LECTURES

ON

PSYCHO-PHYSIOLOGY,

BY

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IN ANY USE OF THIS MATERIAL
BOOTER CELLULOSIC INSULATION
MAY BE GIVEN
ON TELEVISION
PROGRAM ORIGINATING FROM
STILL MATERIAL OBTAINED IN THE PRODUCTION OF

PSYCHOLOGY,
OR
PSYCHO-PHYSIOLOGY.

INTRODUCTORY.

We begin today a course in Psychology for the first time in this institution. It marks an important departure in the curriculum of a medical school. In very few medical schools in this country or elsewhere do we find this subject dealt with. And yet it is a most important branch of knowledge. Its introduction marks the recognition of the unity of man in his tripartite being of body, soul and spirit. If medicine—I use it in the wide sense defined in the beginning of Physiology—professes to preserve the health and life of man and to cure diseased conditions that threaten to destroy his health and life, then it must recognize that the materia medica of medical science must apply not alone to purely bodily and material elements of life but also to that other and not less important part of the human system, the pychic nature. Recognizing that Osteopathy wishes to be a perfect as well as an exact science, we introduce into our curriculum the study of the mind, mental conditions and operations and mental phenomena because these have an important bearing upon the health and the comfort of life.

Modern psychology has been chiefly developed in Great Britain and Germany and the United States. There have been three lines along which psychology has developed. (1) Along the empirical line, based upon so called experience. (2) Speculative, chiefly in Germany, originated by the philosophy of Kant who made reason the central element in psychology. His conception of reason is centralized in the imperative of duty laid down by reason as the basis of all intellectual and moral development. (3) Scientific, this represents the new movement in psychology which received its first and main impetus from the evolution school of philosophy.

English psychology was mainly an analytic consideration of consciousness as its phenomena were manifested in experience. German psychology before Herbart was mainly a psychological analysis of speculative conditions associated with a symi-mythical reason, culminating in Hegelianism which represents the climax of speculation. Kant discussed the faculty of reason in regard to cognitions independent of experience. According to Hegel self-consciousness is the ideal unity in reference to which the entire world must be explained, thoughts like things being parts of a whole, stages in a process, in fact thought is that process itself. Herbart, whose work is known to every scholar, wrought a revolution in German thinking by setting aside the speculative and introducing that of experience, laying the foundation for the union of English and German thought in the scientific school. He represented that spirit of experimental research which has animated German philosophy during this century, himself attempting to build up a psychology of mind based upon the mechanic and static. Thus, to Germany belongs the honor of first treating the mind from a true experimental standpoint.

In America, psychology has been controlled up till quite recently by two currents of thought, (1) the theological, and (2) the educational. After the struggle for existence had finally settled the political independence of America, philosophy began to assert itself, but it was in alliance with theology. For a long time the Jonathan Edwards idea of the free will dominated psychology as it did theology. At first the pedagogical influence was simply a help to theology, largely due to the denominational activity in education, especially the Puritan conception of the close relation of the church and the school. The philosophy which these conditions produced was one closely akin to the Scottish school of realism. This was due to religious influence and especially to the prominent place occupied by Princeton College, two of whose presidents, Witherspoon and McCosh, were called to their position from Scotland. This realistic philosophy was that taught by Reid and Hamilton in Scotland, the basis of which was the observation of the facts of consciousness. By the a posteriori method a priori principles are discovered, observation taking in the field of consciousness as well as that of sense and co-ordinating the facts of experience in both fields. Realism as adopted in America led to the recognition of mental reality, established consciousness, giving to mind a realistic conception, that gave to consciousness a place almost equal to deity. It was this that led up to the Hamiltonian idea of the absolute as the unknown and the unknowable. German philosophy then made its way to America chiefly through the writings of Coleridge and Emerson. On the religious side Channing, and on the philosophical side Emerson laid the foundation of mental activity deep in consciousness. "Mind is the only reality of which man and other natures

are better or worse reflectors." The world is transferred into consciousness for "nature, literature, history are only subjective phenomena." All things are beheld in the mind, for they are all in the intellect. He made the mind real and in this Emerson was the precursor of modern psychology. He it was who helped to free psychology from theology and education and make it independent.

Since 1880 psychology has been separated from metaphysics, theology and pedagogy and the divorce has had happy effects so far as psychological development is concerned. After Herbart it was realized that the facts in the life of consciousness were of importance aside from other questions of being, immortality and education. The Germans began to discuss the question which Locke, Des Cartes and Reid had anticipated, that of the relation of the mind and the brain. It was asked whether brain and mind can be subjected to modification. The Germans concluded that the modification of the brain led to the modification of the mind. Here they saw the possibility of using the scientific method, experiment, in researches into the mind. It was Lotze who first discussed this question in his "Medical Psychology" (1852) by formulating the experimental plan. It was Wundt who first gave it definite form, experimenting extensively and establishing definitely for all time the relation of the mind and the brain, a position he has ably defended in his "Physiological Psychology" (1874). Fechner shortly after Lotze gave publicity to the methods of the new science and the results of extended experiments in regard to sensation states, in his "Elements of Psycho-physics (1860). This represented the first great revolution in Psychology, namely, giving to it a definite basis in Physiology and preparing the way for its utilization in the field of medical education and practice. The entire basis of psychology is changed so that now it is entitled to the term scientific. The second great revolution in the psychological field came from England, the home of the evolution philosophy where Spencer gave to it a new trend in his psychological works.

Both of these currents have been adopted in America. Just as in the peopling of America from an ethnic standpoint it represents the blending of the best elements of Europe, so in the psychological field we find these two lines of revolution clearly set forth. The psychology of America today as compared with the older psychology up to ten years ago may be briefly summarized under two particulars: (1) It is functional, that is, psychology regards mental functions rather than the older mental faculties. (2) Under the influence of evolution these functions of the mind are regarded as developed and developing rather than as formerly, existing ready made. Instead of consciousness being intuitive the functions of the mind develop. So long as every mental operation was regarded as a mental faculty, each faculty was independent of every other, so that un-

der the old system memory was a faculty or power of the mind; so was imagination, thought, etc. Now the mind is regarded as a unit and it is looked upon as acting in this unit capacity, adapting itself to functional action in adaptation to the materials before it. The mind is one. Mental action is a psycho-physical or physiological process. There are no longer divided and distinct faculties, for the mind is undivided and indivisible, but the single mind has several functions in connection with its adaptation to varying conditions under which it acts. The mind has in addition developed to its present condition, both from childhood to maturity in the individual sense and from the lower to the higher in the scale of civilization among conscious and thinking beings. To understand mental facts, both of these points of view must be constantly kept in view. It is to Lotze that this standpoint of psychology is traced back, because he was the first to speak of "The Nervous Conditions of the Mental Processes." Fechner carried out this idea by correlating the functional idea in both psychological and physiological application. Wundt elaborated these ideas in application to the mental phenomena and founded the psychological laboratory at Leipzig in 1879 for the investigation experimentally of these phenomena.

In America the evolution philosophy was introduced mainly through the works of Spencer. Fiske was one of the first and ablest expounders of evolution, taking the view that the cosmic process forms the basis of man's intellectual, moral aud religious being, preferring, however, Weissmann's idea of selection and preformation to the environment and epigenesis of Spencer. The American School of Biology assisted in this, led by Edward Cope, according to which all the modified forms of animal life are to be explained on the principle of growth and by the hereditary effects of habit and effort, there being a development force that controls the line of development. This gives to the psychical, represented in the universal animal desire and effort to live, a priority over the purely physical. Among the foremost leaders and one of the most original of American thinkers is George T. Ladd. He made the first researches and gave the first lectures on experimental and physiological psychology in America. According to him the science of mental life forms the only possible explanation of every problem in life. Associated with this new psychology are Cattel, Baldwin and Sanford, whose work in the laboratory has given to psychology an entirely new form which we will discuss in the lectures that follow.

The line of division in modern psychology arises in connection with the meaning of mental function, one side claiming that it is simply a form of the cosmic process and the other that it is analogous to the play of forces in the physical world. In the solution of this and other questions of psychology the physiologist has as much to say in reference to them

as the psychologist. One of the prominent ideas is that of measurement applied to the mind so far as the determination of time and quantity is concerned. Of course this implies experiments upon the nervous system and the changes which are involved in consciousness. DesCartes long ago tried experiments in connection with the emotions to prove the fact that the mind can be approached through the body. But this was impossible until physiology had opened up the nervous system and its connections with the mind through the brain. Following on this advance made in the physiology of the nervous system psychology presumes, (1) that the mental phenomena are always accompanied by nervous changes of some kind. The relation of mind and body depends upon this presupposition. The physical and the mental changes are interpreted by results, and these changes always go hand in hand. (2) This established relation between mind and body is presumed to be uniform, thus furnishing a basis upon which to conduct experiments in reference to the mental life. Having established this relation and presupposing its uniformity we can analyze the facts of consciousness, measure the facts in relation to nervous changes, notice the modifications which are found in the facts of consciousness correlative with the change in nervous stimulation. By the use of experiment we can discover the difference between natural and arbitrary conditions according as we find the nervous modification due to stimulation of the nervous system externally or subject to the abnormal conditions of the organism. Here we come to those diseased conditions of the nervous system characteristic of certain cerebral conditions, mental changes accompanying organic nervous changes. It is here that mental diseases come up for consideration. This is physiological psychology and pathology. Experimental psychology presents the results of experiments in connection with the stimulation of these organs that affect the nervous system as the medium of mental activity, whether these refer to the normal or abnormal conditions of the mind and the nervous system. This term we will discuss psycho-physiology and next term psycho-pathology and psychiatry.

In order to understand psychology we must dig deep into biology and to follow out the subject we must investigate physiology, neurology, physics and chemestry. The method that we adopt is observation aided by experiments. Hence we hope to find and build up a science consisting of definite principles and considering definite problems. It finds its basis or field in the human body, particularly the nervous system. Action impresses the brain through the organs of sense. The impulses are executed through the motor apparatus in connection with the muscles and bones. Psychology lays down two axioms, (1) that every mental phenomenon is based upon some brain activity; (2) the mind does not possess by nature any perception of number, quality or space. No appreciation of these ex-

ists coeval with mental existence but all perceptions, apprehensions and discriminations mark the mental growth. The brain developes and so does the mind, both of these developments being inseparably connected. To understand the present mental status we must follow its genetic progress from the simplest form. We must study the growth in order to reach the order of mental development, these laws representing the mental progress which is in harmony with all nature's evolution. From the animal upward we find this progressive development. The instinct of the chick exhibits itself on the third day of life so that instinctively the chick will follow after any moving object and thereafter adhere to its leader no matter who, every other moving object creating a feeling of anxiety and producing fear. If this period of instinctive development is suppressed or allowed to pass by it will never thereafter be developed. This is an important psychic principle, that there is an order and a period for the proper development of psychic nature. In man we find a greater number of instincts than in any other animal and these all develop in their proper order. These instincts and the emotions associated with them represent the most powerful of nature's influences. There are various types of human thinking and association. People think and form memory mental pictures in different ways, the type being individual, the capacity generic. This is illustrated in the methods of visual observation, the forms of vocal utterance and the manner of audition. Some people visualize, others vocalize, while others embody in auditory expressions all their thoughts. These represent the three types of mental embodiment in the activity of the mind. This seems to rest on the basis of imitation which is as much instinctive in man as in the lower animals. In order to imitate there must be formed in the mind a definite concept and there must be prower to carry out the concept. The mind thus formulates and through the medium of the brain, the nervous system and the body, executes its plans.

In another direction we find the same idea of the connection of brain and mind, viz., in speech. In the brain we find two lobes, each lobe governing the opposite half of the body. The right hand is controlled by the left part of the brain. In the left part of the brain we find the speech center, close to the hand region. Anthropology and primitive philology have proved that the language of the hand or sign language existed prior to vocal language. In hand language the right hand is the prominent instrument. In line with this we find that right handedness and speech are not found in the animals lower than man.

