colours alone, but also of all mixed colours, including especially white. We have already become acquainted with the transitions of the latter to black, as the sensation of grey in its various gradations.

But after having added to the sensations of the spectral colours the sensations of black, white, purple, grey, brown, grey-blue, etc., we have not yet exhausted all the qualities of the sensations of colour. It is vain to seek simple spectral colours for the colour-sensations of sky-blue, sea-blue, pale green, flesh-colour, and rose. This last group of colour-sensations is essentially characterized by the partial absence of that which we designate as "*colour-saturation.*" The physical stimulus that produces these sensations of less saturated colour consists of a mixture of any given spectral colour with white, or a mixture of two suitably chosen spectral colours that are not complementary. In the same way, without the admixture of white, each spectral colour becomes lighter, or, in other words, less saturated when the intensity of light is increased. If one gradually adds more white to the mixture, or increases the intensity of light, each one of the spectral colours finally becomes

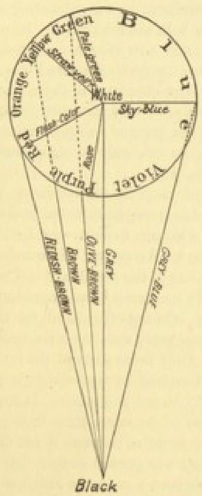

FIG. 13.

apparently white. We may now add, therefore, that a sensation of white is produced not only by mixing two complementary colours, but also by the excessive increase of the intensity of light in which any given spectral colour appears. Thus red gradually passes through flesh-colour, blue through sky-blue, purple through rose into white. If we wish to represent these colours also together with white in the illustration, we must place white in the centre of the plane of the circle representing the colours of the spectrum (fig. 13). The radii of the circle then represent the gradations between complete saturation and white. With these colour-sensations produced by the admixture of white, the qualities of sensations of light are exhausted. By mixing the qualities thus obtained, no other new colours are produced; only the old colours are reproduced according to fixed laws. We are indebted to Newton for the most important of these laws of mixture.

As a brief summary, we may state that the qualities of the sensations of light do not present a simple series as do those of the sensations of tone, but can only be represented by a structure of *three* dimensions (fig. 13).

We are now confronted by the question: In the case of the sense of sight, is each nerve-end trained to a certain pitch, *i.e.* to vibrations having a certain definite wave-length, as is the case in the sense of hearing? We answer this question decidedly in the negative. In the case of the membrane of Corti it is indeed true that each one of its numerous fibres transmits essentially but *one* shade of sensation. On the other hand, the simplest observation shows that in general every spot upon the retina is sensitive to all shades of colour. Only those parts of the retina that lie *near* the periphery are characterized by insensibility to green, the *outermost* parts by insensibility to red and green. It appears beyond doubt that all terminations of the nerve-fibres in the central parts of the retina must be very sensitive to many if not all colour-stimuli.

To-day physiologists in general assume that only three different photo-chemical substances are to be found at the terminations of the optic nerve. All rays of light act only upon these three substances. The red rays decompose perhaps only one substance, the yellow rays perhaps only half of one and half of another—the orange-coloured rays half of the first, one-third of the second, and one-sixth of the third visual substance, etc. In short, the action of each ray of coloured light is undoubtedly limited, and distinguished from all others in that it decomposes a definite relative fractional part of each of the three visual substances. This fractional part is constant for a given wave-length. One can carry this supposition still farther, supported by the so-called "Young-Helmholtz hypothesis." This theory makes a strict application of the theory of specific energy, and assumes accordingly that a special kind of fibre in the optic nerve, a special central connection and a special fundamental sensation correspond to each visual substance, and that therefore every particle of the retina contains three specific nerve-ends. However, it is just this hypothesis which is psychologically difficult to maintain. It is not for us to discuss here in how far the theory of Hering, as opposed to that of Helmholtz, corresponds to the requirements of physiological psychology. It is sufficient here to simply emphasize the fact as undoubtedly established, that a photo-chemical process imparts the action of the rays of light to the ends of the optic nerve. Both the number of visual substances and the arrangement of the single substances with reference to definite colours, or even to special kinds of fibres, are still quite uncertain. They are also *psychologically* of less importance than the above-mentioned representation in which the qualities are arranged in three dimensions. A presentation of the most important physiological theories is to be found in the writings of Helmholtz, Hering, Wundt and Kries.[1]

It is interesting to note that in the development of both individuals and nations, as also in certain pathological cases, the number of qualities of visual sensation varies. At the age of two years the child gradually learns to name the colours correctly, first yellow, then red, and somewhat later, green and blue. Especially blue is for a long time recognised only with difficulty, being often designated as "grey," or "gar nix" (nothing at all) (Preyer). All the colours are not named correctly before the be-

[1] Helmholtz, "Handbuch der physiolog. Optik," 1st and 2nd editions; Hering, Sitzungsber. d. Wiener Acad. Math.-naturwiss. Klasse, Bd. 66, 68, 69; Pflüger's Archiv., Bd. 40–42; Wundt, Philos. Studien, Bd. 4; Kries, Arch. f. Augenheilk., Bd. 17, and Du Bois-Reymond's Arch., 1882.

ginning of the fourth year. This may be explained by the fact that the action of blue and green rays of light on the child's eye is weakened by purely physiological circumstances. We should furthermore consider that there may be possible differences in the ability to discriminate between the various single sensations of colour as regards quality.

Pathological defectiveness in the qualities of visual sensation is generally designated as colour-blindness. Total colour-blindness has been observed in rare cases; the individuals perceived some difference in brightness, but no difference in quality or colour. All nature, therefore, with its great variety of colours, appears to these individuals as a sort of silhouette, having only different shades. So-called violet-blindness is somewhat more frequent. It may be artificially and temporarily produced in a human being by the use of santonin. Violet and yellow appear to be alike to persons that are either colour-blind to violet, or under the influence of santonin. Still more frequent are "red-blindness" and "green-blindness," or cases of colour-blindness, in which red and green cannot be distinguished. Those who are colour-blind to red see but two chief colours in the spectrum, which they generally designate as blue and yellow; red, orange and green appear to them like their yellow, violet like their blue. In the same way those who are colour-blind to green, distinguish two qualities of colour which they designate as blue and red. It has been claimed that colour-blindness existed at certain stages in the cultural development of nations, and that it still exists among certain peoples that have fallen behind in culture. On the other hand, we find undoubted cases of the distinction of colour even in insects. In 1858 the then youthful English statesman, Gladstone, claimed that the Greeks were colour-blind to blue. He based his claims chiefly upon the fact that Homer had no proper terms for blue. The fact that, in describing the colours of the rainbow, some of the colours were entirely omitted and others exchanged has been cited in favour of the existence of partial colour-blindness among ancient peoples. It has, however, been shown that a deduction cannot be made with certainty from the different designations of colour that appear in the literature of a language. A reference to the pages of some of our most modern poets will bring to light some of the most nonsensical designations for colours (as one authority has shown by actual count), which might likewise suggest the diagnosis of colour-blindness. It appears to be a fact, however, that sensibility to colours produced by short wave-lengths of vibration (for example, green and blue), is noticeably slight in ancient peoples, in modern peoples living in a state of nature and, we may also add, in the new-born child. Therefore just these colours are often insufficiently designated in a language and the ability to distinguish them is deficient.

The Bongo negroes in Central Africa seem to have only the word "red" for all colours produced by long waves of vibration; and the word "black" for all those produced by short waves. There can be no doubt that our colour-sense has developed *gradually*. We are also all colour-blind in the peripheral parts of the retina, and are placed in a condition similar to that of colour-blindness when the coloured objects are very far distant from us. All objects then appear to us to be more and more like black in proportion as the intensity of light decreases. In a similar manner the greatest increase in the intensity of light causes the apparent ultimate transition of each sensation of colour to a sensation of white; in other words, the ability to distinguish quality is entirely removed.[1]

In a manner similar to that employed in the last chapter for sensations of tone, we shall now determine the sensibility to differences in colour-qualities in the case of sensations of colour perceived by the normal eye so fixed that objects are imaged upon the centre of the retina. We shall limit ourselves to the series of spectral colours. Here we find[2] that we perceive slight differences in "colour-tone" best in the yellow and blue of the

[1] See further on, however.

[2] KÖNIG and DIETERICI, Ann. d. Phys. u. Chem., 1884. BRODHUN, Verh. d. physiol. Ges. zu Berlin, 1885–86. UHTHOFF, DU BOIS-REYMOND'S Arch., 1889.

spectrum. A change in the wave-length amounting to $\frac{3}{4}$ *millionth millimeter* is sufficient to cause a difference in the sensation of blue (or greenish-blue). The sensibility to differences in quality is considerably less in the case of the other spectral colours. For some distance at the ends of the spectrum we recognise no change of colour-tone at all, but only changes of brightness.

We have now finished the consideration of the *qualities* of visual sensation, *i.e.* the sensations of colour; we turn next to the theory of the *intensity* of colour-sensations. Intensity or brightness obviously depend on the amplitude of vibration; the same as the intensity of sensations of tone. We have already mentioned above, however, that sensations of light cannot be regarded as having a proper intensity. A distinct positive sensation, black, corresponds to the intensity of light o. Here, of course, it is impossible that all stimulus is wanting; we must assume chemical processes, characteristic of the retina at rest, which continually irritate the ends of the optic nerve, thus imparting a sensation of black. If we now permit the light of a spectral colour, red, for example, to act with gradually increasing intensity upon the retina previously at rest, both the intensity and the quality of sensation change at the same time. We perceive at first a very dark reddish-brown, then a lighter reddish-brown, and finally a complete red. This change is due to the fact that the sensation of black produced by a condition of rest in the retina, is mingled with the sensation of red produced by the irritation of the retina, in constantly decreasing proportions. If very weak red rays reach the retina, the sensation of black, when mingled with the weak sensation of red, still retains nearly its complete normal intensity; the sensation of dark reddish-brown is thus produced. Black becomes less and less a factor in the production of the sensation in proportion as the red rays are intensified, and the retina more severely irritated, until finally a sensation of saturated red is produced. On account of this constant commingling of the sensations of black with those of red, we are wholly unable to arrange a scale of the sensations of red, beginning with the intensity o, and ascending without change of quality to constantly greater intensities of brightness. The scale of intensities for sensations of light does not correspond to the scale of tone-intensities characteristic of sensations of sound. This scale, for example, begins with the softest C^1, and ascends to the loudest C^1 without a change of quality. The scale of intensities for sensations of light is mingled with a scale of changes in quality. Therefore observations of pure intensity cannot be employed in the case of sensations of light. If the latter remain the same in quality, it is impossible to obtain any scale of intensities whatever. Even the sensation of white not only loses intensity when the strength of light is decreased, but is also modified in quality by passing through grey into black. The quality may, however, at least be regarded as *approximately* constant on a very small tract, situated in that part of the mixed scale of intensities where the sensations of red, white, etc., are most saturated. This tract could be applied in the measurement of the intensity of sensation. (Fig. 14.)

Before we pass on to these measurements, however, let us carry the above experiments still further. By constantly increasing the intensity of light up to a certain degree we have obtained the sensation of saturated red. Now what takes place when we increase the intensity of light still further? As has already been mentioned above, each simple sensation of spectral colour then passes into a sensation of white. It is inexpedient, however, to consider the transition of sensations of spectral colour to the sensation of white, caused by the constant increase in the intensity of light, as parallel to the transition of these same sensations to the sensation of black, caused by the constant decrease in the intensity of light. In the former process it is possible that other complicated phenomena, due to over-irritation and contrast, are concerned.[1] It is obvious, however, that a pure scale

[1] For example, a very intense green light, despite the continuity of its action, might directly produce the contrasting sensation of red. In consequence of the blending of the two sensations of colour, a sensation of white would be produced.

of intensities rising from saturation to white, is also an impossibility, for the quality changes in proportion as the shades of colour gradually approach white.

For the reasons just given, the testing of Weber's Law will always be more or less uncertain when the law is applied to the intensity of *visual* sensations. The approximate validity of this law is, of course, at once apparent. As we have already learned, the Law of Weber states that we distinguish between intensities of light by virtue of their relative, but not their absolute, difference. A simple demonstration of this may be obtained by the use of Masson's disks (fig. 14). A broken black line of a

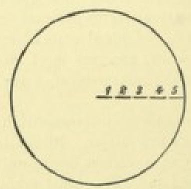

FIG. 14.

definite breadth is drawn in the path of a radius upon a white circular surface. If the disk is rapidly revolved, each component line blends with the white belonging to the same ring of the circle, into a grey ring. The innermost grey ring is darkest and the other grey rings are lighter in proportion to their nearness to the periphery, because each one of the successive components of the broken line occupies a so much smaller part of the ring in which it lies, and is consequently blended with so much more white the nearer it is to the circumference of the disk. Let us next assume that the disk is illuminated by the light of *one* candle, and that the grey ring already produced by the black component line 4 is so light that we cannot distinguish it from the white back-ground. We now light *six* candles instead of *one*, and find to our astonishment that despite the great change in the absolute intensity of light, the grey ring No. 4, is still the one that cannot be "just distinguished" from the white back-ground. It is obvious that in this experiment the absolute difference in brightness was completely changed, while the relative difference remained the same. Hence, in accordance with the Law of Weber, the discriminative sensibility also remained unchanged.

Fechner, the founder of psycho-physics, has called attention to a very striking example of the approximate validity of Weber's Law when applied to sensations of light. It has already been stated that this law may also be formulated as follows: The intensity of sensation increases in an arithmetical ratio while the intensity of stimulus increases in geometrical ratio. For ages the astronomers have classified the stars according to the intensity of the sensations of light which the stars produce in the eye of the observer. On this basis they distinguish stars of the first magnitude, stars of the second magnitude, etc. Since this classification was first made on the basis of subjective impressions, we have succeeded in determining the objective brightness of these stars by the help of photo-chemistry. As a result it has been shown that the apparent (subjective) brightness increases in arithmetical ratio, while the real (objective) brightness increases in geometrical ratio. The most recent, thorough experiments upon the intensity of sensations of light have been made by Merkel,[1] König and Brodhun.[2] The result of their experiments demonstrates that the relative discriminative sensibility, in the case of light stimuli having a medium intensity, is approximately constant and corresponds to the Law of Weber. Deviations occur when the stimuli are very weak or very strong, as in the case of the other senses. The so-called "lower deviation" is due in part to the fact that the retina has a "light of its own" (Eigenlicht). The weak sensations of light are disturbed by slight irritated conditions of the retina that can never be wholly removed. They appear, for example, as a spotted glimmer in the

[1] Philosoph. Studien., IV, H. 4.
[2] Sitzungsber. d. königl. preuss. Akad. d. Wiss., 1888.

field of vision when the eyes are closed. This light which is in the retina itself, also renders it almost impossible to determine accurately the minimum of stimulus for sensations of light.[1]

The threshold of distinction appears to average about $\frac{1}{120}$ for stimuli of white light. It is larger for very weak and very strong stimuli, especially for weak rays of spectral red. Let us remember that we should not rely too implicitly upon these measurements of intensity, especially in the case of great or slight intensities of light. As regards the medium intensities of light and their variations, with which we are daily familiar, it can easily be conceived that in the course of development by natural selection the sense of sight was trained to perceive chiefly the relative differences of brightness and to ignore the absolute. If the law of Weber did not have at least an approximate validity, and the absolute differences of brightness were perceived very vividly, at every flash of sunlight and every time the sun was concealed behind a cloud, all the shades of our environment would be so distorted as to render an accurate and clear perception of the projections and depressions of objects exceedingly difficult. The accuracy with which we form our conceptions of the objects of the world as solid bodies, is essentially dependent upon the constancy of the relative threshold of distinction for a medium intensity of light.

Finally we again raise the important question. How is the sensation affected when not one but several fibres of the optic nerve are simultaneously irritated by the same stimulus of light? We have already seen that the fibres of the optic nerve are, in general, of equal value, *i.e.* each termination of the optic nerve receives a stimulus of any wave-length whatever. Even if we accept the assumption of Helmholtz, that there are three different terminations for each nerve-fibre in each element of the retina, we must still remember that this triad is repeated in all parts of

[1] The more recent experiments of EBERT'S are very worthy of notice. WIEDEMANN'S Annalen, 1888, and LANGLEY, "Energy and Vision," Am. Journ. of Sc., XXXVI.

the retina. The obtusion of the sensitiveness of the peripheral parts in the retina to red, and especially to green, may be disregarded here. Hence, in the case of the sense under discussion, we find relations bearing a close resemblance to those already considered with reference to the sense of touch. These relations depend on a series of terminations of nerve-fibres that are all essentially identical in function. In fact, the sensations of light produced simultaneously by the excitation of different parts of the retina stand in a relation to one another very similar to that of the sensations of active touch when excited simultaneously on different regions of the skin. They neither blend to a unit in quality nor increase their reciprocal energy, but are arranged together spatially so as to form an image of surface. In the sphere of visual sensations also we must abandon the attempt to explain the fundamental fact that the sensations of sight are projected into space, as are all other sensations, thus producing the so-called field of vision. We have simply to accept the general fact that our sensations are combined so as to present a contiguous arrangement; we can only attempt to explain the *order* of this adjacent arrangement. We must therefore restrict ourselves to answering the question: How does it happen that two sensations arising in neighbouring ends of the optical fibres are also combined contiguously in the field of vision? In answering this question we shall make use of means (Fig. 15) similar to those employed in the fourth chapter.

RR' is a cross-section of the retina; *CC'* is the corresponding cross-section of the cerebral cortex; *ML* represents the so-called Macula lutea, the part of the retina most sensitive to light, which is therefore generally fixed directly upon the object for the purpose of distinct vision. The ends of the visual fibres *aa'*, *bb'*, *cc'*, *dd'*, are arranged in the retina in the definite order just given. In the cortex of the cerebrum this succession has been materially changed. In the most favourable case we might suppose that a certain region of the occipital lobe corresponds to the upper parts of the retina, and another to the lower. But it is wholly improbable that the succession of the single fibres in the cerebral cortex remains the same as in the retina. We know, in fact, that the fibres of the optic nerve from the retina of the left eye, for example, terminate partly in the cortex of the left hemisphere and partly in the cortex of the right hemisphere of the cerebrum. Now how does it happen that in spite of this change in the order of the fibres, the sensations which they conduct to the cortex are arranged so as to correspond to the order of the fibres in the retina, and hence also to the order of the visual stimuli, and of the objects that are seen? A very accommodating, but untenable, theory is the so-called *nativistic* theory, which assumes that a definite point in space is allotted to each one of the retinal points from birth; but the theory is not at all in harmony with the

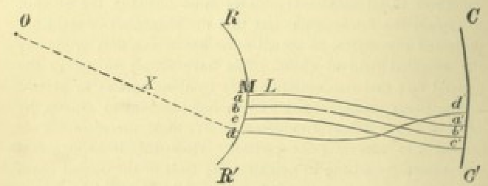

Fig. 15.

empirical data of physiological optics. We shall therefore proceed from the *genetic* standpoint, and attempt to show what data furnished by the physiology of the brain throw any light upon the arrangement of the spatial points, or upon the characteristic features by which they are distinguished. Suppose *O* to be an approximately point-like object, situated in the upper part of the field of vision, from which rays of light are sent to the retina *RR'*. These rays are united at *one* point in the retina by means of the peculiar structure of the eye. This point may be found by drawing a straight line from *O* to *X*, the point in the vitreous humour at which the rays intersect, and by producing this line until it reaches the retina. The object *O* (fig. 15) therefore sends all its rays to *d*, and irritates the ends of the nerve-fibres situated at that point. Let us now move the eye for the purpose of fixing the especially sensitive central point of the retina at *a*, the Macula lutea, upon the object *O* so as to obtain a more distinct image of the latter. In so doing the retinal image passes from *d* over the points *c* and *b* to *a*. On moving the eye a certain distance, it reaches *c*, a somewhat greater distance *b*, and a still greater distance *a*. As the eye is turned, and the retinal image of the object passes from *d* to *a*, we have a continuous series of motor sensations.[1] A motor sensation, having a definite magnitude, is associated with each termination of the nerve-fibres, and the intensities of these sensations of motion form a constant series. One retinal point, situated between two others, is constantly associated with a sensation of motion whose magnitude lies between the magnitudes of the sensations of motion with which the two adjacent points are associated. In this associated sensation of motion, each termination of the nerve-fibres possesses to a certain extent an acquired local sign. By repeatedly passing over all lines of the retina numberless times both from *a* and toward *a*, each retinal point is associated with a definite magnitude in the system of motor ideas. Thus a foundation is obtained for the localization of sensations. If a larger object OO' irritate the four retinal points, *a*, *b*, *c*, *d*, simultaneously, four excitations, d', a', b', c', will appear in the cerebral cortex followed by the corresponding sensations. The localization of these sensations in space takes place neither in complete confusion, *i.e.* according to an arbitrary arrangement, nor according to the succession of the ganglion-cells, d', a', b', c'. On the contrary, we localize the sensations of light according to the scale of sensations or ideas of motion associated with them. In this way each sensation is referred to its definite place. The order of sensations accordingly corresponds to the order of the points on the retina, and hence also to the order of the points on the object. It is clear that an infinite advantage was gained in the struggle for existence

[1] The chief features of the theory here presented originated with LOTZE.

by the first animal that localized its sensations in this way. If the protist, with its pigment-spots sensitive to light, has any sensations of space whatever, it must localize them almost wholly without regard to order. At least those protists in which the direction of the rays of light determines the direction of locomotion (Phototaxis, Strassburger) by the association of the sensation of light in one case with the motions of flight, in another case with the motions of approach, have obtained some basis for the distinction of two directions and for the localization of impressions in two directions. In the course of the phylogenetic development of the animal series that capacity to localize visual sensations was first developed which made the eye a proper organ for the perception of space. We find the wonderful rapidity, with which this arrangement of the sensations is accomplished, inconceivable; at once and without a moment's thought the image is before us, well arranged and unmarred by the slightest error. To be sure, a process of evolution extending through almost endless ages was necessary to produce and train a cortical apparatus of vision that can react with such fitness. The new-born animal or child inherits this apparatus.[1] Each single individual does not need to acquire it again laboriously, but only to learn to use it. A person who is born blind and receives his eyesight by an operation later in life, at first sees only coloured spots floating before his eyes. He recognises a circle or a square only with difficulty. It is only by degrees that he learns to use his cortical apparatus, and to associate the sensations of sight with ideas of motion and touch.

In concluding these investigations we can again render the development of spatial localization clear by comparison. Let us call to mind the position of a musical conductor who leads an orchestra for the first time. Numerous sounds from a large number of instruments are poured into his ears at the same

[1] Munk's more recent investigations, perhaps, throw some light on the physiological and anatomical structure of this cortical apparatus. Sitzungsber. d. königl. preuss. Akad. d. Wiss., 1890.

instant, and at first he is only able to project the masses of sound outward in confusion. But he gradually learns that the tone of this violin always comes from below to the left, the tone of that flute from the right, etc. In short, he learns to localize the tones of the different instruments by means of distinctions that are almost unnoticeable. Certain subtle distinctions in musical sound and in the sensations on the skin that accompany the tones according to the direction from which they proceed, assist him in localizing at once the tone of one violin in this place, and the tone of another violin in that place. In fact, the musical director is finally able to project the tones outward in the exact order in which the sources of sound are really arranged in space, even with the eyes entirely closed. Orchestral leaders have been known to construct in this manner a genuine "field of hearing" similar to the field of vision. This projection is accomplished very rapidly, and entirely without deliberation; it is just as direct and exact (that is, in accordance with the arrangement of the external stimuli) as the projection of sensations from the visual centre.

It is very striking, especially in comparison with the localization of tones which are heard simultaneously, that our visual impressions are characterized by continuity. A gap between them never occurs; in fact, even defects in the continuity of the nerve-ends of the retina, the so-called "blind spot" for example, are involuntarily repaired. We see the object, or the part of an object, corresponding to the blind spot, in the colour of its environment.

An anatomical explanation of this continuity in the arrangement of projected visual sensations may possibly be found in the anastomosis of the nerve-ends of the visual fibres in the retina, or in the universal interconnection of the ganglion-cells of the visual centre by means of the nerve-processes.[1] The chief ground

[1] In fact, according to more recent investigations, these connections are made not by the so-called protoplasmic processes, but by the axis-cylinder processes. Compare Golgi, "Sulla fina anatomia degli organi centrali del

for the continuity of sensations of sight, however, must be sought chiefly in the continuity of the associated ideas of motion.

The following facts in the sphere of visual perceptions are still to be investigated and explained in detail. First, the retinal image in the eye of the vertebrates is inverted; that which is on the right and above in the real object, is on the left and below in the retinal image, and *vice-versâ*. Still we do not see the object inverted, corresponding to the image on the retina, but right side up, corresponding to the object itself. How can we explain the fact that the retinal image is thus fittingly *re*-inverted? In reply we may first observe that the spatial succession in which the visual sensations are projected is not altered at all; it is simply a question of projection in its *totality*. So far as the projection as a whole is concerned, the re-inversion of the retinal image is determined and controlled by sensations of touch. In general we project our sensations of sight so that they agree with the tactual sensations by which we are guided to a certain extent. This capacity has also been acquired phylogenetically and not ontogenetically. We should here call attention to the fact that the inversion of the image on the retina which necessitates to a certain extent a second psychical inversion, is specifically characteristic of the eye of *vertebrates*. The composite image in the compound eye of the glow-worm, for example, is not an inverted, but an upright retinal image. The glow-worm or fire-fly can therefore project its sensations of sight exactly in the position indicated by the retinal excitations.[1]

A second question is suggested by the fact that we see with two eyes, hence a double retinal image is produced by the majority of the objects seen. How is it that, notwithstanding this fact, an object generally appears single to us? Why does it appear double only in very rare cases,—for example, when we push on

sistema nervoso," 1885; and FLECHSIG, Arch. f. Physiolog. (DU BOIS REYMOND), 1889.

[1] See EXNER, "Das Netzhautbild des Insectenauges." Sitzungsber. d. Wien. Akad. d. Wiss., 1889.

the side of the eye-ball with a finger while gazing fixedly at an object? This question has given rise to numberless physiological and psychological investigations and discussions. It is sufficient here to notice that, *physiologically*, the union of the two retinal images is already accounted for by the peculiar partial crossing of the optic nerve-fibres. By this means the excitations produced in the left half of both retinas are conducted *together* to the right hemisphere of the brain, and *vice-versâ*. The blending of the two images is provided for *psychologically* by the association of like ideas of motion, in general, with those points that are situated alike in the two retinas. It is for physiological optics to decide how far these two factors suffice, in a single case, to explain the blending of the two images.

The final question is suggested by the fact that the retinal images are superficial or planiform. It asks, Whence do our visual sensations receive their stereometric character? We see solids and not plane surfaces. In this case also it is obviously a question of association with ideas of motion and touch. It is at least very doubtful whether the two eyes, remaining wholly at rest, could ever achieve the construction of a stereometric image of space.[1] But our eyes are moved, there is a constant play of the muscles of accommodation (the ciliary muscle and the recti interni), the head is turned, the entire body is moved forward, the sensations of sight are controlled by the sense of touch. In this way a large number of new associated ideas of motion and touch is acquired. It is only by association with these ideas that our visual perception receives its stereometric character. Strictly considered, this perception in itself has neither a planimetric nor a stereometric character, since our sensations are at first projected merely in a definite direction, leaving it quite indefinite as to how far from us in that direction the object lies. For example, a person that is blind from birth and receives his eyesight later in life, conceives all objects to be directly in contact with the outer

[1] As to possible physiological conditions, also concerned in this case, see HERING, l.c., HELMHOLTZ, l.c., and others.

surface of the eyeball. He only learns by degrees to project his sensations of sight accurately also as regards distance and hence as regards stereometric relations.

It is self-evident that experiments, applied for the purpose of ascertaining the degree of certainty with which sight-impressions are localized and distinguished in space, may also be employed in the case of vision in accordance with the Law of Weber. Such experiments have shown that, in general, an object can be no longer recognised, even by direct vision, when the visual angle in which it appears becomes less than one minute. As regards the estimation of magnitudes of extension, it has also been demonstrated that the Law of Weber is only valid for the *medium* distances (*e.g.* lines). It appears, for example, that in attempting to determine one distance that will equal another given distance, the average error is about in proportion to the magnitude of the distance.[1] If the distances that are to be estimated become very large or very small, the "relative threshold of distinction" seems to be no longer constant. Furthermore, in the above experiment the individual variations are very great.

We have now essentially completed our investigations of visual sensations. The senses of hearing and sight represent the culminating points of sentient life. In future chapters we shall also find that higher intellectual processes are chiefly dependent upon the sensations of sight and hearing.

[1] This method is designated as the "method of the average or mean error."

CHAPTER VII.

THE TONE OF FEELING AND THE SUCCESSION OF THE SENSATIONS.

We distinguish three properties in each sensation: quality, intensity, and accompanying tone of feeling. To these are also to be added those characteristics of the sensations that have reference to space. The latter, and also the qualities and intensity of the sensations, have been discussed at length in the preceding chapters. In this chapter we turn to the last property belonging to every sensation, viz. the tone of feeling accompanying the sensation. We have already made use of the sign *f* to indicate this property. As we have seen, this tone of feeling is nothing more or less than the feeling of pleasure or pain (displeasure) that accompanies our sensations with varying degrees of intensity. At this point, however, we must beware of mistaking the words, "feeling of pleasure or pain." If we see a friend, we are glad; but this joy has nothing to do with the feeling of pleasure or pain accompanying the sensation, for it is not the sensation of seeing the friend in itself that produced the feeling of joy, but the idea associated with the sensation. The thought that he is our friend, that we can speak with him, etc., first awakens in us the feeling of pleasure. We must therefore make a sharp distinction between the tone of feeling which accompanies the sensation as such, and the tone of feeling that accompanies the ideas or images of memory whose activity has no direct reference to the sensations. We shall here refer at first only to the former. Let us cite a few simple examples of the tone of feeling accompanying sensation. If we strike the chord *c-e-g*, the sensation of sound is accompanied by decided feelings of pleasure. We therefore speak of the chord as harmonious. On the other hand, if we strike *c* and *d* together, the sensation of hearing is accompanied by a lively feeling of displeasure; in this case we speak of a discord. The feelings of pleasure are designated as positive, the feelings of pain or displeasure as negative tones of feeling. These concomitant feelings of pleasure and pain vary greatly in intensity. The chord *c-e♭-g*, the so-called minor chord, also produces a sensation of hearing that is accompanied by a feeling of pleasure; but the latter is considerably less intense than in the case of the major chord *c-e-g*. A solution of quinine has a more or less unpleasant taste, according to the degree of concentration. Finally, there is a long series of sensations that to a certain extent occupy a neutral position as regards the tone of feeling; that is, they are accompanied neither by a distinct feeling of pleasure nor by a distinct feeling of displeasure or pain. To this class belongs by far the greater part of the sensations received through the highest senses. How many visual images, musical sounds and noises daily throng our consciousness! How few of them are associated with any feeling whatever! The few that do give us positive feelings of pleasure or pain do not possess this emotional effect in the mere sensation itself. The emotional effect is for the most part a result of the ideas with which the sensations are associated, as in the above case, when one sees a friend. The emotional tone, or tone of feeling, is therefore by no means a necessary property of sensation. Between the scale of pleasurable feelings and that of painful feelings there is a zero-point or point of indifference. Only a limited number of sensations rises above or falls below this point as regards the emotional tone.

Let us now ask: On what does the emotional tone of a sensation depend? The tone of feeling obviously depends mainly on the *intensity* of the stimulus, or, more specifically, on the intensity of the sensation. A simple tone, lightly struck, generally leaves us indifferent. Feelings of pleasure appear and increase slowly, in proportion to the gradual swelling of the tone. The pleasurable impression of the pure tone has reached its absolute height as soon as the sensation has attained a medium intensity. If the intensity of the tone is further increased, the feeling of pleasure diminishes rapidly and finally passes into a feeling of pain. If the tone reaches the maximum of stimulus the piercing sensation of sound is accompanied by an intense feeling of the greatest pain and displeasure. Similar effects can also be produced in the case of any one of the other senses, The intense light that blinds us is unpleasant; light of a medium intensity imparts the most pleasurable sensations. We can also express this dependence of the emotional tone on the intensity of

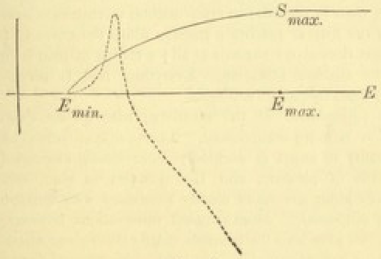

Fig. 16.

the sensation, diagrammatically by a curve. The unbroken lines of the above drawing (fig. 16), are already familiar to us. They represent the relation of the intensity of sensation to the intensity of stimulation. The intensities of stimulation are represented by the axis of abscissas, *E*. *E-min.* designates the minimum, and *E-max.* the maximum of stimulation. The unbroken curve indicates the path described by the increasing intensity of sensation, following the increase in the intensity of stimulation. The intensity of the emotional tone accompanying the sensation is designated by a dotted curve. That part of the dotted curve lying above the axis of abscissas designates a positive feeling, or a feeling of pleasure; the part lying below the axis indicates a negative feeling or a feeling of pain. We see that at the minimum of excitation or upon the appearance of a barely noticeable sensation, the curve of feeling rises above the axis of abscissas. It reaches its height at the medium intensity of sensation. Thence the feeling of pleasure decreases rapidly and changes to an increasing feeling of pain; the curve falls abruptly and sinks below the axis of abscissas.[1]

In certain mental diseases the tone of feeling is very characteristically changed. Thus, for example, melancholia is characterized by a sudden conversion of the feeling of pleasure to one of pain, even in response to much slighter intensities of sensation. Finally the disease reaches a stage in which the curve of feeling no longer rises above the axis at all; a feeling of pain is coupled with the slightest sensation. Everything that is perceived is accompanied by painful feelings.