In line with this animal brain development is normal and there is no variation in one lobe as compared with another. This indicates that the speech organs, the prominent use of the right hand and what they represent, brain centers in the same region and lobe of the brain have an intimate relation to one another. The question of whether this relationship is natural or acquired and therefore a hereditary acquisition has been discussed in the light of development as applied to the mind and the brain. This indicates at least that for mind and mental activity we have a solid and definite basis in the human brain and that there exists a close relation between the mind and the body, both of them developing and in their development being inter-dependent and influencing each other.

It is this that makes psychology of value in the medical field. In the past physiology and medicine have gone on the assumption that the body is something quite distinct from the mind. Psychology had the same view of the mind. Modern psychology and physiology regard manasa unity in mind and body, body being the instrument and medium of mental manifestation, so that one of the first essentials to health is a mind and consciousness determining the body condition. While the body is a machine, it is not a machine that is wound up and capable of going for a number of years wholly under external influence. The molding and shaping of the body proceed from within. Mental function is at the basis of every physical function. Behind the physical acts involved in digestion, respiration and circulation there is the mental state which determines the body condition. It is a notorious fact that civilization has increased disease and body weakness. This is due to the fact that along with civilization comes a mental excitement that is not conducive of body health. There is involved a higher mental effort, a greater struggle for existence which cause the normal development of mind and body to be lost sight of and involve the body in numberless disturbed conditions and diseases. We do not raise the cry, back to savagery; but we do say, back to that condition which it represents on a low plane, viz.: The absence of those mental disturbing conditions which create bodily wrecks, intensify nervous disorders and bring on disease and death. Recognizing the osteopathic principle that drugs are unnatural and that all of nature's remedies are stored up in the human system, we have this psychic law of the mind's ascendancy and to carry it out in the removal of these diseased conditions, the beginning must be made within. The adjustment must be made by the mind and the mental condition must first be adjusted to the body conditions of perfect health. The only prescription that can be given is to cultivate and perpetuate mental equilibrium. Sudden emotions we know affect the circulation, the heart rhythm, the respiration, destroy the secretions, impair digestion and even cause death. If such emotions become chronic, how is it possible to have a perfect nutrition of the system? Physiological chemistry has demonstrated that such a chronic condition produces toxic substances that interfere with every normal body process. So long as these exist, health is impossible, and there cannot be physical immunity from disease, because the system is laid open to all

kinds of germicides. Such conditions whether inherited or acquired form the basis of all kinds of disease and weakness, both physical and mental. Ill health from this standpoint intrudes upon a physical and mental being that ought to be immune and that can be so only when it is well balanced and calm. To heal the mind and give it that place of appointed vantage in the human system, which, instead of depressing, will elevate, instead of wearing out, will tone up and instead of laying open, will raise above all sorts of disease ravages, the human body, such is the design that psychology has in entering the field of medicine.

Psychology in its modern form is largely indebted to other sciences. Just as physiology was revolutionized when explained in the light of physical and chemical processes, so psychology is indebted to physiology, physics and even astronomy. Helmholtz nearly half a century ago measured the speed of the nerve impulses. But the peripheral nerves represent only a part of the nervous system, the brain representing the special medium of mental manifestation. Associated with the mental activity there are certain brain processes and as the individual knows his experience in connection with certain stimuli, stimulation has been applied to different parts of the body with the result that the time necessary for a response in muscular action could be measured. Closely connected with these investigations have been the researches into the nerve functions in connection with the terminal organs, so that the sensory functions are clearly understood in their relations to mental actions. Every experience is based upon some physical basis, and here physics demonstrates the possibility of connecting sensation, emotion and volition with such external objects as are subject to physical laws. These physical sciences have thus opened the way for psychic consideration of the mind from the physiological standpoint. Psychology begins with the nervous system, establishing correlations between the mind and the brain and opening the way for observing psychological laws. The brain requires to be differentiated, the nervous paths must be traced and the molecular action and interaction of the nervous elements must be definitely known. The study of the central nervous system is of great importance because here only can psychology find its perfection.

Plato considered that Deity formed sublunary creatures from the devine nature, these sublunary beings creating the animal body and imparting to it this divine part as the immortal element. In the soul we find, according to him, spirit the seat of intelligence; the animal and material part, the seat of passion, including courage and also the seat of appetite. The spirit was localized in the brain, passion in the heart and appetites including desiresin the lower body parts. In Aristotle we find the psychic operations classified as imagination, judgment and sensation, the heart being with him the mental seat, the brain acting the part of the heart cooler.

Erasistratns was the first to identify the nervous system as a definite system ascribing to it the function of mental phenomena. Regarding the air as the vital force, he traced its passage into the lungs through the heart and then to the brain where it became vital spirit or animal spirit. In this way the mind and the body were closely connected, mental phenomena being inseparably related to nervous functions. Galen by the discovery of the fact that the blood was the essential of life said that the animal spirit must be in the blood. Yet he regarded the brain as the principal nerve structure, the seat of volition and sensation, the purely physical body system in its muscular mechanism being entirely dependent upon the nervous system. This marks the acquisition of knowledge until comparatively recent times. Willis in England is entitled to the honor of presenting more than 200 years ago the genesis of the modern ideas. The brain he regards as the seat of the human soul, the principal mover in the animal mechanism, the source of all motion and conception. The brain convolutions he regarded as cells or storehouses which mark the limitations of the motions of animal spirit, the cortex being the seat of ideas and the central organ of motion and conception. Newton, from the physical standpoint, supplemented this discovery by declaring that the impulses are propagated along the nerve paths as vibrations. Added to this is the fact hinted at by Willis that the nervous system is the basis of reflex action and that this addition to neurology in regard to the differentiation and localization of function due to the researches of men from Bell to Ferrier in these we have the basis of psychological action in connection with the brain and the nervous system. Gradually in history we have reached our present knowledge.

While the nervous system is the basis as well as the medium of the mental operations, we must not forget that in the higher field of psychophysiology the mind is the ascendant power and that in a healthy physiological life nothing less than a healthy mind can secure that vigorous condition of body which is so much desired by all, health and the comfort of life, happiness. The physiologists have largely limited their investigations to the separate parts of the central nervous system without attempting to formulate any plans of systematic action on the part of the system as a whole. This has produced in physiology a tendency to over estimate the importance of specialization of function, overlooking the fact that there is a solidarity and unity of action on the part of the entire system. It is probable that every active operation of the nervous system affects the whole human system; in this way there must be constant activity on the part of the nerve cells accompanied by continual impulses entering and leaving the cells. This forms the basis of "The continuity of conscious e xperience." Behind consciousness, at least, from a morphological standpoint there lies the anatomical structure of the nervous system;

but as yet no one has been able to solve the problem of their relations. The region of consciousness has been gradually moving upwards with the development of physiological theories until, as one physiologist has said, it has had to take refuge in the only remaining region after the sensory and motor areas have been localized, namely, in the anterior portion of the gray matter of the cortex.

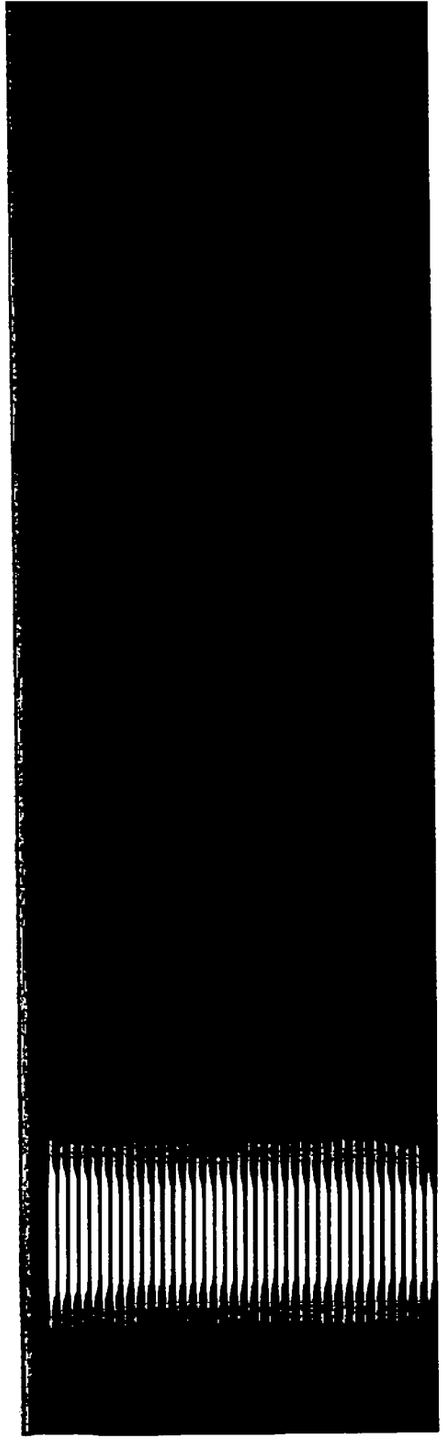
Ancient philosophers did not limit the mind to the brain. With the dawn of the modern Psychology the center of conscious mental, emotional and volitional phenomena was assoiated with the medulla, in more recent times to be localized in the frontal area of the cortex, largely because this is the only portion of the brain left for its localization. Even if we could understand all the changes taking place in this region we should be unable to bridge the chasm between the purely subjective and the objective; much less would we be able to resolve mental phenomena into their preceding causes. Physiology has divided mainly into two schools, the one materializing the mental phenomena by ascribing them solely to physiological and physical causes and the other idealizing them by calling them figurative names which in reality give no explanation of the phenomena themselves. By the combination of both of these ideas we have a fundamental, physical and physiological basis for the ideal interpretation of these phenomena. If we enter into the realm of the transcendental and premise the existence behind all these phenomena, whether physical or mental, of metaphysical essence, then an explanation becomes more clear, because these phenomena of mind and body become simply manifestations of this inner, deeper and truer existence. The difficulty in this case is that such an essence which metaphysics would identify with soul cannot be proven in any possible way by science. At best it is simply a metaphysical conception.

Without attempting to solve this question there is an important physiological question, whether physiology has any ground for localizing consciousness and the entire psychic phenomena in the frontal area of the brain. If we can interpret aright the facts of comparative physiologist then this theory is not founded upon fact. Physiologists localize in the brain sensation, that is, here terminate all those impulses which result in consciousness. Yet the other portions of the nervous system which convey the impulses to this sensorium may have as much to do with consciousness as does the sensorium itself. In the lower animals whose brain development is very simple, possessing none of the characteristic cortical convolutions associated with mental phenomena in man, we find consciousness. This view is based upon the perfect unity of the body and especially of the nervous system. It gets over the difficulty which modern physiology emphasizes of perfect localization of the different functions.

In the earliest conditions connected with cell development we find the

single cell subject to stimulation, undergoing certain molecular changes, these changes sending out impulses to other cells and also along nerve paths to the surface of the body. If the first cell which is more or less differentiated in function by reason of the capacity of receiving and transmitting impulses becomes more fully specialized, by continued stimulation so that its changes are accommodated to this special kind of stimulation and respond to such external stimuli as it has become accustomed to have, we have the first beginnings of consciousness and also of memory. Consciousness even here is not the product of the changes that take place in the cells, because even a knowledge of all the internal changes would not involve consciousness, as the consciousness would only arise in connection with some external manifestations. Some have explained this by assuming that there is associated with matter a consciousness; but this cannot be, because we find no connecting line between physical matter and psychic consciousness. Therefore we find two seeming opposites neither of which is the cause of or is caused by the other. This connection has been completed by some who have identified energy of some kind with the causation of consciousness. Energy, however, is a physical attribute in virtue of which a certain matter or matters possess the power of acting, this action depending upon the active changes taking place in the constituent elements. If these changes which we suppose to take place in the cells upon the basis of molecular activity form the basis of consciousness, then consciousness must be a material and not a psychic quality because the result cannot contain more than is found in the cause. The simple substance-changes or matter-movements cannot therefore explain consciousness,

Consciousness is, therefore, inexplicable unless we hypothecate the psychic as we do the physiological, each one in its own sphere forming the basis of its own characteristic activity. If we consider the nervous system as consisting of a complexity of nervous mechanisms, each mechanism in its simple form constituting an activity in which there is consciousness, then the entire nervous system would represent a complex series of conscious states from the psychic standpoint. Consciousness must exist then not only in the case of the entire brain but in all the cells that constitute the complex brain. If stimulation is applied to a sensory part of the body an impression is carried into the central nervous system, a reflex movement of some kind resulting. There is here a reflex action which has no volition, at least from the brain center and yet there is a consciousness of the changes taking place in connection with the reception and distribution of the impulses. The center of reflex action outside of the brain has a close connection with the cells in the gray matter of the brain so that every sensory area of the body has a connection with some portion of the brain. Impressions may pass outward reflexly from these



cerebral centers to other centers resulting in involuntary movements, but impulses may also pass from these sensory centers in the cortex to the centers of volitional impulses resulting in voluntary movements. Every voluntary action is however essentially a reflex action depending upon afferent stimulation either at the time when the action is called forth or at some prior period.

The impressions made upon the cells or combinations of cells are retained thus constituting memory so that, when the impulses are aroused, volition has a basis upon which to act. If we add to this fact that by means of vision when an image is formed upon the retina the optic nerve transmits it to the corpora quadrigemina where co-ordination takes place from whence it is carried to the optic region in the cortex. This image when impressed upon the cell constitutes a memory picture, which under the influence of impulses, may be awakened in consciousness so as to call forth activity. These sensory impressions may, however, not only be aroused to consciousness in the cerebrum, but also in the cerebellum, where co-ordination takes place. It is probable that sensory regions are found both in the cerebrum and cerebellum. If this is so then the convolutions of the cerebrum and the cerebellum represent, the latter the seat of regular rhythmic movements that are not dependent upon volition, whereas the former represents the voluntary element in all movements. When different sensations are produced by the action of an object or objects as stimuli upon different parts of the sensory surface, molecular changes are set up in different cortical regions, these regions being connected together by the fibers of association so that when consciousness receives these different impressions they are combined to form a single idea. Instead of being combined, however, in the mental picture, these combined impulses may give raise to muscle movements, the movements depending largely upon the stimulating causes. When the stimuli are strong the impulses pass to the nerve cells in the brain where, on account of their strength, they make a vivid impression upon the cells so that after the stimulation has passed away the impression continues, being subject to recall upon a slight stimulation either external or internal.

Here we have the physiological basis of the association of ideas which occupies such a prominent place in psychology and also the basis of memory and recollection. By the constant repetition of these processes the impressions become so closely associated with the cell body that they form an inherent part of the cell life so that by heredity these are transmitted from generation to generation forming the physiological basis of mental intuitions. These intuitions represent modifications of the brain under the influence of mental development, each brain representing its own stage of progress in evolution. Where we have a great number and variety of pimressions we find great variations in the cell changes and a

corresponding variety in the mental phenomena. When these impressions are so fixed in the brain that a stimulus from another part of the brain can call forth a response, we have a fully developed mental condition. In this way the pictures of scenes seen by the sense of vision or objects brought into contact with the sense of touch may be stored up within the brain cells to be awakened at the call of some mental stimulus.

Some physiologists say that they may be aroused spontaneously. This, however, is probably incorrect as what seems to be spontaneous awakenings are dependent upon weak stimulation, often indirect. The sight of an object may arouse impressions formerly associated with such an object or with one analogous to it, the simple call being sufficient to arouse dormant impressions. In this way we find that phenomena which at first seem purely voluntary and arbitrary become purely reflex or at least cease to be associated with conscious volition. In the case of the child persistency of effort enables it voluntarily to walk. After childhood these movements may be quite unconsciously performed. In the same way mental phenomena may become purely unconscious, so much so that certain actions are often spoken of as being done instinctively.

It is generally conceded that there may be unconscious mental activity, the result of this mental action later becoming conscious. Mental development implies the receptive condition of the nerve cells and also the active operation of these cells in the changes involved in molecular development. These are regulated somewhat by the capacity of selection in the case of different impressions, by the concentration upon particular impressions to the exclusion of others, by the activity of the cells in connection with the particular impressions and the power of associating these impressions. Each of these elements has a physiological basis in the central nervous system, and they may become more stable by discipline, the brain development depending largely upon the proper exercise of it. This imples that individuals differ from each other in the the original constitution of their nervous system this forming the basis of different degrees of intelligence and psychic initiatives as we find these among different individuals. These, however, are based primarily upon hereditary acquisition handed down along with the system itself from ancestors.

Thus to each one is given by birth not only a body but also a mind, the basis of mental character and development. When man starts out from this initial point in his mental history his development is determined largely by environing conditions and educative processes. The power of volition may also be increased by exercise so that the inhibitory power depends largely upon these same educative influences. It is this that we mean when we speak of the mind as being a unit, consisting of certain operative functions which mark the stage of mental development, capacity for still further development being the characteristic of every normal mind.

METHOD.—As we have said, physiology and psychology are combined so that the method must be of a dual nature. Physiology represents the means to be used in building up the psychic science, in other words it is psychology with physiological the method. The older definition of psychology referred to it as the science of the human soul. Some make it more specific by way of limiting the soul to the subjective spirit; as Erdmann does only by claiming that it is the basis of the spiritual life. Here we are taking for granted the existence of a metaphysical entity, whereas we have no means of establishing its existence. We realize that it is difficult to define a science, particularly a new science so that we must not make the mistake of adopting an ideal definition and then trying to bring the facts up to our definition. Psychology, therefore, we shall describe rather than define, as that branch of science which investigates from a psychophy-siological standpoint by physiological methods the phenomena of human consciousness. Here we have data that cannot be defined, namely, consciousness and its phenomena.

If we understand phenomena aright we may give them the technical name psychoses or conscious states. Experience alone can discover thsse phenomena; hence to describe these phenomena as they are, to attempt to discover their relations, how the phenomena came to exist and to be associated with one another, is the subject matter of our present investigation. Phenomena, of course, imply something primal behind. Hence we connot investigate the phenomena without implying the existence of a sentient being who can say Ego or I.. What is this Ego? In the abstract we say he is soul, but he practically exists and feels in body. To man, however, pure materialism is an impossibility, for there is only one real world, the world of thought. Thinking and thought create their own environments. It is from the subjective standpoint that man establishes his objective relations, so that matter whether taken from the vegetable or animal scale becomes moulded after the soul likeness and by the soul power of the person himself. In this way by the constructive power of experience man establishes to himself his personal identity, the recollection of this personal equation of being forming the connecting link in his ever varying life experiences. This leads man inferentially to conclude that there is a subject within, which underlies all the phenomena of consciousness. In this light man regards his experiences as his own, his responsibility as his own and not another's, and that this identity or ownness belongs to himself and continues the same from day to day. Hence the word mind or soul is used in this sense as identical with the subject of conscious phenomena. We prefer the word MIND because it is in a sense free from the prejudices associated with soul and it has no particularly embarassing relations with the social or religious life. According to this physiological psychology is the science of the human mind investigated from the standpoint of of its physical and physiological relations.

Physiology is the science that deals with the functions of life as we find life embodied in the physical organism. In psychology we deal with the phenomena of consciousness as these are manifested in connection with the nervous mechanism and also in connection with body movements and actions, so that we must deal with relations and correlations established between the structure and functions of the nervous system and the body mechanism and the phenomena of consciousness. The nervous system is regarded as a mechanism which has intimate relations with, and through these relations controls, the entire body system. Psychology takes the physiology of the nervous mechanism in its origin and structure, consisting of material particles, subject to internal stimulation in connection with adjacent particles and also to external stimulation in connection with external forms. There is thus the action and interaction of molecules constituting the living substance and representing definite relations and influences. These influences and relations represent not only physiological functions but also psychic phenomena.

In regard to the method we have said that it must be dual. In the blending of two sciences both scientific methods must be adopted. Introspection is the only method that can be used in connection with consciousness and its phenomena. Observation and experiment represent the physiological method in dealing with structure, functions and development. As there are thus two sets of facts to be dealt with the two methods must be followed. The only scientific procedure is that of building up a science from particular facts or the use of the inductive method. Hence we must discuss and discover (1) the phenomena that are associated with consciousness; (2) attempt to bring these into certain definite relations and associations so as to find out the laws that govern the production of the phenomena; and (3) rise from the phenomena and the principles regulating their relations to the nature of the thinking subject which underlies the phenomena. Here the method is dual because there are two sets of phenomena and the laws regulating the two sets of phenomena are—if not different have at least different applications to the physical and psychical—of a different order, the one being subject to the necessity of material conditions and the other regulated by a free mind. Here it is that we must establish, not relations, but correlations between the two orders of phenomena by bringing them together and discovering wherein lies the secret of harmonious correlation between the physical and psychic. When we have accomplished this we have a psycho-physical basis on which to rest the mind and a psycho-physical standpoint from which to discuss the nature of the mind itself, its origin and destiny and its claims to be a permanent existence.

As science is knowledge and scientific method the most rational means

of acquiring that knowledge, there can be nothing secret or mysterious. Juvenal says, "from heaven the precept was sent, KNOW THYSELF." Consciousness and conscious methods are rationally used to find the primal facts of conscious life, to analyze these facts into their factors, and to trace their development from the simple to the complex as well as their connections, never loseing sight of the initial fact that man is a living unity. Man is not a disembodied spirit or a mindless meehanism of material particles. The introspective method of consciousness is, "looking into one's own mind." Herbart has objected to this method that in looking at these phenomena the facts themselves are torn from their necessary relations and become abstractions. According to Comte the mind is both subject observing and subject observed, each tending to annihilate the other, because to observe one's self activity must cease, and here you obliterate what you wish to observe. These, however, forget that in modern psychology the nervous system represents the condition and the medium of mental activity, so that in observing phenomena we are observing how the mental life expresses itself or how the mental phenomena "graft themselves upon the more general manifestations of physical life." Introspection does introduce error into the observation, but all observation does the same thing. If I wish to concentrate my observation upon one fact I must withdraw it from its necessary relations, and in abstraction I observe it. This would be true of any observation.

Brain and mind are not exactly identical. Mental phenomena and brain, or at least nervous changes, may be correlative, but an idea cannot be explained by simply analyzing the brain or nervous changes that accompany it. We can never resolve mental states into brain conditions, however close the relations between them may be. In other words, brain functions may correspond to mental operations, but they cannot be identified. We find a psycho-physical parallelism. "Mental life is a chain of events parallel to another chain of physical events." It is claimed by some that the mental phenomena are too complicated to find a parallel in the neural mechanism. If this parallelism is of any value it must be complete, and it must be complete in the development of both, from the origin to the close. If these are psychic processes, which are not dependent upon or correlative to neural processes, then these belong to the field of metaphysics. So far as we are concerned the mind is viewed from the standpoint that it has a physical basis and that the phenomena of consciousness would be non-existent for us if such a physical basis did not exist.

CONSCIOUSNESS.—Before entering upon the main discussion of the subject we must make a preliminary study of consciousness. In the stream of consciousness that is marked by phenomena there is the unity of mind. This unity, however, must not be pressed too far. Every mental phenomenon is at the same time associated with three mental processes associated with intellect, feeling and conation, these forming the basis of the triune mental nature. As these represent the elementary psychic activities they must lie at the foundation of all mental activity, the more complex processes being simply the result of the combination of these elementary processes under the influence of development. While this is true there must be some general term applicable to all the phenomena. Hence we call them the phenomena of consciousness.

Consciousness is almost impossible of definition. It is impossible to conceive of unconsciousness in regard to the mental life, for from the psychic standpoint it is a negative idea. Complete unconsciousness would be the absence of mental states or processes. It is possible that the mind is capable of certain metaphysical processes that are above consciousness, but these states are beyond the psychic phenomena. Hence, from the psychic standpoint unconsciousness is entirely negative. The mental life is conceived as a stream of consciousness, in other words, the life of the mind has no points of separation, marking off definite boundaries as we find in the case of objects in space. In addition to this in the mental life no lines can be set up as separating one period from another so far as the processes are concerned. The life is continuous without any breaks that are absolutely complete between the mental processes. Neither is consciousness to be regarded as ever simply in a passive condition, for the simplest mental condition is that of activity. The varying mental processes must themselves be subjected to mental activity before they can be recognized. An unrecognized condition has no psychic meaning, for example, a prick with a pin that is not discriminated as such represents a physiological, not a psychological phenomenon. Ladd has defined consciousness as "synonymous with psychical state, regarded as discriminated, however faintly, in respect of content and related, however imperfectly, to the stream of mental life." The phenomena of consciousness represent mental activities. To be conscious is to be conscious of this psychic activity, consciousness being considered "as a form of functioning." To analyze the mental states implies that consciousness discriminates, and to discriminate conscious states involves the activity of the mind which is itself consciousness. Hence consciousness is the recognition of mental activity from the standpoint of psychic unity in relation to the conscious states. Some identify it with self-consciousness as "the power by which the soul knows its own acts and states." (Porter.)