The dependence of the emotional tone on the *quality* of sensation is more complicated. Among the sensations of taste the quality of sweet is decidedly more closely associated with sensations of pleasure, and the qualities of sour, salt and especially bitter are more closely associated with sensations of pain or displeasure. More accurate observations, however, show that in this case also the intensity chiefly determines whether the sensations are pleasurable or painful. We like our food a little salty, and we find a slight taste of bitter or sour pleasant, while on the other hand the most concentrated solutions of sweet are distasteful to us. Thus pleasurable feelings are coupled with the

[1] HORWICZ (Psychologische Analysen, II, 2, S. 26), emphasizes several not unjust objections to this presentation, which has been essentially adapted from WUNDT. He also emphasizes (with BENEKE) that very weak sensations are not seldom associated with feelings of pain. Hence the curve of feeling, before rising at all above the line at the zero-point, would first sink beneath it a short distance, at least in the case of certain qualities of sensation.—An acceptable synopsis of the appertinent literature is to be found in CESCA, "Die Lehre von der Natur der Gefühle." Vierteljschr. für wiss. Phil., 1886, X. Compare also in the same Ztschr., XI, O. KÜLPE, "Zur Theorie der sinnlichen Gefühle."

slighter intensities of sensation and painful feelings with sensations of greater intensity. It is worthy of mention that bitter produces feelings of displeasure even in degrees of intensity that are relatively much slighter; sweet, on the contrary, awakens such feelings only when the degrees of intensity are relatively very much greater. It is obvious that this fact is to be understood as merely a product of phylogenetic development. The mother's milk contains a 4% solution of sugar, besides its fatty and albuminous constituents. The sucking babe, in which especial feelings of pleasure were coupled with the sensation of sweet, sought the mother's breast more zealously, was better nourished and consequently enjoyed better chances of growing up. This peculiarity has been nourished thousands of years until to-day it is universal.

The tone of feeling accompanying sensations of smell has quite the same characteristics as in the case of sensations of taste. The intensity of sensation also chiefly determines the character of the emotional tone; the most unpleasant smell is converted into a perfume by appropriate attenuation.

The tone of feeling accompanying dermal sensations is of especial importance. In this case, indeed, the concomitant feelings of pleasure are considerably less pronounced than the feelings of pain. Tepidity, slight cold, a soft touch, impart but very slight positive tones of feeling. But the feeling of displeasure is just so much more pronounced when the sensation of warmth, cold, or pressure rapidly increases. In the case of heat, cold, and pressure, these intense feelings of displeasure are generally designated as pains. Pain, therefore, is no especial quality of sensation, but merely a special designation for the painful or unpleasant feeling that accompanies very intense dermal sensations. We also speak occasionally of a "painfully piercing tone," or a "painfully blinding light." It is worthy of mention in connection with painful dermal sensations, however, that the negative tone of feeling frequently obscures the quality of the sensation in consciousness. When very powerful effects are produced by heat, or cold, or by some very potent mechanical stimulus, as, for example, the thrust of a sharp instrument, we are finally convinced that we feel only pain, *i.e.* we perceive the tone of feeling quite apart from the sensation. On this account some authorities have often designated the sensation of pain as an especial quality of the dermal sensations.[1] But neither special "pain-spots" on the skin, nor a stimulus especially adapted in quality to cause sensations of pain have been shown to exist. It can be very easily understood also, why, on account of very intense stimulation, the feeling of pain has such an ascendancy only in the case of dermal sensations. As we shall find later, the voluntary action following a sensation is essentially dependent on the accompanying tone of feeling, as regards both its character and the rapidity with which it is executed. The more disagreeable a sensation, just so much more speedily and energetically do we seek to remove it; we either flee or defend ourselves. Now in the development of the animal series, the earliest, greatest, most frequent, and most direct dangers to the animal organism consist of mechanical and caloric stimuli. The animal organism must be able to accommodate itself to these stimuli, to respond with extraordinary rapidity by the execution of motions in defence or flight. Such reaction is in fact most fittingly attained by the association of a feeling of displeasure, so completely dominant as that of pain, with all sensations produced by intense mechanical and caloric stimulation. The claim has also been advanced that the sensation of pain is especially produced by irritating some part of the nerve-trunk or one of its chief branches, instead of the nerve-ends. This claim is sufficiently accounted for by the fact that irritation of the nerve-trunk of course affects a much larger number of fibres. It has also been thought that separate paths of conduction must be assumed in the spinal cord for sensations of touch and those of

[1] RICHET, "Recherches sur la sensibilité"; GOLDSCHEIDER, Arch. DU BOIS-REYMOND, 1885, S. 90. The remarkable statement of the latter, that even the intense caloric stimulation of heat-spots and cold-spots produces but a relatively slight pain (at least considerably slighter than that produced by the stimulation of the cuticle between temperature-spots), still requires explanation and confirmation.

pain. The reasons for this assumption are twofold: (1) Schiff has observed isolated analgesia (insensibility to pain) in animals after having severed the grey substance of the cord, the removal of the sensibility to pain being accomplished without disturbing the sensibility to touch; (2) in certain diseases, such as tabes, analgesia occurs without anæsthesia, *i.e.* without the loss of sensibility to touch. In fact it frequently happens in the case of tabes that the patient, on being pricked with a sharp instrument, first reports a sensation of touch and a few seconds later one of pain. Schiff's experiments in this line, however, are by no means free from all objections, and it is possible to explain all the other phenomena just quoted without assuming that there are separate paths of conduction in the spinal cord for sensations of touch and sensations of pain. It is sufficient to assume that, in the case of tabes for example, the nerve-fibres are sometimes altered by the pathological process so that they can still receive the weak stimuli and conduct the excitation to the cerebral cortex, although unable to transmit the more intense stimuli. If the latter produce any effect whatever, they are either first weakened before transmission, or the greater part is conducted more slowly.[1] Since we are almost entirely ignorant of the nature of the pathological changes affecting the conductivity of the sensory paths, however, it is difficult to see why this assumption should be rejected *a priori.* It is sufficient to explain both "analgesia without anæsthesia" and the separation of a sensation into two successive sensations, viz. a weak, painless sensation and a strong, painful one. As a result of these considerations we find that there is no ground whatever for regarding pain as a special *quality* of dermal sensation. On the contrary, we define that it is merely the strong *feeling* of pain accompanying the dermal sensations.

The tone of feeling that accompanies sensations of simple tones

[1] The more recent investigations by Golgi, Ramón y Cajal and Kölliker should be considered in connection with this question. According to these the sensory fibres, having entered the spinal cord, divide and also send off innumerable collateral processes further on.

having a medium intensity is not very strongly marked. There is a large number of qualities that exert no influence whatever upon the tone of feeling. Only very high or very low tones are generally more likely (*ceteris paribus*) to be accompanied by negative tones of feeling. The influence which is exerted by the quality of a tone-sensation is much more noticeable in the case of sensations of noise or musical sound, *i.e.* in the case of acoustic sensations that are produced by the combination of several simple tones. The most important fact for our consideration is that the irregularly periodic vibrations characteristic of noises, are, in general, not accompanied by positive tones of feeling; only the regularly periodic vibrations of musical sounds can impart a positive emotional tone. As we have already mentioned, when a key is struck on the piano we really hear not a simple tone, but a musical sound; that is, we hear a chord with very distinct overtones, which decrease in intensity in proportion to their distance from the fundamental tone and the numbers of whose vibrations stand in a simple numerical relation to each other. Each pure tone of the piano generally imparts a slight feeling of pleasure, and is, in fact, as we already know, produced by the *regularly* periodic vibrations of the particles of air. But we also know that certain combinations, both of simple tones and of musical sounds (the chords of a piano for example) possess a consonance incomparably more pleasant than that of either the simple tone or the simple musical sound. These are the so-called consonant chords. It is one of the most interesting and difficult problems to determine under what general conditions a combination of tones is consonant or dissonant, *i.e.* imparts a positive or negative tone of feeling. To begin with, it is conceivable, in fact obvious, that the consonant chords (for example, the common C-major chord, *c-e-g*) must consist of tones, the numbers of whose vibrations stand in a simple relation to each other. For we know it is only when this condition is fulfilled that a chord can be produced by a regularly periodic form of vibration. A regularly periodic form of vibration is the "conditio sine qua non" of strong positive emotional tones. In fact the numbers of vibrations of the tones *c-e-g*, for example, stand in the relation of the simple numbers 4 : 5 : 6. Not all chords whose component tones possess numbers of vibrations standing in so simple numerical relations, however, are consonant. For example, the simple chord *c-d* generally sounds quite dissonant, that is, it produces an entirely negative tone of feeling, despite the fact that it is a musical chord. The numbers of vibrations producing *c* and *d*, in fact, stand in the relation of the simple numbers 8 and 9. Hence not every chord of a regularly periodic form of vibration imparts the feeling of pleasure that accompanies a consonant chord. There are chords whose form of vibration is quite regularly periodical, but which are nevertheless dissonant. Now, why is the cord *c-e-g* consonant and the chord *c-d* dissonant? Both are not noises, but musical chords in the broadest sense;[1] both depend upon the regularly periodic vibrations of the particles of air. We might take into consideration the influence of the overtones that are mingled with each tone of the piano, for example, and refer the dissonant character of the chord *c-d* to the fact that in this chord the over-tones disturb the regularity of the form of vibration, which is not true of the chord *c-e-g*. This attempt at explanation fails however. *C-e-g* is consonant and *c-d* dissonant also when the chords are produced by tuning forks that have no overtones. Of the many answers that have been given to the above question, we shall consider only the one which Helmholtz has given in his noted "Theory of the Tone-Sensations." In framing his theory Helmholtz proceeds from the fact

[1] A musical sound (Klang) is in general any combination of tones that has a regularly periodic form of vibration or, in other words, a combination of simple tones whose numbers of vibrations stand in simple numerical relations. A tone of the piano is a special case of the simplest form of a musical sound. In this case the numbers of vibrations producing the separate component tones are in the relation 1 : 2 : 3 : 4, etc., and the intensity of the component tones decreases the higher they are above the fundamental tone. Conversely, the chord is a musical sound, or combination of musical sounds, whose component tones are all of approximately like intensity, and whose numbers of vibrations stand in the relation $m : n : o : p$, etc., the letters m, n, o, p, representing only whole members in general.

that when two tones having but slightly different numbers of vibration sound simultaneously, numerous so-called "beats"[1] or "throbs" can be distinguished; that is, the intensity of the sound alternately swells and diminishes. The number of these "beats" per second corresponds exactly to the difference between the numbers of vibration. These "beats" are also very unpleasant to the ear, especially when some twenty to forty of them occur in a second. The chord receives by means of these beats a peculiarly rough character. It can also be shown that the chord *c-e-g* produces no unpleasant beats, but that the chord *c-d* produces very unpleasant beats. In order to establish this separately for each chord in each octave, it is necessary to take into consideration more exactly the overtones mingled in the chord, and also the so-called "summation-tones," "difference-tones," and those tones which König designates as "Stosstöne." By this means, at least, Helmholtz thought to reduce the dissonance of discords without exception to the production of unpleasant "beats." It is probable, however, that still other elements act in connection with these beats to render one chord consonant, another dissonant to the ear. Perhaps, for example, the fact should also be considered that in dissonant chords the numbers of vibrations are generally in a more complicated relation (8 : 9 or 8 : 15), and that therefore the so-called "period" of the wave is considerably lengthened. In case of the combination of musical tones into consonant chords, it is possible that the agreeable character of the latter is determined in part by a number of partial tones common to all the members of the chord, as urged by Wundt.

The simple visual sensations having a medium intensity are accompanied only by a very slight positive tone of feeling. Even our joy in beholding the blue sky does not belong to the mere sensation. Associated ideas—such as the idea of the infinity of the blue vault above us, etc.—accompanied by *their* tones of feeling are also active to a great extent. Therefore the quality

[1] The accepted term in acoustics is "beat."—*T's.*

of the visual sensations, colour, has almost no significance for the tone of feeling. It is true that older psychologists, such as George, attempted to compare each colour with a definite taste; by this means they hoped to be able to ascribe a definite tone of feeling to each colour. Thus red was to correspond to salt, yellow to sour, blue to bitter and white to sweet. These are, however, mere subjective comparisons suggested by associated ideas (for example, "white," "sweet," "milk"). On the other hand, Goethe distinguished a plus and a minus side in the series of spectral colours. Red and yellow were to constitute the plus-side and act as excitative; blue and violet, the minus-side acting as depressive. Green was to be the transition between the two sides. In view of this classification Italian psychiaters have proposed to bring individuals afflicted with melancholia into a room containing red light, and those afflicted with mania[1] into a room containing blue light, for the purpose of dampening the morbid inclination to extreme abnormal tones of feeling. It is obvious that these views are due to the association of certain colours with certain ideas and their tones of feeling. Red reminds us of flaming fire; yellow of the life-giving light, etc. Hence in these cases the tone of feeling does not accompany a sensation but an idea. At most we may state perhaps that the qualities of sensation produced by dark colours, especially by those that represent the transitions of the spectral colours to black, such as red-brown, are less easily united or associated with positive tones of feeling. The tendency of black itself to produce a negative tone of feeling is due, in part at least, to the idea of something dismal and dangerous with which it is associated.

There are no "colour-accords" in the same sense that there

[1] The reader should bear in mind that the term "mania" is used by German psychiaters in a much more restricted sense than by English psychiaters. The German alienist includes under the term "mania" only those mental diseases that are characterized by the presence of morbid, gay emotions. It is to be understood in this sense of course in this translation. See also Chapter XII.—*Tr.*

are musical chords. Mixtures of colour produce sensations of colour that are just as simple as those produced by simple colours. We are unable to analyze the sensations produced by mixed colours. Therefore the consonances or dissonances of different colour qualities must be sought only in their spatial arrangement. In fact, a comparison of the paintings by the best masters of the Italian school shows beyond a doubt that certain combinations of colours are decidedly preferred. Thus Helmholtz calls attention to the triad,—red, green and violet, that are in fact combined in so many pictures with wonderful effect. However we know nothing as yet concerning the constancy and the exact conditions of this consonance of certain colours.

Besides intensity and quality, the *spatial arrangement* of the sensations is an essential factor in determining the accompanying tone of feeling. In this connection we shall consider only sensations of touch and sensations of sight as products of those senses that are characterized by the most highly developed and perfect relations to space. As regards the former, it is sufficient to mention that in general the positive tones of feeling accompanying *sensations* of touch produced by extended contact with a surface, are in proportion to the constancy and regularity of the surface.

The unpleasant sensations of a rough surface are produced particularly when the tactual sensations arising from extended contact with a surface are irregularly distributed and of unequal intensity; when some few *un*irritated nerve-ends always intervene between the *ir*ritated nerve-ends. The spatial arrangement of the *visual* sensations is of much more importance for the tone of feeling. Let us observe a straight line for the purpose of designating some point upon it that seems to us to divide the line into pleasing proportions. Fechner put this question to a large number of persons. As a result it appeared that, besides the point bisecting the line into halves, one other point was especially preferred, viz. the point that divides a line approximately in the extreme and mean ratio, or the "golden section." It is also exceedingly instructive to study the Italian works of architecture of older times; their wonderful effect is due almost wholly to their wonderfully symmetrical arrangement, *i.e.* to the division of the lines bounding the mass as a whole. However, regularity and especially symmetry in the spatial arrangement of visual sensations are by no means the only conditions of positive emotional tones.[1]

As a rule the periodic recurrence of a certain spatial arrangement produces a positive tone of feeling. It is much more difficult to establish a universal rule for curved lines. No one believes any more in Hogarth's absolute curve of beauty. In the case of curved lines the constancy of the sensation is a very essential factor in the production of feelings of pleasure; as a rule a straight continuous line makes a more agreeable impression than a row of points. The very minuteness of the interruptions in the sensations disturbs the impression. A crooked line constantly imparts associated sensations of motion; to a certain extent the eye follows the entire course of the line. The appearance of positive tones of feeling is largely conditioned by the constancy of the associated sensations of motion. The radius of curvature, therefore, should not change suddenly, particularly the constantly repeated slight. Irregular changes also have a very disturbing effect upon the sensations produced by crooked lines. The sensation must change either by a constant ratio, or if the change is very sudden it must also be very great. For this reason gentle arches play such an important *rôle* in ornamentation, and very flat angles are rarely found. But we have room here for only a very few short suggestions. As regards these same spatial forms, the æsthetical department of physiological psychology is still in its infancy.

Finally, the emotional tone of sensations depends very essentially on those properties of sensation that have reference to time. We shall make use of this opportunity to discuss the time-characteristics of sensations, which have thus far been hardly mentioned. Each sensation has a definite duration which in general corresponds to that of the stimulation. In the case of the excitation *Ec* in the cerebral cortex, we must accept this

[1] Fechner, "Vorschule der Aesthetik." Th. 1, Abschn. XIV.

statement as unconditionally valid. On the contrary, the statement that the duration of sensation corresponds to the duration of irritation is not quite correct as regards the excitation at the periphery, *Ep.* As an example taken from the sphere of visual sensations, let us call to mind the so-called "after-images" that appear in colours like, or complementary to, the colour of the primary image. If we observe a bright red disk and then close the eyes, we often see a red or light-coloured after-image which lasts some seconds after the external stimulus has vanished. This after-image then appears in blue-green, the colour complementary to red, and is often very intense. This phenomenon is produced, as we know, by the after-effects of stimulation upon the retina; the external stimulus *E* therefore was shut off by closing the eyes, but not the peripheral retinal excitation *Ep.* For this reason the sensation lasted longer merely as the result of a physiological phenomenon.

Let us now ask first, In what relation does the intensity of a sensation stand to the original stimulation when the latter continues for some time? We can easily employ an experiment to answer this question by listening to the approximately constant rushing of water through the faucet of a water-pipe. If we watch our sensations attentively, we observe that some seconds pass before they reach their greatest intensity; then they retain this maximum intensity for some time with but very insignificant deviations, after which they very gradually but not altogether constantly lose their intensity. The constant increase noticeable at the outstart of the experiment is obviously to be explained by physiological adaptation, especially in the peripheral organs. To some extent the ear must first be placed in a position favourable to stimulation. The quite unimportant variations in intensity during the maximum of sensation plainly have an approximately rhythmical character. According to the experiments of Lange[1] the intensity of sensation swells regularly *once* in about every 2·5–4 seconds. The length of these periods

[1] Philosoph. Stud., IV.

appears to differ for different sensations. We can perceive the fact most easily ourselves by holding a watch at such a distance from the ear as to render its ticking barely audible. By this means we are able to follow best the swelling and ebbing of sensation. It is very probable that these periodic variations in intensity are dependent on variations in the excitability of the auditory path from the labyrinth to the auditory centre in the temporo-sphenoidal lobe. Other slight variations are probably due to the fact that we cannot always regularly exclude other intercurrent sensations and ideas. The ultimate definite decrease in the intensity of sensation is undoubtedly due to a physiological fatigue that begins to be felt along the entire course of the sensory paths to the cerebral cortex, and to the simultaneous appearance of other ideas which constantly become more and more intense.

A further question is as follows: How long must stimulation last at least in order to impart a sensation? At first it would appear that, in general, an immeasurably brief duration is sufficient to produce a sensation. The intensity of stimulation, however, and in the case of optic stimuli the magnitude of the spatial image also, are of great importance. It appears furthermore that stimuli of very short duration impart sensations that are no more distinct in quality than sensations produced by very weak stimuli. At least, when the change of stimuli is too rapid, it is impossible for us to recall correctly, by association, the quality of a sensation (whether colour, pitch, taste, etc.) after it has taken place. The quality was too indistinct to awaken the related image of memory, or, in other words, the term designating the colour, the pitch of the tone, etc.

Thus at least eighteen vibrations are necessary in order that the pitch of a certain tone may be recognised. Since this law appears to be valid with approximate uniformity for high and low tones, the absolute duration of stimulation, in the case of the sense of hearing, is of less importance in the recognition of a tone than the absolute number of vibrations. It is very difficult to decide experimentally the degree of sensibility to differences in time, as in the case of acoustic impressions. It is worthy of mention, however, that Mach[1] found the difference noticeable when a tone lasting $\frac{1}{5}$ of a second is compared with one $\frac{1}{100}$ of a second longer. As far as these experiments have been carried at present, the Law of Weber does not appear to be valid in the above case.

Two or more sensations that follow one after the other at very short intervals blend into a series of sensations in time in a manner very similar to the way in which sensations produced by adjacent stimuli in space blend into a line. The interval of time that must elapse in order that two sensations may be perceived as separate in time varies exceedingly, according to the quality of the sensation. For the eye an interval of at least $\frac{1}{50}$ of a second is requisite, while only an interval of $\frac{1}{500}$ of a second suffices for the ear. This blending of sensations that follow one after the other very closely, is probably due to physiological causes.

On the other hand, however, let us call attention expressly to the fact that the projection and arrangement of our sensations with reference to time, the same as with reference to space, cannot be explained psycho-physiologically; we must simply accept the fact for the present, although we shall touch upon the question again at the close of these lectures. In this connection let us call attention to an essential difference between the perception of space and the perception of time. We project our sensations into a space of *three* dimensions, while not only our sensations but also their mental images, the ideas, are arranged with reference to time in but *one* dimension.

We can now introduce the question as to how many sensations we can have in general at the same time. The number of sensations possible from *one* sense at the same time is almost unlimited. We have already seen that co-existent sensations of sight and feeling are arranged together so as to produce an image of space and that co-existent sensations of hearing are blended to a complex of sound. But it is much more doubtful whether we can perceive a sensation of sight and one of hearing, *i.e.* two or more sensa-

[1] Sitzungsber. d. Wien. Akad., Bd. 51.

tions from different senses, simultaneously. In this case the weaker cortical excitation produced by a slight momentary sound, for example, often remains without a concomitant psychical process or, as we may say, unnoticed in consequence of the preponderance of another stronger cortical excitation, such as an intense stimulus of light acting at the same time. Therefore the sensations or, more properly, the sensory cortical excitations arrest one another, in very much the same way that, as we shall see in the future, the ideas check each other. This question must not be confounded with that as to how many simultaneously appearing sensations can be *recognised* or *counted*. Cattell[1] has made experiments for the purpose of investigating the latter question. He found, for example, that from 3 to 6 lines, visible 0·01 second, can still be correctly counted. In this case it is obvious that the facts of sensation are not alone concerned, but also the association of ideas, especially of ideas of number. This association is only possible in the case of a limited number of simultaneous, momentary sensations.

We can now return to our first question: How is the tone of feeling accompanying sensations dependent on their duration and succession in time? A long duration of sensation generally dampens both positive and negative tones of feeling. The manner in which several sensations follow one another in time only has an essential influence on the tone of feeling accompanying sensations of musical sound. A series of like sensations of tone, following one after the other, generally becomes wearisome; even when the quality of the tone changes an unpleasant feeling soon appears.

In order to obtain the pleasurable feeling belonging to rhythmical division, either the intensity or the duration of the single tones must be subjected to a more or less regular periodic change. In musical tempo and the versification of poetry we have sequences of acoustic sensations in which certain sensations

[1] Philosoph. Stud., III. Cattell's interpretation, however, cannot meet our approval.

are especially accented or intense, and all together have a definite duration.[1] In this connection it is not necessary to consider that two quarter-notes or a triplet can take the place of a half-note, etc., or that two short syllables may be substituted for one long, or two unaccented for one accented short syllable. Such uniformity, which we generally designate as tempo or verse, is constantly repeated with but slight change. At all events, the total duration of the sensations of sound and the arrangement of accentuation is constant for each new tempo or kind of verse. The qualities of sound, *i.e.* the notes and words, change, but the intensities of tone, the accentuations and diminutions, constantly recur at definite intervals or periodically. In poetry the close of such rhythmical periods can often be emphatically marked by choosing very similar tones with which to close the periods. In this form of emphasis lies the importance of the *rhyme.*

As regards the succession of sensations, therefore, a regular periodicity is the chief condition for the appearance of feelings of pleasure. It is not mere chance that maniacs and those afflicted with emotional paranoia often speak in rhythm and rhyme. Such phenomena harmonize rather with the morbid, positive emotional states characterizing these forms of psychosis.

From the preceding considerations we conclude that the appearance of positive or negative tones of feeling depends on very different conditions. This conclusion brings us to a problem that is just as interesting as it is difficult to solve. It is the question as to whether these various conditions may be comprehended under one common point of view,—the problem as to the nature of these tones. In answering this question it must be taken into consideration that, as mentioned in the beginning, not only the sensations, but also without doubt the ideas, have their emotional tones. Therefore we can first put the question as to whether the ideas borrow their tone of feeling from the

[1] The old style of metrical composition places more weight on the duration, the new style more upon the accentuation. The Alexandrine regards merely the number of sensations of sound.

sensations, *i.e.* whether they have simply received the tones of feeling belonging to those sensations of which they are the images of memory. This supposition is undoubtedly to be granted in many cases. The *idea* "enemy" and the idea "hate," therefore, are only associated with feelings of displeasure because we have often *felt* the attacks of foes and the effects of enmity to be unpleasant. But, on the other hand, it cannot be denied that the reverse is also true. Ideas often transmit their tones of feeling to the sensations. Thus as children, or perhaps later, we have heard a certain musical combination produced frequently in connection with a certain mournful song. The succession of tones in the chord, as sensation, does not partake of a mournful character but because mournful ideas contained in the words so often accompanied it, the negative emotional tone gradually becomes associated also with the sensations of sound; finally the chord itself is sufficient to produce a negative change in our tone of feeling that is quite independent of the mournful words. All attempts to assign certain constant tones of feeling to definite chords, rest upon just such a transmission of the tone of feeling from the idea to the sensation with which the idea is associated.[1] The sensation of black, as mentioned, probably produces a feeling of displeasure the more easily because the idea of something dismal or dangerous is associated with darkness. Hence, although the mere sensation of black is not necessarily connected with negative emotional tones, the colour of black has become the symbol of mourning among occidental peoples.

It is probable that the quality of sensations, in general, *originally* influences the tone of feeling only in this indirect way by means of their association with pleasurable or painful ideas, and that therefore only the intensity of the sensations and their succession in time and space have any direct effect upon their

[1] As regards chords, E. T. A. Hoffmann has probably taken the most extreme standpoint, since he believed that he was able to characterize each chord by a special state of feeling;—for example the chord of B-major was to express harmless joy; C-major, wild desire; A-flat minor, longing.

tone of feeling. A *universal* rule has not yet been found which shall state just *what* intensity and *what* arrangement in space and time produce feelings of pleasure or feelings of pain; and since the influence of these factors has been developed phylogenetically and will continue to so develop, no such rule can ever be formulated. As to the nature of emotional tones, it is obvious that they are to be regarded as *qualitative* characteristics of the sensations. Hence another quality, a feeling of either pleasure or pain, is often to be added to the qualities of sensation already discussed. This new quality, the tone of feeling, is capable of increase in intensity quite the same as the other qualities of sensation. To make use of an explanatory comparison, which is, however, somewhat inexact as to particulars, each sensation may be regarded as mixed with a certain proportion of black or white. The tone of feeling represents, as it were, a sixth sense which has only two qualities,—feelings of pleasure and feelings of pain or displeasure. One of these two qualities is united with impressions received from the other senses, and, under certain conditions, also with the ideas; the emotional feelings never occur wholly independently of sensations or ideas. But, apart from their dependency on other psychical states, and their relation to ideas, these emotional feelings are essentially distinguished in still another important respect from the proper sensations. The common quality of sensation is determined (1) by the nature of the external stimulus *E*, and (2) by the structure of the sensory apparatus (including from the peripheral sensory organ to the cortical centre) that receives the stimulus and converts the *E* first into an *Ep* and finally into an *Ec*. The simplest illustration of this is furnished by the mechanical stimulus, which imparts a sensation of pressure when applied to the skin and a sensation of light when applied to the retina. Innumerable qualities of sensation correspond to the innumerable qualities of stimulus. But the tone of feeling has in general only two qualities,—the feeling of pleasure and the feeling of displeasure or pain. The emotional quality of sensation is also dependent on the external stimuli and the sensory apparatus; but only the *two* emotional qualities of pleasurable and painful feelings, in their different degrees of intensity, correspond to the numberless qualities of stimulus and the different sensory apparatus. Each stimulus may be subsumed under one of these two qualities. Those properties of the stimulus and of the sensory surface receiving the stimulus, therefore, that cause the appearance of emotional tones, must be of a very general character. We must assume that indifferent stimuli merely produce an *Ec* in the cerebral cortex, while stimuli that are not emotionally indifferent (for example a too dazzling light) add something else to the physical process *Ec* in the irritated cortex of the cerebrum, the psychical correlative of which is the emotional tone. Therefore, properly considered, this emotional tone involves a reaction of the cerebral cortex upon the stimulus coming from without. This also explains the fact that like stimuli of the same intensity do not always impart the same definite tone of feeling. The qualities of sensation, *sensu stricto*, also depend in fact on the constitution of the cerebral cortex; but they are determined by constant properties of the latter, while the tones of feeling are determined by its variable properties. For the sake of completeness and perspicuity, let us cite once more the example of a light falling upon the eye. The excitant *E* is a light of medium intensity which produces a cortical excitation *Ec* and a sensation *S* corresponding to this excitation; if the intensity of the light increases, both *Ec* and *S* also increase. It is only when a definite intensity of light is reached that *Ec* and *S* no longer merely augment. From this point, at the same time that *Ec* and *S* are increasing, a new physical process is associated with *Ec*, and an emotional tone with the sensation. Naïve thought is therefore quite right in generally ascribing a more subjective importance to the tone of feeling, and a more objective importance to the common qualities of sensation.

A phylogenetic factor of great importance should be included in the characterization of the emotional tone. Those stimuli that are associated with feelings of pleasure in many cases directly accompany the acts necessary for the nourishment and propagation of animal life; those that are associated with feelings of pain often accompany situations in which animal life is endangered. Accordingly the stimuli of the first class generally incite approach to the stimulus, those of the second class urge withdrawal or flight. It is quite possible that this peculiar property of the cerebral cortex which enables it to react upon stimuli that are either generally injurious or useful with an entirely new psychical process, or, in other words, to add the so-called tone of feeling to the common sensation, has been developed phylogenetically to a higher degree of excellence from these motions of flight or approach. In the lowest stage of development the sensation directly imparts a motion that is generally fitting; in the highest stage the tone of feeling is introduced between sensation and motion. This tone of feeling, as we shall see, is of the greatest importance in voluntary action. It is of great advantage to us to possess the capacity for emotional tones, for the sensation itself generally furnishes the appropriate warning or allurement, but at the same time, by postponing the act of flight or approach, time is gained for the association of ideas and the play of motives. These conclusions will become more intelligible as soon as we have investigated the influence of the emotions upon the association of ideas and the motions of expression.

CHAPTER VIII.

SENSATION—IDEA—CONCEPTION.

In the preceding chapters we have followed in detail the development of sensation from external stimulation. Now, what becomes of the sensations which have appeared corresponding to the excitations of the cerebral cortex in the manner described, and which now become factors in the activity of association? Let us at first assume one of the simplest cases.

The complex sensation of a rose, for example, appears for the *first time* as the psychical correlative of an excitation in the cerebral cortex. This sensation is followed at once by the conscious play of motives or the association of ideas. But at the same time an image of the rose seen is deposited in the memory, or, expressed in the language of physiology, a trace of the cortical excitation that has taken place, is left in the cerebral cortex. We are compelled to come to this last conclusion by the fact that we recognise the rose when we see it again, that we are able to remember it, and that we can reproduce its image in memory. This *image of memory* or *mental image* that is deposited by each sensation we have designated as an *idea*.[1] What are the psychological elements of this image of memory, and by what excitation of the cerebral cortex is it produced? The older psychology pronounced the ideas to be only copies of the impressions or sensations, and to be only distinguishable from the sensations by

[1] The use of the German word "Vorstellung" in this more restricted sense was first introduced by Hegel and his disciples. It has since been used in the same sense, especially by LOTZE.

(According to the standpoint of the author, as expressed in his introduction, the corresponding English word is "idea."—*Tr.*)

their slighter vivacity. This view was emphasized most forcibly by Hume, whose noted "Treatise of Human Nature" cannot be too well recommended as a propædeutic course in psychology. On the contrary, however, we must now emphasize that images of memory or ideas are quite different from the sensations themselves. The *idea* of the sun, which is merely recalled to memory, has nothing of the brightness or splendour of colours which characterize the *real* sun, or the sun when seen. The idea of the sun is therefore by no means merely a faded sun; in this respect the great English philosopher is mistaken. It is not a difference in *intensity* between the idea and the sensation, but above all a qualitative difference.[1] The *sensual* vivacity, characteristic of every sensation, does not belong *at all* to the idea, not even in a diminished intensity. The *ideas* of the slightest rustling and of the loudest thunder, therefore, exhibit no difference in intensity whatever; in fact, all sensual vivacity is wanting in both. Hence we conclude that the different intensities characteristic of thunder and rustling as sensations are lost in the ideas. We may easily have an idea of the greater intensity of one sensation, but the idea itself is no more intense on that account. If we try to imagine thunder ever so vividly we do not hear the slightest rolling. But in what does the qualitative difference between sensation and idea consist? Or, to put the question in another form, what process takes place when a sensation disappears and its image is deposited in memory? Apart from the rare phenomena of "after-images" the sensation generally disappears almost instantly upon the removal of the stimulus. But with this removal of the stimulus the cortical excitation is not wholly obliterated, for the cerebral cortex never fully returns to its previous condition; some sort of material change still remains as a trace, a sign (σημεῖον), as Plato calls it.[2] This so-called

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[1] Also Bain ("The Senses and the Intellect," 3rd ed.) denies the qualitative difference between the sensation and its image in memory. His views are not based on sufficient grounds, however.