The German psychologists argue against this theory, because they say every psychic phenomenon does not involve this self-knowledge. Both of these views are extreme, for while consciousness is associated with all the psychic phenomena, there can be no knowledge of these without a more or less distinct self-consciousness. Self-consciousness arises

whenever the subject recognizes that the psychic states are related to one another and to consciousness. Consciousness involves the physiological basis found in the nervous mechanism consisting of the central system, the nerve paths and the terminal organs. Upon these in a healthy condition involving the proper nutrition of the brain and nerve paths depends the functional activity of the conscious life, Consciousness is not limited to a single fact at one time as there is always involved in it a group of facts or objects. Consciousness varies considerably in different individuals from the standpoint of intensity and even the rapidity of the mental processes. These can only be understood in the light of conscious development. In the child there is no self-consciousness and no consciousness of facts or objects such as we find in the matured individual. The mind is undoubtedly the same in both stages but by development the power of discrimination has been so minutely refined by the processes of mental activity, in comparison and contrast, that the conscious knowledge has been greatly enlarged. To be conscious then is to live a mental life, this mental life developing as the mental functioning becomes more perfect. In this psychic development, the difference between "I" and "not I" marks the principal feature of the evolution, accomplished by comparison and contrast. As this field of consciousness becomes differentiated and separated in consciousness from the conscious subject the mind reaches that higher consciousness that is characteristic of its matured condition. We must remember that throughout the entire history of consciousness, it "does not continue to exist when the processes of which we are conscious have passed away; it changes constantly with their changes, and is not anything that can be distinguished from them." (Wundt.)

PART I.

Physiological Basis of the Mental Phenomena in the Nervous System.

Thomas Brown says, "that which perceives is a part of nature as truly as the objects of perception which act on it, and as a part of nature is itself an object of investigation purely physical." This seems an entirely different idea from that of Schelling when he defines life as the "principle of individuation." And yet these are not irreconcileable, for wherever we have ganglionic cells in the nervous mechanism there we have the basis of that individuation which represents the crowning climax of the human life. Ziehen in his introduction to Physiological Psychology says that he accepts, to start with, the antithesis of material and psychic phenomena in the hope of later finding a bridge to span the chasm of two contraries. It makes no difference to us whether all psychic phenomena are accompanied by concomitant material processes or not; to us

from a physiological standpoint there can be only psychic processes that have their concomitant neural processes, for if there are any that have no such neural processes they belong to the field of metaphysics. There is sufficient basis for psychic activity in the physiological organism. Evolution has introduced two new standpoints from which the organism is to be viewed. Every truly biological idea must conform to two kinds of adjustment, (a) "that of the organism to its environment;" and (b)" that of organs to functions." (Comte.) For the present we are to consider the second of these two adjustments, leaving for future consideration the adaptation of the organism in the development of the nervous mechanism. We will find that as the organism becomes more complex, specialization of functions becomes more perfect. Experiments, for example, indicate that the cortical centers are separated from one another, and this separation has its basis in the brain substance.

The human body like that of any of the higher animals consists of two parts, (1) the mechanism of the organic life in connection with which we have the blood and whatever constructs the body tissue, keeping the blood in circulation and purifying it; (2) the mechanism of animal life, including the muscles, nerves and sense organs. These two are essential for the completeness of the human organism. Both of these mechanisms are really under the control of the nervous system, because through the blood, respiration, alimentation and secretion, it displays its force. In all the higher animals the nervous mechanism represents the instrument of all the functions of the animal life, whether psychic or physical. Wherever we find a distinct nervous system we find two elemental parts of the structure, consisting of nerve trunks which extend to the different parts of the body and ganglia which sometimes appear in small knots along the trunk and in other parts in large central cell collections, the latter being represented by the brain and spinal cord, and the former by the nerve fibers. As distinguished from the plants, all animal forms, except some of the very lowest, have a nervous system. The animal system represents a material mechanism designed to fulfil a purpose. Nerve tissue is characteristic of animal life. The nervous tissue and its functional activity very closely resembles the contractility found in muscle tissue, the nerve tissue being closely connected by end plates with muscle, at least in the case of the motor nerves. There are, however, essential differences between muscle and nerve tissue, the functions of the nerve tissue being peculiar to itself, especially in relation to the central system, the brain and the spinal cord. The first great function of the nervous system is to unite the various elements, purely physical as well as psycho-physical, into harmony. Different parts of the system, no matter how far removed from each other, act in dependence and correlation, because of the nervous system. The entire body mechanism is associated with

the external world in the same way. Mental development is conditioned upon nervous conditions. All our sensations arise through and our perceptions of external things have their medium in the nervous system. The circulation of the blood, respiration and all the other body functions are meditaed by the functioning of the nervous system. When a cold draught strikes the body the nerves takes it up, carry impulses that modify the heart, the lungs, and produce muscular contractions; the body secretions are altered and even the psychic balance may be disturbed. All this is accomplished through the nervous mechanism, in connection with terminal organs, conducting nerves and centers. The sight of an object is followed by certain thoughts, producing action on the part of the muscles that modify all the physiological actions and relations of the body.

Using the term, NERVOUS MECHANISM, to describe the physiological basis of the mental phenomena we have first to examine into the primal elements of the nervous system, (1) in regard to the structure, composition and form; and (2) in regard to their functions. Histology, Anatomy and Physiology really furnish us with this necessary structural and functional basis. We must begin with these because these form the foundation upon which psychology is built and if we do not lay a solid foundation in these our psychology will be like a castle built in the air. Man differs from animals only in the development and enlarged sphere of the functions of the nervous system. This development from the the standpoint of the organism and the organs in adaptation to their functions, we will consider after we have considered the fundamental basis in the present chemistry, anatomy and physiology of the nervous system.

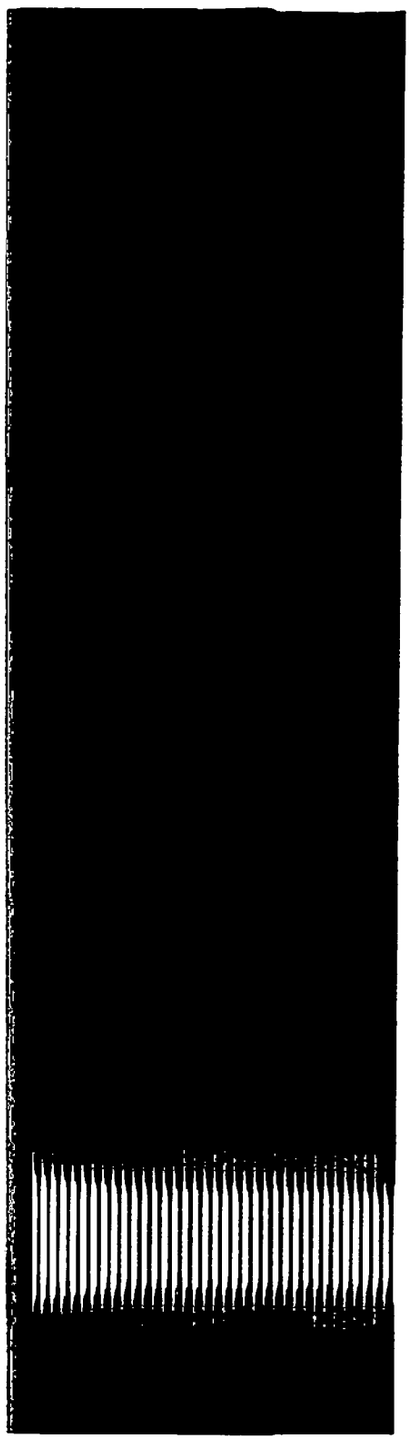
In regard to the chemistry of the nervous system it is not understood because the living elements while alive cannot be subjected to analysis. Many of the chemical substances are life products which when death comes cannot be said to exist or at least to exist in the form of life. Besides the complex and unstable character of the combinations associated with the nervous system render it more difficult to analyze the nerve mechanism chemically. There are undoubtedly at every mental change certain correlative changes in the nervous substratum, so that all the mental phenomena are at least manifested in connection with some change, material or vital, in the nerve elements. It is certain that chemical changes play a very important part in the nervous mechanism. This much we know in regard to nerve tissue, it contains constituents that are very complex in character, readily becoming decomposed, the elements consisting largely of C and H that possess a large combustion value. How the synthesis takes place we do not know but we do know that in connection with nerve tissue there is such a synthesis, the nutriment furnished by the blood forming a very unstable combination of albuminoid compounds, these being of high energic value and during decomposition furnishing potential energy to the nerve substance. It is in this that we find what Coleridge calls "the inmost principles of its possibility as a steam engine." Nervous tissue is white or fibrous and gray or vesicular, these differing in specific gravity from one another. According to Dainlewski the specific gravity of the gray matter varies from 1029 to 1039, and that of the white matter from 1039 to 1043. The difference in weight arises from the differing proportions of water and solid constituents. In the fœtal brain there is found from 89 to 92 per cent of water and in the adult brain from 69 to 84 per cent, the white substance representing about 69 and the gray about 83. We find variations in these relative amounts in the different regions of the brain and spinal cord, the lumbar region of the cord containing a larger proportion of water than the cervical region. In connection with the nerve centers we find that more than 50 per cent of the solids in the gray matter and about 25 per cent in the white matter consists of albuminous matter. Such albuminoid compounds are always present in connection with the active living cells, although the nature of these substances is not known. In addition we find cholesterin, neurokeratin, cerebrin and lecithin, cholesterin representing an alcohol substance found especially in the white matter of the nerves and cerebrospinal axis; the neurokeratin is found in the gray substance of the nerve centers and in connection with the medullated nerve fibers but not the non-medullated; cerebrin is a non-phosphorized substance precipitated in connection with the brain substance boiled in baryta water. These substances have been supposed along with fats containing phosphorus to be derived from the decomposttion of protagon. Associated with the nervous composition there seem to be these phosphorized fats. It is especially in connection with the nerve centers that these phosphoric compounds are found, protagon and lecithin being the chief of these substances. Protagon was discovered by Liebreich in 1865 who called it protagon because he believed it to be the first of the definite constituents of the brain substance. It is so far the only phosphorized compound in the brain and represents the only chemical substance that can be pointed out as existing in the brain and forming a chemical basis for physiological and psychological functions. Hence it is spoken of as one of the proximate principles of the brain. Lecithin represents an organized phosphoric compound found in large proportions in the nerve tissue, possessing according to some a larger phosphorus proportion than protagon. In connection with protagon or lecithin decomposition we find neurin representing the end product of changes in the brain. In connection with functional activity we find certain metabolic processes in which there is the production of the extractives lactic, kreatin, uric acid, xanthin, together with formic and acetic acids. These arise as in a muscle in connection with functional activity, so that in the functioning of an idea there is a change in the organ-

ized matter which marks degeneration in the production of the energy necessary to thought. This indicates the close analogy of nerve to muscle, the end nerve products in the case of activity being the same. Similarly the brain reaction during rest is neutral, during great activity as well as under the influence of putrefactive changes after death becoming distinctly acid. In connection with mental activity associated with brain activity there is a nerve disintegration going on the phosphorus being thrown off in the form of phosphates in the urine.