[2] Beneke ("Lehrb. der Psychologie als Naturwissensch.," 2nd ed., 1845,

"deposition" of the image in memory takes place entirely unconsciously; it has no concomitant psychical process whatever. We see a rose for the first time; the sensation of sight causes a series of actions: we stop, perhaps, stoop to the rose and then pass on, other visual sensations soon occupying our attention. We are by no means aware that in the mean time a trace of the visual sensation of the rose has been deposited. This is accomplished, as we say, *latently*, or without our being conscious of it; we only conclude that a latent image was left in the memory by the first sensation, because we are able to recognise the rose when we see it again. Let us, therefore, guard against the rough conception that the mental images are deposited in the ganglion cells of the cerebral cortex as an indefinite psychical product, an unconscious idea. On the contrary, there is no *psychical* element left of the sensory excitation *Ec* corresponding to the sensation, but only a permanent *material* change which we designate as *El*. This *El*, the remanent material trace, has no psychical correlate whatever. We can conceive of this *El* most easily as a definite arrangement and constitution of the molecules composing the ganglion-cells; in other words, it is a latent disposition. This purely material trace only becomes psychically active as an image of memory or an idea when we see the rose again or when, by means of the association of ideas or the play of fantasy, some related idea occurs to us; as, for example, the idea of red or of a fragrant flower. In order that the dormant image of memory, which is as yet only potential, may be aroused, therefore, the ganglion-cell having the disposition *El*, must first receive a new impulse from a new and similar sensation, or from some related idea with which it is associated; that is, the *El* must be still further changed in some definite way, becoming an ideational excitation which we shall designate as *Ei*. Hence the ganglion-cell is trained to a certain extent for a definite idea. We can

§ 27) very aptly designates *El* (latent excitation) as disposition ("Angelegtheit") but ascribes a psychical existence to the *El*'s without sufficient grounds.

illustrate this by comparing the ganglion-cells to the wheels, stars, monograms and other figures formed out of gas-pipes, as we see them used in illuminations. Unlit, they resemble the so-called latent images of memory; the disposition is already there in the form, structure, etc. But a spark must first light the gas that escapes from the innumerable holes of the pipes, in order that the latent form may become a living reality. It cannot be too urgently emphasized that the sensation in the psychical sphere corresponds to the excitation of the cerebral cortex imparted by the stimulus, but that *nothing* of a psychical nature corresponds to the residue of this material excitation. The designation "latent image of memory" is very convenient, but it contains a contradiction. Only either a new and similar sensation or the association of ideas can so change this residue of the material excitation as to produce a concomitant psychical process, a conscious image of memory or an idea. In the future we shall often designate these material traces or dispositions simply as images of memory, but only for the sake of brevity, and always with the restriction just mentioned.

Let us now follow the same process also physiologically. On seeing a rose, innumerable nerve-ends of the retina are irritated, and innumerable fibres of the optic nerve transmit the excitation to the visual centre in the occipital lobe of the cerebrum. It is very probable that the relations of the retina are to a certain extent reproduced in the visual centre, so that the superior margin of the retina, for example, corresponds to the anterior margin of the visual centre, etc. When the rose is seen, numberless ganglion-cells are excited in definite regions of the visual centre that correspond to the irritated portions of the retina. To this excitation of numerous ganglion-cells corresponds the visual sensation. But now where is the mental image of this sensation of sight deposited? In the same elements whose excitation produced the sensation? Physiological psychology can afford to quietly await the answer of physiology and pathology to this question; its conclusions harmonize just as well with the supposition that sensation and idea are dependent on the same cortical elements as with the contrary supposition. Nevertheless, for the sake of clearness, it is advisable to adopt one or the other of these two suppositions as a basis in the following researches. Therefore, if we assume in the future that sensation and idea depend upon *different* cortical elements,[1] it is because this supposition seems to correspond better to the physiological and pathological science of to-day. For example, it has been shown that the extirpation of a definite portion of the visual centre of a dog, or also the disease of definite parts of the human occipital lobe produces the condition of so-called mental blindness; in other words the animal on which the above-mentioned operation is performed and the diseased human being still continue to *see*, as appears from the fact that they follow objects held before them with the eyes, and avoid obstacles placed in the way; but they no longer *recognise* what they see. The dog no longer crouches before the threatening whip, nor dodges the stone thrown at him; the man stares at the most familiar objects of his environment as if they were wholly unknown to him and recognises them only when he touches them. This condition of mental blindness[2] without physical blindness, as also the analogous condition of mental deafness without physical deafness, must in fact be explained by the assumption that the sensations and the images of memory are dependent on separate elements of the cortex. Those who wish to investigate this very interesting question more particularly can refer to the competent treatises of Munk, Mauthner, Nothnagel, Wilbrand and others.[3]

[1] The antiquated idea of SCHROEDER VON DER KOLK, which has recently been adopted again by the school of Meynert (Vienna), does not place the seat of sensation in the cerebral cortex, or at least only partly. It substitutes for the latter, either exclusively or in part, the corpora quadrigemina. The first of these two suppositions is wholly incompatible with more recent pathological experiences; the second can only be made to agree with them with difficulty (compare also Chapters I and II).

[2] The cases of the loss of visual phantasy, described by CHARCOT, are also worthy of mention.

[3] MUNK, "Ueber die Functionen der Grosshirnrinde," Berlin, 1881; MAUTHNER, Wien. med. Wochenschr., 1880; WILBRAND, "Die Seelen-

We assume, therefore, that the sensation of the rose is produced in certain ganglion-cells, and that these numerous *sensory cells* transmit their excitation further to *one* other ganglion-cell, a *memory-cell.*[1] Hence if *a, b, c, d, e, f* represent ganglion-cells of the visual centre to which the fibres of the optic nerve lead, and if the rose, for example, excites only those fibres of the optic nerve which lead to the ganglion-cells *b, c, d,* the visual sensation of the rose corresponds to the actual material excitation of the ganglion-cells *b, c, d.* As soon as the rose disappears, the material excitation of the cells *b, c, d* is extinguished and at the same time the concomitant sensation vanishes. Only a part of the material excitations of *b, c* and *d* is secured in the distant ganglion-cell *I* where it leaves a merely material trace or change, the image of memory. In a manner which we shall describe later more exactly, this image of memory becomes psychically active only when we see the rose again, or when it is reproduced by the association of ideas. Let us remember that this scheme is by no means the only one conceivable, but it is the one most in harmony with present scientific knowledge. We shall ourselves be able to apply all the following discussions without difficulty to any other scheme, for they are essentially independent of this or any other physiological hypothesis.

Let us now continue our discussion, still retaining some definite sensible object, such as the rose, for example, from which to proceed. The rose not only produces a sensation of sight and its proper image of memory, the visual idea, but its fragrance also produces a sensation of smell, and its soft leaves produce a sensation of touch. These sensations also leave images of memory, an idea of smell, and an idea of touch. Hence, at least three images of the rose, different in quality, are deposited in memory, corresponding to the number of sensual organs upon which the

blindheit als Herderscheinung," Wiesbaden, 1887; NOTHNAGEL, Vortrag auf dem VI. Congress für innere Medicin; REINHARD, Arch. f. Psychiatrie, XVII and XVIII; LISSAUER, Arch. f. Psychiatrie, XXI.

[1] The expression "memory-cells," so far as we know, originates with HORWICZ, Psycholog. Analysen, I, S. 287 ff.

rose acted as stimulus. But the olfactory centre is far remote from the visual centre, and both of these are far distant from the centre of touch. Therefore, latent ideas are deposited in three ganglion-cells that are far remote from one another and in quite different parts of the cerebral cortex. The following sketch represents in rough outlines a hemisphere of the cerebrum. At *V* lies the visual centre, at *F* the centre of feeling (in the restricted sense including touch), at *H* the centre of hearing, and at *Sm* the

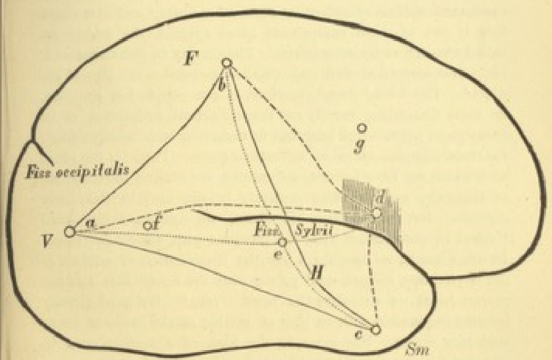

FIG. 17.

olfactory centre. Three component ideas of the rose have been deposited in the ganglion-cells *a*, *b*, and *c*. The ganglion-cell *a* is connected by the associative fibres with both *b* and *c*, and in the same manner *b* and *c* are connected with each other. Furthermore *a*, *b* and *c* have been often incited simultaneously,—that is, we have often seen, touched and smelled the same rose at the same time, and the corresponding images of memory were accordingly deposited in the cells *a*, *b* and *c*. As a result of this frequent simultaneous appearance of the three component images, if *b* is excited, *a* and *c* are also always excited sympathetically. When we discuss the laws of association in a future chapter (IX), we shall learn why only the cells *a* and *c* are sympathetically excited by *b* with which they have often been simultaneously active, although *b* can be shown to be connected by associative fibres with many other ganglion-cells. For the present it is sufficient to know that the component ideas of an object of sense are deposited in different parts of the brain, that these component ideas are connected with one another by associative fibres,[1] and that therefore, if one of these component ideas appears, the others are called into action by association. The totality of the component ideas thus associated with one another constitutes the idea of the object. The idea "rose," therefore, is not simple but complex, its unity depending merely on the reciprocal association of its component parts. But language furnishes us with another unity for these complex ideas of sensual objects. Thus far the ideas with which we have become acquainted are entirely independent of language, and therefore probably belong also to the lower animals. But man names his ideas; we articulate the word "rose" in connection with the complex idea above described. In other words, we execute a peculiar combination of motions of the larynx, lips, tongue, and palate with the result that another person hears us articulate the word "rose." We have already become acquainted with an idea of motion as the cause of every voluntary action. For example, the idea of a motion used in grasping the pen comes into the mind and without further impulse we seize the pen. In a similar manner we must conceive of the *ideas* of articulation as the cause of the motions of speech. These ideas of articulation are mental images that have been laboriously acquired by the repetition of the motions necessary for speech.[2] This assumption has received a very decided

[1] HERBART designates this associative connection of component ideas, imparted by different senses, as "complication."

[2] The contradiction that seems to be contained in this statement will be explained in a subsequent chapter (XIII).

confirmation from pathology. If the portion of the brain represented by the hatched spot in the drawing is destroyed, we observe a remarkable phenomenon. The person thus afflicted still retains command of all his sensual ideas; he still understands what we say to him; he moves the tongue, the larynx, the lips, and the palate the same as before the appearance of the disease. But he has irretrievably lost the delicate combination of movements performed by the tongue, larynx, lips, and palate, necessary for the articulation of any word,—"rose" for example. The mental images or ideas of his motions of articulation have been destroyed.

These ideas of articulation, which can be shown to be deposited in the posterior, inferior part of the frontal convolution (at *d*, fig. 17), are connected with the component ideas of an object of sense by the associative fibres. Thus for example, as the accompanying illustration shows us, the ganglion-cells *a*, *b*, *c*, in which the component ideas, or images of memory, of the fragrance, colour, and form of the rose[1] are deposited, are not only connected with one another by paths, but also with a single ganglion-cell or complex of ganglion-cells situated in the frontal lobe and containing the complicated idea of motion, necessary for the articulation of the word "rose." In the drawing we distinguish all the cortical elements that stand in relation to speech by the shading. The same facts that characterized the component ideas *a*, *b*, *c* in their relations to one another also characterize the idea of articulation *d* in its relations to *a*, *b* and *c*. As soon as *a*, *b* or *c* appears, *d*, the word for the thing seen, smelt or felt occurs to us, and *vice versa*. The idea of articulation *d* is especially adapted to be a higher unity for the three component ideas, because it is uniformly and directly connected with these three ideas, without being itself a component idea immediately dependent on a special object of sense. Hence its general character.

But the idea of articulation *d* does not constitute the sum total

[1] In the case of an object acting also upon our senses of hearing and taste, of course, two more component ideas would be added.

of all the elements of speech related to the whole idea "rose." When we *hear* the word "rose," we understand what the word means, and the colour, form and fragrance of the rose occur to us. Therefore an image of this sensation of *hearing* the word which we have heard spoken by another must exist in the cerebral cortex and be in connection with *a*, *b*, *c* and *d*. It is obvious that this "acoustic image" of the word "rose," or the idea of the spoken word "rose" which we have *heard*, is to be sought in the auditory centre in the temporo-sphenoidal lobe. In fact there is quite a definite region in the superior temporal convolution at *e*, the destruction of which by disease leaves all the functions of the human brain, including speaking and hearing, intact with the exception that the ability to *comprehend* words is removed. A person in whom the region at *e* has become diseased still hears words that are spoken to him very well, but does not understand what he hears. Once familiar words sound to him as if they belonged to a foreign language; but if he sees the same words written, he knows at once what they mean. Evidently this individual has lost the acoustic images of memory that once gave him the power of recognising words; in the language of anatomy, he has lost the acoustic *memory*-cells, but retained the acoustic *sensation*-cells; he is *mentally* deaf to words. Hence the complex idea "rose" is still further aided by the "idea of the spoken word as heard" (*e*); the latter idea is connected with *a*, *b*, *c* and *d*, and also contributes towards establishing a unity for these partial ideas. This explanation can be carried still further; the educated person has a *visual* idea (*f*) of the word which he has read, the anatomical location of which is also comparatively well established, and an idea (*g*) of the motion used in writing the word. Both of these ideas must be taken into consideration. However, it is not necessary here to continue the discussion of these component ideas further, for analogous deductions can be made in each case without difficulty.

We can sum up the foregoing deliberations as follows:—The idea "rose" consists of three partial or component ideas, corresponding to the same number of qualitatively different sensations imparted by the real rose; with these are also associated two ideas of language, the idea of the motions used in pronouncing the word and the acoustic idea of the word as heard. The total complex of these five ideas we also designate as a *sensual* or *concrete conception* of the rose. A single definite rose produces but one single idea which consists of various partial ideas. These single ideas as a rule are not connected with the special idea of a word, except in the case of proper names. Only after many single roses have deposited their images of memory or single ideas in the mind, are all these single ideas connected with the one comprehensive idea of speech, "rose." The sensual or concrete conception, therefore, has in almost every case a certain general character. The development of concrete conceptions, as we understand them, is therefore closely connected with the development of speech. We may here mention a fact incidentally that is very interesting. Pathology demonstrates almost beyond a doubt that the component ideas constituting a concrete conception (*a*, *b* and *c*, for example) all exist twice in the brain. Each hemisphere has its visual idea of the rose. For this reason complete mental blindness is only known to occur in human beings when the corresponding regions of the occipital lobe are destroyed in both hemispheres. On the other hand, in the case of man, the linguistic ideas, both those of articulation and those of hearing, are deposited in the two specified regions of but *one* hemisphere,—in the left hemisphere of right-handed persons, and *vice versa*. We must refer to the physiology of the brain for an explanation of this fact, which at first seems to be exceedingly strange.[1]

The first and simplest concrete conceptions are the most specific. We see a hundred single roses, and thus repeatedly experience a constant combination of a definite colour, form,

[1] WERNICKE, in his little work "Ueber das Bewusstsein," (Allg. Zeitschr. f. Psych., Bd. 35), was the first to analyze concrete conceptions physiologically in a manner similar to the above presentation. MEYNERT also pursues a similar course in his "Mechanik des Hirnbaues."

fragrance, etc., but with different surroundings. These repeated experiences are sufficient to produce a somewhat more general conception of the *rose* in the cerebral cortex and to associate it with a word or, more correctly, with ideas of language. A much greater generalization is requisite for the deposition of the far more general conception "*plant*" in the cerebral cortex and its association with ideas of speech. The most of these more general conceptions are produced in the following manner. Experience furnishes the cerebral cortex with numerous concrete individual conceptions consisting of several component ideas, for example, the concrete conceptions of tulip, rose, oak, etc. Despite great differences, some of the partial ideas of these single conceptions either possess certain similarities, or they are entirely alike. Therefore, according to a law of association with which we shall become more exactly acquainted later, these similar ideas become associated with one another. For example, all have the green colour of the leaves in common. Therefore, while the component ideas of the rose together constitute a very compact complex with which the word "rose" is associated, the totality of the concrete conceptions of rose, tulip, oak, and numberless other plants, constitutes a far more comprehensive but less compact or definite complex with which the word "plant" is associated. The appearance of the conception "plant" in consciousness is also accompanied (1) by the appearance of the linguistic ideas of the word "plant" both as spoken and heard, (2) by the sympathetic excitation of the innumerable component ideas belonging to the concrete ideas of all single plants, or as it has often been expressed, by their "sympathetic vibration." For this reason the more general concrete conceptions are not so simple as has been presumed; on the contrary, the more general a concrete conception is, the greater is the number of loosely associated, single ideas which it sympathetically excites whenever it appears in consciousness, and hence the greater is its complexity. An apparent unity is only furnished by the idea of the one word with which all these individual ideas are associated. Hence when we think of "plant," and, apart from the word, endeavour to define the content of this conception more accurately, definite individual plants appear before the mind's eye at once, though somewhat indistinctly. These are in fact those very individual ideas that were sympathetically excited by the appearance of the conception, and especially those that we have met with most frequently, and which therefore act most forcibly. Hence a physiological process that extends over almost the entire cerebral cortex corresponds to the act of thinking a concrete general conception; the extent of this physiological process is much greater than that accompanying the thought of a concrete individual conception. For this reason the ideas of words, both as articulated and heard, are of greater importance to the more general conceptions than to the more specific conceptions. The loose complex of ideas constituting the former would not hold together without the common bond of connection between the component ideas which is furnished by the idea of the word. The manner in which we acquire concrete general conceptions goes far towards proving this presentation. As children we often see a rose, a tulip, or an oak; at the same time we hear the word "plant" pronounced, and we repeat it. Thus both a motor and an acoustic idea of speech are formed and associated with numerous concrete individual ideas all of which have a certain similarity to one another despite all differences. The entire system of these associations of concrete individual conceptions, with the idea of the one word applied to all, constitutes the *general concrete* conception "plant."

Another particular kind of concrete conceptions consists of those which are produced by associating the idea of a single word with a series of successive concrete ideas. To these belongs the concrete conception "thunderstorm," for example; it comprehends a series of visual and acoustic ideas representing events that do not all occur simultaneously, but in part successively.

As we have seen, concrete conceptions consist either of complexes of ideas, or of a succession of such complexes that are associated with an idea of speech. These complexes of ideas are all directly derived from certain sensations; for example, the concrete conception of a thunderstorm may be reduced to a succession of ideational complexes—dark-grey clouds, rain, lightning, thunder, etc. All of these ideational complexes further consist of ideas produced directly by sensations; for example, the complex "rain" consists of the component acoustic idea, acquired by having heard the pattering of the rain, and the visual idea, acquired by having seen the falling drops.

In the concrete conceptions with which we have thus far become acquainted all the component ideas refer directly to the sensations. All conceptions also that express the relations of concrete objects to one another may be directly referred to sensations, and are therefore to be considered as concrete conceptions in the sense understood by us here. Let us take the conception "similarity" for example. On innumerable occasions, when the child sees two or more similar objects, it hears the word "similar" pronounced, perhaps at first with reference to two similar play-things. In the beginning the child has similar sensations from both objects, but as yet knows nothing about this similarity of its sensations. Then it hears the word "similar" in reference to the two playthings for the first time. The word "similar" at first signifies to the child only those "two definite similar playthings." But the child hears the word "similar" frequently on other occasions; it hears two similar trees, two similar houses, etc., designated as similar. In other words, the child's idea of the word "similar" becomes associated with innumerable *pairs* of similar concrete images of memory. The idea of the word "similarity," that originally signifies to the child "two definite similar playthings," gradually changes as more and more of these different pairs of similar ideas are associated with it. The ultimate result is the idea of a word that is associated with numerous pairs of similar ideas whose specific content (playthings, trees, etc.) it has entirely lost. The content of the idea "similar" thus finally depends merely upon the fact that certain pairs of ideas are similar. Such concrete conceptions we shall designate as *concrete conceptions of relation.* We have just seen how the child, the individual, acquires these concrete conceptions of relation, and what their physiological basis is in the adult. The difficult question as to how these conceptions of relation have developed phylogenetically, that is, in the human race, does not demand our attention here. A subsequent chapter (IX) will explain how it is that we are able to find the pertinent conception at once on seeing an object, or the appropriate conception of the relation of similarity when two objects are seen. At present let us call attention to the fact that primarily these conceptions of relation are also concrete, *i.e.* they are derived directly from sensations. This is made still further evident by the fact that the terms of a language for such conceptions of relation as "proportion," "sequence," "consequence," etc., are derived almost without exception from special concrete cases.

With the above we have exhausted the most important kinds of *concrete* conceptions. From these we shall now pass directly to the physiological deduction of *abstract* conceptions. Logicians have by no means always understood the same thing by "abstract conception." The scholastic philosophers called "white" a concrete conception and "whiteness" an abstract conception. Likewise, in the present century, the famous author of "A System of Logic, Ratiocinative and Inductive,"[1] John Stuart Mill. Others have designated that which we called a general conception as an abstract conception; accordingly, "this rose" and "this plant" would be concrete conceptions; but on the other hand, "rose" and "plant" would be abstract conceptions.

Physiological psychology leaves but little room for the assumption of so-called abstract conceptions. We shall designate as abstract conceptions those conceptions that cannot be directly reduced to sensations and their mental images. We have already seen above that the simplest concrete conceptions consist of a complex of component ideas that are associated with one another and with the idea of a word. This association of the component ideas, as, for example, the fragrance, colour, and form of the rose, corresponds to the combination of sensations which we have often

[1] People's Ed., p. 17, § 4.

experienced and which produced the ideas. In fact, the combination of ideas is merely a consequence of the combination of sensations. But our ideas are not only produced when awakened by sensations; they are also produced when there is complete absence of sensation; when eyes, ears, and all the other organs of sense are at rest, our imagination or thought may still be active. Thus, in a manner well known to us, the component ideas that have been derived from the sensations are brought into new combinations or complexes which do not occur at all among the sensations. These new combinations of component ideas we shall designate as *imaginative ideas* or *reflective ideas*. If we imagine a garden, it may, indeed, be some definite garden that we have often seen; the partial ideas that are reproduced are chosen and combined in exactly *the same* manner in which the sensations were often actually produced by that definite garden. But the association of ideas, which in the special case about to be considered we are wont to designate as fantasy or the faculty of imagination, can select and combine the component ideas "tree," "bed," "rose," etc., in a new complex different from any that ever really occurred with the sensations. Then we have the idea of an imaginative garden that we have never actually seen. These imaginative or reflective ideas do not originate directly from the sensations; in other words, they do not refer directly to an external object. The imaginative ideas also occur successively or in series, the same as the concrete conceptions that are derived directly from the sensations. Of still greater importance is the fact that these ideas of the imagination may also be generalized the same as the concrete conceptions, and that even the most general concrete conceptions may be newly combined in thought. By this means we also form general conceptions and words that have no direct relation to any object outside of our consciousness. Such conceptions we may designate as abstract, in case we desire to employ this term which is not, however, entirely suitable.

Here we shall pause.

It is sufficient to have established the manner in which the stimulus produces the sensation, to have shown how the latter leaves its idea or image in memory and how the idea becomes a concrete conception through its association with ideas of speech as heard and spoken, thus reaching the first degree of generalization. The concrete conception may then be more and more involved in generalization or it may also express relations, but it always refers directly either to sensations of concrete objects or to the ideas originating in these sensations. The abstract conceptions represent combinations of ideas to which analogous combinations of sensations have never corresponded. We see that the preceding conclusions have prepared the way for a new classification of our psychical processes. This further analysis of the data with which we are furnished, the sensations, ideas, and concrete and abstract conceptions, requires the assumption of two parallel worlds—the world of physical phenomena and the world of psychical phenomena, to the latter of which belong the sensations that should be considered as the effects of the physical phenomena. This classification of phenomena is further warranted by the observation of our fellow-beings, who give us oral information as to their inner conscious life. The further continuation of this subject, and especially the question as to whether this division of phenomena can be justified or not, we must leave to quite another science, namely, *epistemology*.

The more exact deductions of this science would necessarily depend to a great extent upon that conception of relation which we designate as cause or causality. For the purposes of physiological psychology it is sufficient to accept both series as given; this science merely borders on the problems of epistemology in the deduction of the abstract conceptions.

Let us now return to the images of memory or ideas having a *concrete* content. We remember that in connection with the theory of sensation we distinguished three properties of sensation, (1) quality, (2) intensity, (3) tone of feeling or emotional tone. To these were also added under certain circumstances, those properties of sensation that refer to space and time. Now can we distinguish similar properties also in the mental image of the sensation, in the idea? The simplest deliberation demonstrates that ideas differ from one another *first* as to their *content* or, as we may also express it, as to their *signification* or *meaning*. For example, the ideas "king" and "plant" have very different contents. A *second* difference lies in the *vivacity* or *distinctness* of the ideas. For example, we have a very lively or clear idea of a "rose." We have experienced the complex of sensations imparted by the rose so many times, that the image of memory or the idea "rose" is very vivid and distinct. Our idea of a rhododendron's blossom is probably much less distinct and vivid. The reason is obvious, the complex of sensations produced by the blossom of a rhododendron has been much less frequently experienced by us. But the vividness of the idea varies also when the content remains the same; the botanist or the gardener has a much more vivid idea of the flower of a rhododendron than one not schooled in botany. In fact, our own idea of the rhododendron's flower changes in the degree of vividness and distinctness. If we see the blossom of this plant to-day, perhaps for the first time, to-day and to-morrow its idea or image in memory remains very vivid. After a few days[1] the distinctness of the image is seen to have diminished somewhat; in case we do not see the flower again, the lapse of a year will suffice to remove both clearness and vividness almost completely.

A *third* property of the ideas, besides content and vivacity, is their *emotional tone*. The idea of *this* man is accompanied by a pleasant tone of feeling; the idea of *that* man, by an *un*pleasant tone of feeling; in other words, the general idea "friend" is

[1] The investigations of PANETH (Centralbl. f. Physiol., 1890, No. 3) is very interesting. According to these investigations it may be assumed that the mental image does not diminish perceptibly in sharpness at all during the first five minutes after the sensation has vanished. It then begins to lose its sharpness slowly. This gradual loss of the power of distinct recollection is by no means merely a diminishing of the *intensity*. At the same time that the latter decreases, a peculiar constant change takes place in the *quality* of the image. This change is hardly to be described, but is generally designated by us as the *fading* of the image from memory; it is identical with that which we designate as the loss of distinctness or sharpness.

accompanied by a feeling of pleasure; the general idea "enemy," by a feeling of displeasure.

Finally, we have to consider the characteristic features of ideas with reference to time and space. As regards space it is obvious that the ideas are not generally projected into space in just the same manner as are the sensations. The complex of sensations produced by a definite tree is decidedly of a spatial character. The idea or image of this definite tree in memory, an image which we reproduce in recollecting this definite tree, also has a certain decidedly spatial character. But many ideas, especially those that are most general, are not characterized by any reference to space whatever. Even the general idea or conception "tree" has almost wholly lost its spatial character; this is still more the case with the more general conception "plant." The spatial characteristics of the conceptions generally become less pronounced in proportion as the ideas are combined in more extensive generalizations. The ideas partake of the character of time quite as much as do the sensations, *i.e.* they are characterized by a certain duration and sequence. One idea occupies us perhaps but a moment, another two seconds, etc.

We now pass at once to the question as to whether more than one idea ever appears at the same time or not. Simultaneous ideas blend to complex ideas; hence two separate ideas cannot appear in the same moment of time.

Thus we find that the images of memory, or the ideas, also have three properties apart from those characteristics which refer to space and time. Therefore we might very easily conceive of the content of the idea as corresponding to the quality of the sensation, the vivacity of the idea to the intensity of the sensation and the emotional tone of the idea to the emotional tone of the sensation. In fact, it may be added that the content of an idea depends essentially upon the quality of the sensation which leaves the idea in the mind. This statement however is not to be regarded as unexceptionable. If we see but two definite kinds of dogs during our lifetime, as a greyhound and a poodle for example, the general idea "dog," which we construct from our ideas of these two kinds, would receive a very different content according to whether the poodle or the greyhound had been seen more frequently. The idea would in fact bear a decidedly greater resemblance to the animal that had been more frequently seen. Therefore not only the quality, but also the frequency of the original sensations determines the content of the ideas,—at least the content of the more general ideas. The vivacity of the ideas presents a similar case. The intensity of the original sensation is indeed a very essential factor in determining the vividness of the mental image. An intense flash of chain-lightning will generally leave a more vivid image in memory than faint sheet-lightning. But other factors are just as important for the vividness of the images. In this case the frequency with which the complex of original sensations has been experienced, is of especial importance. If we *often* see a certain man, the latent material trace of this complex of sensations is more deeply imprinted on the elements of the cerebral cortex than when we see him but rarely. We can recall the idea of this man more easily and more *vividly* if we have seen him often. As above mentioned, we must imagine this material trace *El*, which we designated conditionally as a latent image of memory, to be in reality a definite spatial arrangement and a definite constitution of the molecules. Originally this arrangement is very unstable; not until after the same sensation has been very frequently experienced does the molecular arrangement which it creates and leaves, become stable. Only after the ganglion-cell has acquired in this manner a very definite and fixed disposition of its molecules can a *vivid* idea be awakened from this disposition by association. At the same time the idea is more easily awakened by association, the more fixed the arrangement of molecules, *El*. But there is another factor which affects the vivacity of ideas besides the degree of stability with which a latent image is fixed in memory. The vividness of the actual ideas varies according to the energy of the impulse which the ganglion-cell containing the disposition *El*, receives from the association of ideas. If we see rain-clouds on a hot day, for example, the association of ideas immediately following the visual sensation, gives an impulse to two ideas, the idea that our person will be drenched and the idea of the cool refreshing air that is to be expected. In this case the former idea will probably receive the stronger impulse, and will therefore appear most vividly in consciousness. Hence the vividness of an idea by no means depends alone on the intensity of the original sensations, but also on a number of other factors. We can advantageously distinguish two kinds of vivacity dependent on different factors: (1) That vivacity of ideas which depends upon the more or less complete stability of *El*, and is accordingly intimately concerned in the qualitative distinctness of the content of an idea; (2) that vivacity of ideas which depends on the energy of the impulse that changes *El* to an actual idea or the latent image of memory to an active image of memory. Psychologically the two kinds of vividness are by no means wholly identical. Vividness as dependent on the first factor may be designated specifically as *distinctness*,[1] that dependent on the second factor as the *energy* of an idea.

Finally, we can draw one more simple conclusion with reference to the latent images of memory. If these are in fact only material dispositions, the material change in the ganglion-cell will not be without influence upon this molecular disposition. In other words, if new and more or less similar sensations do not again renew this disposition, in the course of time it will imperceptibly lose its stability and be finally obliterated. The simplest introspection agrees with this statement. This loosening and final destruction of the latent mental images is nothing more than that which we call forgetfulness; we forget ideas that are not constantly and repeatedly re-excited by similar or like sensations.

With the above we have essentially completed our theory of the idea or image of memory, and are acquainted with the entire material of which the association of ideas makes use. We must now investigate the nature and laws of the association of ideas itself.

[1] It is obvious that this "distinctness," strictly considered, is a qualitative property of the idea; it expresses the exactness with which *El* corresponds to the original sensations.

CHAPTER IX.

THE ASSOCIATION OF IDEAS.