The cells are largely protoplasmic and for this reason they are very abundant in albuminous substances. The gray matter is found to be more deficient in the phosphoric compounds than the white matter, the white substance of Schwann being very abundant in the phosphorized bodies and cholesterin. Almost nothing is known of the relation of the chemical composition of the nervous system to the nervous functions and especially to the mental phenomena. Yet its extremely delicate organization and sensitive structure indicates its peculiar adaptation to its special kind of work. Chemically it consists of a number of complex and unstable combinations, indicating that it is possessed of great energy capacity, yielding the energy freely when the molecular motions are aroused. Very freely these substances yield to chemical changes in conncetion with the oxygen supply. The nerve fibers require but little oxygen, whereas the nerve centers require a large amount of oxygen, the oxygen being necessary for the great molecular changes taking place in the cells. In this way cell activity in the brain depends upon the oxygen supply and this is furnished by the great vascularity of the central nervous system, which indicates its great activity and finds its basis in the rich oxygen supply. In this way the phenomena of consciousness depend upon the chemistry of the brain or upon the supply of oxygen furnished to the brain in connection with the respiratory center in the medulla, the vasomotor center and the higher brain centers. As we are coming to know more of these conscious sensations we are discovering more chemical phenomena behind and at the basis of all our sensations. In connection with our color sensations we are discovering that color is subjective, the color fibers being in all probability associated with certain chemical processes taking place in connection with the retina in connection with vision. As to the relation of these processes with the constant phenomena we are unable to trace out any connections between the purely chemical changes and the psychic phenomena. Mind does not represent the matters that are thrown off as waste elements, but the energy aroused in connection with the formation of these products of nerve activity. When function is active there is a consumption of matter. Whether the matter consumed is supplied by the blood directly or is a part of the cell substance cannot be definitely settled, although it would seem that in some way the cell

substance is used up since activity results in cell exhaustion and where there is activity in the form of function there is a definite determination of the cell substance that forms the basis of the same function to be exercised in the future. The presence of lecithin, protagon, etc., in such large quantities in the brain seems to indicate that these substances are not simply carried hither in the blood stream but are found in connection with the actual disintegration of the nerve cells in the brain. There may be a permanent structural part in the cell but there seems to be certainly a number of very unstable compounds which are constantly being disintegrated and reintegrated again during the brain processes. What is taken into the cell from the blood becomes a part of the cell substance and in yielding up part of the substance during activity the chemical compounds are broken up in connection with cell activity.

In regard to the structure of the nervous system we find much light upon psychology from anatomy. It is generally supposed that nerve fibers and ganglion cells represent the nervous structure. This seems, however, to overlook the fact that the neuroglia, which is not properly connective tissue, but in some way represents nerve tissue, may have an important bearing upon nerve function. Henle says it differs from connective tissue in its chemical properties, and from this standpoint has an important chemical relation to nerve activity. The nerve fibers represent paths of impulse. The nerve cells represent: (1) The ganglion cells, which form irregular masses of protoplasm with a nucleus and several nucleoli with one or more processes; (2) Corpuscular bodies of irregular shape, consisting of nuclei alone or of nuclei with a small amount of protoplasm, representing probably developing ganglion cells; (3) The neuroglia of granular matter filling the interstices between the fibers and cells. The first two represent the nerve cells and the last represents sustentacular tissue. The nerve fibers are divided into two kinds, the medullated and the non-medullated, the former being whitish and the latter grayish in color; the former belonging to the central nervous system and therefore being of interest in psychology, while the non-medullated are chiefly found in the sympathetic system and are of interest as the connecting link between the emotions and the physiological conditions. In the medullated fibers we find the primitive sheath of Schwann or the external membrane with nuclei; the white substance of Schwann, an interior layer of granular white matter semi-fluid in the living condition; and the axis cylinder, a cylindrical band of fibrillated albuminous substance. The axis cylinder is supposed to represent the real nerve structure because many nerves have nothing but the axis cylinder, the sheath being regarded as chiefly for protection and for trophic purposes. The non-medullated fibers do not have the medullary sheath, being grayish in color with flattish nuclei lying at intervals on the surface. The size of the



nerve fibers varies throughout the body, the non-medullated generally being smaller than the medullated. The number of fibers also varies as we find them in the individual nerves, 5,000 and even 10,000 having been distinguished in an ordinary motor nerve.

Next to the nerve fibers we find the nerve cells which, while they vary considerably, have certain general characteristics. They represent irregular protoplasmic masses with a well marked nucleus, sending off one or more processes. In the gray matter of the brain and of the cord they are embedded in the neuroglia; in other parts of the nervous system. such as the ganglia, they are associated with connective tissue. In connection with the cell we may distinguish, (1) A mantle of fibrillary form continuing the fibrils of the axis cylinder; and (2) a finely granular mass of protoplasm with a nucleus inside of which we find one or more nucleoli. The cells may differ in size and shape; they may be unipolar, bipolar or multipolar, the branching processes determining the size and shape. The shape is characteristic of the different parts of the nervous system; for example, the motor cells are large, irregular cells being found in the anterior horns of the gray matter of the cord, the pyramidal in the cerebral cortex and the ovoidal in the gray matter of the cerebellum. Ranvier has tried to identify all nerve structures with ganglion cells as a primitive type of the nerve cell. It is said that all these cells send out processes, the nerve fibers being regarded by him as simply extensions of the nerve cells, consisting essentially of the nerve cell substance, the extension forming the connection between the different cells and between the cell and the muscle fibers in the end organs. The nerve fibers are simply cell elongations. This is coming to be accepted more generally than heretofore, one of the cell processes being regarded as continuous with the nerve fiber in some form in connection with the axis cylinder.

Having these two primitive elements in the nervous system we are left to consider what functions these can discharge. This is important because these functions represent the foundation factors in the physiology and the psychology of the human system, namely, the nerve fibers collected into nerves and the nerve cells collected into ganglia. These combinations represent the entire nerve basis of the psychic phenomena. We find that they possess certain general functions in common. In the case of the cells and nerves we find the common function of molecular activity which is distinctly nervous in contrast with muscular activity. When this mobility has been originated there is the capacity on the part of the nerves and cells of transmitting it from place to place within the neural structure. In other words the nerves and cells have the properties of irritability and conductivity, peculiar to the nervous system. This is the primal function of both the nerve elements and forms the basis of

all nerve activity. It involves the origination, transmission, alternation and distribution of the neural impulse. It is not true that the highest and most perfect expression of neural activity is the origination and conduction of psychic influences; because we are dealing with the physiological basis in a material nerve structure consisting of certain molecules of a peculiar kind, and of this nerve structure the characteristic function is that of neural excitation and conduction. This represents, it is true, two distinct parts in a single function, that of excitability and conductivity. While there are phenomena associated with the nerve elements, these phenomena are not self-caused or spontaneously generated. The neural excitation originates at a point in the nerve structure by the application of certain stimuli. These stimuli may be external to the nervous system or internal, such as variations in the blood due to the presence or absence of oxygen and carbon dioxide. When a nerve responds to external stimulation, it is said to manifest irritability, and when the stimulation gains no further response, it is said to have lost irritability. When the stimulus is internal in connection with the nervous molecular composition, the nervous system is said to be excited.

When the nerve elements come to be combined into a system they are modified in their internal excitability and external irritability, representing modifications of function. The nerves play the part of conductors, the end organs or the central organs performing the functions connected with originating such stimulation as is subject to conductivity. Among the central cells many are not subject to direct stimulation but can only be stimulated through the nerves. External stimuli may be applied to the end organ, producing an irritation corresponding with the nature and function of the end organ itself. The afferent nerves are stimulated by these end organs, conducting the stimulation towards the central system; while the efferent nerves aroused by the central organs conduct the impulses to specific muscles, glands, etc. While the function of the nerve fibers is that of conducting, that of the nerve cells is not so simple because the nerve cells are, (1) conductors of impulses, representing the tracts of the nervous system; (2) they act as receivers, modifiers and distributors of impulses, the chief function of the cell being that of redirecting the impulses. In this work of redirection the cells may classify and even condense the impulses or rearrange and divide the impulses. The special functions that are associated with the cells are said to be threefold, (1) Automatic. This refers to the origination of what are called the vital impulses, independent of any external stimulus. This automatic action originates from within, but in what way is unknown. This automatism according to Eckhard is twofold, a regular automatic action in connection with the rhythmic movements of the heart and lungs; and an irregular au-

thmatic action by which the muscular tonicity is controlled. In neither case can we explain how the automatism originates. (2) Reflex. When impulses reach the central cells they are reflected back along efferent paths, the reflection including changes that take place by way of modifying and redistributing the impulses. This indicates definite cell activity and definite metabolism of the cell substance in transforming an afferent into an efferent impulse. The reflex action represents the simplest nervous process and according to Ferrier it does not differ from the highest intellectual process. In this sense it is claimed that reflex actions may be so modified and improved in connection with certain stimuli as to become automatic, the agency in this development, according to Ziehen, being natural selection. (3) Inhibition. Wundt says that certain impulses when they enter the cells are retained there. This is said to account for the length of time required to travel along the tracts of the nervous system. That nerve cells have the power of increasing or lessening the power of impulses when received is certain. If afferent impulses enter the cell during cell activity the result is either inhibition or the increase of activity. By stimulating a muscle until it becomes tetanized, it is found that the number of shocks and the number of muscle vibrations correspond, indicating that the nerve cells control the impulses in connection with the muscles, this control depending upon nerve cell changes. This forms the basis of the inhibitory action of the central nervous system.

The nerves have been classified according to the different functions they discharge. They have been classified as nerves of motion, inhibition, secretion, trophic nerves, or nerves which have a direct influence on nutrition, centripetal nerves that have no sensory functions and sensory nerves, or those the excitation of which may result in conscious sensation. A better division of nerves according to their functions is that of afferent and efferent. The nerve impulse is presumed to be a molecular vibration passing in the form of waves associated with certain definite chemical changes. The question is, is this distinction of function based upon structure, or does it represent simply difference in function. It has been urged that they differ in the processes that take place in connection with the different functions, this distinction being based on experiments in regard to the effect of heat and certain chemical substances upon afferent nerves, no contraction taking place in connection with the muscles supplied. The afferent and efferent nerves seem to conduct the impulses about the same rate. The physiological processes taking place in the nerves seem to be almost identical, the variation in the effect produced being due to the cause and origin of the stimulation, the one being excited by the end organs and the other by the central organs. Attempts have been made to cross the two sets of nerves and so demonstrate the possibility of one performing another's function. Various unsuccessful and partially successful attempts were made before Bert was successful in reversing the course of the nerve fibers in a rat's tail, by flexing back the tail and embedding it in the back. When the healing process was complete, the tail was divided close to the root and found to be sensitive in the order opposite to the natural one. This seems to indicate that an afferent nerve can when reversed transmit afferent impulses along a formerly efferent path. Recent experiments by Dr. Cunningham of New York in connection with the dog have proved that the central part of one motor nerve will unite with the peripheral part of another motor nerve, the impulses producing incoordinate movements of the muscles supplied by the crossed nerve. In the case of crossing two motor nerves of muscles with similar function, the nerves when crossed will unite and the muscle movements will not be inco-ordinated to any great extent, while in the case of muscles innervated by crossed nerves where the muscular functions are entirely different, co-ordination of movement is lost, although the nerve fibers when crossed regenerate. These later experiments seem to indicate that the central nervous system will not accommodate itself to changed peripheral conditions of innervation so as to follow the guidance of the peripheral nerves. In other words the impulses are not accommodated to the peripheral organs. This seems to indicate that there is a specific difference in the functions of the nervous system depending upon probably structural conditions and the molecular changes in connection with different nerves. When we add to this the difference in the organ from which the stimulus originates, whether the end organs or the central organs, we have the modifying conditions that determine the specific functions of the afferent or efferent nerves. This is an important psychic point, because it involves the fact that the medium of the conduction of impulses is steady and constant, its functioning being structurally determined beyond the possibility of change.

Hence we conclude that mental acticity depends upon the nervous structure and its proper nourishment in connection with the blood supply. The nerve cells are undoubtedly the center of mental activity. They are active in so far as they are supported. Therefore the support of the nerve substance is the essential condition of statical thought, involving mental and nerve equilibrium, the thought becoming dynamic in connection with the changes in the nerve elements, these changes leading to mental manifestation. Thus when a thought exists in the mind there is a correlative brain change, without which it could not exist. This brain change involves movement, whether in connection with rhythmic vibrations or molecular changes, the movement forming the basis of stimulation, and the stimulation producing nervous responses which lie at the

foundation of impulses that are sent along the conducting nerve paths. In connection with these movements and impulses time is a necessary element, muscular changes, heart rhythm and lung rhythm representing the time element from the physiological standpoint. The human system then is not only a great neural and muscular mechanism, it is also a psychic mechanism which has definite time relations with every part of the organism, definite space relations through the peripheral end organs with which external objects have contact, and in these twofold relations we find clearly established all the relations that the human subject can sustain in life.

Systematic Combination of the Primal Nerve Elements.

We considered last week the primal elements as independent without any relations and combinations. These however do not exist in abstraction, so that wherever we have analytical elements in the nervous system, there is combination into definite organs which are connected together to form a symetrical whole. The condition and function of the separate parts are dependent upon the condition and function of the entire neural organism. "In all the higher processes of the brain," says Foster, "we must recognize, that in nervous material at all events, action determines structure, meaning by structure molecular arrangement and disposition." It is true that we can examine microscopically and electrically a nerve fiber and a nerve cell. But this represents a separation of the organic relation it sustains to the whole system and therefore a pathological condition, so that their normal function is interfered with. The nervous mechanism consists of the interdependent relation of the parts of the system and the interfunctional activity of the combined elements. We find the cells and fibers in very large numbers in the nervous system, the combination of these nerve elements varying considerably in different parts, representing differentiation of function.

If we take the nervous system as a whole its main function is to unite all the diverse body functions, so as to form a united plan of organic development. This involves a large amount of work and a variety of functions harmonized. To unite the different nerve elements so as to harmonize these diverse nerve factors, represents the supreme function; in other words there is here an economic division of labor. In the case of the amoebic life we find a small mass of protoplasm seemingly undifferentiated, in which we find a nucleus. So far as differentiation exists it is found in the division of the external layer from the internal granular matter. Small as this organism seems, it consists of a great number of delicate molecules, all of which are combined in the discharge of metabolic, respiratory and reproductive functions. The chemistry of amoebic life involves changes of the protoplasm, breaking up the old and forming the new, in connection with O absorption and CO_2 excretion. In connection with the protoplasm we notice irritability and automatic mobility, manifested in amoeboid movements, depending upon the changes in the internal mechanism. In other words it has within it a self-regulating power, the beginning of a mind. As we rise from this lowest of the animal forms to the higher and highest of animal lives, man, we find increasing complexity of structure accompanied by increasingly complex and varying functional development, so that the primary division we find in the amoeba of the external and internal forms but the precursor of the increasing division of labor manifested in the differentiated functions of the highest forms of animal life. The irritability and automatic motion from within found in the amoeboid molecules simply suggest the differentiation taking place in which the former comes to be associated with answering the external stimuli, and the latter with originating automatic impulses that are closely connected with vital activity. This gives us a superficial and an internal functional division, but these must be united in some way. How? To accomplish this we find in the more primitive nervous system and even in the highest organism, (1) surface cells which respond to and receive external stimuli; (2) internal cells that can initiate internal impulses, and (3) a connecting pathway of nerve tissue uniting these two, the external and internal. In order to complete this union we must add another element (4) that the muscles are brought into direct relation with these central cells and into direct relation with the superficial cells so as to be under the control of automatic and reflex impulses. These represent then the fundamental elements associated with a combined nervous mechanism, the basis of mental phenomena.

When this mechanism becomes still further differentiated in development, we find (1) that the superficial cells become distinguished from one another by the special function discharged in the case of each, representing (a) the sensory organs, as the organs of sense, and (b) the motor organs like the end plates and terminal organs of motion; (2) the central nerve cells also become differentiated, (a) in the reception, modification, classification and distribution of the sensory impulses after co-ordination from reflex action, (b) in regard to the initiation of automatic impulses, and (c) in connection with the conscious phenomena of the sensitive life; (3) the fibers and tracts of conduction in the union of the external and internal elements of the nervous system represent the sensory, afferent and centripetal and also the motor, efferent and centrifugal functions. This represents from the standpoint of psycho-physiology the complex development of the human nervous system as a whole. It is here we find the basis of sensation, intellection, emotion and volition, all the highest functions being developed from the primal sensations and motions.

"Every cerebral element," says Hering, "is subject to the educating influence of those sensory fibers with which it is automatically connected." This furnishes the key-note of psychology that begins with sensations associated with a sensory apparatus as the simplest psycho-physiological fact. We find the nerve fibers collected into nerves and nerve trunks, while the nerve cells are collected into ganglia more or less complex, such as we find in the scattered ganglia, in the brain and spinal cord. We find two great systems, the sympathetic and the cerebro-spinal, the former consisting of neural cords, one on each side of the spinal cord with three great plexuses in the thoracic and abdominal cavities, together with ganglia scattered over the body in connection with the vascular system and a large number of distributing and communicating nerves, the former bringing it into close connection with the internal organs and blood vessels, and the latter uniting it closely with the cerebro-spinal system. The three main ganglia represent nerve cell and fiber collections at the base of the heart, in the upper portion of the abdominal cavity and anterior to the last lumbar vertebra. According to Gaskell the sympathetic ganglia represent its close connection with the spinal system as the posterior ganglia of the cord. The sympathetic system forms a link between the sensations, emotions and ideas which originate in the molecular condition of the cerebro-spinal centers and the body organs, establishing close relations with the heart and the abdominal organs which are closely connected with psychic conditions. It is in this way that emotion influences the circulation, heart action, alimentation, etc. Much of the stimulation arising in connection with the thoracic and abdominal organs passes through the sympathetic system to the central organs. Maudsley says that the ganglion cells of the sympathetic system, in co-ordinating the separate elements in the tissue, represent the simplest form of the principle of individuation.

The cerebro-spinal system is represented by the two great central elements, the brain and the spinal cord. Associated with these we find certain membranes, the dura mater close to the cavity of bone, differing anatomically in the cranial and spinal cavities. The cranial cavity is divided by the three dura mater processes into two halves. Next we find the arachnoid which contains the fluid that fills up the interspaces in connection with the area formed by the dura mater. Lastly we find the pia mater which represents the vascular membrane of arteries and veins bound up in fine connective tissue, containing the branchings of the blood vessels as they pass to and from the brain and spinal substance. The cerebro-spinal nerve substance is closely bound together and protected in connection with these three membranes, the pressure and blood circulation forming important elements in the brain nutrition. The spinal cord extending along the spinal canal from 15 to 18 inches, weighs about 1 1-2 ounces. It is divided by the fissuers into two halves, each half being divided into three columns, anterior, posterior and lateral. The two halves are united by the commissures, the anterior white and the posterior gray, the latter being much larger than the former, except in the cervical and lumbar protuberances where the white is larger. Along the entire length of the gray commissure lies the central circular canal lined with ciliated cells. In the white substance of the spinal cord we find the lymph and blood vessels, together with connective tissue and nerve fibers, the chief constituent of these fibers being the axis cylinder, the nerve fibers varying in size and also in direction, the majority being vertical, while others are horizontal and others oblique. In the gray substance of the cord we find the same elements as in the white, together with the nerve cells. The nerve fibers are non-medullated and differ from those in the white substance in their minute sub-divisions forming plexuses. The number of the nerve fibers is very large, Birge having counted in the anterior roots of the spinal cord of frogs from 5,984 to 11,468. It is impossible to trace the nerve paths in the spinal cord. As the spinal cord develops there is a later development of the medullary substance of the nerve fibers so that these can be distinguished in some cases. When divided from their origin the nerve fibers degenerate, the connective tissue filling up the vacant space, so that the nerve paths can be followed out to a certain extent.

There have been differentiated two tracts in the antero-lateral columns called the pyramidal and direct lateral cerebellar tract, the former being traced from the anterior pyramid of the medulla, the latter lying between the lateral pyramidal tract and the external surface of the cord. Other tracts like the Goll tract, have been traced out. These facts indicate that the combination of the spinal cord furnishes nerve paths for impulses and also has a series of reflex centers; the tracts representing the afferent and efferent nerve impulses, and the centers varying points of functional activity, all of which are united in connection with the upper centers. Here lies the possibility of connecting the inner and outer.

The same nervous elements, including cells and fibers, with connective tissue and neuroglia bound up in the encasing membranes are found in the structure of the brain. Structurally we find that it consists of (1) the medulla, the enlarged extension of the spinal cord, (2) the cerebellum covering the upper posterior part of the medulla and extending on the two sides beyond it with a superficial lobular division; (3) the pons Varolii enlarged to the anterior and above the medulla; and (4) the cerebrum above both the pons and cerebullum, divided into two hemispheres and filling up the larger part of the cranial cavity. In the medulla we find as in the cord, gray and white matter, the gray matter being here collected into masses, the gray matter continuing that of the cord and also in inde-

pendent masses. In the cerebellum we find the reverse arrangement of gray and white matter to that in the cord and medulla, the gray being external, the white substance representing three great nerve collections connected with the three crura cerebelli. It forms a complex combination of cells and nerves, lying outside of the direct nerve tracts and united by the crura to all the other parts of the brain. The pons Varolii represents the common meeting ground in connection with the nerve tracts between the central organs and the other parts of the nervous mechanism. It is really an enlargement of the wall of the fourth ventricle. The cerebrum represents the larger part of the brain, consisting of a number of parts, varying in size and in function. In it we find the cerebral hemispheres, the large basal ganglia, the corpora striata and optic thalami, the corpora quadrigemina and the pineal gland. It is divided into two hemispheres by the median longitudinal fissure. By dissecting this fissure the hemispheres are found to be united at the bottom by the corpus callosum. The external surface of the hemisphere is convex fitting the cranial cavity, while the internal surface is flattened along the median fissure, separated from each other as hemispheres by a process of the dura mater. The bottom surface is divided from the cerebellum and pons by another process of the dura mater. On the upper surface of the hemispheres we find the gray matter, arranged in convolutions, these convolutions being separated by sulci or fissures, some of these being so well marked as to form natural dividing lines of the brain lobes, the less marked processes dividing the lobe into convolutions.

It is this lobular and convolution division that gives the brain cortex its special nervous functionality and its psychic importance. The general structure of the cerebrum is similar to the cerebellum, an internal portion of white matter being surrounded by a superficial cortex of gray matter. The two lateral sides of the white matter are bound together by strong fibers of a commissural character (corpus callosum) which is overlapped by the gyrus fornicatus. The corpus callosum forms the roof of the internal cavity in each hemisphere, the lateral ventricles which are surrounded by a delicate transparent wall and filled with ventricular fluid. At the floor of each of these ventricles we find the surfaces of the basal ganglia. Here is found a large pear shaped body the narrow end outward and the large end projected into the anterior cornua of the ventricle, called the corpus striatum, the two parts of which are divided by the internal capsule. Between the projecting parts of the corpora striata we find the oblong optic thalami. Posterior to and beneath the optic thalami we find two pairs of bodies, the corpora quadrigemina.

The fiber fascicles of the cerebrum connect its hemissheres, unite these with the lower parts of the brain and when bound together form the origin of some of the nerves. The crural fibers are formed into two

groups divided by gray matter, the former being continuous with the longitudinal fibers of the pons as these come from the medullary pyramids, terminating in the corpora striata and passing through the internal capsule to the gray matter of the cortex cerebri. The nerve elements in connection with the basal ganglia are all arranged in such a way as to prepare this portion of the brain to act as a co-ordinating center in connection with all the motor nerve paths and the sensory nerve paths, giving to these basal ganglia very characteristic sensori-motor functions of a reflex and automatic nature, in subordination to the cerebral centers. The pathways to these higher cerebral centers are found from the basal ganglia in connection with the corona radiata, formed by the radiating fibers of the corpora striata, the optic thalami, the internal capsule, leading direct into the convolutions of the cerebral hemispheres. These convolutions of the cerebral hemispheres from an external standpoint vary very much. In development some of the convolutions are well marked from early foetal life, permitting the division of these convolutions into three classes. The first represents the main division of the surface of the hemispheres into five lobes, the frontal, parietal, sphenoid, occipital and central, although the dividing lines are not clearly marked off from each other. The second and third classes represent minor sub-divisions of these lobes by sulci running in different directions. The gray matter is uniformly arranged on the surface and the white matter in the interior of the cortex cerebri, but there are marked differences in the cells and in their arrangement. Meynert points out that the common arrangement is that of five laminal layers, the entire cortex being about one-tenth of an inch thick. These layers consist of a matrix with a few gobular cells, the next two layers having the pyramidal cells; the fourth layer having a large number of small irregular and gobular cells; the fifth layer having the spindle shaped cells with long branching processes, these cells being compactly bound together and sending off lateral processes.