THE association of ideas is accomplished by the use of two kinds of elements; new sensations are received from the external world and the mental images of former sensations are already at hand in the cerebral cortex. These latent ideas are constantly called up in consciousness and associated with the new sensations. We see a dark cloud, *i.e.* a stimulation, *Ec* (cloud) has been transmitted from the retina to the sensory cells of the cerebral cortex. The psychical correlate of this material excitation of the cortex is the visual sensation of the dark cloud. A series of related ideas are connected with this sensation by association,—for example, among others, the idea of rain. The material excitation, *Ei* (rain) in the memory-cells of the cortex corresponds to this idea of rain, which is associated with the visual sensation of the cloud. This material excitation *Ei* (rain) did not exist before, only the material disposition *El* (rain) was already at hand in the memory-cells where it had been deposited by one or more former visual sensations of rain. Previous to its excitation no psychical process corresponded to this *El*; it was merely a material trace—a *latent* image of memory. Only after the association of ideas has changed the *El* into *Ei* does a psychical phenomenon, the idea of rain, also appear as the correlative of *Ei*. In the same manner this one idea is followed by numerous others; latent images of memory are constantly called up above the threshold of consciousness, or, as it is often expressed, *reproduced*. It is just this process of reproduction that we designate as the association of ideas or ideation. We must, however, guard against viewing the association of ideas either as an active or passive *being*. On the contrary "association of ideas" is a brief term designating the *process* of the reproduction of ideas. Our present task is to establish the laws according to which this association of ideas takes place, and to render them physiologically intelligible. Why is the sensation of a grey cloud followed by the idea of rain, and the latter by the idea of being drenched, of returning home, or of raising the umbrella? This is all that we are called upon to explain in the general laws of the association of ideas. We shall now consider the process somewhat more accurately, and for this purpose we shall distinguish two cases. The sensation that introduces the association of ideas may either be more or less new, or we may have experienced it before in a more or less similar manner. Accordingly the content of the first idea with which the sensation is associated is either like or different from that of the sensation. We have already often seen just such a grey cloud, or at least one very nearly the same in appearance; but we have probably never seen the "northern lights." Upon seeing the grey cloud or an old acquaintance, either one is recognised at once; upon seeing the aurora borealis there is no recognition. In the first case the idea of a *like* cloud, formerly seen by us, may appear. In the second case the idea of a *similar* sensation of light—the sun, for example, may be reproduced. Therefore the association of ideas may begin either with or without a recognition. Let us next consider the first case and attempt to explain the physiological basis of recognition. We see a grey cloud for the first time; let us assume that a series of sensory ganglion-cells, for example, b, c, d, e, in the cortex of the visual centre are stimulated. In the manner explained above a latent image of memory is now deposited in another ganglion-cell. Let this other ganglion-cell, the memory-cell, be designated by α. This α (fig. 18) is probably connected either directly or indirectly with all of the sensation-cells, a–i, etc. On the other hand, many other memory-cells β, γ, δ, etc. (only one of which, β, is represented in the drawing) are also connected with the sensory cells a–h, etc. The sensation is associated with the latent image of memory deposited at α

instead of the one deposited at β, simply because the resistance to conduction happens to be least in the paths leading to α. Now let us suppose that a rain-cloud appears in the visual field for the second time. The psychological process is clear; when the cloud is seen again, the mental image of the cloud that we formerly saw occurs to us again. But what is the physiological basis of this process? Let us assume that upon seeing the rain-cloud for the second time, certain other sensation-cells, as *g*, *h*, *i*, for example, are excited. How does it happen that upon seeing

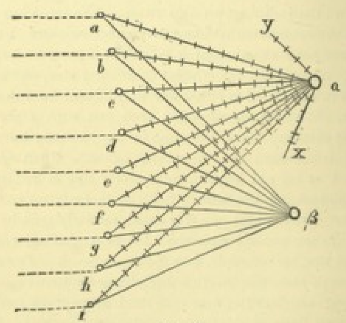

FIG. 18.

a cloud for the second time the mental image of the first cloud is recalled, or, in other words, that the excitation of the sensation-cells *g*, *h*, *i*, is transmitted directly to α and not to one of the other memory-cells connected with *g*, *h*, *i*, as β for example? The explanation of this fact is as follows: The ganglion-cell, α, and the paths of conduction leading to it have been definitely trained or, as we may say, "tuned" by the first excitation; that is, since they were first stimulated they have been much more sensitive to every *similar* excitation and much less sensitive to every dissimilar excitation. This sensitiveness to a definite excitation is indicated in the illustration by cross-lining the paths $b\,\alpha$, $c\,\alpha$ and $d\,\alpha$, etc. The specific sensitiveness however is not restricted to α and the paths $b\,\alpha$, $c\,\alpha$, $d\,\alpha$, that were directly stimulated when the object was first seen, but extends also to all paths leading to α,—$a\,\alpha$, $e\,\alpha$, $f\,\alpha$, $g\,\alpha$, $h\,\alpha$, $i\,\alpha$, $x\,\alpha$, $y\,\alpha$, $z\,\alpha$, etc. Hence if we see a cloud for the second time and the sensory cells g, h, i, are thereby stimulated, the excitation of g, h, i finds numerous paths open by way of which it may be conducted to various memory-cells—to α, β, or γ for example. But since the cloud was first seen, certain of these numerous paths (viz., those leading to α,—$g\,\alpha$, $h\,\alpha$, and $i\,\alpha$) have been much more definitely "tuned" or highly sensitive to that special excitation which produces the image of the cloud. For this reason the seeing of the cloud is the only visual sensation that calls up just the mental image of the cloud from but the *one* memory-cell and no other, no matter what sensation-cells may be excited. Therefore in a certain sense a selection is made from the paths that are open to the further transmission of the excitation after it has arrived in the cerebral cortex.

In the above paragraph we have attempted to explain in brief what physiological processes may occur in the cerebral cortex during an act of recognition. Let us call attention, however, to the fact that, in view of our limited knowledge concerning the processes of excitation in the cerebral cortex, this explanation is wholly hypothetical as to particulars; it can therefore be absolutely correct only in its fundamental features. We have already mentioned in a previous chapter that the local separation of the sensory elements from the memory elements has not yet been demonstrated, although it is comparatively probable. With very little trouble we can transform the presentation given above so that it will harmonize with the assumption that sensation and memory depend upon one and the same material substratum. We have furthermore always spoken of sensory *cells* as the substrata of the sensations and memory-*cells* as the substrata of the mental images; but this is also hypothetical. It may be that it is not the ganglion-*cells*, but the network of *fibres* in the cerebral cortex that experiences the excitation corresponding to the sensation and that acquires a certain fixed material disposition corresponding to the images of memory. It is also comparatively unessential whether the above-mentioned fixed disposition be regarded as confined to the cells or as extending to the paths of conduction as well.[1] The essential features of the process as just described remain entirely untouched and unchanged by these various different assumptions. A certain stimulus causes a material change or excitation, *Ec*, whose psychical correlative is the sensation. This *Ec* does not wholly disappear when the stimulus vanishes; on the contrary, it leaves behind a trace of the excitation, the disposition *El*. If a stimulus, similar to the one that first produced the sensation, again acts upon the cortical elements, the excitation thus caused finds numberless *El*'s already at hand. By virtue of the above-mentioned fixed and specific dispositions characteristic of the different elements, this second stimulation acts only upon that *El* which was formerly produced by the same or similar stimuli, and changes it into *Ei*; thereupon the latter is accompanied by a parallel psychical process that was wanting in the condition *El*. Only this *one El* "responds," as we may express it. But as soon as *El* becomes *Ei*, the image of the cloud formerly seen comes into the mind; we *recognise* the cloud.

Let us not imagine, however, that this recognition takes place as a special act in the case of every sensation that is perceived again after having been once experienced. Commonly we do not *recognise* the things with which we are already familiar at all; we simply perceive them.[2] The appearance of the mental image of former similar sensations to a certain extent determines only

[1] The disposition of the memory-cells would then be simply identical with *El*.

[2] MÜNSTERBERG, Beiträge z. experim. Psychol., H. 1, S. 136. ERDMANN, l.c. The latter is quite right in emphasizing that in the case of recognition the sensation and the idea of former like sensations do not appear separately, but as a single process or phenomenon (HERBART's "Verschmelzung" = "blending").

the starting point and chief course of the ideation that follows. This is already the case in the example which we cited at the beginning of this lecture. Especially those ideas that, combined with the image of memory which first appeared, constitute the concrete conception of the object, are as a rule immediately associated. We see a rose in the distance and at once recognise it as such; the visual idea "rose," deposited in the memory by the sensations of many former roses, has directly occurred to us. Very often, however, this does not take place at all as a special act; but the other component ideas which together constitute the concrete conception of the object rose—the ideas of its fragrance, of the smoothness of its leaves and, above all, of articulating the word "rose"—are directly associated with the visual sensation. If the last of the above-mentioned ideas—the idea of articulating the word "rose"—is sufficiently intense, it immediately imparts the movements of articulation, and we exclaim "a rose!"[1]

Let us now pass on to the second case: we have a sensation that we have never formerly experienced. It is obvious that such a sensation finds no path that is entirely suited to it; the excitation will therefore doubtlessly follow that path which is best adapted for its conduction. Strictly considered, almost all our sensations are *new*; a sensation rarely recurs in *exactly the same* manner or form. When we see a definite rose again that we have seen before, the mental image of the same rose as formerly seen recurs in the mind. In this case, of course, one might say that the sensation first reproduces an idea of like content. But if we see any rose whatever, or some flower that is entirely unknown, only the general idea "rose" or "flower" appears; we have never before seen a rose or flower with which the one that we now perceive exactly corresponds. Therefore in this last case the sensation first reproduces an idea having a *somewhat similar* or *related* content; an idea having a content *like* that of the sensation does not exist at all. But absolute dissimilarity as distinguishing a

[1] Compare LEHMANN, Philosoph. Studien, Bd. V.

new sensation from all other former sensations is still more rare than absolute likeness between a new and a former sensation. Let us remember that our sensations are generally complex and that therefore certain similarities between the elements that compose both the former and the new sensations will very rarely be found to be entirely wanting, despite the fact that the newly experienced sensations are more or less distinctively characterized. Therefore the investigations that we have made above in connection with the first case may also be applied in the second case when the sensation is apparently quite new. We may recapitulate both cases as follows: *The first idea which is associated with the introductory sensation is determined by its complete likeness, or, more frequently, its similarity to the latter.* The association of the *following* ideas or, in the language of physiology, the further propagation of the excitation within the cerebral cortex, is accomplished according to another law, with which we must now become accurately acquainted.

This chief law of the association of ideas, psychologically expressed, runs thus: *Each idea reproduces as its successor either an idea that is similar to it in content, or an idea with which it has often appeared simultaneously.* Association of the first kind may be also designated as *internal*, that of the second kind as *external* association.[1] The principle of external association is *simultaneousness* or *synchronism*, that of internal association, *likeness* or *similarity*. We think of a landscape and at the same time the idea of the friend in whose company we have seen it occurs to us. This is a case of external association. Associations of similarity are considerably less frequent. When a sensation enters into the association of ideas, the *first* idea with which it is associated is always reproduced by some similarity between the two, as we have seen above. But when the first idea has been once awakened by the sensation, the further ideas follow almost ex-

[1] The external association corresponds approximately to Herbart's "indirect reproduction," the internal association to a combination of the "indirect" and "direct reproduction."

clusively according to the principle of simultaneousness, *i.e.* by external association. Let us above all, however, guard against considering the so-called external association as unessential or superficial, and the internal association as closer or more intrinsic. The contrary is true. The entire process of education endeavours to awaken related ideas in the child *simultaneously*, *i.e.* to combine them by means of external associations. The child asks: "What is that?" and he is answered, "A tree." Thus the first external association between a visual idea and an idea of hearing is established. The ideas of sight and hearing are wholly unlike each other, but by virtue of constant simultaneous appearance they become very closely associated. We shall trace this influence of external association even as far as the logical processes of thought. On the other hand, the internal association of ideas or the association by similarity is very superficial wherever it occurs in its *pure* form; it is probably confined almost exclusively to the acoustic ideas of words that sound alike. Thus, for example, the acoustic idea of *chest* can reproduce the idea *guest*; the acoustic idea of *pain*, the idea *rain*.

Let us now seek some physiological basis for external associa-

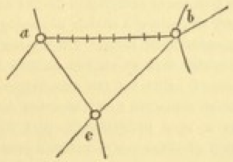

Fig. 19.

tion. The question arises first: Why does one idea reproduce only some other idea with which it has often appeared? Let *a*, *b*, *c* (fig. 19) be three ganglion-cells in which, under the conditions already often mentioned, we conceive three mental images or ideas to be deposited. All three are connected with one another and with numberless other cells by fibres. Let us suppose the three ideas corresponding to the three ganglion-cells to be wholly different from one another; furthermore, let the ideas *a* and *b*, or the sensations corresponding to them, be supposed to have appeared very often simultaneously, but not *a* and *c* nor *b* and *c*. Whenever *a* and *b* are stimulated at the same time a sympathetic excitation takes place in all the paths issuing from *a* and *b*. It is obvious that this sympathetic excitation is particularly great in the path *ab*, uniting *a* and *b*. In consequence of the more frequent simultaneous excitation of *a* and *b* the path *ab* will become more practised, *i.e.* it will acquire an entirely specific disposition fitting it for the transmission of an excitation taking place at *a*, to *b*, or of one taking place at *b*, to *a*. By means of this frequent sympathetic excitation, the resistance of the path *ab* to conduction is diminished, and accordingly every excitation taking place in *a* or *b* will follow the path *ab* as the best conductor. Expressed in the language of psychology,—if a given idea *a* is present in consciousness this moment, the next idea to be associated with it will be *b*, which has already often appeared simultaneously with *a*.[1] But this is nothing more or less than the law of external association of ideas stated above, which, as we have seen, governs the process of association almost exclusively.

It is unnecessary to deduce a similar physiological basis for the law of internal association of ideas. On the one hand we should only repeat essentially that which has already been stated concerning the fitness of paths for the association of the *first idea* with a given *initial* sensation; on the other hand this internal association plays a very insignificant part in thought. The internal association of ideas can sometimes predominate over the external in cases of mental disease, especially whenever the so-called "flight of ideas" (Ideenflucht) rules. These maniacs at times combine rhyming words in entirely senseless associations, —hound—bound—sound, for example. Here the similarity of

[1] Ultimately, of course, this coexistence of the ideas *a* and *b* may be reduced to the coexistence of the sensations from which they originated.

the ideas of articulation produces these combinations. Formerly association by contrast was also assumed as co-ordinate to the association by similarity. Contrast, however, is only a special case of similarity. Only, and in fact, *just* those ideas contrast that differ in one point while they are similar in very many other points. Therefore association by contrast is but a special case of association by similarity.

The following proposition is merely a deduction from the chief law of the association of ideas. Complex ideas that have certain component ideas in common also reproduce each other reciprocally. Thus the idea of a sleeping person may reproduce that of a corpse. The idea of a sleeping person is to be regarded,

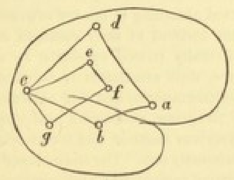

FIG. 20.

psycho-physiologically, as composed of very many component ideas that correspond to numerous excitations in very different parts of the cerebral cortex. The same is true of the complex idea of a corpse. In the above diagram (fig. 20), for example, the excitation of the ganglion-cells *a*, *b*, *c*, *d*, corresponds to the idea of sleep; the excitation of the cells *c*, *e*, *f*, *g* to the idea of death, so that the excitation of the cell *c* corresponds to the component idea of rest common to both the complex ideas of sleep and death. Let us now ask whether it is an association of similarity or of simultaneousness when the idea of sleep reproduces that of death? It is obviously an association of simultaneousness, for the component ideas *a*, *b*, *c*, *d* are associated with one another, and the component ideas *c*, *e*, *f*, *g*, with one another according to the law of synchronism. Now if the component ideas *a*, *b*, *c*, *d*, which together compose the idea of sleep, are present in consciousness during the first moment, each one of these component ideas is capable of reproducing in the second moment another series of ideas with which it has been previously associated according to the law of synchronism. But the component idea *c* is also associated with *e*, *f*, and *g* in accordance with the law of simultaneousness, and is therefore able to reproduce these component ideas also, and hence ultimately the idea of death. Hence the principle of simultaneousness is quite sufficient to explain the association of two such ideas as "sleep" and "death." Expressed in more general terms, the association of those complex ideas which have one or more component ideas in common, is effected according to the law of synchronism. These complex ideas, on account of their common component ideas, are obviously internally related or similar to each other; and yet, as we now see, their association is accomplished according to the law of simultaneousness, and not according to the law of similarity. The foregoing statements now enable us to fully understand our previous assertion that the association of ideas by resemblance is extremely rare. The resemblance of ideas depends chiefly upon common components, and complex ideas that have common component ideas reproduce each other mutually by an association of contiguity.[1]

We have still a few words to add with reference to the principle of synchronism that governs the association of ideas to so great an extent. This principle is not to be understood as signifying that the simultaneousness must be complete or absolutely exact in every case. On the contrary, ideas mutually reproduce one another also when they themselves, or the sensations by which they were produced, follow *one after the other in direct succession.* The idea of the blow *seen*, and that of the blow *felt*, are essentially connected by such an association of succession in

[1] J. STUART MILL and BAIN, on the contrary, have in vain attempted to reduce all association by contiguity essentially to association by resemblance.

time. This direct succession operates quite the same as simultaneousness; in this case also a certain path of association is specifically fitted for conduction. The word "contiguity" very suitably comprehends both ideas, simultaneousness and direct succession. Such ideas as "lightning" and "thunder," produced by sensations that do not follow one after another in direct succession, but are separated by a greater or less interval of time, owe their association to the fact that they are generally and preferably combined into a concrete conception (thunderstorm), in the manner formerly discussed, by means of a common idea of articulation. The ideas "lightning" and "thunder" are synchronically contained in the conception of thunderstorm, though the sensations that lie at the foundation of these ideas in reality always occur successively.

In our further discussions we shall proceed entirely from the chief law as just discussed, that the successive members of a series of ideas are associated by simultaneousness or contiguity. Let us now recollect once more that the above presentation of the law of association by synchronism represents the simplest case of association. We conceived the simple idea *a*, present during the first moment, to be followed by the simple idea *b* in the second moment, and both *a* and *b* to be located each in *one* cortical element. But most of our ideas are in fact not simple but very complex; accordingly, as we have seen, each complex idea is not connected with *one*, but with *many* elements scattered over the entire cerebral cortex. Most ideas are units only in so far as they are psychical phenomena, not as physiological phenomena. Accordingly the association by simultaneousness does not occur in reality between two simple elements *a* and *b*, but between the numberless component ideas, or component excitations contained in *a* and *b*. Without further explanation we can see that the deductions made above are also equally valid for the most complicated ideational combinations. But now let us consider that every total idea, as *a*, is not only associated with *one* other total idea *b*, but also with *many*, *b*, *c*, *d*, etc., and that furthermore all the component ideas contained in *a* (a_1, a_2, a_3, etc.), participate in a large number of other associations, in part with total ideas, in part with component ideas. The question now arises at once,—which one of the many ideas associated with *a* or its components will actually follow *a* in consciousness? In other words, why is *a* followed by *b* in one case, and by *c* in another, etc.? Why is the image of a friend followed in one case by the idea of a landscape that we have seen in his company, in another case by the idea of the city in which he now lives, and in a third by the motor idea of going to him? In a certain sense there is a contest between numerous ideas for the next place in the moment following the appearance of *a*. As the simplest self-observation teaches, only *one* of these ideas is victorious; this *one* may be very complex, *i.e.* numerous component ideas may be excited sympathetically; but with the exception of this *one*, all other ideas remain latent as purely *physiological* dispositions without a psychical correlative. They remain E_1's without becoming E_1's. Now what decides in favour of *one* idea to-day, and in favour of another to-morrow? One theory, that may be designated as the theory of apperception, and which is still very popular in Germany, assumes that a faculty of apperception has control over the association, and, as a superior power, decides or chooses to turn the attention now to this, now to that idea. Thus to a certain extent it controls the association of ideas. It can be easily seen that this theory creates a very problematical, hypothetical faculty of the soul, thereby rendering a relapse to the old unscientific psychology inevitable. We must therefore ask whether the elements contained in the association of ideas itself are not sufficient for the explanation of this "choice" from among a large number of ideas. An accurate investigation shows beyond a doubt that this choice may be very satisfactorily explained by facts with which we are already familiar. In the first moment we have the idea *a*; of the ideas *b*, *c*, *d*, *e*, etc., that may be possibly reproduced in the second moment, some are very closely associated with *a* because they have very often appeared simultaneously with it. We could easily conceive the idea following *a* to be already unconditionally determined by this factor. If this was the only determinative factor, that idea, as *b*, which has most frequently appeared simultaneously with *a* would always immediately follow the idea *a*.[1] But other just as essential factors must be considered here. One of the chief among these is the intensity of the different mental images in question. Ideas that *formerly* often appeared simultaneously with *a*, but that have seldom appeared *recently*, will generally be overcome in the contest. How many of the oft-repeated associations of childhood are "forgotten," as we say, at a more advanced age. The path of association has lost its capacity for conduction and the ganglion-cell its peculiar disposition E_b in consequence of the material changes that have been in progress many years and the absence of any new actual excitations. Of still greater importance than the intensity is the emotional tone of an idea. Those ideas that are accompanied by the more vivid emotional tones, be they positive or negative, always have the best chance in the contest of association, and are far more liable to leave their latent state E_b and become E_i's. Let us think, for example, of the university town in which we have formerly studied; the verbal idea of the name of the town will in by far the majority of cases remind us first of our pleasant or unpleasant experiences there. All those ideas will first occur to us that are accompanied by any comparatively intense, emotional tone. In short, we give our attention to those ideas that are most interesting to us.

Therefore the choice of ideas is not alone determined by the energy with which the latent ideas in question are associated with *a*, but also by their intensity and tone of feeling. The co-operation of all these factors alone is sufficient to make sure of great variability in the association of ideas; but there is still a fourth important factor to which we must now turn our attention. Let *b*, *c*, *d*, *e*, *f* be five latent ideas, that may be considered as possible

[1] It is self-evident also that the time which has elapsed since the last simultaneous appearance of *a* and *b* is not without influence. The specific fitness of the paths of association is also gradually lost if no adequate excitation occurs for a long time.

successors of *a*. As a rule, these ideas, *b*, *c*, *d*, *e*, *f* themselves, are associated with one another by direct or indirect paths of association. In this connection we shall make use of an important law which we derive from the general physiology of the nerves. A statement of this law, suitable for our purpose, is as follows:—If an excitation of a definite intensity (*m*) take place in one cortical element, *b*, and another excitation of a different definite intensity (*n*) take place at the same time in another cortical element, *c*, which is connected by a path of conduction with *b*, the two intensities of excitation may reciprocally modify each other. This modification may manifest itself either by arresting or by inciting the excitation. Let us now return to the latent ideational excitations, *b*, *c*, *d*, *e*, *f*, all of which, in a certain sense, desire to become psychical. In accordance with the law that we have just cited, these latent ideas, which are at first material excitations, all stand in a complicated reciprocal relation; they mutually arrest or incite each other.[1] In consequence of this reciprocally arrestive and incitant influence, an idea that is affected chiefly by arrests may be overcome in the contest of ideas despite its greater distinctness, its more vivid emotional tone and its closer association with the initial idea *a*. On the contrary, an idea that is perhaps less favourably conditioned as regards these three factors, but that is aided by the incitant influence of other latent ideas and by the absence of any arrestive influence, may be victorious, that is, it may be associated with the initial idea *a*. Hence a fourth factor which conditions the succession of ideas, must always be taken into consideration. We may designate this factor briefly as the "grouping"[2] of the latent ideas. Furthermore, we can easily perceive that this grouping is exceedingly changeable. For this reason the series of ideas will constantly change. To-day *c* follows *a*; at some other time *a* will be fol-

[1] To the above should also be added particularly the arrestive or incitant influence that is exerted upon the nascent ideas to a great extent by those predecessors of *a* that were actual ideas shortly before *a*'s appearance.

[2] In the Original, "Constellation."—*Tr.*

lowed by b, which will have been freed from its arrests in the meantime. Only by this means can we explain the wonderfully great multiplicity of our thoughts. The same sensation, the same idea can remind us of one thing to-day, and of another to-morrow; to-day it can reproduce the thought of that which is nearest our environment, to-morrow the idea of that which is most remote.

Wahle[1] relates a very beautiful example illustrating this influence of the grouping of latent ideas. For a long time he had had no recollections whatever of Venice, although the Gothic Rathhaus[2] of his native town, which he daily passed, with the lattice-work on the arches of the windows, was well fitted to recall to his mind a memory of the arches in the arcades of the Venetian palace of the Doge. The Rathhaus brought him numberless other associations, but never one of Venice. Suddenly, one day, upon seeing the Rathhaus, the image of the palace of the Doge recurred to him. After some reflection, he remembered that two hours before he had seen a brooch, in the form of a Venetian gondola, worn by a lady. In this case the influence of the grouping of latent ideas is obvious.

Herbart, the psychologist of Königsberg, was the first to teach this reciprocally arrestive or incitant influence of dormant ideas, although he did so in another form, and without any knowledge of its physiological basis. He thought it possible, in fact, to estimate the effect of an arrest mathematically. His reasoning was about as follows: Given two ideas, A with the intensity a, and B with the intensity b. Herbart now assumed that the total arrestive force is equal to the intensity of the stronger idea, *i.e.* equal to b for example. This arrestive force b is sustained by A and B in common, and, in fact, in an inverse ratio to their intensity. Let A have a portion of the arrestive force equal to x, and B a portion equal to y. Let us now compute the values of x and y.

[1] "Beschreibung und Eintheilung der Ideenassociationen." Vierteljahrschrift f. wiss. Phil., 1885, Jahrg. 9.

[2] City-hall, or town-hall.—*Tr.*

$$x+y=b,$$
$$\text{and } x : y=b : a;$$
$$\text{hence } x : x+y=b : b+a, \text{ or}$$
$$x=\frac{b^2}{a+b},$$
$$\text{and } y=\frac{ab}{a+b}.$$

Therefore *A* loses by the process of reciprocal arrest

$$\frac{b^2}{a+b}, \text{ and } B \text{ loses } \frac{ab}{a+b}.$$

Of course this calculation of Herbart's is undoubtedly incorrect, chiefly because the relations are far more complicated than Herbart assumes. Particularly the content of the two ideas is by no means unimportant in determining the force of the arrest. The above computations may, however, give us some approximate idea of the quantitative relations that exist between the arrestive forces of different ideas.

The succession of our ideas, or, expressed physiologically, the path of excitation in the cerebral cortex, is unequivocally determined by these four factors:—associative relation, intensity, emotional tone and grouping. The processes of thinking are strictly necessitated. The condition of the cerebral cortex in any one moment necessarily follows from its condition in the preceding moment; the idea *a* corresponds to the latter, the idea *b* to the former, etc. We do not need any faculty of apperception, which might be regarded as ruling over the ideas at will, for the explanation of either the normal or the pathological psychical processes.

Thus we have become familiar with the fundamental features of the association of ideas as it takes place when introduced by either a sensation or an idea. The process of association therefore presents a series of pyschical phenomena, which we can render easily intelligible as follows:—S_1—I_1—I_2—I_3—I_4—I_5—I_6, etc. We are already acquainted with the laws that determine the choice of these *I*'s. We have now only one more question to ask: Is it always necessary that only *ideas* follow the first sensation produced by an external stimulus? May not one sensation first impart another sensation before it imparts any ideas, and without a second external stimulus? To put the question in general terms, can a sensation be produced without an external stimulus? Among the normal processes of thought this phenomenon is exceedingly rare. We probably recall in this connection what has already been said concerning the so-called after-sensations. If we gaze steadily at a light green square for some time, after closing the eyes we see also a similar square in the complementary colour, purple. In this case one sensation appears to directly impart a second without the intercession of a new stimulus. But this is not true; on the contrary, it is highly probable that the inner process of stimulation is not extinguished when the external process of stimulation produced by the piece of green paper ceases, but that a new process of excitation—probably induced by exhaustion or weariness—as a secondary inner stimulus produces the after-sensation. We shall therefore not occupy ourselves with this so-called "successive contrast" here. We certainly meet with cases in which sensations occur without an adequate external stimulus when the brain is pathologically affected; the series of *I*'s is suddenly interrupted by one or more *S*'s. We shall have occasion to refer to this subject briefly when we come to the discussion of the abnormal processes of thought.[1] Our chief task in the next chapter will be to become familiar with those facts of the association of ideas that have reference to time.

[1] See Chapter XII.—*T's*.

CHAPTER X.

RAPIDITY OF THE ASSOCIATION OF IDEAS. JUDGMENT AND CONCLUSION.

In the last chapter we became acquainted with the chief law for the association of ideas. It runs thus: The ideas follow one another by association in a definite order, according to the various combinations in which they have simultaneously occurred at some former time. We shall now attempt to estimate the rapidity of these successive associations. In so doing we must again proceed from the introductory sensation S, which the series of ideas I_1, I_2, I_3, etc., follows. We have already seen that generally a complete recognition of S does not take place at all; in other words, the idea of like sensations that have been formerly experienced is not generally reproduced at all. If we see a rose at some distance, our thought represents at once its perfume; we associate the idea of the perfume of the rose, or the word-idea "rose," directly with the sensation of sight. The idea of visual sensations formerly produced by definite, similar roses does not appear at all. The complete recognition involves a comparatively complicated judgment; the new sensation of sight must be determined as like or similar to a series of former sensations of sight. Hence the method of recognition is but little fitted for experiments in measuring the average velocity of association. It is much more expedient to measure the time that intervenes between one sensation and the first new idea following it. Various apparatus, often very ingeniously constructed, have been used for this purpose. In all of them the scheme is essentially the following: (1) The moment at which the sensible stimulus takes effect is marked upon a rotating drum; (2) The person upon whom the experiment is being made gives a signal-motion, previously arranged, as soon as the first idea, I_1, follows the sensible stimulation. It is also expedient to command the person who is being tested to pronounce at once distinctly the word for the first idea that appears. The signal-motion is so arranged as to close an electric stream, so that by this means the moment of its execution is also marked upon the drum. If the velocity of the rotation of the drum is known, the space lying between the two points marked upon the drum may be employed in directly estimating the time that has elapsed between the sense-impression and the motion. This entire time we will designate as T. It consists of several sections as follows:—

(1) The time which the stimulus needs in order to pass from the peripheral sensory surface to the sensitive cortex of the cerebrum, where it imparts a sensation.

(2) The time that elapses between the sensation and the appearance of the first idea.

(3) The time that elapses between the appearance of the first idea and the appearance of the ideas of motion requisite for the production of the signal-motion and the pronunciation of the word.

(4) The time necessary for the transmission of the central motor excitation to the muscle, and the production of contraction in the latter.

We shall designate these four parts as t_1, t_2, t_3, t_4; hence $T = t_1 + t_2 + t_3 + t_4$. We determine the sum total, T, by experiment. We wish to determine t_2, the time of association elapsing between sensation and idea. Both t_1 and t_4, the duration of centripetal and centrifugal conduction, are known to us, approximately at least, through physiology; t_3 is quite unknown to us; it obviously represents the time of association between two ideas. Let us now consider that the idea of motion which closes the section t_3 is very easily excitable on account of our close attention; in other words, the paths leading to this idea of motion are especially capable of conducting the excitation. Hence t_3 is much shorter than the time of association that intervenes between any two ideas, but it is not to be ignored on this account. For this reason we must abandon the attempt to ascertain t_2 alone; we can only determine $t_2 + t_3$. It is impossible to determine the amount of time that intervenes between the sensation and the first idea following; for the present we can only measure how much time elapses between the sensation and a motion that directly follows the first idea imparted by the sensation.

In the light of the experimental investigations that have been employed up to the present time, what is the magnitude of $t_2 + t_3$? Unfortunately these experiments are very limited. The reason for this scarcity of available trustworthy investigations lies especially in the fact that a certain theory, which is to be mentioned at the close of this chapter, and which is, in fact, incorrect, has forced the experiments into a very different line. Only the investigations of Trautscholdt[1] are applicable, in part at least, in answering this question. Galton had already made similar experiments before Trautscholdt. They should be mentioned despite their obvious inexactness, because they are to be very highly recommended as preliminary experiments which we can easily repeat. Galton[2] wrote seventy-five words on different strips of paper, and at intervals of several days he laid such a strip, at first half concealed, under a book so that he could only read the word when he leaned forward. As soon as he leaned forward and saw the word he started a chronometer, stopping it again only after some four ideas suggested by the visual sensation of the word, had occurred to him. The result of these experiments showed that 660 seconds were necessary for 505 associations of ideas, according to which the average time of association would amount to almost $1\frac{1}{3}$ seconds. We recognise the errors in this method at once. It is only necessary to mention one of them. At the same time that Galton himself set the chronometer in motion a new sensation of sight and a new motion were introduced. Trautscholdt, on the other hand, spoke

[1] Philosoph. Studien. I, S. 213.

[2] Brain, 1879, July.

a monosyllable to the person on whom the experiment was being made, and the latter gave a signal by a simple motion of the hand, thus breaking a galvanic current the moment the first idea was awakened by the sensation of sound. The person thus tested only gave oral expression to the associated idea after the current had been broken by the motion of his hand. As a result, in numberless experiments, the entire time of reaction, from the calling of the word to the execution of the signal motion, amounted on the average to from 0·9–1·0 of a second. The following experiment is then employed for the purpose of facilitating the computation of the association-time. Another monosyllable is spoken to the person whom we have previously tested, and he is requested to make a signal at once as soon as the word is heard. By estimating the time intervening between the call and the signal movement, we obtain various results varying from 0·1 to 0·225 seconds. Later we shall have to consider this so-called "simple reaction-time"[1] more exactly for the purpose of learning what can be assigned as the cause of its variable magnitude. The first reaction-time that we obtained above, 0·9–1·0 seconds obviously corresponds to $t_1+t_2+t_3+t_4$. The simple reaction-time corresponds to $t_1+t_3+t_4$, since, in fact, the time that elapses between the sensation and the idea is omitted in the second case.

Of course we must here take into consideration that t_3 does not have the same value in both cases. Hence, by subtracting the physiological time from the more complicated time found above, we can only expect an *approximately* correct value for t_2, or the time of association between sensation and idea. According to the numbers given above the association-time t_2 is to be estimated approximately at 0·7–0·9 seconds.[2]

It is not to be wondered at that the time of association is

[1] Also called physiological time.—*Tr.*

[2] Trautscholdt's computation is different, since he agrees with Wundt in assuming the interposition of an apperception that stands above the association. However, the assumption that the word called must first be recognised as such by an apperception is wholly arbitrary, for a special recognition in very many cases never takes place.

subject to such great variations. There are individuals in whom every sense-impression awakens ideas by association with the greatest rapidity, and there are others that react much more slowly in this respect. Not only does the speed of association vary among individuals, but the time of association varies considerably also in the same individual according to his state of feeling, physiological condition, etc. We shall hear still more concerning these differences later. From the standpoint just mentioned it will appear to us improbable *a priori* that the time of association should be invariably constant.