In the neuroglia are found small corpuscular bodies and cells, representing simply nuclei. The white substance all originates in connection with the gray cortex substance, the nerve fibers being either peduncular, commissural or arcuate, the first connecting the cerebrum and the lower protions of the brain; the second formerly supposed to connect the two hemispheres, but as the tract lies in the corpus callosum, the fibers intersecting each other on the way to the cerebrum hemispheres and therefore forming decussations; while the third connects the gray matter of the separated convolutions in the same hemispheres. Meynert considers the gray masses and the converging and diverging tracts of the cerebro-spinal nervous mechanism as a series of projection systems, the sensory nerves being the feelers and the motor nerves the arms of the cortical gray substance. The gray matter represents therefore a sensory and

motor cortex in which the afferent impulses collect and the efferent originate and are distributed. It forms therefore a projection system in connection with the muscular system. The gray substance of the brain lower than the hemispheres, according to Meynert, represents in connection with this projection system, either interruption masses or a reduction region in connection with the entire system. Here we find the nerve paths from the cerebral cortex broken up and diverging in different directions. This represents an important functional point in establishing the relations of the cerebrum with the lower parts of the nervous system and therefore one of the points of psychic interest.

Thirty-one pairs of spinal nerves and twelve pairs of cranial nerves bind the cerebro-spinal system to the terminal organs of sense and motion. The spinal nerves arise from the cord, passing out through the intervertebral foramina, representing the cervical, thoracic, lumbar, sacral and coccygeal regions. The cranial nerves originate from the cranial base and pass out of the foramina on the floor of the cranium, representing the sensory nerves of special sense, the first, second and eighth; the motor nerves supplying the eyes, the face and the tongue, the third, fourth, sixth, seventh, eleventh and twelfth; and the sensori-motor nerves that supply the facial, laryngeal and pharyngeal muscles and the membranes and internal organs of the body, the fifth, ninth and tenth.

These represent the complete systematized nervous mechanism. The one conclusion we reach is that by differentiation, becoming more and more complete the entire nervous mechanism is fitted into the body system, so as to discharge the distinctly nervous functions of conducting media, end organs and central functions, which represent the three great functions of the nervous system. While we speak of these functions as in a sense distinct, yet as Meynert says there is but one single functional energy inherent in brain cells that of sensitiveness, the sensory nerves being the keys that regulate the nervous mechanism and lead to the activity of the muscles. "Specific energies," says Meynert' "depend altogether upon the peculiarities of the end organs and sensitiveness is the only specific property of brain cells. Within the forebrain sensitiveness is converted into actual sensations." It is here that the anatomy of relations we have traced out is of special significance in connecting this seat of sensation with all the rest of the nervous mechanism. Here in the cerebral cortex, not in any one part of it, intelligence and consciousness are localized. Each hemisphere consists of "projection systems" which unite the cortex with the sensitive regions and also the motor organs; the white substance forming "association systems" of minute fibers and nerve collections which unite all the parts of the cortex and form the basis of all mental perceptions and judgments. This makes possible what has been called the "sensations of innervation," in other

words the centers that are identified with definite activities in connection with the muscles and body organs, the sum total of these centers constituting individuality. The individuality of psychology consists of this primary physiological individuality expanded and developed in connection with the secondary individuality that springs up out of secondary mental perceptions conjoined by association. We see in this how fully mind is conditioned by the nervous system.

The end Organs and their Functions.

In the general division of labor that we find in the cells during development some of the more superficial cells become very sensitive in connection with external stimuli. This results in the specialization of these cells which are so altered so as to receive and modify these stimuli transforming them to neural commotion and transferring them to the conducting nerves. The end organs, therefore, play an important part in establishing the connection between the stimuli and the nerves. In other words they form the specialized superficial neural organs adjusted to certain stimuli. This neuro-muscular mechanism therefore represents the medium in establishing a relation between mobility as found in the relations of the external and the organ and the mobility of the neural processes. In the end organs the sensory nerve fibers terminate in close relation with the muscular fibers and cells. Hence these organs consist of the nerve processes and the arrangements of muscle, membrane, bone, etc., by which the stimulus is received, modified and prepared for transmission to the nerves. The sense organs represent therefore nervous and muscular combinations and modifications of cell and fiber; the motor end organs represent similar neuro-muscular adaptations in connection with the termination of the motor nerves in the muscles of motion.

(1) SMELL. The sense of smell is associated with the mucous lining in the upper nasal cavity in the region of olfaction. We find the cells in two forms, olfactory and epithelial, the former being fusiform in shape with rounded nucleus and fine processes, and the latter greater with oval nucleus covering the epithelial surface. The olfactory nerve processes are enveloped in minute granular and neural substances. In order to excite the sense of smell, the irritant must float in the moving air so as to cause its contact with the lining membrane, the process of inspiration carrying the stimulating substance in the inspired air to the membrane.

(2) TASTE. In connection with the tongue along the margins as well as at the point and root are found papillary eminences of two kinds, the circumvallate consisting of connective tissue that is filled with epithelium. When the epithelium becomes thinner at the sides, we find a taste zone reaching up to where these papillae are not covered by the lateral wall.

The fungiform papillae represent eminences covered all around with epithelium. The taste bulbs which are found in the fungiform and circumvallate papillae are like barrels filling up the cavities of the papillae, the bottoms resting in the connective tissue and the upper portion being elongated like the neck of a flask. Each bulb contains a number of cells, these being of two kinds, the gustatory long and narrow with a definite eliptical nucleus and the epithelial being also long and narrow. The taste nerves are the glosso-pharyngeal that passes to the posterior part of the tongue entering the papillae and ending in a granular plexus, and the lingual which innervates the apex of the tongue in connection with trifacial. The sense of taste is not so particularly localized as smell, although smell and taste are intimately connected, Kant defining smell as taste at a distance.

(3) TACTILE SENSATIONS. The sensory nerves that branch off into the skin which give rise to touch in the more general sense terminate either in connection with delicate fibrils or in connection with special tactile bodies. We find different forms of the sensory end bulbs, corpuscles of Pacini found in layers, the internal layers being arranged in concentric form around a softened nucleated matter. In fine fibril form the axis cylinder enters the corpuscle. These are associated with the palmar portions of the hands and feet. The end bulbs of Krause are small, nucleated corpuscles, the fibrils ending in the bulb substance. The Wagner corpuscles represent oval bodies in conical form, the fibers creeping in around the papiliae winding around the corpuscles and uniting into coils. Contact represents the simplest sensation; this passes very readily into pressure and pressure soon passes into the sensation of pain. Pain is defined as "the prayer of a nerve for pure blood," a physiological truth which indicates that the mechanism is abnormal in some way, signalling a danger point and indicating the need of repair. The entire skin is sensitive but not to the same degree, so that the fibrils terminate in different ways in the skin, indicating that some fibers represent contact, others pressure, others heat and cold, while the excessive stimulation of any of these represent pain. In connection with the Pacinian bodies which are found in abundance close to joints, ligaments, periosteum, we find tactile sensations associated with the muscular sense in connection with flexure, extension, rotation and all the voluntary muscle movements. Accompanying all voluntary muscle movements is the sensation of effort depending on the force of contraction forming the basis of the muscular sensations, the brain being kept in close touch with the external conditions of the body and the actions of the contracting muscles.

(4) HEARING. The sense of hearing like that of sight, utilizes a part of the structure as a mechanism for collecting and concentrating the

auditory elements so as to present the stimulation to the neural elements. The auditory apparatus consists of the eighth nerve in its connections with the epithelial and and neural elements. The auditory mechanism is divided into three parts, (1) the outer ear, which consists of a shell shaped structure of value in judging the direction of sound waves, and of the outer meatus, a winding passage leading from the concha to the tympanum, protecting it and acting as a resonance box in the modification of sound waves, modulating and intensifying sounds; (2) the middle ear, which is a hollow cavity of bone, connecting the external meatus and the inner ear. At the bottom of the external meatus is the tympanic membrane which is the outer wall of the membrane set in a bone cavity. The internal partition dividing the middle and inner ear has two openings, the oval foramen partly filled by the orbicular membrane and the fenestra rotunda, closed by the secondary tympanic membrane. Anteriorly there is an opening into the eustachian tube, a chain of little bones stretching across from the outer to the inner wall. In the tympanic membrane are three layers, the middle mucous membrane representing the vibrating membrane. In connection with the tympanum the sound waves are transmitted to the internal ear, certain modifications taking place in order to adjust the sound to the receptive organs. When the sound waves reach the membrane they have a large extent and a small intensity, the vibratory waves producing vibrations of the taut membrane and changing both amplitude and intensity as the vibrations strike against the membrane. It is very responsive to those vibrations that are not in harmony with its own and repels those that diverge from its keynotes, until it has harmonized these partial notes. Hence the membrane has no predominant key, but by reason of its funnel shape in connection with the malleus whose handle attaches at the center, and on account of the chain of bones with which it is weighted so as to dampen any peculiar tone of its own, in this way it is able to take up and adjust a wide series of tones. The top of the funnel points internally so that the force of the acoustic waves is pulled in towards a point of concentration. The simultaneous vibration of the auditory bones is around a common center, the variations depending upon the nature of the tones that reach them in connection with the acoustic waves, so that out of diverging notes they can form a symphony. The increase in the tension of the tympanic membrane dampens the movements of the auditory bones, making the membrane capable of responding to higher notes and increasing the rate of the auditory sensations. The eustachian tube which communicates between the tympanum and the air, is partially open and closed so that the air renewal takes place and by cilia action the mid ear secretion is carried to the pharyngeal opening and maintains a condition of equilibrium in the cavity. The auditory bones are moved

in connection with the tensor tympani which contracts only at the beginning of a sound, whereas it relaxes if the sound continues. When the malleus is pulled in the tympanic membrane is tightened. The stapedius dampens the movements of the stapes and the orbicular ligament in the case of harsh and loud sounds closing them out from the labyrinth. The fifth nerve supplies the tensor tympani by a branch from the otic ganglion, and the seventh supplies the stapedius, the paralysis of the fifth resulting in dull hearing, and of the seventh in sensitiveness to loud sounds. The mid ear modifies the wave vibrations fitting them for transmission to the inner ear. (3) The inner ear. Here we find three double organs consisting of bone channels and membranes, in the petrous part of the temporal bone. This labyrinth of bone consists of the cochlea or convoluted shell tube divided into two compartments an upper and a lower in the central part of which is a spiral pillar, the compartments communicating by a foramen; the vestibule or central cavity, the membranous part forming two sacs, and communicating with the scala vestibuli so that the perilymph is continuous with the cochlea; the semicircular canals or winding channels, three in number, opening into the utricle, the endolymph having free communication with the vestibule and cochlea. The three canals have their planes at right angles to each other. The endolymph fills the membranous portions which are suspended in the perilymph these having an important modifying influence on sound vibrations. The end organs terminate in connection with the membranous portion of the labyrinth. When the auditory nerve comes near the labyrinth it divides into a vestibule and cochlear portion, the former dividing again into minute processes that terminate in the cells, while the latter passes through the mediolus and then distributes its branches. The function of the inner ear is to receive, modify and transmit the auditory waves. In the canals the sound vibrations are divided, the movements producing stimulation of the nerve endings. Sounds that reach the ear are of two kinds, noises and notes. Out of these by the sympathetic action of the auditory apparatus harmonious sounds are produced. It has been claimed that the vestibule and the canals respectively receive noises and notes but this has been disproved by recent researches which seem to point to the fact that there is no such distinction of sounds physiologically. According to Helmholtz in the internal ear we find a series of resonators each one capable of answering to a special vibratory note and as all the minute fibers end in minute organs, the rods of Corti being vibrating structures, the vibrations are transferred to the nerve processes. These represent piano keys, 3,000 in number, each with a perceptible pitch. In his later theory he lays hold of the cells arranged on the surface of the basilar membrane. Hensen thinks that the radial fibers in connection with the basilar membrane are all pitched, the motions of theses timulating nerves. The other theory is that the analysis of sounds does not take place in the ear but in the brain, the corti rods or the minute fibres vibrating as a whole at every audible sound, the vibrations stimulating the nerves giving form to the neural commotion telephoned to the brain where the analysis takes place.