We have now established, at least approximately, the amount of time that elapses between a sensation and the first idea that is associated with it. It is a much rarer special case when the first idea associated with the sensation is the image that former like sensations have left in the memory, *i.e.* when a complete recognition takes place. The attempt has also been made to determine the duration of this so-called "*time of recognition*," but this is just the case in which the results are most uncertain.[1] We are much more interested in the further question as to how rapidly the ideas I_2 and I_3 continue to follow one after another as soon as I_1 has appeared. It would obviously be natural to assume that I_2 generally follows I_1 just as rapidly as I_1 follows S, for in both cases it is merely a question of the reproduction of a latent image of memory. The experiments in this case especially have given very mutable results. Ideas that rarely appear together require more than a second for their mutual reproduction, while ideas that have been associated with one another very frequently reproduce each other within one-third of a second. Ideas, whose relations to one another are very complicated, especially complex ideas, reproduce each other much more slowly than ideas less intricately related, as, for example, the ideas of words that rhyme. On the other hand, a complex idea, whose component ideas are so constituted that only a single other idea is associated with their totality, reproduce this one idea very quickly. Therefore

[1] In this case the above-mentioned *judgment* of likeness is introduced.

the question, "Name a work of Goethe's!" is much more slowly answered than the question, "What is the first drama of Goethe's?" Association of the latter kind is said to be unequivocally determined. The less equivocal the determination of an association is, *i.e.* the smaller the number of possible associations is, just so much more rapidly does the association take place as a rule.[1] The relation between the contents of the ideas that are associated also has considerable influence on the rapidity of association. The same is true of the above-mentioned grouping of the latent ideas. It is generally an unfavourable, accidental grouping of the latent ideas that renders it occasionally difficult for us to recall a name or any other word. But the rapidity of association varies also for the same act of ideation; it is different in different individuals and varies in the same individual with his changing moods. There are individuals in whom the association is accomplished with greater rapidity, others in whom it takes place more slowly. To-day our thoughts seem to fly, and to-morrow when we are tired they seem to crawl. Above all, the influence of the emotions on the rapidity of association is very important. If ideas and sensations that are accompanied by feelings of pleasure predominate, the thoughts flow more easily and rapidly; on the contrary, feelings of pain or displeasure exercise an arrestive influence upon the association of ideas. We find the most interesting illustrations of this influence of the emotional tone in the sphere of mental diseases. Psychiaters are acquainted with two forms of mental disturbance, known as melancholia and mania. They possess diametrically opposite psychological characteristics in almost every respect. Melancholia is characterized by the morbid predominance of feelings of displeasure that border on pain and are entirely without a motive; mania is characterized by the morbid predominance of feelings of joy without a motive. In what relation do the two diseases stand as regards the rapidity of association? Innumerable experiences demonstrate that the association of ideas is very greatly retarded or arrested in the

[1] Compare MÜNSTERBERG, l.c.

case of melancholia, but exceedingly accelerated in the case of mania. We therefore sometimes designate the ideas that occupy the thoughts of an individual afflicted with mania as "flight of ideas." This acceleration of the association of ideas reacts, on its part, upon the content of the ideas. In fact those ideas are associated by preference, which stand in a merely superficial associative relation, as, for example, that of similarity or rhyme. We have already seen above that such relations evince a remarkable capacity for speedy association. In the following example we have a typical case of such capricious ideation in a slighter degree. It occurs in the letter of a young maniacal woman to her brother, and runs thus: "Es grüsst Dich und alle die nach mir fragen mit Zittern und Zagen. Es hatte einen Haken und nun sind wir frei. Eure Schwester in Christo aber nicht in Misto sonst kommt Mephisto."[1] On the contrary, a woman suffering from melancholia often requires several minutes before she is able to associate the necessary ideas and to give the correct answer as to the date of her birth, for which she has been asked. We can designate this disturbance of the association of ideas as difficult recollection or mental inertness; the mental images, or the so-called memory, are still intact, but the association of these images of memory is accomplished with extraordinary difficulty and slowness. A very apt illustration is furnished by alcoholic intoxication. After the first glasses of wine have been drunk the thoughts flow more rapidly; the association of ideas is unusually accelerated, the state of feeling is pre-eminently gay. But after a certain point has been reached the thoughts flow more slowly again in proportion as the number of glasses increases, until

[1] The sense of this passage, so far as it contains any sense whatever, is about as follows: "A greeting to you and to all who inquire after me in fear and trembling. There has been a hitch and now we are free. Your sister in Christ, but not in dung, else the devil will come." In this case the selection of the words "fragen," "Zittern," "Zagen" (ask, tremble, fear) and "Christo," "Misto," "Mephisto" (Christ, dung, devil or Mephistopheles) seems to have been determined entirely by the possibility of rhyme and alliteration.—*T's.*

finally an abnormal heaviness and inertness appears in the association of ideas.

We must now make the acquaintance of another way in which ideation may be accelerated. Let us turn our attention to a series of ideas I_1, I_2, I_3 . . ., which are connected with each other by association. We remember that these three psychical elements correspond to the material process Ei_1, Ei_2, Ei_3 . . . and that the Ei's originated in El's that had no concomitant psychical processes. Let us take, for example, the series of ideas: cloud, rain, umbrella. The associative connection between them is at once plain. Some one says to us, for example, that there are clouds in the sky. The idea of clouds causes us to think of the possibility of rain, which reminds us of our umbrella. In fact, however, we think much more rapidly; the intervening idea of rain I_2 is very often entirely omitted. In this case the cloud reminds us at once of the umbrella, although the idea of rain does not expressly appear in our consciousness. The entire process is obviously the following. At first Ei_1 is produced from El_1 or, expressed in the language of psychology, the idea of the cloud (I_1) first appears. The material excitation is now transmitted still further and reaches El_2; but instead of changing the latter to Ei_2 so as to produce the idea of rain (I_2), it either touches El_2 but lightly, or at least so little that Ei_2 and I_2 do not appear at all. But on the contrary, only as soon as the excitation has been conducted to El_3, does the latter receive an impulse that is sufficiently long and intense to convert it into Ei_3, upon which the idea of the umbrella (I_3) appears. There is no good reason for speaking of an unconscious idea of rain (I_2) in this case. As we already know, unconscious psychical processes do not exist. We must simply grant that the intervening idea, "rain" (I_2) has been omitted; expressed with reference to the material processes that take place, the transformation of El_2 to Ei_2 has been omitted. El was touched by the excitation in the course of its conduction and undoubtedly influenced the latter; at all events, it underwent certain changes, but these changes were either not sufficient or not of the right kind to convert El_2 into Ei_2 and produce the idea

I_2. In the above process we recognise another very important form or way in which the acceleration of ideation may be accomplished: intervening ideas may be omitted, and the association of ideas thereby abbreviated. Our thinking would be an immensely tedious[1] task, if we had to go through the process of recollecting all the intervening ideas every time. In our usual thought we constantly skip numberless ideas; in fact, the genius is distinguished from other less gifted individuals in that he omits greater series of intercedent ideas, and therefore, figuratively speaking, advances in seven-league boots. On the other hand, that which we call practice also frequently depends upon such an abbreviation of the association of ideas. The practised chess-player, for example, skips numberless intercedent ideas in his combinations or associations, while the amateur is compelled to think through the entire series according to the order in which the ideas occur. If we now conceive of this process of practice as still further perfected by the omission of all intervening ideas whatever, including ultimately also the idea of motion which imparts the final action, we have an automatic act. In this connection it is only necessary to recall what was said in a former chapter concerning the gradual development of automatic action from the so-called voluntary action. It is hardly necessary to emphasize that practice as such tends to directly facilitate the association of ideas besides exercising an indirect influence by abbreviating the process of thought. The shortening of the process of ideation is also often facilitated pathologically; in such cases we often speak of thought as "incoherent."

Thus far we have considered the association of ideas merely as a succession of *discrete* ideational elements. The only bond connecting the successive ideas I_1, I_2, I_3, etc., was, in accordance with the chief law of the association of ideas, either their frequent previous simultaneous appearance or their similarity. We have now to learn the more complicated forms of ideation. In fact, we

[1] Ger. "langweilig," which in this case may also be understood in the apt literal sense, as signifying "*great length of time.*"—*T's.*

do not constantly think in simple, progressive series of ideas; a higher stage of thought consists of the so-called judgments and conclusions. Let us now inquire whether these two chief logical functions of judging and concluding may also be subsumed under the processes of ideation, or whether we must regard them as entirely new, heterogeneous psychical faculties. Of course we shall decide in favour of the latter only in case of necessity. It will undoubtedly be more satisfactory if we are able to reduce logical thought, *i.e.* the judgment and the conclusion, also to the simple process known as the association of ideas. Let us begin with a simple judgment,—for example: "The rose is beautiful." In this judgment we have two ideas, (1) the idea "rose," and (2) the idea "beautiful." It is evident that these two ideas are not associated because of some merely incidental connection between them in the sense of the simple law of ideation with which we are thus far acquainted, but that the second idea stands in some much more intimate relation to the first. This more intimate relation is expressed by the word "is," it is true; but even if we regard this "is" as an intermediate idea, we by no means avoid the fact that the judgment is not concerned with three ideas that are merely arranged in succession. On the contrary, we must correctly assume that the mediate idea "is" not only refers to the preceding idea "rose," but also to the succeeding idea "beautiful." Now is it quite impossible to explain the origin and development of this double relation of the mediate idea "is" physiologically? By no means. Thus far we have not investigated the material process that takes place in the cerebral cortex during the association of ideas as a continous whole; we have only selected a few single moments of the process in which certain phases correspond to separate ideas. It is evident that this is not quite correct. Between the material condition Ei_1 and the material condition Ei_2 there is a mediate material process, and we have no cause whatever for assuming that this intermediate process takes place entirely unaccompanied by a psychical correlative. On the contrary, it is highly probable that the foundation for the continuity of our judgments, or, in other words, for the reciprocal relation that exists between the ideas as combined in the judgment, is furnished by this process of conduction. It should also be considered that in the majority of judgments only the words, *i.e.* the motions of articulation, form a successive series, while the two ideas ("rose" and "beautiful" for example) appear simultaneously as the component ideas of a complex idea. The separation of the ideas and their arrangement in a continuous series is only accomplished when they are expressed in language. Of course the above explanation is at present purely hypothetical. Furthermore, in view of the limited knowledge on this subject which we now possess, we need not yet attempt to give a really adequate psycho-physiological explanation of the continuity of our thought in judgment. On the contrary, it is sufficient to have demonstrated the possibility of such an explanation. We have shown that such an explanation is *possible* upon the grounds of physiological psychology and without exceeding the bounds of the association of ideas or fabricating a new, entirely hypothetical psychical faculty.

From the above standpoint, therefore, the formulation of judgments is to be regarded as a higher stage in the development of that which we commonly designate as ideation or the association of ideas; the former process is by no means wholly dissimilar to the latter. But what has thus far been said does not constitute a complete presentation of the psychological characteristics of the judgment. An essential feature of the judgment is its dependence on a much more intimate and abundant association of its component ideas. Supported by this close relation of its component ideas, we are able to claim for the judgment the right to be valued as correct. Psychologically "to be held as correct" simply means the absence of contradictory ideas. The common series of associated ideas, "rose—leaf—summer," depends on no other condition of association than some former incidentally simultaneous appearance of the ideas or their corresponding sensations. The judgment, "the rose has dentate leaves," is distinguished from the simple series of associated ideas just mentioned (1) by the thorough relation of the ideas to each other,

(2) by the much more *frequent* former simultaneous appearance of the ideas contained in the judgment or of the sensations that produced them. In fact, contradictory ideas are entirely wanting in consequence of the very intimate association of the ideas composing the judgment; this absence of contradictory ideas (in the above case, for example, the idea of smooth-edged leaves) gives us the right psychologically to consider our judgments correct. The association, "rose—leaf—summer," rarely occurs without other intermediate members; for this reason it bears the character of a chance association. On the contrary, the association of ideas in the case of the judgment is, almost without exception, an intimate association of simultaneous ideas, and an association in which conceptions of relation are of especial importance. Of all possible associations, a judgment is just that select association in which no contradictory ideas occur.[1]

Hence we find that our conception of the association of ideas must be somewhat modified, if it is to include the judgment also. The association of ideas is not a process in which we consciously leap, as it were, from one discrete idea to another. On the contrary, we must claim for the judgment, as a psychical process at least, the same continuity that the concomitant material process undoubtedly possesses. The association of ideas that are less closely related, with which we first became familiar, is therefore but one form, and the so-called judgment a second form of ideation.

"School-logic" teaches further, that judgments are combined to form conclusions. Let us recollect the well-known,—

Caius is a man—
All men are mortal—
Hence Caius is mortal.

It is indeed without doubt an interesting fact that our logical

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[1] This *selection* is especially emphasized by HERBART. LIPPS ("Grundthatsachen des Seelenlebens," Bonn, 1886), has emphasized with undue partiality, as characteristic of the judgment, the fact that we are conscious of its reality and hence of its validity.

series of judgments can be arranged according to the above scheme, or any one of the other schemes familiar to the logicians. For certain purposes it may even be quite advantageous to arrange our series of judgments according to such a scheme. But we must decidedly oppose the idea, that our common, naïve course of thought ever conforms to these syllogistic forms of the school-logic. When we think naturally, we know nothing of a major premise or a minor premise; we simply make use of the association of judgments,—"Caius—man—mortal," and the conclusion has been reached. For example, we *see* "Caius"; with the visual sensation is associated the idea "man," with the latter the idea "mortal." Therefore every conclusion, the same as every judgment, is merely a form of the association of ideas; but as a distinct form of association it is of almost no importance whatever psychologically.

It is of course impossible here to develop the entire structure of scholastic logic upon this psychological basis. We have only space for a cursory glance over the field of logic here, as formerly over the field of æsthetics. It is for physiological psychology to establish merely how thought actually takes place and what material processes accompany it. The problem of logic, as to which formal processes of thought lead to the so-called *true* judgment and which do not, does not belong to the sphere of psychology. The great problem of physiological psychology consists in the reduction of the many different forms of thought, including even the most complicated demonstration, all to the simple ideation or the association of ideas and its laws. But physiological psychology is still far from having reached a complete solution of this problem; for this reason we have only been able to sketch in *about* what direction the solution is to be sought. It is probable that some of our deductions will undergo still further modification when the light of continued investigations is brought to bear on them. The fundamental conception that all processes of thought can be reduced psychologically to the association of ideas, will at all events endure.

Of course we shall not attempt to disguise the fact that particularly in Germany another school of psychology is predominant, that does not recognise this fundamental thought. Wundt[1] stands at the head of this school. He and his scholars claim that there is a large number of ideational combinations that cannot be explained merely by the association of ideas. They therefore assume a special psychical faculty, superior to the association of ideas, which they designate as apperception. The association of ideas constantly supplies this apperception with new material for ideas, and the apperception itself selects from this material. It turns first to this then to that idea, and is then called attention; or again, it combines one idea with another and forms a compound idea; finally it imparts volitional motor impulses through the nerves and is then called will. We see that this hypothesis is very convenient. All that cannot be easily explained by the association of ideas is ascribed to the activity of a higher power or special psychical faculty. The latter, however, is an entirely unknown factor. All of the arguments that have so often and so justly been advanced against the theory which assumed so-called "faculties of the soul," may be also directed against this metaphysical theory of apperception. The theory of apperception also arbitrarily assumes an active subject as the efficient cause of a series of conscious processes. Wundt has also given his theory a physiological tinge by adding the hypothesis that this apperception is located in the frontal lobes of the brain. In making this assumption, however, he only succeeds in placing the contradictory features of the entire conception in a still more glaring light. A supposed psychical faculty which, according to the very hypothesis in which it is assumed, acts independently of all mechanical causality, is thus localized in a definite part of the brain for the purpose of gaining some connection with the physiology of the brain and of rendering the theory more harmonious with the spirit of natural science characteristic of the

[1] WUNDT'S "Grundzüge der physiolog. Psychologie"; besides in this work, a presentation of the theory in question is also to be found in WUNDT'S "Logik," Bd. I, S. 10ff.

present age. But the physiology of the brain must reject this connection and with it the entire theory and hypothesis of apperception. The frontal lobes of the brain do not possess this function at all. Large portions of the frontal lobes of the brain may be destroyed without disturbing [1] that activity of the intellect which the school of Wundt ascribes to apperception. Changes in character and certain mental disturbances may appear in any disease of the brain, no matter where it is located. A great deal of argument has often been based upon the fact that part of the encephalon of lower animals corresponding to the frontal part of the human brain is relatively dwarfed. This fact has been used in attempting to explain the supposed absence of apperception in the lower animals. This application of the fact, however, is not justifiable. The motions used in speaking and writing, and finally also the motions of the trunk, are imparted by the cortex of the frontal brain; accordingly speech, writing and upright locomotion are wanting in the animals below man. If we take the absence of these three characteristics into consideration, the frontal brain of the ape is, relatively at least, just as large as that of man. Therefore there is no ground whatever for assuming that this hypothetical apperception is localized in the frontal brain. Thus another prop, which was subsequently introduced for the support of the theory, falls. For reasons above discussed, we shall reject this metaphysical assumption of a psychical faculty. Instead we have attempted to explain the more complicated processes of thought, without apperception, by making use of the association of ideas. To do this requires, of course, much more pains than to simply refer or ascribe all of the more complicated processes of thought to a problematic apperception. Furthermore, in making such an assumption we make no progress toward an explanation of the processes that occupy our attention; on the contrary, we deprive ourselves irretrievably of the possibility of understanding them in the light of psycho-physiological research. Let us repeat—many of our explanations may still need cor-

[1] Compare L. Welt, Dissertation, Zürich, 1888.

rection, but the way now opened before us is undoubtedly correct; it is the only acceptable way for physiological psychology. Our explanations at least demonstrate that we can succeed without the assumption of a new psychical faculty, even though the progress of knowledge may correct them somewhat; we have demonstrated the *possibility* of reducing all the so-called higher processes of thought to the association of ideas. In a certain sense we regard the ideational life as republican. *All* of the latent ideas enter into the contest, each one wishes to push its way into consciousness; but it is not a higher power which hovers over the ideas and determines the victory of one idea over another and thus fixes the order in which they appear, but merely the intensity, the accompanying emotional tone, the grouping and the associative relations of the ideas themselves.

CHAPTER XI.

ATTENTION—VOLUNTARY THOUGHT—THE EGO—MEMORY.

In the last chapters we became acquainted with the chief characteristics of the association of ideas. We investigated the simple recognition and reproduction of mental images. We found that the reproduced images of memory appear together first in less compact series, then in combinations of a higher order, the judgments. Thus far in our discussions we have intentionally ignored one element which, however, plays an important part in the processes of thought. This element is that which we commonly call "*attention.*" We say that "we turn our attention now to this sensation now to that sensation," or that "we turn the attention now to this line of thought now to that." It seems to be left to our option; apparently we direct our attention to this or that sensation, this or that idea by preference. Hence we might fear that we shall yet be compelled to decide in favour of assuming an apperception, which is superior to the association, and which attends to, or disregards the sensations and ideas at will. This is not the case however. Let us first investigate the *attention* as directed to the *sensations*, making use for this purpose of a definite example. Suppose the left eye to be closed and the right eye to be open and motionlessly fixed upon the field of vision before us. Let the field of vision be designated by the circle, fig. 21, which contains a large number of objects. In the figure, but three of them are designated by letters; one, situated somewhat apart from the centre of the field of vision and corresponding to the macula lutea of the retina, is designated by C, and two others, situated anywhere near the periphery, by P_1

and P_2. Now it is an undoubted fact that we generally turn our attention to the object C situated in the middle of the field of vision. We fix the eye, as it is commonly expressed, on the object C, and we believe that we are able to do so with greater or less energy. Does this mean that an apperception generally *prefers* this C, to which it accordingly *voluntarily* turns the attention? Certainly not. On the contrary the facts in the case are as follows: C is the point situated near the centre of the field of vision corresponding to the macula lutea of the retina; hence, according to the teachings of physiological optics, it is much more distinctly seen than all other points situated nearer the

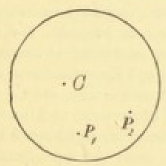

FIG. 21.

periphery. P_1 and P_2 in general cast but comparatively confused and indistinct images upon the retina. Consequently the sensation produced by C, *i.e.* the material cortical excitation *Ec* corresponding to the sensation, will also be far more intense and correspond much more closely to former sensations produced by similar objects than the sensations produced by the objects P_1 and P_2 which are located nearer the periphery. In this case, therefore, we find several sensations active at the same time and, in a certain sense, entering into a contest for the privilege of awakening the next image of memory and determining the course of ideation. The result of this contest, as we have termed it, depends upon two factors, (1) the intensity, and (2) the distinctness of the sensation in question. It is obvious that the stronger sensations, or the more intense material processes accompanying them, possess a far greater ability for converting latent *El*'s into *Ei*'s or, in other words, for awakening the images of memory and determining the course of ideation. But the distinctness or sharpness of a sensation is also essential. We have often distinctly seen a tulip, for example; hereafter it will be quite essential whether a new visual sensation of the tulip is like the former, *i.e.* equally distinct and sharp, or whether it is unlike former visual sensations, *i.e.* is indistinct and confused, the object, tulip, being too far off or being seen only by the peripheral parts of the retina. It is obvious that in the latter case recognition of the object will be more difficult; let us recall in this connection what was formerly said concerning the training of the nerve-paths necessary for recognition. The *indistinct* sensation of the tulip finds no path exactly trained for its purpose. For this reason, both the first reproduction, the awakening of similar images of memory formerly experienced, and the excitation of other ideas associated with the mental image of the tulip, will be rendered exceedingly difficult.[1] Therefore distinctness and intensity are the most important factors in determining which sensation will prevail in the contest with others, cause the reproduction of certain mental images and thus determine the association of ideas. This also explains why only the object situated in the centre of the field of vision generally determines the association of ideas; it is just the object that produces the most intense and distinct sensation. No "apperception" exercises any arbitrary control over the process whatever. The association of ideas is inevitably necessitated from the beginning to the end. Such are the objective facts accompanying the phenomena of attention. But whence arises the peculiar sensation of self-activity characteristic of attention? Self-observation teaches that this sensation is a sensation of motion produced by the innervation of numerous

[1] Of course this important distinctness of visual sensations is very closely connected with the intensity of the sensations received from the macula lutea. The latter give rise to the greater number of associations because they are the most intense; they are therefore the *most distinct* retinal images of the objects seen.

muscles (particularly the muscles of accommodation and the musculi recti interni) which serve to fix the eye upon an object. By means of this fixation of the eye, the distinctness and intensity of the retinal images and hence of the corresponding sensations are increased. The feeling of a greater or less tension of the muscles regulating the eye, is itself produced by association; it is imparted by the stimulus which acts upon the macula lutea. The tension thus perceived, in its slighter degrees of intensity, is the product of reflex action[1]; in its greatest degrees of intensity it is voluntary action proceeding from the cortex. Particularly in the latter case, the innervation that has taken place imparts very numerous and intense motor sensations which are the cause of the exceedingly intense feeling of close attention. Therefore the *feeling* of attention is in fact merely a concomitant phenomenon. The essential objective characteristic of attentive or active sensation, in distinction from the merely passive sensation, is the influence which the former exerts in determining the choice and order of ideas by which it is followed. This influence is not at all characteristic of a merely passive sensation to which the attention is not directed.

We will now assume that P_1, one of the objects situated near the periphery, possesses a very unusual intensity of stimulation; for example, a dazzling light suddenly appears near the periphery of the field of vision. What happens in this case? It is true that P_1 is very unfavourably situated for producing an exact image on the retina and that *C*'s situation is far more favourable; but the greater intensity of light in the former case will more than equalize the unfavourableness of situation. Despite its peripheral location, P_1 will produce a stronger excitation of the retina and consequently a more intense sensation than *C*. Hence, in this more exceptional case, the attention is turned to the more intense sensation P_1, despite its greater indistinctness. Again, this "turning of the attention" is strictly necessitated; it means nothing more or less than (1) the sensation P_1 (and not *C*), by

[1] According to MUNK it is reflex action proceeding from the cortex.

virtue of its greater intensity, reproduces the next following images of memory and thereby determines the further course of the association of ideas; (2) either automatically or voluntarily (*i.e.* consciously) the eyes are turned to the dazzling light P_1, and the motion of the eyes thus executed produces motor sensations which constitute the peculiar feeling of activity accompanying the change of attention. Therefore in this case also we discover nothing more than a process of association with certain muscular sensations. With some pains we can also occasionally succeed in directing the attention to the peripheral object P_1 without making the movement of the eye necessary to bring P_1 within the range of the macula lutea. But if we observe sharply during such an experiment, we perceive a constant inclination of the eye to move so as to bring the image of the object P_1 upon the macula lutea. Generally we are unable to entirely repress these motions; our eyes occasionally deviate in fact toward one side or the other, although we again instantly correct each lateral deviation. Hence, in this very exceptional case also, motor sensations and motor ideas influence the feeling which accompanies attention.

Let us now consider certain other factors, besides the distinctness and intensity of sensation, that help to determine the degree of influence which a sensation exerts upon ideation. Let us retain the example of the eye at rest, as used above. We shall suppose that the object P_2, situated near the periphery of the field of vision, produces a stimulation of but very slight intensity; it therefore imparts a sensation that is but little fitted to draw the attention or to determine the association of ideas. Let us now, however, also assume that the object P_2 produces a very lively feeling of pleasure; in other words, the sensation imparted by P_2 is accompanied by a very strong positive tone of feeling. For example, a star, faint indeed, but glimmering with the most beautiful colours, appears within and near the periphery of the field of vision. Despite its slight intensity of light and greater or less indistinctness, this retinal image will at once attract the attention. The eye is accordingly turned toward the star and the following ideas are determined by this sensation and not by that imparted by *C*. The same thing is just as true of sensations that are accompanied by strong negative tones of feeling; despite their slight intensity and distinctness, such sensations, by virtue of their strong accompanying feeling of displeasure, are able to divert the attention from sensations that are more intense and distinct, but that have a weaker emotional tone. In a certain sense they contest, as it were, with the latter for the influence upon the course of ideation. For example, a soft chord can fetter the attention in the midst of numerous louder noises. We hearken—that is, we tighten the ear-drum and turn the head in order to hear the chord as distinctly as possible, and our thoughts become occupied with the chord. In this case we again find all the elements characteristic of attention in general. A sensation, by virtue of certain of its properties (in the above case, for example, by virtue of its strong positive emotional tone) produces, either by reflex or conscious action, certain motions, and, what is still more essential, determines the course of ideation. The motor sensation produced by the motions gives the attention that peculiar feeling of activity by which it is characterized. A very similar process takes place when a slight, but very unpleasant, discord occurs in the midst of a number of tones or noises. It likewise attracts the attention very forcibly. Hence we find that still a third factor also largely shares in the influence which the sensation exerts upon the association of ideas; the *intensity* of the *emotional tone* is to be added to the distinctness and intensity of the sensation. But we have not yet exhausted all the factors that influence the attention. The decision of the question as to which sensation shall determine ideation is by no means wholly independent of the ideas that have preceded in the last few minutes or hours. It is not a matter of indifference as to which of these ideas are still very active and which are not, or as to which are mutually arrestive or mutually incitant. In brief, that which we formerly designated as the grouping of the ideas, likewise exerts an influence upon the attention. Let us take another simple example. While we are taking a walk, numberless visual sensations constantly throng our consciousness. If the idea of meeting other strollers, for example, is in condition to be easily reproduced, the visual sensation of an approaching friend or stranger attracts our attention and determines our further movements and ideas; but if this idea is checked by the predominance of other thoughts, we pass the approaching person in a state of absent-mindedness without heeding him; we turn our attention to the landscape, for example, which happens to produce a visual sensation more favourable to the momentary grouping of the latent ideas. Under certain circumstances the visual sensation of a friend may be ever so distinct and intense and possess ever so strong an emotional tone, and yet in consequence of an unfavourable grouping of the latent ideas, other sensations will prevail, and determine the course of ideation. The phenomena which we designate as "seeking" and "intense expectation" are typical cases of the influence exerted upon the attention by the grouping of the ideas. The visual idea of the object sought or expected constantly fills the mind; numberless sensations appear, but despite their distinctness and intensity, none of them fix the attention. On the other hand, as soon as the image of the object sought but appears near, and within the periphery of the field of vision, be it ever so weak and indistinct, it is at once noticed and the attention directed to it; it then determines further movements and ideas. In this case the *grouping* of the latent ideas is the factor that governs the attention; it is aided especially by the feeling of pleasure which accompanies the desired sensation, and which is, in fact, the cause of the seeking.

We shall designate the totality of all factors that decide whether a sensation shall become the object of attention and determine the following association of ideas or not, as the *associative impulse* of the sensation. We have seen that the associative impulse, or the *associative power* of a sensation is dependent on (1) the intensity, (2) the distinctness,[1] (3) the strength of the accom-

[1] In this case the "distinctness" of a sensation, as one of the conditions of the "associative impulse," might also be designated as the "associative relationship."

panying emotional tone, and finally (4) the chance grouping of the latent ideas.

These four factors decide in favour of one among several concurrent sensations. We have undoubtedly already noticed the analogy that exists between the contest of the sensations for the attention[1] and the contest of the latent ideas for the position I_2. This analogy is easily understood if we recollect that the succession of ideas can be conceived of as the attention passing from idea to idea. There is, however, an essential difference between the two contests; the sensations that enter into a contest are all conscious, *i.e.* actually present as psychical phenomena, while the ideas that are struggling for the supremacy, with the exception of the *one* momentarily prevailing, are psychically latent.

Thus far we have not especially mentioned the *contrast* of successive or simultaneous sensations among the factors that constitute the associative power of a sensation, although it undoubtedly exerts some influence upon the attention. We find that a small black spot upon a white cloth is especially striking; and the more suddenly an object appears with its full intensity upon a differently coloured background, the more forcibly does it attract the attention. It is obvious that this influence exercised by contrasting sensations, whether simultaneous or successive, can be reduced to the factors already mentioned above. As we have already seen, a sensation that is characterized by great uniformity or monotony in its relations to space or time, rapidly loses its intensity and the strength of its accompanying emotional tone. The activity of the ideational process is soon exhausted, the favourable grouping of latent ideas is expended. It can therefore be easily understood why each new sensation that suddenly appears in contrast with these monotonous sensations prevails over them in the contest for the attention. Generally, in the case of the contrast of simultaneous sensations, both the strong

[1] In a certain sense, for the right of naming the first idea, I_1.

emotional tone and the grouping of latent ideas exert an influence in favour of the single contrasting sensation.

Let us again emphasize that in by far the greater number of cases, the first idea to be imparted by the prevailing sensation is an idea of motion. In fact, it is generally the idea of just that motion which is fitted to adjust the organ of sense so as to receive the prevailing stimulus, thus heightening the distinctness and intensity of the sensation still further. We already know, furthermore, that the motor idea (its sufficient vivacity being assumed) is itself an ample, in fact, the *only* cause of the respective motion. Therefore the first consequence of most sensations to which we direct the attention,[1] is a motion which serves to place the organ of sense in a favourable position. These movements are most highly developed for the eye and ear. When the attention is drawn to sensations of the skin, a general tonic contraction of the neighbouring muscles usually first appears; only then does the association of ideas follow. According to these facts we may conclude that each sensation possesses a certain motor power or motor impulse. It is without doubt extraordinarily fitting and the outcome of a long process of natural selection, that this motor impulse always tends to render the sensation more distinct and intense by a more favourable adjustment of the sense-organ with reference to the stimulus. The sensation that is to occupy our thoughts is, to a certain extent, preparatively intensified before any thought occurs. We can easily imagine how the phylogenetic development of this expedient connection between the motor impulse and the subsequent association of ideas has been accomplished.[2] It is only necessary here to emphasize once more that many of these accommodative movements take place without our being conscious of them; in other words, they are purely material processes, either

[1] We designate those sensations to which the attention has been turned as *perceptions* (Wahrnehmungen). The word perception, however, has been used by psychologists in so many different meanings that its applicability has been impaired.

[2] At first, especially because it renders possible more complicated and more exact defensive movements.

reflex or automatic actions. The motor idea is omitted from consciousness; only the fact that the movement placing the organ of sense in a favourable position has been accomplished, makes us aware that a latent motor idea has been excited. For example, the turning of the head in the direction of a sound is in many cases an entirely unconscious act. Finally, there are certain movements by means of which certain organs are adjusted, such as those executed by the optic muscles of accommodation, which take place constantly, or almost constantly, as purely reflex acts.

We have already become acquainted with the further course of the association of ideas after having been once excited by sensations, in previous chapters. This further process of thought may be of two kinds. We generally distinguish between so-called *voluntary* thought and *involuntary* thought. This is not a fundamental distinction, however. Our thinking generally seems to us to be voluntary when we are occupied with those phenomena of consciousness which we designate as "reflecting," "*trying* to recollect," "making up the mind," etc. The laborious mental occupation of the child with its puzzle, or of the adult thinker with his problem, are both simply varieties of that psychical process which we variously designate as "reflection," "contemplation," "meditation," and "cogitation." Now what causes the process of reflection to seem like a voluntary act?[1] Let us have recourse to accurate introspection. The so-called voluntary thought is characterized by the fact that the desired idea is always known to be already contained in the initial ideas that introduce the associative series, as well as in the following ideas; the associations necessary for its discovery, however, are often very complicated. But there is still another important factor characteristic of voluntary thought, as it is called. When we are occupied with deep reflections, a series of slight muscular innervations appears; these are only to be discovered upon close introspection. This muscular innervation is seldom entirely absent whenever we are occupied

[1] Compare the somewhat similar deductions in MÜNSTERBERG'S "Die Willenshandlung," Freiburg, 1888.

with so-called voluntary thoughts. We wrinkle the brow slightly, press the teeth somewhat more firmly together, and frequently there appears a slight tonic contraction of the lips and the muscles of the neck.[1] All these innervations of the muscles are generally accomplished unconsciously. Furthermore, we have no isolated sensations of the single motions, but their combined action produces that peculiar total sensation which we generally have when "trying to recollect," or when absorbed in so-called voluntary reflections. The English language very aptly designates this condition as "attention" (primarily from *tendo*, to stretch).[2] This combination of motor sensations often gives our thought the character of attentiveness and an appearance of volition and self-activity which in fact do not belong to it at all. We cannot think as we *will*, but we *must* think as just those associations which happen to be present, prescribe.

But there is still another circumstance which would seem to strengthen this appearance of volition. In the course of the ontogenetic development of the individual, a peculiar complex of associated images of memory is constructed, which we designate as the idea of the "Ego." The child laboriously acquires the idea of its own body as distinct and separate from the rest of the world about it. In the beginning the child knows no difference between the hand touching and the object touched. The moon which it tries to reach, and its own foot which it grasps, seem to the child to be equally near to it. This condition

[1] It is interesting to note that among the lower animals, particularly in the case of the ape, the wrinkling of the brow, as a motion expressive of attention, does not seem to occur. Darwin, however, observed a young orang-outang which undoubtedly produced motions expressive of attention by closing and protruding the lips.

[2] It is very interesting to note that in the case of the observations made by Lange, already mentioned, the appearance of visual images of memory is frequently accompanied by slight unconscious movements of the eyes. For example, one thinks of a long street, and at the same time unconsciously moves the eyes slightly from one side to the other, as if following the line of buildings.

The English expression "attention" corresponds exactly to the German "Spannung"—*T's.*

of affairs changes but gradually. The child learns to distinguish between those objects, or spatial complexes of visual and tactual sensations, that are associated with active sensations of motion and those that generally appear without active motor sensations. The former, in their totality, correspond to the idea of one's own body; the latter, to the idea of all objects of the external world. Many other factors tend to fix and complete this distinction. When two complexes of visual sensations of the second kind, *i.e.* two external objects touch each other, *no* sensation of touch appears. If on the other hand two complexes of visual sensations of the first kind, *i.e.* two parts of one's own body, as the hand and face for example, touch each other, a *double* sensation of touch appears. Finally, if a complex of visual sensations of the first kind, (*e.g.* the hand) touch one of the second kind (*e.g.* any object), a *simple* sensation of touch appears. The totality of all sensations of the first class—in other words, the sum total of all the distinct and separate sensations of one's own body, leaves a composite image in memory, the idea of one's own corporeal ego.[1] At first this idea varies considerably. Primarily the ego of childhood or babyhood is nothing more than alternate feelings of hunger and satiation, or pain and joy in beholding a light or in self-motion. The idea of the surface of one's own body as the limit of a definite portion of space, and with it the idea of one's own body as a whole, are only developed gradually. To the latter is also added by degrees the slowly developing idea of one's own mental ego—that is, a total idea of all the images of memory deposited at any given time in the cerebral cortex. This complex idea of the intellectual ego is much more laboriously acquired than that of the corporeal ego. At this point we must refer to what has already been said in a former chapter concerning the development of conceptions without an external or objective foundation in the sensations. We demonstrated that our entire psychical being is composed of sensations and ideas; that the latter are primarily produced as a rule by the combination of sensations,

[1] Compare MEYNERT, "Gehirn und Gesittung," Vienna (1889).

but that combinations of ideas also take place within the mind itself, and in their totality correspond to no actually experienced combination of sensations. On the contrary, these ideas represent wholly subjective ideational combinations. In this manner a complex of ideas is also developed, in which our paramount, most intense lines of thought, accompanied by the strongest emotions, participate as elements. The sum total of our present inclinations and our actually dominant ideas constitutes an essential part of our idea of the ego. But besides the idea of one's *present* corporeal and mental ego, there is still a third member participating in the usual ego-idea. This is the very essential total idea that has been deposited in memory by the succession of one's most important mental and physical experiences in the past. It will seem striking to us, perhaps, that the ego-idea, which is designated by the short, small word "I," should be such a complex structure, composed of three chief members in which thousands and thousands of component ideas participate. But let us reflect; the word is, indeed, short, but that its intellectual content must be very complex is readily shown by the fact that we should be at once embarrassed if called upon to state the mental content of our so-called "idea of the ego." We should at once think of the body, of our relation to the external world and our relations to family and to property, of our name and title, of our chief inclinations and dominant ideas, and finally of our past experiences. In so doing we should demonstrate for ourselves how exceedingly complex this idea of the ego is. The reflective person, of course, reduces this complexity of the ego-idea to relative simplicity by placing his own ego, as the subject of his sensations, ideas and motions, over against all objects and other egos of the external world. To be sure, this simplification of the ego-idea by placing it as subject in opposition to the rest of the world as object, has a deep foundation in epistemology; but regarded purely in the light of psychology, this simple ego is but a theoretical fiction. Empirical psychology recognises only that complex ego whose chief characteristic features we have just briefly described. When we are occupied with the common processes of natural thought we pass from idea to idea and from judgment to judgment without the appearance of this complicated idea of the ego. It is very different in the case of the so-called voluntary thought to which we have already referred above. Here the idea of the ego often appears between the single ideas and judgments; in this case we make a mental reference to the ego-idea as the cause of the series of ideas and judgments with which it is associated. However, the concomitant activity of the idea of the ego is not always present. In the case of very deep reflection or rumination we often forget that it is we ourselves who are thinking. But in general it is true that the so-called voluntary thought is accompanied by the idea of the ego.

Let us now recapitulate the three factors that characterize so-called voluntary thought. They are as follows: (1) The peculiarity that the idea desired and sought is known to be already contained in the initial series of ideas. (2) A complex of accompanying muscular tensions that produces the kinæsthetic sensation characteristic of attention, and finally (3) the concomitancy of the ego-idea with the series of ideas that constitute thought. We have also seen that these three factors are all generally, but not always, present at the same time, and that they appear singly also in the case of involuntary thought. From what has been said, however, we may also conclude that this voluntary thought by no means occupies a unique or peculiar position among psychical processes. On the contrary it remains quite within the limits of the association of ideas with which we are already thoroughly familiar. Our thoughts are never voluntary; like all events, they are strictly necessitated. The freedom, which we think to possess in the so-called voluntary processes of thought, is only semblance; but this appearance of freedom is fully explained psychologically by the three above-mentioned factors.

Both the common usage of language and of philosophical and psychological theories, have distinguished many other special forms of the association of ideas besides those that we have mentioned. These special forms have received special designations, such as "understanding," "reason," "power of judgment," "sagacity," "fantasy," etc. At the same time there has always been a tendency to render these special activities, that may be distinguished more or less justly, independent entities by ascribing them to just as many different psychical faculties. On the contrary, however, we shall hold to the fact that all these activities simply represent varieties of the association of ideas. It would not be at all difficult to reduce all these forms to the one fundamental form of association by purely psychological reasoning. The difficulties that cling to these conceptions are due to their alliance with certain conceptions of metaphysics and epistemology and to the fluctuating applications in which the corresponding terms have been used by different peoples and philosophical schools. We shall now emphasize only one other phase of the association of ideas, the *memory* or faculty of *recollection*. In this example (the memory) we shall illustrate how such psychical activities are to be viewed as a rule and how they are to be reduced to the association of ideas. It is obvious that two things are necessary in order that we may recall the mental image of an object or sensation: (1) the image of the object in memory must be intact, and (2) the association as such must take place normally. The latter is abnormal only in cases of great fatigue or of mental disease. Under such circumstances the association of ideas may be so retarded that it is finally completely arrested; no mental image or idea is reproduced. The latent mental image *El* is intact, but the material process, which should convert this *El* into *Ei*, and thereby bring the image of memory into consciousness, is not sufficiently vigorous to accomplish the task. This forgetfulness is but transitory. But the loss of memory, caused by the destruction of the mental images themselves, is a very different matter. We have already heard in a previous chapter that during the first five minutes after their deposition the images of memory lose very little or nothing at all of their intensity and distinctness. Then the slow process of material change begins, gradually effacing the material dispositions—the *El*'s. To express it in the language of psychology, the images of memory gradually lose their intensity and distinctness. The more seldom they are reproduced, the more rapidly does this change progress. Also different individuals are very different in this respect. In one person the images are less firmly deposited and more speedily eradicable than in another. In this case we ascribe a "good memory" to the latter, and a "bad memory" to the former. But even with a due consideration of all these circumstances, "memory" and "loss of memory" still remain comparatively relative conceptions. Let us consider that the reproduction of an idea at any definite moment also depends upon both its associative relation to the preceding idea and the grouping of latent ideas. If these are unfavourable, even the most intense mental image may remain latent. We are then accustomed to say that this or that thought or idea "does not occur to us." We see, therefore, that this apparently simple faculty of memory resolves itself into a much more complicated process. In all its variations, however, it depends on nothing more or less than the association of ideas and its laws, with which we are already familiar.[1]

From the above we can judge how extraordinarily difficult it is to investigate experimentally either the retentive power or the forgetfulness of the mind. It is hardly possible, for example, in attempting to determine the influence of passing time upon the retentiveness of the memory, to retain all other factors, such as the state of feeling, grouping of ideas, attention, etc., entirely constant during the full series of experiments. However, in the case of the memory we have the very trustworthy, painstaking researches of Ebbinghaus.[2] Ebbinghaus arranged syllables in series of different lengths, but without regard to sense. He then memorized these series by repeatedly reading them aloud until he

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[1] HERING ("Ueber das Gedächtniss als eine allgemeine Function der Materie," 1876) has ascribed memory to all organized matter. In this case the word memory is also applied to processes that cannot be shown to be accompanied by parallel psychical processes. We shall here exclude this expansion of the conception. Compare also MEINONG, Vierteljahrschrift f. wiss. Philos., X. JOH. HUBER, "Das Gedächtniss," 1878. PLATO, "Theætet."

[2] EBBINGHAUS, "Ueber das Gedächtniss." "Untersuchungen zur experimentellen Psychologie," Leipzig, 1885. WOLFE's dissertation (Philos. Stud., III.) contains a special investigation of the memory for tones.

was just able to reproduce them. After certain intervals of time (for example, 20 min., or 1 or 2 days) had elapsed, he determined by experiment how many times he had to *re*-read the partly forgotten syllables in order to be able to reproduce them again. By this means he obtained a standard for measuring the degree of forgetfulness. As the result, it appeared that the process of forgetting progressed very slowly at first, then more rapidly and finally very slowly again. An hour after the series had first been memorized, the process of forgetting had advanced so far that more than half the time originally employed was requisite for committing the series to memory again. Eight hours later two thirds the original time was required for learning it anew, a month later about four-fifths the original time. These numerical relations may be expressed, approximately at least, in the following law: "The quotients of the amounts retained by the amounts forgotten are to each other inversely as the logarithms of the various periods of time that have elapsed." The result obtained by the same author, in making use of series in which the syllables are arranged so as to produce sense, is worthy of mention. For example the verses of an epic poem can be ten times more easily retained than senseless series of syllables. Without investigating the correctness of the number *ten*, we see that it is undoubtedly true that the ideas composing a series are more firmly fixed in memory when they are more closely associated with each other, especially by means of judgments. Ideas thus thoroughly associated mutually assist one another in reproduction by means of that which we have designated as the grouping of ideas. As Herbart expresses it, they are "mutual aids" (Hülfen). Ebbinghaus found further that one reading is sufficient to memorize a series of from seven to eight syllables, but that forty-four repetitions are necessary for a series of twenty-four syllables.

Investigations that are just as exact as those supplied by Ebbinghaus for the memory, are wanting for most of the other pyschical processes. We must therefore restrict ourselves to repeating once more that they may all be explained without difficulty by the association of ideas and its laws.

CHAPTER XII.

MORBID THOUGHT—SLEEP—HYPNOTISM.

THUS far we have considered only the thought processes of the healthy man in his waking moments. Let us now descend, as it were, into the labyrinthic realms of insane or morbid thought. Right among these psychical anomalies we shall observe numerous phenomena that confirm the propositions thus far advanced. We remember that we reduced every psychical process to essentially the same simple scheme. An initial sensation S is followed by a definite series of ideas, I_1, I_2, I_3, etc., in accordance with the laws of association. The sensation S is always conditioned by an external stimulus E; the ideas I_1, I_2, I_3, etc., originated in former sensations. These material dispositions, the El's that have been left by former sensations, are changed by the associative process into Ei's, or I's, and are thus reproduced, *i.e.* called into psychical life. Now what deviations from this normal process occur in the conscious life of the insane? Let us here first call attention to a peculiar phenomenon that has been termed "secondary sensation." This phenomenon occurs when a sensation of one quality that has been normally produced by an adequate external stimulus, at the same time imparts a sensation of an entirely different quality for which there is no corresponding external stimulus. A simple example of this secondary sensation is as follows: We hear a very loud, shrill sound, and at the same time see a flash of light before the eyes. In this case the visual sensation of the flash of light has been produced without any adequate stimulating cause in consequence of a normal sensation of hearing. On the other hand, a bright light sometimes produces the secondary acoustic sensation of a high tone besides the primary sensation of light. It is obvious that this phenomenon depends on the sympathetic excitation of the elements of the auditory centre to which the cortical excitation primarily produced in the visual centre has been transferred by means of the associative paths. This process differs from the process of association with which we are already familiar only in the fact that the latter is the association of mental images or ideas, while the secondary sensations, on the contrary, are produced by the association of sensations. The image of fire may remind one of a crackling noise; the sound of a trumpet may recall the idea of yellow. In both cases, however, the association is accomplished by means of ideas and only the *mental image* of red or yellow is reproduced. On the contrary, in the case of secondary sensations the primary sensation *directly* imparts another *sensation.*

We shall do better therefore to avoid the expression "association" in connection with secondary sensation and make use of the term "radiation." We are all aware that the pain caused by a carious tooth may often spread in a somewhat remarkable way until it finally attacks the entire half of the head.[1]

The effect which prolonged pain produced in the case of *one* sense is transferred in the case of secondary sensations from one sense to another. Among the secondary sensations, "photisms" (*i.e.* secondary sensations of light or colour) are decidedly the most frequent; "phonisms"[2] (*i.e.* secondary sensations of tone or noise) are considerably rarer. The quality of the secondary sensations is always the same in the same individual, but on the other hand, often different in different persons. For this reason it is only possible to formulate a few general laws. As a rule, bright photisms are produced by sensations of high tones, or also

[1] The interesting observations of URBANTSCHITSCH's upon the changes in the sensibility of the trigeminal nerves accompanying diseases of the ear, also present a certain analogy. Compare also PFLÜGER's Archiv, Bd. 42.

[2] The use of the words "photism" and "phonism" has been borrowed from the German for the sake of brevity. Their meaning is parenthetically indicated above.—*T's.*

by intense pain and sharply defined sensations of touch; dark photisms are produced by sensations of an opposite nature. In the same manner high phonisms are produced by sensations of bright light and sharply defined sensations of touch (small, pointed objects). The phonisms generally partake of the quality of noises; the photisms generally appear in the colours of red, yellow, brown or blue. Sometimes a definite colour is associated with a definite pitch, vowel or noise. There is a case of one German lady[1] who is known to associate the acoustic sensation ă with the sensation of the colour yellow, ā with white, ē with blue, ō with red, and ōō with black. The same lady also sees the printed vowels glimmer in the same colours whenever she reads. In accordance with a proposition made by Fechner, the academic philosophical union in Leipzig instituted a collection of statistical data on a large scale. The result of these data showed that on the average, though not always, lighter photisms correspond to the vowels ă, ā and ē, and darker photisms to the vowels ō and ōō. Both diphthongs and polysyllabic words appeared to the above-mentioned patient in mixed colours. French authors have very characteristically designated this as "audition colorée," or "coloured hearing." The localization of the secondary sensations is also interesting. Photisms produced by sound, *i.e.* secondary sensations of light induced by sensations of tone, are generally localized in the field of hearing from which the primary sensation proceeds; the rare photisms produced by sensations of taste are generally localized in the appropriate region of the buccal cavity, and photisms produced by sensations of smell, in the neighbourhood of the object smelled, or in the cavity of the nose. Much more rarely the localization is within the head (de Rochas, Ughetti). It is also well worth mentioning, that an unpleasant emotional tone accompanying the primary sensation may be followed by an agreeable emotional tone accompanying the secondary sensation. In by far the majority of cases the secondary and primary sensations seem to appear simultaneously; in

[1] A patient of the author's.—*T'r.*

rarer cases an interval of some seconds has been observed to elapse before the appearance of the secondary sensation.

The question now arises: are these phenomena pathological or normal experiences of the psychic life? Bleuler and Lehmann[1] found such secondary sensations in one-eighth of all the men whom they investigated. The questions (Fragebogen) of Fechner[2] brought together 347 reliable cases in which colours were associated with sounds. Of course it is probable that not all of these cases are genuine, but that on the contrary, in a part of them, certain associations of ideas, originating partly in earliest childhood, are the cause of the secondary sensations. It cannot be doubted, however, that genuine cases occur. In these genuine cases, almost without exception, we find a neuropathic disposition. The above-mentioned lady suffered from severe reflex neurosis. At the time that Nussbaumer[3] first imparted his self-observations to Germany before the medical fraternity of Vienna, Benedict had already called attention to the psycho-pathological features of these symptoms. In very many cases there is an inherited disposition. Nussbaumer's brother had likewise had secondary sensations; also several of Bleuler's relations besides himself. In mentally healthy individuals, who are free from all neuropathic disturbances, these secondary sensations are at least just as rare as the hallucinations that are to be considered presently. There is no doubt that inherited associative paths of abnormal capacity for conduction are, in the above cases, the means of communication between the separate cortical centres of sensation.

[1] "Zwangsmässige Lichtempfindungen durch Schall und verwandte Erscheinungen auf dem Gebiet der anderen Sinnesempfindungen," Leipzig, 1881.

[2] STEINBRÜGGE, "Ueber secundäre Sinnesempfindungen," Wiesbaden, 1887. In this work are also to be found further, though incomplete, literary references. To the above work should be added GIRANDEAU, "L'encéphale," 1885; DE ROCHAS, "La Nature," 1885; and numerous Italian authors. The first description was given by LUSSANA as early as 1865.

[3] Wiener med. Wochschr., 1873. FECHNER's first communication appeared independently of NUSSBAUMER's in the "Vorschule der Aesthetik," 1876.

Normally, the sensation should always cause the appearance of ideas only, and not of sensations; the sensations themselves should not appear without adequate stimulation. The secondary sensation is not produced by adequate stimulation, but by the action of some other sensation; it therefore departs from the nature of the normal or primary sensation. We shall now consider another case of morbid sensation—the *hallucination*. In this case not only the adequate external stimulus, but also the primary sensation are wanting. The persons subject to hallucinations sees persons and landscapes in the cloudless sky, and hears voices in the most profound stillness. At the same time his visions are often so realistic and so true in colour, and the auditory hallucinations[1] that he hears are so loud and distinct, that it is absolutely impossible to distinguish them from the reality. They appear when the eyes and ears are closed the same as when they are open. They often correspond to the actual content of the invalid's thoughts; in this case he complains that all his thoughts are at once "set in scene" and "illustrated," or that they "become loud." Again, the visions are often entirely strange and surprising to the patient himself; he sees faces that he never saw before, and hears words that have not the remotest connection with his thoughts or even combinations of syllables that he never heard before. In still other cases the invalid possesses the power of producing this or that hallucination at will, somewhat as Goethe relates of Ottilie in his novel, "Wahlverwandtschaften."[2] Genuine hallucinations of taste, smell and touch are considerably more rare. Certain hallucinations in the case of motor sensation are highly interesting. One invalid told the author that he felt his larynx and tongue move as if he heard the word "parricide" issuing from them. It is not improbable that such hallucinatory motor sensations at times cause actual involuntary motions, thus producing the articulation of the respective word. As regards localisation, the voices heard are occasion-

[1] Ger. *Akoasmen*.—*T's*.
[2] Natural or elective affinities.—*T's*.

ally, the visions very rarely located within the head; much more frequently both are projected outward. Their location, when perceived as external to the invalid himself, appear to vary; the variation is only in part dependent on the movements of the invalid's eyes while experiencing the hallucinations. Those cases are remarkable, in which the hallucinations are always heard with but *one* ear, or seen in but *one* half of the field of vision. The author also recollects a case in which the agreeable voices always spoke into the right ear, and the disagreeable voices into the left ear. Squinters often see their visions double. Sometimes it is necessary for the invalid to give especially close attention, in order to distinguish words among the indistinct hallucinatory murmurings. The hallucinations generally have a stronger influence upon the association of ideas than the concomitant normal sensations, which are often, in fact, overshadowed. For this reason, when a large number of hallucinations continues many years they very rarely fail to beget insane ideas.

In many cases of hallucination a disease of the invalid's organ of hearing or sight can be diagnosed; but in numberless cases no such disease of an organ of sense is present. Individuals whose optic nerves have been atrophied for a number of years can have visions. On the contrary no persons have ever been known to have optic or acoustic hallucinations, who were *born* blind or dumb.[1] The stillness of solitude, as in the case of solitary confinement for example, favours the appearance of acoustic hallucinations; the darkness of night or the bandaging of the eyes after an operation for the removal of a cataract, favours the appearance of visions. These two statements do not express entirely universal rules, however. On the contrary, there are even cases in which slight stimuli of sight or hearing, of any kind whatsoever, are sufficient for the appearance of hallucinations. It also appears in some cases that a normal sensation of one quality is requisite to produce hallucinatory sensations of another quality (Kahlbaum), so that in a certain sense a primary sensation is still necessary.

[1] Leidesdorf, "Lehrb. d. psych. Krankh.," 1865.

Hence many hallucinations vanish when the eyes are closed; many do not.

Now, how shall we explain the origin of these hallucinations; how can a sensation be produced without stimulation?

Let us remember the former distinction that we made between sensation-cells and memory-cells. We have already shown that the sensation and image of memory are probably not connected with the same material elements. We designated the material process in the sensory cells, corresponding to the sensation, as *Ec*; the material disposition that remains in the memory-cells, as *El*; the material process attending the awakening or reproduction of the latent image of memory and corresponding to the conscious idea, as *Ei*. Normally, the sensation-cells are only excited by stimulation coming from the periphery; *Ec* is only produced by a stimulus *E* that acts upon the sensory path. This is different in the case of hallucinations. In this case it is the images of memory that produce lively sensations without external stimulation; the *El*'s or *Ei*'s are the cause of *Ec*'s. The process of sensation which normally always proceeds from the sensory elements to the memory elements, now takes the reverse course from the latter to the former. Generally, this only occurs under pathological circumstances. It is only when the sensory cells are morbidly irritable, that they react upon a stimulation from the memory cells, which, under normal conditions, would have no effect upon them, but which has been pathologically intensified. The sensation-cells are sympathetically excited, as it were. It is obvious that but two chief cases are to be distinguished. The ideas that sympathetically excite the sensory cells are either the ideas actually present in consciousness at the time (*i.e.* the *Ei*'s), or the ideas that are psychically latent, *i.e.* more accurately expressed, the material dispositions that still lie below the threshold of consciousness. In the first case the hallucinations correspond to the momentary content of consciousness, as has already been described; in the second case they emerge from among the latent ideas very suddenly, surprising even the invalid himself. It is evident that in general hallucinations of the second class occur only when very considerable changes in the excitability of the sensation-cells have taken place, while the actual conscious ideas produce hallucinations even when the excitability of the sensation-cells has but very slightly increased. For this reason hallucinations of the second class are generally much more vividly perceived than those of the first class, since in the former case the sensation-cells are more affected by the morbid phenomena than in the latter. As we already know, both sensation-cells and memory-cells are located in the cerebral cortex; the hallucinations are therefore decidedly of cortical origin. The assumption that the peripheral parts of the sensory nerve-paths (corpora quadrigemina, retina, etc.) are sympathetically excited to a certain extent in case of hallucinations, wants sufficient grounds. On the other hand it can be shown that in a large number of cases of hallucination, some external stimulation in the broader sense is not entirely wanting. It appears, in fact, that subjective sounds, produced in the peripheral parts of the organ of hearing, or entoptic disturbances in the vitreous body for example, and especially excessively augmented "mouches volantes" are very frequently the cause of hallucinations. Such subjective sounds, resulting from peripheral causes, may exist for years and be perceived in their true nature, *i.e.*, for example, as a simple buzzing or humming in the ears. If, however, a mental disturbance is developed in the individual, these noises are soon heard as words and voices. In a similar manner the "mouches volantes" appear to one delirious from the use of alcohol to be numberless mice or bees swarming about him. It is very apparent that in this case, and in many other similar cases, the sensation-cells do not receive excitation from external stimuli in the narrower sense, that is, from such as are external to the body, but from those external stimuli that are situated in the sense-organ or in some part of the sensory nerve-path up to the cerebral cortex. Under normal circumstances a very simple sensation corresponds to this excitation; the individual hears a buzzing in the ears or sees dark spots in the visual field. Under abnormal circumstances the memory-cells act upon the sensation-cells in such a manner as to transform the excitation into more complicated sensations; the buzzing in the ears becomes words, the dark spots become forms. In many respects these hallucinations [1] already approach the illusions which we shall forthwith discuss more fully.

Also, in this connection, we shall now ask whether the hallucinations may occur in healthy persons, or whether their appearance is limited merely to mental diseases? An exact investigation of this subject shows that in this case also the many individuals who have inherited tendencies toward mental diseases, although not mentally deranged themselves, experience hallucinations. Of still greater importance to us is the fact that even men who are very gifted mentally, particularly artists who possess a very vivid imagination, have hallucinations. The Italian painter, Spinello Aretini, is said to have *copied* his Madonnas, as it were, from a vision; an Italian composer is said to have composed his sonata in imitation of music heard during hallucinations. The well-known vision of Goethe's—the rider in pike-grey mantle upon the Sesenheim ride—was probably a simple illusion. Hallucinations are recorded of Schumann, Pascal, Cardanus, Mendelssohn, Jean Paul, Spinoza, Byron, Tieck, Johnson, Pope, and numerous others. To be sure, in many of these cases we have to deal with very doubtfully authenticated reports; in many the phenomena may have also been mere illusions. In the normal man, at least, even the liveliest emotions generally produce nothing more than illusions, never hallucinations. Fechner and Henle report of themselves that at night objects with which they had been occupied during the day often appeared to them again as phantasms in the dark. The peculiar hypnagogic hallucinations

[1] The literature upon the subject of hallucinations is extraordinarily comprehensive. At the present moment extracts from over 300 works lie before the author. As a preparatory introduction to the theory of hallucinations, HAGEN, Allgemeine Zeitschrift für Psychiatrie, Bd. 25, is to be especially recommended. Also KAHLBAUM, ibidem Bd. 23. LAZARUS, Zeitschr. f. Völkerpsychologie, Berlin, 1867. KRAEPELIN, "Ueber Trugwahrnehmungen," Arch. f. Psych., Bd. 14. KANDINSKY, Arch. f. Psychiatrie, Bd. 11. A brief presentation of the doctrine of hallucinations is to be found in MENDEL, Berl. klin. Wchschr., 1890.

that appear just before falling asleep are also very interesting. They have been most exactly described by Hoppe.[1] Almost every one can observe these in his own case occasionally. They appear only upon closing the eyes, and are, without exception, visions of but slight sensual vivacity, generally indistinct visages or landscapes.

By *illusions* we understand those sensations that are, in fact, produced by external stimuli, but that do not correspond to the same in quality. We are all familiar, perhaps, with the poem of Schiller's, which runs as follows :—

"Hör' ich das Pförtchen nicht gehen?
Hat nicht der Riegel geklirrt?
Nein, es war des Windes Wehen,
Der durch diese Pappeln schwirrt."

"Seh' ich nichts Weisses dort schimmern?
Glänzt's nicht wie seidnes Gewand?
Nein, es ist der Säule Flimmern
An der dunklen Taxuswand."[2]

Or let us recollect the well-known example of an insane person who, while observing a real portrait, suddenly perceives the painted head protrude its tongue, the vision possessing all the sensual vivacity of the real act. Again, a lady who was mentally deranged once related to the author that as often as she travelled upon the railway, she heard a voice call out from the rattling of the wheels, "crazy Bremer, crazy Bremer,"—Bremer being the patient's name.[3] Let us now inquire what processes lie at the

[1] HOPPE, "Erklärungen der Sinnestäuschungen," Würzburg, 1888.

[2] The above selection is from Schiller's "Erwartung." The reader who is not versed in German will probably be able to derive greater benefit, so far as its specific application above is concerned, from a more literal translation in prose than from a free poetical translation. The former is as follows: "Do I not hear the wicket open? Was it not the bolt that clicked? No, it was only the wind sighing and murmuring through these poplars. . . . But do I not see something white, gleaming there? Is it not the flash of a silken robe? No, 'tis but the columns that glisten against the dark wall of yews."—*T's.*

[3] The German words, when regularly repeated, bear more or less resemblance to the rhythmical, but monotonous noise of car-wheels in motion. "Verrückte Bremer, verrückte Bremer" (⏑–⏑–⏑, ⏑–⏑–⏑).—*T's.*

foundation of these phenomena. It is obvious that at first a sensation is produced in the normal manner. The sighing of the wind in the tops of the poplar-trees, the white columns seen against the dark background of yews, the portrait, the rattling of the railway coaches, etc., are the external stimuli that impart sensations. But these sensations are transformed. The rustling of the poplar leaves sounds to the expectant person like the noise of an opening door; the white column assumes the form and appearance of a white robe; the head protrudes the tongue; the rattling is changed into words. This transformation is produced by the influence of actual, or, in the last two cases, of latent ideas. The memory-cells, as it were, add certain hallucinatory elements to the sensations. Such transformed sensations are designated as "illusions." It should be carefully noted, however, that these are not merely cases of mistaken or deceived judgment. The rustling of the leaves in the wind is not falsely judged in the case of illusion, but the quality of sensation itself is directly changed; it has a sound different from that corresponding to the stimulus. On the contrary, our judgment is often able to rectify such illusions.

These illusions are of frequent occurrence, and appear in connection with all of the senses. In fact, we may say that the influence which the images of memory exert upon sensation is never entirely wanting. The proper nursery of the illusions, however, is the emotional life; among the various emotions, expectation, both when accompanied by fear and by hope, is of especial importance. We shall now understand also why we formerly designated those hallucinations, that depend upon entoptic and entotic stimuli, as illusions; they are obviously merely the result of a transformation of sensations imparted by actual stimuli. Without doubt the illusions are also produced through the influence of a recurrent excitation of the sensation-cells by the memory-cells.

We can dispose much more briefly of those pathological disturbances in which the images of memory themselves, and the association of ideas are affected. We shall very briefly mention only the most important, and for normal psychology the most interesting phenomena. One of the chief among these is *imbecility* or *dementia*. We remember that the most probable anatomical basis for the association of ideas was found to consist of numberless so-called "associative fibres," which connect the ganglion-cells with one another by running through the white matter, partly in arcuate courses, from one part of the cerebral cortex to another. The ganglion-cells themselves are most naturally to be regarded as those elements which we have designated as memory-cells, and in which the so-called latent images of memory are deposited. Now it is of the greatest interest that the investigations of pathological anatomy have furnished positive results in the case of that mental disturbance which inevitably leads to complete imbecility, the so-called softening of the brain, or *dementia* paralytica. It consists particularly in the destruction (1) of the ganglion-cells themselves, and (2) of the associative fibres uniting them. We find that these facts, to a certain extent, once more confirm all our previous deductions, *a posteriori*.

The abnormal acceleration and obstruction of the association of ideas, and also its morbid incoherency have been already mentioned above. It only remains for us to consider briefly two other psychopathic phenomena that deserve a very especial interest,—the *delusive idea* and the *compulsory idea*. The two phenomena are alike in being associations of judgment that have no sufficient foundation in the external world. They differ from one another in that in the former case the invalid believes in his delusion, while in the latter he is fully conscious of the incorrectness and morbid nature of the idea which is forcing itself upon him. A patient who believes that he is Jesus Christ is suffering from a delusion; one who, while cutting his bread, is constantly harassed by the thought that he is cutting his brother in two, and who, although he recognises the idea itself to be false and laughable, is still unable to rid himself of it, and is driven to the point of refusing nourishment, is the victim of a compulsory idea, or an idea which forces itself upon him. How do ideas of these two kinds arise? Normally the association of ideas, especially association that produces judgments, develops under the constant influence of sensations, that we are always experiencing anew from moment to moment; the latter condition and determine the former. This influence of the sensations affords the possibility of a constant correction of the judgments that are being produced by the association of ideas. Incorrect judgments are suppressed in the very act of formation. Thus both fantasy and judgment are under the control of the external world, and may never become too contradictory to it. We commit "errors" of judgment, in fact, because our sensations themselves do not always correspond exactly to the external excitants, and particularly because the chief law of the association of ideas, the law of simultaneousness, obviously permits or even causes at times quite illogical conclusions and unwarrantable generalizations;[1] but such errors become neither delusive nor compulsory ideas. In general the parallelism of the associations of judgment and the series of external excitants or processes of the external world remains comparatively intact. In invalids who are suffering from delusions or compulsory ideas the regulative influence of the sensations or of the external stimuli upon ideation has either been removed or has lost the persistency of its action. Hence the association of ideas produces judgments that are completely contradictory to the processes of the external world. In fact, in the case of these invalids the process is reversed; the association of ideas influences the sensations. The latter are interpreted so as to harmonize with the existing insane ideas and remodelled accordingly; a further stage brings illusions and hallucinations. It is not mere chance that illusions and hallucinations so very frequently accompany delusive or insane ideas. All three are symptoms that the ideational life has been wrested from the control of the sentient life. Delusive and compulsory ideas are only distinguished from each other as regards their origin. In the latter case *correct* judgments are still made as well as incorrect,

[1] MÜNSTERBERG is right in declaring that the errors of judgment can be far more easily explained psychologically than its constant correctness.

and greatly exceed the latter in numbers, while in the former case, on the contrary, correct judgments are not formed at all, or at most only in very limited numbers.

We must now content ourselves with these few hints concerning the theory of morbid disturbances in mental activity, and pass on to the psychological presentation of a condition that has often been directly compared, though of course without sufficient grounds, to the morbid mental conditions, viz. the condition of *sleep* with its dreams. We do not yet know with certainty what the physiological basis of sleep is, whether merely a chemical exhaustion of the cerebral cortex, or a universal or partial change in the circulation of the blood.[1] Psychologically, sleep appears to be a more or less complete removal of all psychical processes. One might designate this condition, if so desired, as unconsciousness. The *Ec*'s of the cerebral cortex remain too weak to produce a concomitant psychical process or sensation, and the *El*'s are not aroused from their state of latency. Psychical processes appear in but *one* form during sleep,—in the form of dreams. The study of dreams is extraordinarily interesting, and urgently to be recommended as a subject for introspection. The results of our self-observations will only be exact, however, if we follow the example of Lazarus by laying paper and pencil beside us before falling asleep, so that, as soon as we waken in consequence of a dream, its contents can be written down at once. If we wait longer, till morning perhaps, the greater part of it will have vanished from memory. An accurate analysis of the process of dreaming shows that its elements are imaginative ideas (in the sense which we have already discussed above), but that these ideas are also often equipped with almost as great a sensual vicacity as the sensations themselves. On this account they may be regarded as peculiar somnial hallucinations that appear in longer successive series, but that are generally even more closely connected with one another than the hallucinations experienced

[1] More recent investigations seem to indicate at least a partial *anæmia* of the cerebral cortex.

when awake by those who are mentally deranged. It can be shown that in very many cases, at least, the somnial phantasms are more or less due to peripheral stimulation. For example, a severe neuralgia not infrequently causes the somnial sensation of a dagger-thrust in the neuralgic part of the body; with this sensation the image of the murderer and his threatening words are then associated, appearing with all the vivacity of hallucinations. At first, therefore, an illusion, and not a hallucination, appears; the hallucinations are only secondarily associated with the illusions. Generally those mental images are reproduced as somnial hallucinations, that participated in the association of ideas not directly, but some hours before falling asleep. This is not unexceptionably the case, however. It is often very striking that the somnial visions are colourless, although of course the most vivid colours occasionally appear. Above all, the almost complete absence of motor reactions is also characteristic of somnial phenomena. The muscular system seems to be lamed; even in the deepest sleep the phenomena accompanying the activity of the tendons, otherwise so accurate an index of the existing muscular tone, have disappeared. We have, indeed, motor ideas; in our dreams we believe that we are walking or fighting, and yet we scarcely move. It is only in the most vivid dreams that either men or animals (especially the hunting dog, for example) give a weak expression to the somnial ideas of motion by a few slight movements of the trunk and extremities.[1] In sleep, therefore, (1) the initial element of the psychical process, the sensation, is produced by ideational stimulation, and (2) the final element, the motor idea or the action, is almost entirely omitted.

One characteristic of the dream, its speedy disappearance from memory, deserves an especial discussion. As a rule the repro-

[1] It is of interest in this connection that Laura Bridgman, who was born blind and deaf, is said to have gesticulated with her fingers during sleep a great deal. In this case intensified motor ideas to a certain extent compensate for the absence of visual and acoustic ideas.

duction of even a vivid dream is no longer possible with any degree of completeness five minutes after one has wakened. But we are also unable to reproduce a long series of sensations or ideas that have been experienced in waking moments entirely without omission. Let us remember that the association of two ideas which have no other connection than that of mere succession in time is very loose; on this account we reduced the association of ideas by succession, in so far as the latter is not quite direct, to the association of simultaneous ideas. Such associations as the latter are never entirely wanting. Hence we are able to reproduce even the long series of our experiences that we have when awake, passably well. In so doing we are also aided especially by the vivacity which the images, left in the memory by the successive sensations, possess in different degrees and by the complete and close relation existing among the successive sensations or ideas. The series of somnial sensations or ideas offer much less favourable relations for reproduction. The sensations in dreaming are always less intense and much more disconnected; they are characterized by many abrupt transitions. The separate successive ideas are but rarely combined into conceptions, and conceptions of relation are rarely introduced.

Finally a sudden awakening produces abrupt changes in the circulation of the blood which are followed by immediate and important changes in nervous excitability that are probably not the same for all parts of the cerebral cortex; numberless stimuli act at once upon all the sensory organs, and produce an equal number of sensations. By this means that which we designated as the grouping of latent ideas is wholly changed; the new grouping is in all respects unfavourable to the mental images that have been deposited by the somnial sensations. This explains the difficult reproduction of the images of a dream, or, as it may also be expressed, the *amnesia* of somnial processes. However, the nature of the dream-images is by no means less psychical than the series of sensations and ideas that are experienced when one is awake. If we have entirely or almost entirely forgotten a small occurrence that happened while we were awake a short time ago, we are not on that account justified in concluding, however, that we had no proper psychical process, and were hence unconscious. The same is true in the case of dreams. The fact that we have forgotten them is not sufficient ground for the conclusion that during the dreams we were not fully conscious or that we were unconscious.[1] The psychical phenomena of the dreams and the conscious life of waking hours are different, but the two do not have a different psychical *value*. A removal of psychical processes, *i.e.* unconsciousness, occurs only in the case of sleep without dreams, which is comparatively rare.

Besides sleep there is still another series of different alterations in the psychical life, all of which are characterized by a greater or less derangement of the conditions attending normal excitability of the cortex, and by a consequent more or less complete amnesia. To these belong particularly the dazed or stupefied conditions of many epileptics, in which they perform the most complicated actions, or sometimes even commit crimes, that they are afterwards totally unable to recollect.[2] In very rare cases it sometimes happens that both phases of psychical life, with their different groupings of latent images of memory, alternate; each phase is characterized by amnesia of the preceding unlike phases but by recollection of all former like phases. This morbid phenomenon has received the very unsuitable designation of *double consciousness*."[3]

Hypnotism is another phenomenon that claims especial interest. Under this term we shall comprehend all those data that remain after a thorough critical elimination of the phenomena of animal

[1] The use of the word "unconsciousness" also in forensic psychiatry, and especially the *conclusion* that there must have been *un*consciousness because there was amnesia, are thus placed in a very unfavourable light.

[2] Compare SAMT, Arch. f. Psychiatrie, Bd. 5 and 6, and also the manuals of psychiatry by GRIESINGER, KRAFFT-EBING, and SCHÜLE.

[3] Compare EMMINGHAUS, "Allgemeine Psychopathologie." RIBOT, "Les maladies de la personnalité," etc.

magnetism, mesmerism, etc., and that have now become an object of exact scientific investigation. Hypnotism depends chiefly on the fundamental fact that certain individuals may be placed in a remarkably changed psychical condition. This condition is itself designated as Hypnotism. It is produced either by requiring the person that is to be hypnotized to gaze at a glittering object and then by gently stroking his forehead, or by constantly telling the subject, "you must sleep, you shall sleep." The first-named method we designate as the physical method; the second method is commonly known as "suggestion." Both methods can be still further modified in various ways. In general "suggestion" is the more effective. Bernheim has recently attempted to reduce all hypnotism to "suggestion," and to this end has sought to show that a hidden indirect suggestion of sleep is always contained in the acts of fixedly gazing at an object or stroking the forehead. Success is most rapid when one makes use of both methods, the stroking of the brow *and* the suggestion of sleep. But the essential peculiarity of the hypnotic condition, without regard to the manner in which it is produced, in fact, probably the only peculiarity common to all hypnotic conditions, is the power of suggestion. We may command the hypnotized person to perform any actions we please; he performs them like an automaton. We may suggest any sensations whatever to him and he has them at once, just as vivid and realistical as if they were hallucinations. If we tell him that his left arm is insensible to pain, he does not feel or notice the severest thrust of a needle into that arm. We may suggest any idea to him that pleases us, for example, the delusion that he is king; the subject conducts himself at once as a king. If we fold his hands as if in prayer, these passive motor sensations at once produce the hallucination of a church, a priest, etc. In short, the person who is hypnotizing excites in the brain of the hypnotized individual, either by speaking to him or in some other manner, any idea that he desires, and the idea thus aroused at once assumes sway over the association of ideas. All contrary ideas and even the sensations that are actually present are suppressed, and the ruling idea almost alone determines the course of association, while, at the same time, the mental images reproduced acquire a sensual vivacity amounting to hallucination. If the delusive idea of being king is suggested, the hypnotized patient forgets his real title and beholds himself clad in the coronal robes instead of in his own simple garments. It is obvious that this condition in which the subject can be swayed by the power of suggestion, presents a peculiar change in the cortical conditions of nervous excitability. This change is manifest chiefly in the disarrangement of the grouping of ideas, in the alteration of the intensity of latent mental images, and in the abnormal receptivity of the sensation-cells for stimuli imparted by the memory-cells. It is impossible here to give even an approximate idea of all the numberless variations of the hypnotic condition.[1] In what manner the above-mentioned methods produce this condition is as yet entirely unknown.[2] The hypnotic condition is followed by a more or less complete amnesia of all its processes. Of course, when the amnesia is complete, it is still a matter of doubt (as also in the case of the total amnesia of acts that occur during the stupefied condition of epileptics), whether despite their complicateness, all the acts of the hypnotized individual are not motions accomplished without any concomitant psychical process. Since the person who has been the subject of experiments is unable to give any account whatever of possible conscious processes during the hypnotic state, the criterion which we formerly employed in distinguishing between voluntary actions and automatic actions now leaves us in the lurch. We cannot decide with certainty whether actual, *i.e.* psychical or conscious images of memory have

[1] A good introduction to the subject of Hypnotism is given in the two articles upon hypnotism by PREYER and BINSWANGER in the EULENBURG "Realencyklopädie der medicinischen Wissenschaften." MAX DESSOIR (Berlin, 1889), has furnished a very complete summary of the entire literature upon the subject of hypnotism.

[2] Perhaps a dim light is thrown upon the subject of the production and nature of the hypnotic condition by the experiments of BUBNOFF and HEIDENHAIN; PFLÜGER'S Archiv, Bd. 26.

accompanied the psychical acts or not. It is sufficient here to state the problem; in the closing chapter we shall meet it again in a general form and attempt to solve it. At all events the amnesia as such cannot be cited as an argument either for or against the existence of concomitant psychical processes during the hypnotic state.[1] It is equally probable that the sudden change in the cortical excitations, as soon as normal consciousness returns, renders the association of the ideas experienced in the normally conscious condition, with those of the hypnotic condition impossible, or that both ideas and sensations are entirely absent in the latter state.

We are now familiar with the most essential deviations from the normal association of ideas, and can therefore turn to the final element of the psychical process, *action*, in the following chapter.

[1] Even the recollection of the hypnotic psychical processes would not necessarily argue *in favour of* their existence during the hypnotic state. Let us call to mind a former example,—that in which we pass a friend without noticing him; it only occurs to us subsequently that we have seen him. For obvious reasons, however, this *subsequent* appearance of the psychical process is only possible within a very short interval of time after the appearance of the stimulus.

CHAPTER XIII.

ACTION[1]—EXPRESSIVE MOTIONS—SPEECH.

THE psychical process began with the sensation. The association of ideas, *i.e.* a series of successive ideas, followed the sensation. The result of this association of ideas may be a motion, and such a motion we call "action." The association of ideas immediately preceding an action we generally prefer to designate specifically as the "play of motives." Let us begin by asking, How has this new element, the motion or the motor innervation, been added to the sentient and ideational life? How has man acquired his motions—motions that are, in fact, advantageous, that in general correspond with remarkable accuracy to his ideas, and show the highest degree of fitness? That much neglected department of psychology which seeks to establish some theory as to the evolution of the child's soul, is alone able to assist us in obtaining the correct answer.

The new-born child, the same as the new-born animal, at first executes very few, if any, movements that could be designated as voluntary motions or actions. It performs only reflex or automatic acts, although part of these are already extraordinarily complex. This statement agrees well with the fact of physiology and anatomy, that the nerve-fibres leading from the thalamus opticus to the periphery are already fully developed in the new-born child,

[1] By "action" the author signifies that which has generally been termed "voluntary action." The latter expression in the present work is only acceptible when understood in the sense of "conscious" or "*desired* action as the result of ideation," not "*willed* action." See pages 25–29, 247 and 265–269.—*Tr.*

i.e. in particular, they are already encased in medullary sheaths; while the large nerve-path, which extends from the so-called motor region of the cerebral cortex to the anterior horns of the spinal cord and thence to the different parts of the muscular system, and which, as has been demonstrated, conducts the innervating excitations to the muscles in the case of voluntary acts,[1] has not yet been provided with medullary sheaths. It also agrees with the further fact that electric stimulation of a definite part of the motor region in the adult cortex always produces movements of the opposite arm, stimulation of still another part movements of the opposite leg, and stimulation of a third part motions of the opposite facial muscles; but that electric stimulation of all these parts of the motor region, in the case of the new-born animal, produce no results whatever. From all these facts we must conclude that during the first months of its life the child gradually learns to make use of voluntary motions, or, as it may be more correctly expressed, of motions that are conditioned by psychical activity. We shall now inquire into the particulars of the process by which these actions are acquired. From the moment of birth the brain of the new-born animal, at first only capable of imparting "infracortical" reflex and automatic motions, is thronged with numberless sensations, produced by the numerous stimuli that stream in through all the sensory avenues. These sensations leave in the cerebral cortex (particularly in its sensory regions)[2] mental images which correspond to the material processes of excitation. At once the association of ideas begins. The sensory excitation is propagated along the paths of association and everywhere reproduces images of memory in the cerebral cortex. The material excitation thus propagated in the cerebral cortex also

[1] This is shown simply by the fact that if this path is broken at any point by disease all voluntary motions of the corresponding half of the body are no longer possible.

[2] In this connection it is not necessary to take into consideration the statement of many authorities on the physiology of the brain, that the size of the cortical centre for dermal sensations, the so-called "centre of feeling," corresponds to the size of the motory region.

reaches the motor region by means of associative paths and is discharged toward the periphery along the great motor path, the so-called pyramidal tract. At first this motor "discharge" is quite irregular. Certain paths of association, however, will have inherited specific capacities for conduction, which render them better prepared than others to receive certain specific stimuli. On this account the excitation will be directed along these paths from the beginning. These statements explain the fact that the chick, which has just been hatched, is able to pick up corn at once.[1] It is not necessary in this case, however, to assume that the chicken has inherited ideas of the kernels of corn; on the contrary, it is sufficient to suppose that at birth it already possesses an inherited associative path which is especially fitted for conduction between the visual centre and that part of the motor region from which the innervation is discharged to those groups of muscles active in the motions of picking up food. But apart from such dispositions as these, which the child possesses from birth, its first movements are in general fitting. The selection of fitting motions is only accomplished gradually and by practice; it acquires these motions in very much the same way that the adult, later in life, acquires a new motion or a series of motions, as those necessary in playing of a selection on the piano, for example. The extraordinary rapidity with which a child learns to execute so many and so complicated motions is to be explained simply by the inheritance of a favourable disposition in the associative mechanism. The exercise of this mechanism consists in the constant repetition of motor discharges until the irritant is removed. The child continues to reach after an object that acts as an irritant upon his sense of sight, until, after numerous unsuitable motor discharges, the fitting motion is at length hit upon. As soon as the object is seized the stimulation disappears and the motions just previously executed in trying to grasp the object cease. More correctly stated, the stimulation changes as soon as the object is seized, its position changed and the consequent

[1] Not excluding the possibility of an automatic act in this case, however.

sensations of touch appear; then the child is at once occupied in attempting to execute new motions that have different ends in view. In this manner a gradual process of selection, that is in fact astounding, produces the thorough fitness of our so-called voluntary motions. They are gradually adapted with extraordinary exactness to the stimuli of the external world, or—which is the same thing—to the sensations. In the meantime, however, another still higher stage of perfection is gradually effected in the cortical motor apparatus. The motor discharge that has just been described, is at first accomplished entirely without a concomitant psychical process. It is true that sensations and ideas may precede the motor discharge, but primarily they contain no element that is concerned in the resulting motion. It is only after the motion has taken place that the child acquires any knowledge of its own motor act. This knowledge is acquired by means of the sensations of active motion that we have already described in full. The active motions stimulate the nerves of the joints, tendons, ligaments, and skin, and the complex sensation thus produced we briefly designate as a motor sensation. Also the visual sensation, by which we are made aware that the position of the limbs has been changed by the active motion, blends with the motor sensation; by the latter term we shall hereafter designate a complex sensation which includes both the sensation of sight and the feeling of motion. Therefore the sensation of motion, which informs us that a series of ideas has resulted in a definite motion, directly follows the ideas immediately preceding it without the aid of any intervening element. An idea is now deposited by this motor sensation, just as mental images or ideas are deposited by all sensations. Hence we have also designated the image of a motor sensation in memory as a motor idea. Like all other ideas, these ideas of motion also participate henceforth in the association of ideas; like all other ideas, they also acquire the ability to produce motor discharges. At first only the visual sensation and idea, or the tactual sensation and idea of an object produce the motion which is executed in grasping it. After the motion of grasping has frequently taken place the *motor idea* of grasping the object is itself able to impart the motion. The complete associative connection that exists between the initial elements of the voluntary motor path and all cortical elements, is of just as much advantage to the motor ideas as to the ideas produced by any one of the senses; in other words, an especially intimate associative connection is established between the motor ideas and the excitations in the initial cells of the motor path. In fact, *every* single movement produces a synchronous association between the ideas and the excitations in the motor path, thus specifically training the associative path for conduction. Hence the motor ideas that were entirely secondary products, and that were only associated with the motor elements secondarily, finally acquire an almost complete sway over these motor elements. Later, when a series of ideas, I_1, I_2, I_3 . . . composed of ideas of sight, hearing, and touch, appears, they generally do not directly impart the motor innervation; on the contrary, the association of ideas first produces the appropriate motor idea, and only the latter causes the motor innervation. Recently Münsterberg[1] has justly called attention to the fact, that it is this precedence of the motor idea, indeed, which causes the motion to seem *voluntary*. "We *will* execute a certain motion" properly signifies, "we are conscious of the idea of the motion," or, "of the motor idea." The feeling which leads us to suppose that we are exercising a will-power is strengthened by the simultaneous innervation of certain muscles of the body, the musculus frontalis for example. This muscular innervation accompanies the voluntary movements the same as every effort of attention, and gives rise to peculiar concomitant kinæsthetic[2] sensations.

The results of modern investigations in the field of cerebral physiology also harmonize well with the above presentation of the subject. The so-called motor-zone of the dog, that region of

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[1] The above presentation of this subject agrees with MÜNSTERBERG'S writing, "Die Willenshandlung" (Freiburg, 1888) in the most essential points, although it deviates from it in some of the less essential particulars.

[2] Motor sensations in the restricted sense.

the cerebral cortex which produces contractions of the muscular system when electrically irritated, contains the primary elements of the motor path. In the dog the motor sensations and the motor ideas also appear to be located in this same region. At least this conclusion may be drawn from the experiments made by Munk; according to these experiments, the extirpation of the motor region from one hemisphere removes all ideas of movements performed by the opposite half of the body. In fact, according to Munk, both sensations and ideas of active and passive-touch and of position, in the case of the dog and ape are deposited in this same region. If the motor region governing the muscles of the dog's fore leg be extirpated from the left hemisphere, the right fore leg may be placed in the most uncomfortable position, and the animal makes no attempt to correct it. In descending a flight of stairs it misses the steps and frequently slips with the right fore foot. If it was trained to offer the right fore paw in response to one definite signal and the left in response to another, the latter is offered as before, but not the former. The dog that has thus undergone vivisection only reaches for a piece of meat with the left foot, never with the right foot, the cortical centre of which has now been extirpated. We see, therefore, that in these animals the different ideas of position, touch and motion are located in *one and the same* cortical region. In the case of man a greater local separation of these functions seems to have been effected. We should also consider that the motor idea is complex and that it contains a visual element besides the tactual. From the facts that we have thus far presented, it is at least obvious that the material process which takes place in the large initial cells of the motor path during innervation, occurs without a concomitant psychical process; psychical processes only accompany those physical processes that correspond to the antecedent motive sensations and ideas and to the motor idea following these and immediately preceding the motor innervation. Only sensation and idea are psychical processes; the motion or motor innervation has no psychical *concomitant* and is only the *effect* of a psychical process.

Of course a great deal of interest centres in the question as to how great the velocity of the nerve-process is in certain simple cases of action. We remember that, in connection with our experiments for determining the velocity of the association of ideas, and in anticipation of future investigations, we have already emphasized the importance of exhaustive researches in this sphere. In fact a large number of experimental works upon this subject have appeared, the majority of which are productions of the Wundt school. We shall here present the results of these investigations briefly, although the *interpretation* of the numbers given by the Wundt school will have to be greatly modified of course in order to harmonize with our standpoint.

When a very simple sensation imparted by a momentary excitant, produces a movement that is as simple as possible—a movement of the hand for example—we have the simplest case of action. In accordance with the precedence of Exner and Wundt, we designate the time that elapses between the stimulation and the resulting motion as the *simple reaction*-time.[1] It is of course very important that this simple reaction-time should also be determined when the person who is being tested does not know beforehand what stimulus will probably act upon him and when he has not been previously told to react with a certain movement. However such an arrangement of the experiments, especially as regards the second point, is obviously difficult to attain. On the contrary, the experiment is generally so arranged that the person who is being tested knows beforehand the stimulus which he has to expect and a definite movement which has been previously determined. The experiment is further arranged so that both the moment in which the stimulus takes effect, and the moment in which the reactionary movement is executed, are registered upon a rotating drum. We cannot here enter into a description of the numerous apparatus that have been applied in ascertaining the reaction-time; it is sufficient to name

[1] In accordance with our nomenclature, we should prefer the designation "simple *action*-time." (Also called "physiological time."—*T's.*)

simply Hipp's chronoscope and Wundt's chronograph.[1] The reaction-time is generally stated in thousandths of a second (σ).

These experiments for measuring the reaction-time very soon showed that the latter varies considerably, according to whether the tested person directs his attention to the expected sense-impression or to the hand which is to perform a certain movement. In the first case we speak of a *sensorial* reaction, in the latter case of a *muscular* reaction. The muscular reaction is always considerably quicker than the sensorial, the difference being [2] about $\frac{1}{10}$ second or 100 σ. The muscular reaction is therefore designated also as the *shortened*, and the sensorial as the *complete* reaction-time. According to the experiments of Ludwig Lange, the simple reaction-time in the case of stimulation by light, electricity and sound, amounts, in round numbers, as follows :—

Stimuli of—	For sensorial reaction.	For muscular reaction.
Light	290σ	170σ
Electricity (on the skin)	210σ	100σ
Sound	230σ	120σ

The most noticeable fact, at all events, in the above table is that the reaction upon impressions of light is considerably slower than in the other two cases. Individual differences are strikingly slight as soon as each person tested complies with the proper conditions, and turns his attention either *exclusively* to the sense-impression or *exclusively* to the movement. The reactions of one who undertakes to become the subject of experiments for the first time without preparation, are at first half muscular and half sensory, the attention is divided and fluctuates between the expected sense-impression and the movement agreed upon. On this account the reaction-time in this case varies greatly also according to the point toward which the attention is chiefly

[1] Compare Ludw. Lange, Philosoph. Stud., Bd. 4, S. 457.

[2] Wundt, "Physiol. Psychol.," Bd. 2, S. 267; L. Lange, Philos. Stud., Bd. 4, S. 479.

directed. In registering the time of astronomical phenomena, this vacillation of the reactions has been found to affect the accuracy of observations. A slight difference in the time of registration appears when two observers view the same phenomenon; it is in this case necessary to make use of especial so-called "personal equations" for the purpose of eliminating the error. Only a few trustworthy series of experiments have been made with the other qualities of sensation. The statement made by v. Vintschgau and Hönigschmied is very interesting; according to this, the time of reaction is greater when the tip of the tongue is stimulated with quinine than when stimulated with sugar, while the relation between the two reaction-times is reversed when the back part of the tongue is tested. This recalls the fact already mentioned, that the nerve-fibres which impart the sensation of sweet are located chiefly in the anterior third of the tongue, and those that impart the sensation of bitter, chiefly in the two posterior thirds of the tongue. There are as yet no concordant experimental results in the case of olfactory irritants. v. Vintschgau[1] and Steinach have determined the reaction-times in the case of mechanical and thermic stimulation of the skin. For pressure the reaction-time amounts to about 120–150σ. When the stimuli are applied to one and the same region on the skin, the reaction-time in the case of heat-stimulation is longer than in the case of stimulation by cold, and the reaction-time in the latter case is longer than for stimulation by pressure. The reactions appear more quickly when stimulation by heat or cold is applied to the right half of the face than when applied to the left half. The fact that individual differences are very considerable, as mentioned above, is of great interest.

Now what do these numbers signify? It is obvious that the action-time as just determined is occupied by three processes: (1) the centrifugal conduction of the stimulation from the peripheral sensory organ to the centre of sensation in the cerebral cortex, (2) the intercentral process of association which takes place within the

[1] Pflüger's Arch., Bd. 43.

cortical elements, (3) the centrifugal conduction from the motor region of the cortex to the muscle. We shall disregard any possible periods of latency or inhibition at present, for the sake of simplifying our investigations. Only the second of these three processes is accompanied by a concomitant psychical process. Since the duration of the first and third are known to us through physiology, at least approximately, the duration of the second process may also be computed with comparative accuracy. Thus, for example, in the case of electric stimulation of the skin, some 60–80σ of the 210σ complete reaction-time, may be calculated for the sensory and motory conduction, leaving only about 0·1–0·15 sec. for the psycho-physical process of association. In the case of muscular reaction a still smaller fractional part of a second remains. This last statement harmonizes well with the fact that reactions often go astray in the latter case; the tested person often executes the movement agreed on before the stimulus has taken effect at all. Now in what particulars are the two forms of reaction to be distinguished from each other? It is obvious that the direction of the attention to the expected sense-impression means nothing else than that, before the sensation appears, ideas which bear some relation to the impression, are already present in the mind of the person upon whom the experiment is being made. Among these ideas is especially the mental image of the expected sense-impression, which is already familiar from the fact that its effects have been previously experienced. This psychical state is very closely connected with a corresponding physical phenomenon, the innervation of the muscles of accommodation governing the respective organ of sense, particularly of the musculus ciliaris and the tensor tympani.

These phenomena are changed in the case of muscular reaction. Here the attention is directed to the motion that is to be executed,—in other words the motor idea, specifically the idea of the movement of the hand agreed on, occupies the mind of the person who is being tested at the time the sense-impression appears. This psychical state generally manifests itself in a slight, constant, tonic contraction of the muscles of the hand and arm which is present long before the reaction takes place. Hence the difference between the two reaction-times is very satisfactorily explained. The predominant mental image of the stimulus, in the case of sensorial reaction, acts almost as a direct check. The especial reproduction of this image is not at all necessary in the entire process of association,—in other words, an especial recognition of the excitant is superfluous. Therefore, while the tension of the muscles of accommodation in sensorial reaction can, in fact, generally facilitate the process of reaction, the image of memory which is present in consciousness at the same time compels the association to take an indirect course, as it were, or to introduce a superfluous, intercedent act of recognition. In the case of muscular reaction the reception of the stimulus is neither facilitated nor delayed; but by means of the dominant motor idea the intercentral paths of conduction, the motor centre, the motor paths of conduction, and finally even the muscular system are to a certain extent adjusted and prepared for the coming stimulation. The stimulus only needs to barely tilt the full vessel, as it were. The excitability of the paths of conduction is heightened by the idea of motion. This very favourable disposition of motor elements explains the remarkable abbreviation of the process which characterizes muscular reaction.[1]

Muscular reaction is very apt to become an automatic action, that is, a reaction in the proper sense; after some practice the concomitant psychical process is easily omitted and the movement of the hand is mechanically executed. This is much more seldom the case with sensorial reaction. This fact is easily explained by what has been stated above; in the case of purely muscular action the psychical act is to be regarded as of minimum duration, since the innervation, as such, has no psychical correlate whatever. In muscular reaction also the sensation exerts a much less essential influence; it merely imparts the reaction. Many psychologists assume that in such cases, where the voluntary action be-

[1] There are no sufficient grounds whatever for the subcortical or cerebella localization of muscular reaction assumed by LANGE.

comes automatic by practice and the psychical process is at the same time lost, the material process of excitation gradually takes another shorter path. They imagine that the intermediate cortical centre is entirely omitted from the process, and that the transmission of the excitation from one sensory centre to another motor centre is accomplished below the cortex. This assumption unavoidably leads to contradictions. In those cases where the psychical acts become automatic, the path leading across the cortex is more and more thoroughly trained in consequence of constant practice; now the same thing occurs that we have already met in the case of the association of ideas,—intercedent ideas are omitted in proportion as the process is more and more facilitated. If the process is constantly developed, one intercedent idea after another is omitted until the last one finally drops out. Thus, when a high degree of practice and facilitation has been attained, the entire psychical process is omitted, especially if at the same time the intensity of the initial sensation is reduced by other more intense sensations or ideas approximately to zero. The path of excitation in this case probably remains quite the same; it is simply more rapidly traversed. In this manner reactions and even reflex actions are developed from psychical acts. The above-mentioned psychical omission of a cortical centre as an element in the production of action is *only* accomplished *phylogenetically*.

But let us return to our experiments for measuring the time of actions. Thus far we have only investigated the simplest form of action. We shall now consider some more complicated cases. We next require the person whom we are testing, to execute the concerted movement of the hand only when he has expressly *recognised* the sensible stimulus, *i.e.* when a complete recognition has taken place. The reaction-time will, of course, be rendered considerably greater by this means. Apart from the special reproduction of the mental image, another process, a judgment, is generally introduced, for the person only reacts after having made the judgment "now I have recognised the light" or "the sound." We must observe, however, that no well-defined distinction exists between this act of recognition and the simple sensorial reaction;

for (1) in the case of sensorial reaction in its most complete form, the appearance of the mental image and the introduction of a judgment similar to the one just mentioned, are hardly to be avoided; (2) in the case of *reaction after recognition* the attention of the person who is being tested is generally directed chiefly to the expected sense-impression. As may be easily seen, those experiments employed to determine the reaction-time in the case of recognition are best in which there is a constant change of sense-impressions selected from a definite number. By this means the person who is the subject of the experiment is most easily compelled always to introduce the above-mentioned deliberation and recognition, instead of simply reacting. Thus the recognition-time becomes also the "*discernment-time*" or "*distinction-time.*"

A still further complication of the process may be presented by so arranging the experiment that upon one definite sense-impression reaction always takes place with the middle finger, upon another always with the fore-finger. In this case a *choice* must be introduced in addition to the *distinction* or *recognition*; accordingly the reaction-time becomes still greater and is designated as the "*selection-time.*" For obvious reasons it is difficult to obtain either *purely* sensorial or *purely* muscular reactions; in experiments of this kind the mode of reaction is generally more or less mixed. Finally, if we introduce one or several more ideas, *i.e.* a complete association of ideas, between the sense-impression and the movement, we obtain an example of action in its most complex form and return once more to the problem of the velocity of association which we have already discussed in full. We shall purposely avoid stating more exact numbers for the so-called "complex reaction-times" just discussed, for the reason that the experimental investigations made by Cattell,[1] Friedrich,[2] Münsterberg,[3]

[1] "Psychometrische Untersuchungen," Philosoph. Stud., Bd. 3, S. 305 and 452, Bd. 5, S. 241, Bd. 2, S. 635.

[2] "Zur Methodik der Apperceptionsversuche," Bd. 2, S. 66, and Bd. 1, S. 39.

[3] "Beiträge zur experimentellen Psychologie," H. 1.

and others in this field, despite their numerousness and the care that has been devoted to them, are not yet sufficiently concordant.

On the other hand, we shall find still another question of interest. How does the simple process of reaction vary when the different psychical factors vary? The most important fact bearing upon this question is that the reaction-time decreases as the intensity of the sensation increases. Furthermore, the reaction-time is always considerably lengthened by the simultaneous presence of other sensations or ideas which, as it is expressed, divert and distract the attention. Wundt has also established the interesting fact in particular, that the disturbing effect of synchronous sensations is greater when the stimuli are disparate than when they are of the same kind. Therefore if the subject of the experiment is to react upon a spark of light, a synchronous *noise* is more disturbing than a synchronous *light*. Finally, the state of feeling which is dominant in the subject at the moment of experimentation, is not without influence upon the reaction-time, as may be easily understood from former discussions. By "state of feeling" we understand the resultant of the positive and negative emotional tones that appear at any definite time. The more the positive tone of feeling predominates in the state of feeling, the more rapidly, *ceteris paribus*, do all the reactions take place. Among other things this accounts in part for the abnormal acceleration of motor reactions, the so-called motor excitement, accompanying mania, which, as we have already mentioned, is characterized by the predominance of positive emotions.

The reaction-time is also changed by the use of toxicants. For example, Kraepelin[1] found that certain drugs, such as nitrite of amyl, ether and chloroform, first increase and then shorten the reaction-time, while alcohol, on the contrary, first shortens and

[1] Philosoph. Stud., Bd. 1, S. 417 and 573; also recently a discourse before the Jahresversammlung des psychiatrischen Vereins, 1889. Compare also DIETL and v. VINTSCHGAU, PFLÜGER'S Archiv, Bd. 16.

then lengthens the reaction-time. In these experiments of course the difference between muscular and sensorial reaction has not yet been considered. Furthermore, in proportion as the doses of alcohol are increased, that phase of its effect which is characterized by an abbreviation of the reaction-time becomes less and less pronounced and noticeable.

We shall now turn from these experiments for measuring the time required for the discharge of an action to the different *forms of action* that may be distinguished. Here it is psychologically most important to determine whether the initial sensation, or the total content of the mental images participating in the play of motives, or the emotional tone of both sensations and ideas has had the predominant influence upon the character of the resulting motion. In the first case we speak of an "impulsive action" or an "action from impulse,"[1] in the second of an "intellectual action" or an "act of calm deliberation," in the third case of an "emotional action." The movement of defence that one makes in response to the visual sensation of a threatening blow is an impulsive action. The numberless actions that are daily and hourly performed for the satisfaction of some desire are emotional actions. Most deliberate actions are intellectual actions in the sense in which we understand them. This distinction, however, is by no means always so sharp as may appear from the above statements. Most actions are affected by all three factors; the impulsive acts are always more or less determined also by some emotion. The voluntary motion in the narrower sense, *i.e.* that motion which is accompanied by the most deceptive feeling of free and voluntary choice, finds no especial place in this classification. We have already mentioned the characteristic features of this voluntary action. We may here add that in the most pronounced cases such action is always chiefly emotional; in fact, the predominant factor is the positive

[1] WUNDT designates as impulsive actions those movements that are unequivocally determined by a single motive. It is obvious that the two definitions only partially agree.

tone of feeling accompanying the motor idea that precedes the motion. The impulsive act approaches most closely, of course, to the automatic act;[1] the intellectual action is furthest removed from it.

Of far greater importance than the classification just given is the distinction of a definite group of actions from another standpoint. This group is composed of the "*motions of expression*," or "*expressive movements*." All movements of expression are alike in being the motor discharge of a psychical process, but the chief effect of this motor discharge consists merely in betraying the psychical process to other individuals. Every other movement has some other definite external effect, and only incidentally and indirectly betrays the psychical state of the person who is acting. But on the contrary, in the case of motions of expression, any further external effect is merely incidental. If we seize a glass of water, it is simply incidental that others perceive in this movement of the hand our intention to drink. On the other hand, if we laugh, the chief effect is the expression and ultimate betrayal of our state of feeling to others. We designate the grasping of the glass of water as an intended or voluntary action, while many expressive motions, such as laughing, crying, etc., we generally designate as more or less involuntary. Finally, there is a series of expressive movements also that are produced by non-striated muscles, which, according to the common terminology, are never subject to the will at all; among these are blushing, crying, the bristling of the hair, the ruffling of the feathers, and other movements affecting the various cuticular appendages, etc. These expressive movements of the face and of the dermal appendages do not of course exhaust the series of expressive motions. The gesticulations of the hand, the shrugging of the shoulders, the bowing of the head, the bending of the body, and others are all also to be regarded as expressive movements.

[1] MEYNERT ("Psychiatrie," Wien, 1888) has attempted to demonstrate that all voluntary motions develop from automatic motions; such a development in fact seems to be conceivable for many impulsive motions.

The most important group of expressive movements is that which comprehends the movements of speech. As we know, these motions represent the sum of extraordinarily complicated, co-ordinated muscular movements of the lips, palate, tongue and larynx. While the expressive motions first mentioned—laughing, crying, etc.—generally express especial emotions, the movements of articulate speech become the expression of our sensations and their images of memory the ideas. The enormous number of actual sensations and ideas naturally requires a correspondingly large variety of articulative movements. Both speech and thought are the result of a parallel development; each one is developed *in* and *with* the other. The importance of the articulative movements for the combination of component ideas into uniform conceptions we have already discussed in a former chapter. We shall now understand also why the expressive movements of speech have so great an influence in determining the higher development of man. This fact may be further shown in the anatomical structure of the surface of the brain. If we compare the brain of the ape with that of man, we find in the latter a complex convolution on the back part of the lower frontal convolution, that is as entirely wanting in the brain of the ape as if it had been scooped out with a gouge. At this place, as science has known for fifty years, lies the cortical centre of articulate speech. If this so-called "convolution of Broca" is destroyed in the left hemisphere in consequence of having become the seat of disease, the invalid is still able to execute the grosser movements of the lips, tongue and larynx, but has lost the finer complex movements of these organs that are necessary for speech, and will never recover the control of them. The function of the corresponding place in the right hemisphere of the human cerebrum is not exactly known. It is probable that it is more or less concerned in the articulation of interjections, such as, "my God!" "yes," and "no."[1] At the same time that the development of this

[1] Compare GOWERS, "Vorlesungen über die Diagnostik der Gehirnkrankheiten," Vorl. 9 and 10.

motor-centre of articulate speech is taking place an auditory word-centre, in which the mental images of words that we *hear* articulated are deposited, is developed in the auditory centre of the cerebrum in the temporo-sphenoidal lobe. If the so-called region of Wernicke in this centre be destroyed in the left temporo-sphenoidal lobe, words are still heard, indeed, but not understood. Finally in the case of the civilized and cultivated man a new stage of expressive movements appears in the motions of writing to which the visual ideas of reading correspond in the sensory sphere. It is only possible here to cast a very hasty glance at these highly interesting relations of the cerebrum to speech; the study of the respective writers on this subject is to be urgently recommended.[1]

The *development* of expressive motions is a question of paramount interest. Duchenne, the celebrated author of "Physiologie des mouvements" and "Mécanisme de la physiognomie humaine," still considers the expressive movements to be a gift with which God has especially endowed mankind. Either the divine wisdom or the divine fantasy, according to this conception, has arbitrarily designated this or that muscle as the means by which mankind is to give expression to a definite emotion. Darwin[2] was the first to open the way for a phylogenetic explanation of this subject. The expressive movements of man are also developed through thousands of years from the expressive movements that are found in the lower animals. It is very probable that almost all motions of expression have only developed secondarily from the common inexpressive psychical actions. Let us take a definite example: The facial expression of rage and hate in man is manifested chiefly in the retraction of the lips and the exposure

[1] WERNICKE, "Der aphasische Symptomencomplex," Breslau, 1874, and also especially the more recent compositions of the same author in FRIEDLÄNDER'S Fortschritten der Medicin, 1886. Further GRASHEY, Arch. f. Psychiatrie, 1885. LICHTHEIM, Deutsch. Arch. f. klin. Med., Bd. 36.

[2] "The Expression of the Emotions in Man and the Lower Animals." 9th Edition, 1876.

of the teeth; particularly the corners of the upper lip are elevated so that the canine teeth become visible. This movement is undoubtedly inherited from the lower animals. In quite the same way the dog, cat and ape expose the canine teeth in the presence of a foe whom they intend to attack, or by whom they expect to be attacked. Originally this movement is not an act expressive of passion in these animals at all; on the contrary, it is a highly fitting preparation for the impending battle. Because of its fitness, this motor discharge, produced by the unpleasant sensation of seeing a foe, has been fostered by a process of selection until it has become a universal phenomenon in this series of animals. In the case of man the original advantage accompanying the movement has disappeared, since, in fact, the teeth rarely serve mankind as a weapon in battle at the present day; but the movement has been retained as the expression of the specific painful emotion which accompanies the seeing of a foe. But still further, other sensations that resemble the visual sensation of a foe as to their tone of feeling, or that are associated with the idea of a foe, also impart this same movement of expression. This is true also in the case of the lower animals very often when the possibility of battle and of using the teeth is entirely excluded. A passionate person also often shows his teeth when fortune has failed to fulfil some desire. We should also mention that in the large majority of cases, in fact, these expressive motions lose their original and immediate advantage (defence, etc.), but at the same time gradually gain another just as great advantage. The young animals' cries of distress call the mother to their side; the adult animal's cry of rage terrifies the intruder. In by far the greater number of cases it is useful to animals thus to become cognisant of one another's passions. In man the development of these expressive movements reaches its highest stage. Since language has a special word, *i.e.* a special expressive movement executed by the muscles of the larynx and mouth, for each sensation and each idea, and not alone for the emotions, as is the case with the expressive movements of the lower animals, social community and culture are possible, and man gains an immeasurable advantage in the struggle for existence.

It is still very uncertain from what special expressive movements language or speech has developed. It is by no means a human invention, as has been recently asserted, that has come into use in consequence of a universal agreement. On the other hand, the construction of words appears to have taken place chiefly in two ways: (1) by development from the animal's cry, (2) by so-called onomatopœic development. The animal's cry already expresses manifold psychical states, although they are chiefly of an emotional nature. As the enticing call of the male, it expresses sexual feelings; as the cry of distress, it expresses the fear of impending danger; as the cry of rage, it expresses hate, etc. Particularly the suddenly appearing *visual* stimuli (a passing animal in flight, lightning, etc.) impart a cry that approaches very closely to the nature of reflex action. By the process of selection these cries become differentiated more and more, in the manner that we have so often noted, until finally they become the colossal treasure of words that constitute a language. Onomatopœia has exerted a more secondary modifying influence upon language. It is especially[1] important in the case of *acoustic* stimuli. A sound that is often heard in nature, is imitated; in other words, the motor discharge which is imparted by the acoustic sensation of a roll of thunder, for example, is gradually modified until the movements of the organ of speech finally produce a sound resembling thunder. We are as yet far from having arrived at an understanding of this imitative impulse from the standpoint of the Darwinian theory, but its importance in the development of language is not to be doubted. That many individuals are able to understand a large number of words thus developed may be easily explained in both cases by laws of association with which we are already familiar. Let us consider that both the reflex cry and the onomatopœtic imitation,

[1] But not exclusively; compare LAZARUS, "Leben der Seele." STEINTHAL, "Abriss der Sprachwissenschaft."

in the case of one and the same sensation, would necessarily result the same, in different, but similarly constructed individuals. The great influence which heredity exerts upon the movements of expression is most forcibly revealed by the fact that persons who are born blind and deaf (as Laura Bridgman for example) express their joyful emotions by the typical form of laughter. In the development of the normal child, most of the expressive motions only appear comparatively late; for example, weeping seldom appears before the third month after birth.[1] It is very interesting to note that in almost all the races of mankind the mimic motions expressing feeling are very nearly identical. As regards the movements of expression in speech, we know that comparative philology has already established very great analogies between the different languages. We have already mentioned above that the lower animals also exhibit numerous expressive movements that resemble those of man in a high degree.

Another very interesting part of this subject is the anatomical localization of the nerve-paths and nerve-centres for motions of expression. As we have already heard, the centre for the most complicated expressive movements, those of speech, is undoubtedly located in the cortex. The path that conducts the motor impulse of speech from the cortex to the muscles of articulation appears to be contained chiefly in the pyramidal tract; no interruption of this path whatever takes place in the large ganglia. This is different in the case of the mimic movements of expression. Their centre is probably located in the Thalamus opticus. After the entire cortex of the cerebrum has been removed from a rabbit, it still performs its characteristic movements of expression—the bobbing of the tail for example.[2] According to the more recent clinical observations of Nothnagel's,[3] the Thalamus

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[1] Compare PREYER, "Seele des Kindes." BINSWANGER has observed laughing already in the 15th week after birth; smiling appears in the 7th and 10th weeks.

[2] BECHTEREW, VIRCH. Arch., Bd. 101. ZIEHEN, Arch. f. Psych., XX.

[3] NOTHNAGEL, Zeitschr. f. klin. Med., 1889, Bd. 16, H. 5 and 6.

opticus seems to be undoubtedly of great importance also in the case of the mimic expressive movements of man. This infra-cortical localization is also justified by the psychological fact that the mimic motions of expression—laughing, for example—are imparted by a psychical factor, indeed, but that they are very little subject to the process of association. In fact, we may say that they take place almost involuntarily. It is obvious, however, that there must be still another path to impart to the Thalamus opticus the cortical excitation which corresponds to the psychical state of the gay mood. Such internuncial fibres are, in fact, known to exist in large numbers between the Thalamus opticus and the cortex of the cerebrum. Finally, certain expressive movements, such as the bristling of the hair, blushing,[1] etc., probably have their centre in still deeper parts of the brain, particularly in the Medulla oblongata. This again harmonizes with the fact that these expressive movements also result from psychical causes, but are virtually not subject to the volition or, more properly, to the process of association at all; they cannot even be voluntarily suppressed.

We must now content ourselves with this hasty view of "actions." The task next awaits us of determining what place in our psychology shall be assigned to the so-called will.

[1] In a certain sense, the peculiar changes of the pulse that accompany the emotions of excitement belong to this class of expressive movements. Compare ZIEHEN, "Sphygmograph. Untersuchungen," 1887.

CHAPTER XIV.

WILL—GENERAL CONCLUSIONS.

We have traced the cortical excitations back to the numberless material stimuli of the external world; in the psychical sphere the sensations correspond to the cortical excitations. We also followed the cortical excitation in the cerebrum by way of certain associative fibres to the motor centres. From these the excitation is again conducted toward the periphery to the muscular system, and imparts certain muscular contractions. Psychically the process of the association of ideas corresponds to the material process of nervous excitation that takes place in and across the cortex; to the resulting motion we gave the psychological designation of "action." We were able to deduce action very satisfactorily from the sensation and the mental images of former sensations, the ideas, in accordance with the laws of association. In so doing we had traced the psychical process to its close. At this point, however, we meet a hypothesis that has been taught by all former psychologies almost without exception,—a hypothesis at which, as it would seem, the common understanding of humanity has arrived naïvely and unconsciously. This is the assumption of an especial will as the cause of our actions. This hypothesis introduces between the process of ideation and the action the further activity of a special psychical faculty. The association of ideas only supplies the motives; it is the will that finally decides which of these motives shall prevail. While the other faculties of the soul (understanding, judgment, etc.), as such, have rapidly lost ground since Herbart, the doctrine of the existence of an especial will-faculty still obtains with the greatest pertinacity.

Now, as we have already seen, nothing has as yet compelled us to assume a new and entirely hypothetical factor in the conscious life. We can therefore with complete justice shift the *onus probandi* on to the shoulders of those who champion the doctrine of a special faculty of the will. We have explained all psychical processes without it; they would not be rendered any more intelligible by using it. What does it mean when we say "I *will* go"? or, to state the question more correctly, what psychical content do the movements of speech producing the words, "I will go," express? Obviously they only express the fact that the motor idea of going occupies the consciousness with great intensity, and is accompanied by a very pronounced positive tone of feeling. At the same time the grouping of latent ideas is such that those ideas which aid the appearance of the motor idea of going predominate over those ideas that would arrest its appearance. When we imagine how fine it would be to climb yonder mountain, this idea may be very vivid and yet we may not come to the conclusion that we *will* go up there. In this case a visual idea accompanied by a positive tone of feeling almost exclusively occupies the attention; there is only a very weak idea of the motions to be performed by the limbs. Numerous arrestive ideas, as that of the remoteness of the mountain, etc., do not permit the motor idea to gain strength. We go one step further and say, "I *would like* to climb yonder mountain." What does this "would like"—this "desire" mean? In this case also the content of the idea remains the same; the motor idea is still checked despite the great increase of its positive emotional tone. Finally, the last step is taken when we say, "I *will* climb yonder mountain." The motor idea has become extraordinarily intense, the positive tone of feeling has reached its height, and, above all, the assistant ideas predominate over the arrestive. The expression "I will" designates not only the subjective sensations at a definite moment, but also the objective *status quo* of the brain, in particular the grouping of latent ideas. Here we may distinguish three cases. If *another* person says of us that we will do this or that, he means properly that the grouping of our latent images of memory is favourable to the appearance of this or that idea of motion accompanied by a strong positive emotional tone, or to the appearance of the appropriate action. On the other hand, when *we will* do something, *our own psychical content* at that moment is only distinguished from other psychical contents by the fact that the idea of a desired action, accompanied by a positive emotional tone, is already contained among the sensations and ideas that are then actually present. In addition to this also, those peculiar oft-mentioned motor sensations appear, which are produced by the unconscious innervation of the appropriate muscles corresponding to the increase in attention. Finally, still a third case is to be distinguished,—our own psychical content when *we say,* "*I will do something,*" *i.e.* when we interrupt the voluntary action for a moment and reflect upon it. This "I will do something," when spoken, is a series of motor ideas of speech with which are associated (1) the Ego-idea in the sense formerly discussed; (2) the idea of a future act, accompanied by a positive emotional tone; (3) motor sensations accompanying attention; and (4) the idea of a causal relation existing between the Ego-idea and the desired action.[1] All of these elements are already known to us; none of them is new. The idea of a causal relation is an idea of relation quite the same as the idea of similarity, formerly discussed as a paradigm of all ideas of relation. *Therefore this analysis also gives no ground for the assumption of a special faculty of the will.*

Psychiatry also furnishes an interesting confirmation of the above conclusion. It has arrived, quite empirically, at the assumption of two chief forms of psychosis, the one originating in the intellectual sphere, the other in the emotional sphere of psychical life. Psychiatry knows of no special psychosis of the will. The attempts to set up special diseases of the will under the name of monomania, or a general disease of the will designated as moral insanity, have all been recognised failures. All disturbances of voluntary action that we find in cases of mental disease, without

[1] Compare the discussions of TH. WAITZ, "Lehrbuch der Psychologie als Naturwissenschaft," that in many respects already anticipate this standpoint.

doing violence to or neglecting any facts, may be reduced either to disturbances of the sentient life, especially of the emotional tone, or to intellectual disturbances, *i.e.* disturbances of the ideas or of the association of ideas. The so-called loss of volition (abulie), the inability to come to a decision, for example, is a frequent symptom of mental disease; but this so-called loss of will-power may always be reduced either to the exceeding sluggishness of of the association of ideas, to the abnormal negative tones of feeling, or to other similar afflictions. Pathology also argues against the assumption of a special faculty of the will.[1]

We have yet to discuss the question as to how we come to regard the idea of our ego as the cause of our actions; and finally, whence the feeling of freedom that accompanies our actions arises. It is obvious that we finally come to regard the ego-idea as the cause of our actions because of its very frequent simultaneous appearance with each action. It is almost always represented several times among the ideas immediately preceding the final movement. But the idea of the relation of causality is an empirical element that always appears when two successive ideas are very closely associated.

The feeling of freedom in actions is to be explained the same as the feeling of freedom in the association of ideas formerly described. We must here emphasize once more that this feeling of freedom depends upon the absence of external compulsory motives, and therefore upon the fact that not the sensations alone, but also the images of memory, determine our movements. This notion of a free will is also furthered by the fact that the idea of "not performing" a movement, or the idea of another movement than the one which is accompanied by the stronger tone of feeling, and which is finally actually executed, appears and takes part in the play of motives. But that which finally causes the latter idea to prevail and suppresses the former is not a special faculty exercising free will, but only the stronger emotional tone

[1] Compare RIBOT, "Les maladies de la volonté," a work, however, that ascribes decidedly too much importance to the ego in acts of the will.

and greater intensity of the prevailing idea, combined with the favourable grouping of the latent mental images. Our actions are as strictly necessitated as our thoughts;[1] we cannot but come to this conclusion, for both action and thought are in fact quite identical when viewed in the light of their fundamental psychical characteristics. Thought consists of a series of ideas, and the psychical element of an action is likewise a series of ideas whose sole specific characteristic is that its last member is an idea of motion. Both are governed by entirely the same laws; both are associations of ideas. The final motor effect in the case of action, according to this standpoint, is rather an incidental accession which in itself has no concomitant psychical process. We should not forget, furthermore, that slight motor elements—the slight muscular tension accompanying attention, for example—affect the process of thought. On this account thought has also been very suitably designated as *inner action*; and action that is manifested in the contraction of the muscles, as *external action*.

In this connection we must consider another reason that many seem to regard as of especial importance in arguing the freedom of the will. It is a common belief, in fact, that if the will in general and the freedom of volition in particular are denied, all ethical distinction between actions and all accountability for actions are thereby removed. Let us consider the two arguments separately. *Psychologically* an "ethical distinction" means that certain actions (for example, murder) produce a negative tone of feeling, others a positive tone of feeling. This difference between the accompanying tones of feeling is by no means destroyed by any of the doctrines that we have advanced. In the sphere of ethics "good" and "bad" designate respectively positive and negative tones of feeling, just as "beautiful" and "ugly" express respectively positive and negative emotional tones in the sphere

[1] The memorable expositions of SPINOZA ("Ethik," P. II, Propos. 49, and especially the following Scholium) should also be compared with the above conclusions.

of æsthetics, or the sphere of sensation. The ethical feelings, the same as the æsthetic, cannot be reduced by the empirical psychologist to a certain chief formula. It can be shown that almost all actions, which we now regard as crimes, have at some time been regarded as good by human beings of other ages or of other places, *i.e.* they were accompanied by positive emotional tones in mankind. *Absolute* ethical laws are as little to be expected from *psychology*, as *absolute* æsthetical laws. Both the ethical and æsthetical emotional tones fluctuate, (1) historically: they are the product of an historical, if not phylogenetic, development; and (2) also among the same people at any definite time; they are fully agreed upon only by a large majority and not by *all.* We shall certainly not condemn empirical psychology for not establishing ethical laws, for of what assistance would any possible laws which the psychologist might establish be to the moral philosopher? They could only have an empirical character, and not that absolute character customarily required by the ethical philosopher. In this work we are only concerned with laws *in* us, and not laws *above* us.

It is very different with the conception of moral accountability or responsibility. This conception, in fact, is contradictory to the deductions of physiological psychology. The latter teaches that our actions are strictly necessitated; they are the necessary product of our sensations and ideas. Therefore, according to physiological psychology, we could no more hold a man guilty and accountable for his bad action than a flower for its ugliness. Hence the action remains bad, even when viewed psychologically, but in itself does not impart guilt. The conceptions of guilt and accountability are—to designate the antithesis briefly—either religious or social conceptions, and on that account may be disregarded here. Psychology, let us repeat, does not deny absolute æsthetical or ethical laws in so far as they can be demonstrated from some other standpoint; but psychology itself, limited to empirical data, can only establish empirical laws.[1]

[1] The following authors are to be especially recommended for a further,

Hence the investigation of the so-called voluntary processes has given us no grounds whatever for the assumption of another psychical "something" in addition to the series of sensations and ideas.

The metaphysician can perhaps arrive at the theoretical fiction of a being which is the subject of the sensations, ideas, and actions, and may name this subject Ego or Soul. Physiological psychology, however, cannot exceed the bounds of its empirical data; at the close of its investigations we have simply to ask whether it can offer us any further empirical facts that will throw some light upon the nature of that parallelism which, from the beginning, we have supposed to exist between the psychical processes and the material physiological processes of the brain.

Let us now briefly consider how science has hitherto accounted for this parallelism, which primarily means simply a regular coexistence. For this purpose we distinguish dualistic and monistic theories.

The dualistic theories all accept the dualism of the two series (material and psychical), and avoid every attempt to resolve it. In so doing the complete interdependence of the two series, in fact the very thing that we have called parallelism, remains wholly unintelligible. On this account Leibnitz, one of the chief champions of the dualistic theory, was forced to have recourse to the theory of a pre-established harmony. Geulinx's occasionalism also belongs to this class of theories. Of course the fact that the psychical series of phenomena is much shorter than the material or physical series is somewhat unfavourable for this

more exact study of the theory of the will: HERBART, "Psychologie als Wissenschaft"; SPENCER, "Principles of Psychology"; LIPPS, "Grundthatsachen des Seelenlebens"; STEINTHAL, "Einleitung in d. Psychologie u. Sprachwissenschaft"; BAIN, "The Senses and the Intellect," and "The Emotions and the Will." The views of WUNDT, which are in general diametrically opposed to the views of these researchers, and which agree with older authorities in the assumption of a special faculty of the will, are to be found in his "Grundzüge der physiologischen Psychologie," and also in his "Ethik."

dualistic theory. Experience demonstrates parallel psychical processes for only a small part of the material processes, namely, for the physiological processes of the brain. For this reason the attempt has been made to equalize this difference in "length"—if we wish to preserve the comparison with lines—by hypothetically lengthening the psychical series. Hence certain philosophers came to assume parallel psychical processes, not only for all physiological processes of the brain, but also for all *organic* material processes. This hypothesis may be designated as the *animistic* theory. Among its champions is Wundt. Finally the doctrine of hylozoism goes still further, and ascribes life, and hence parallel psychical processes, to all inorganic processes. Fully and logically applied, this theory views each atom and each molecule as the possessor of a concomitant psychical substance. In opposition to all these theories, it should be remembered that they all lead unavoidably to the assumption of unconscious psychical processes, an assumption that is in itself contradictory, as we have already seen.

Among the monistic theories we shall consider those first that assume the subordination of one series to the other. Here but two theories are possible; either the material series of phenomena is to be regarded as a function of the psychical, or the latter as a function of the former. Neither the first-mentioned *spiritualistic* view, nor the last-mentioned *materialistic* view is able to give any sufficient ground whatever for the subordination of one series of phenomena to the other which it assumes. Those monistic theories that preserve the co-ordination of the two series, but would still establish their unity, have sought to accomplish the task by regarding both series as attributes of *one* substance. Accordingly Spinoza ascribed the two attributes of extension and thought (*extensio* and *cogitatio*) to his *one* absolute substance, the Deus *sive* mundus. This view of Spinoza's is in harmony with that of many natural philosophers who ascribed (1) extension and (2) a psychical property, as memory for example, to their molecules, in that it merely creates a formal logical unity for the two separate series. But these undemonstrated hypotheses do not give us any insight whatever into the connection that exists between the two series.

Another variety of the monistic theory likewise accepts the two series as co-ordinated, but attempts to remove their difference by more or less sophistical arguments. The two series are supposed to be originally and properly identical "in the absolute," and to have become differentiated only by a "disunion of the absolute." The metaphysical histories of creation, found in the "philosophy of identism," or the "doctrine of identity," belong to this class of theories.

The last of the monistic views may be designated as the *critical*. It is the only one that remains within the bounds of empirical psychology as a natural science. This critical view does not accept the two series without further test; on the contrary, it investigates the manner in which we have come psychologically to assume the existence of two series and endeavours to determine whether the material and psychical data are equally primary or not. Such a critical test demonstrates quite irrefutably that our first data are only those contained in the *psychical* series of phenomena.[1] We shall now discuss somewhat more thoroughly this last and most important proposition of empirical psychology, a proposition that is too easily ignored, especially on the part of the natural sciences.

We first became familiar with reflex and automatic acts. Neither is accompanied by a psychical process. Such a process appeared first as a concomitant of action. We should not forget, however, that action is not produced *because* a concomitant psychical process is introduced. By no means. On the contrary, the material process that lies at the foundation of an action is complete in itself, exclusive of the concomitant psychical process; it can be perfectly understood also without the aid of sensation or ideation. On the contrary, sensation and ideation to a certain

[1] That strictly speaking only the psychical series of *one* individual is primarily given, may here be disregarded. The exclusive consideration of this fact leads to so-called *solipsism* or egoism in epistemology. Comp. v. SCHUBERT-SOLDERN, "Kampf um die Transcendenz."

extent present complications of the process. The unintelligible fact which requires explanation is that, contrary to the automatic and reflex acts, the action is found to be accompanied by an entirely new element, the concomitant psychical process. The material elements of the action are in themselves quite clear. The action would not be any different even if the excitation of the sensory cell should not produce its correlate, the sensation, nor the material disposition left in the brain (the *El* or *Ei*), its correlate, the image of memory or idea. We could render the general fitness of our actions just as intelligible as the fitness of automatic and reflex acts, or the fitness of a bird's plumage. In both cases the process of selection is the essential factor in the development of this fitness. In the case of the bird's plumage, of reflex action, and to some extent of automatic [1] action this selection is essentially a phylogenetic process; in the case of actions it is an ontogenetic process. Strictly considered, all *actions* must first be attained by practice during the ontogenesis of the individual,—for example, the practising of a selection for the piano. Only the cortical mechanism, an apparatus highly adaptable to the training of voluntary actions, is phylogenetically acquired, *i.e.* inherited. Therefore the fitness of actions is quite conceivable, at least, as the result of material laws; as a simple matter of explanation, the parallel psychical processes are useless and superfluous. Let us repeat that, according to the above statements, the appearance of concomitant psychical processes themselves is the only fact that needs explanation. Accordingly the question arises: What material processes are accompanied by these psychical processes? It is not sufficient to answer that the cortical

[1] The above throws new light upon the nature of the automatic act, the intermediate position of which has already been mentioned. In fact, apart from the absence of concomitant psychical processes in the case of automatic action, and their presence in the case of action, there is no well-defined distinction between many automatic acts that are ontogenetically developed and pure action. The unconscious automatic playing of the piano, acquired by practice, as a material process, is hardly to be distinguished from the conscious act in any essential point.

processes alone are accompanied by psychical processes. Numberless material processes of the cortex take place *without* the concomitance of psychical processes. One and the same *Ec* produces a sensation to-day, but none to-morrow, according to the variations in the grouping of the latent ideas. There is no answer to the above question whatever. But empirical psychology now raises that critical and decisive question, by means of which it tests its own foundations: How do we come by this separation of the empirical data into two series, the material and the psychical? With which series are we directly and primarily furnished? Let us test the matter upon ourselves. We see a tree, for example. Apparently in this case both series of data are already present, the *seeing* and the *tree*. But is this an exact statement of the facts in the case? By no means. That which is empirically furnished us is simply and alone our visual sensation, tree, *i.e.* merely a psychical process. We only employ this sensation in a very remarkable way by constructing an idea of *the object* tree as the cause of our *sensation* tree. The same is true of all objects of the external world. In every case we have only the psychical series of sensations and their ideas. We only adopt a universal hypothesis, when we assume that a material series exists in a casual relation to the psychical series. Epistemology and metaphysics, in so far as there is such a science, must decide as to the justice of this hypothesis. The proposition itself, that the material and psychical series of phenomena are not equally direct and primary as factors in cognition, contains all that is ot importance to us here. We are only directly and empirically furnished with the psychical series of phenomena; the other series is simply inferred. The material series may be regarded as an idea that we have abstracted from our sensations and their ideas. Modern physics harmonizes well with this view. Ultimately nothing of the so-called matter is left to the natural scientist but infinitesimal points in space, that are conceived ot as possible centres of power, *i.e.* that can effect sensations. This so-called matter, apart from its hypothetical causal relation to the sensations, is otherwise an entirely unknown element. Now the same thing is true of the material cortical processes that is true of all material processes. They are also merely inferred, and not primary, empirical data, as are the psychical processes. Strictly speaking, we arrive at the inference of a material series of phenomena as follows: We have numerous sensations, and by means of these we acquire ideas; we then *assume* external objects as the causes of these sensations and ideas. Among our sensations are also those with which we have met in our anatomical and physiological investigations of the cerebral cortex. Here, the same as in the case of all sensations, we also assume that a material cause, the cerebral cortex, produces the sensations which we have in seeing and investigating the same. Further research shows that just these material cortical processes also have a very special relation to all psychical processes; that, in fact, the former never occur without the latter, nor the latter without the former. Empirical psychology does not need to occupy itself with a further solution of this complicated problem. Every attempt to reach a complete solution would necessitate its departure from empirical grounds. It therefore relegates the further handling of the problem in so far as it is capable of any solution whatever, to a possible metaphysics, or to epistemology. On the other hand, our science must depend so much the more upon the empirical fact itself, that primarily we have only psychical data, and nothing outside of or beyond these. Thus far psychology remains within the bounds of natural science, and is quite true to its empirical character. It is of interest that in this last proposition our science stands in the closest harmony with the founder of the critical philosophy, Kant. Locke, Berkeley, and Hume had prepared the way for the great truth which Kant finally expressed, that primarily we have only the psychical series, the series of appearances or "phenomena," as he called them. The hypothetical "cause" of the "phenomena," or of the psychical series, is (1) merely inferred, and (2) a factor of which we know absolutely nothing.

Thus the psychophysical dualism or parallelism finally proves to be only a semblance.

Hence, since the psychical series is the primary series, we can also understand why we frequently met with psychical factors in our previous researches for which there was no material basis. Let us recollect, for example, the projection of our sensations into space and time, a psychical fact for which we were unable to obtain any psycho-physiological explanation.

With this last proposition our task is completed; the sphere of empirical physiological psychology is brought to a close. Each further step would be a metaphysical procedure, and would inevitably lead to a problematical metaphysics. Physiological psychology, however, must remain a natural science or betray its cause.

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