(5) SIGHT. Here we have the sensations of light and color. The eye is an optical disc made in camera form whose lens is self-adjusting, the image being cast upon a neural membrane. We find three concentric layers of covering, the sclerotic a rough fibrous coat, the interior part being white and the middle part translucent as the cornea; the choroid of pigmented and vascular material, consisting of folds and a diaphragmatic portion which is bathed in æqueous humor; the retina or internal sensitive coating covering the choroid as layers of membrane. The refraction in the eye takes place in connection with four media, the cornea, the aequeous humour behind the cornea, the crystalline lens lying between the iris and the fourth medium, the vitreous humour between the lens and the retina, a semi-fluid mass enclosed in the hyaloid membrane, forming a very transparent body. In connection with these the muscles aid in the completion of the structure especially in giving mobility to the eye in the process of constructing its field of vision. The mobility of the eye is controlled by the recti muscles that have their attachment in connection with the bony wall, while the oblique muscles aid in the movements of the eye in different directions. The refraction of the a of light in connection with a curved surface depends on the radius of curvature and the variation in the refraction indices of the two media through which the ray passes. The refraction indices of the four media are all greater than air, that of the cornea, the aequeous and vitreous humour almost the same as water and that of the lens greater on account of the number of layers. In connection with these terminal organs of vision we find a structure in connection with which the impressions made upon the organs build up sensations of light and color so that variations in connection with the number, character, color and order of these sensations give rise to the visual picture of the size, form, location and mobility of the external objects of visions. The important part of the eye from this standpoint is the retina, in connection with which the image formation takes place. The four media of refraction represent different surfaces each succeeding surface forming an object for the next succeeding surface. In the lens we find that each layer has its own index of refraction so that the differences permit of more refraction taking place. The optical problem therefore is complicated by the differences in the refractive indices and the varriations in curvature. The power of accommodation represents the capacity to change the refracting conditions for differing distances. This is accomplished by changes in the convexity of the lens particularly on the inter-

ior surface. This takes place under the direction of the brain in connection with the exercise of the voluntary power. According to Helmholtz the resting lens is in a condition of tension depending upon the elasticity of the lens and the attached suspensory ligaments. The ciliary muscle by drawing it the opposite direction removes the tension permitting the lens to gouge on its own elasticity. When the ciliary muscle contracts the vitreous humor is driven into the open spaces at the sides of the lens resulting in convexity of the suspensory ligament. The nerve fibers to the ciliary muscle come from the motor oculi nerve through the posterior roots. Arising in the posterior portion of the floor of the third ventricle contiguous to the origin of the nerve that controls the internal rectus muscle in this way harmonizing activity from nerve origin in connection with accommodation. The retina becomes active when the image is formed upon it supplied by nerve fibers from the optic nerve. After entering, the branching fibers radiate in all directions, the filaments being distributed among the cells not of nervous matter. The rods and cones represent rows of palisades side by side, the one cylindrical and the other conical in shape, representing the sensitive layer of the retina, probably associated with certain chemical changes when the ray of light falls on the retina resulting in stimulating the terminals of the optic nerve and producing impulses resulting in visual sensations. The point of clearest vision is the yellow spot with a depression in the center. At a short distance from this to the interior the optic nerve breaks into the retina forming the blind spot which does not seem to act because of the absence of the nerve elements. The neural process of vision begins in the rods and cones, although they are not immediately subject to impression by the light in the production of the sensations of vision or till certain changes take place that result in the injury of the eye. In connection with the rods and cones a chemical decomposition is supposed to take place stimulating the nerves. Light from a physical standpoint is a vibration, the vibrations affecting the retina, producing molecular changes that stimulate the optic nerve. The light that enters the eye is partly absorbed by the pigment and partly reflected. The rays reflected return through the pupil uniting with the entering rays to form a picture. Thus when an image is reflected on the retinal surface it is reflected on the arc of a spherical surface. Color as distinguished from light is a sensation aroused by the action of the rays of light of a certain length upon the retina, that is color depends upon the rays that fall on the retina during a definite period of time. With a certain number of rays we get a sensation of red, and with about double that number of rays the sensation would be violet. The white light is compound, the waves of red being of such a length that 451 billions of them reach a given point in one second of time while the waves that produce a violet are much shorter, 764 billions reaching a

given point in one second of time. The waves of intermediate length form the other colors of the spectrum. Thus color is a sensation due to a particular kind of stimulus. It seems therefore that the eye is a delicate mechanism adapted to very complex physiological and mental conditions. This forms the reason of the eye sensations having such a close relation to psychic activity.

In connection with the motor fibers we find the terminals in muscles, glands and electrical bodies. The nerves branching among the fasiculi of the muscles divide and subdivide, forming numerous ramifications, the single delicate fibers ending in muscle fibers. Losing the medullary sheath the axis cylinder is divided into minute fibrils. The axis cylinder passes through the sarcolemma, the neurilemma becoming continuous with it. As these fibers surround the disc shaped bodies inside the sarcolemma they form the motor end plates. The form and structure of these vary in different muscles, the terminal characterizing the particular muscle. Thus we see the close and inseparable relation of the nervous mechanism to the muscles, bones and ligaments, indicating the close relation of mind and the mental phenomena to the delicate structure of the body, so that the mind is localized in the body rather than in the neural mechanism.

THE NERVE CONDUCTORS. Having discussed the end organs, we must now discuss the neural path between the end and central organs. As soon as the end organs have transferred the molecular process into a neural process, it is sent out over the nerves as conducting cords. Excitation represents the origination of the neural commotion. Conduction is the continuance by propagation from one point to another, so that each nerve point has something to do in the communication of impulses. Thus excitability and conductivity represent the same commotion from a different standpoint, the progressive movement taking place along the nerves. From this point of view all of the nerves are alike in their conduction of impulses. The general physiology of the nerves looks upon the nerve in its abstraction from the neural mechanism and under stimulation externally to itself. Each part of the nerve can stimulate the adjacent part and receive stimulation from it. An attempt has been made to identify nerve current with electrical current. But recent investigations have shown that there are essential differences between nerve processes and electrical currents. For the general physiology of nerve we must refer you to the results of the electro-physiological experiments discussed in physiology.

Neural functionality is the important point in nerve conduction, and this depends upon three important conditions. (1) Neural vitality. In order that a nerve may perform its function of conductivity it must be alive. Hence the function is physiological. It is not necessary that the

nerve die when the body dies, or even when the nerve is taken out of the body. It is hard to say when a nerve dies as it has no rigor mortis. When the nerves die they manifest two distinct phenomena, (a) as soon as they are divided there is an increase of irritability, (b) after which it gradually decreases till it is lost, these changes varying in different parts of the nerve. The lower part of a divided nerve maintains vitality longest, hence, the Ritter-Valli law, that nerves degenerate from the center to the periphery. When a nerve is divided in its place in the body its irritability increases temporarily, afterwards gradually losing vitality, degeneration taking place from the division to the periphery. Regeneration may take place by the growth of the axis cylinder from the central part piercing out into the Schwann sheath in the peripheral portion. The conductivity of the nerve is regained earlier than its irritability. (2) Neural conductivity depends upon the proper nutrition of the nerve and this takes place in connection with the O supplied in connection with the arterial blood. O does not seem to be so necessary for the conducting nerves as for the central nervous system, because irritability can be preserved in a nerve in a damp vacum, although some oxygen seems to be essential to the neural vitality. (3) When nerves are exhausted they cease to perform their functions, at least efficiently. It is not easy to separate nerve fatigue from the fatigue of the central organs or the end organs. The nerve is much more difficult to exhaust than muscle, endurance being a characteristic of nerve fibers and neural tissue. It is claimed that most of the nerve exhaustion is simply muscular exhaustion in connection with the end organs. There is a point, however, where nerve fatigue may take place, although this is more true of the central system and the end organs. Even if neural fatigue is dependent upon these it represents a condition that we find in the nerve, in its connection with the nervous mechanism.

When a nerve is called into activity in the transmission of a nerve commotion certain phenomena are found depending on the nature, extent and method of applying the stimulation. From a psycho-physiological standpoint it does not matter very much what the physical properties of nerve are. Nerves are irritated by all kinds of mechanical stimulation resulting in pain from excessive stimulation in the case of the sensory nerves and in contraction in the case of the motor nerves. Compression may be so increased as to suspend the power of conductivity if the shock is sudden. It is not known whether nerves have any heat in themselves or whether they can conduct heat, but heat has an important stimulating effect. Heat seems to hasten the death of a nerve when removed from the body, and cold seems to retard death. A great many of the chemical substances destroy the nerve, although changes in the amount of water in the nerve composition seem to affect the nerve functionality, the decrease in water intensifying irritability, increasing contraction until tetanus results. Nervous stimulation by electricity has the same effect on the nerve as on muscle, although in different degrees. Nerve conductivity of an electric impulse is about 15 times that of pure water. Constant currents if they remain steady do not excite the nerve, whereas variations in the current do excite the nerve. The irritation depends on the direction in which the current goes, and also on the strength of the current, increasing with the increase in strength till a maximal point is reached. It also depends on the nerve length subjected to irritation and also on the angle at which the application of the stimulus is made. If the current flows exactly at right angles to the nerve axis, it does not stimulate the nerve. It is considerably influenced by the length of time during which the current is applied, no effect being found unless the stimulus is applied for at least .0015 of a second. When a nerve is subject to the influence of a current, the effect of stimuli applied to any part of the nerve is increased if we estimate the result from the sensations produced in connection with the muscles. This alteration in the condition of the nerve from its physiological function, is called its electrotone. Nerve irritability when the nerve is subjected to a constant current is increased at the point where the current leaves the nerve, and it is lessened at the point where the current enters. Conductivity, however, is altered in a different way, for when the nerve is electrotonic, the conductivity is less at the point where the current leaves than at the point where it enters the nerve, indicating a difference between the beginning of the nerve impulse and its transmission along the nerve.

When the nerve commotion is transmitted through a nerve, certain processes are originated within the nerve itself. No visible mechanical changes take place in the nerve, although certain changes are found in the nerve cells as the result of irritation, prolonged excitation producing shrinkage of the cells in connection with the nucleus and the protoplasm estimated as amounting to 25 or 30 per cent. No appreciable thermal changes are found associated with nerve excitability. Certain chemical changes, it is claimed, take place, the nerve after prolonged exertion or stimulation becoming acid in reaction. Some electric phenomena are also said to arise in connection with nerve excitement. By dividing a nerve and then applying an electrometer, the normal nerve surface is positive to the cross-cut surface. A current of rest flows from the cut end in the direction of the equator indicating the existence of electrical variation when a nerve is stimulated.

In regard to the principles that regulate nerve conduction almost nothing can be said. The first principle may be stated as, that conduction takes place in all nerves similarly. In trying to compare the amount

of stimulus with the amount of the resulting commotion, the only available means is electrical measurements. Measured by the result in muscle contraction, it is found to be in direct proportion to the stimulus. Notable exceptions to this principle have been observed. When the stimulus is increased beyond that necessary to secure the initial maximal contraction, there is a second phase of the contraction during which a second maximal is attained; sometimes this second phase represents a decreased contraction, followed by another increase. Variations are found in excitability among different nerves and even in the different parts of the same nerve, the entering current affecting the lower part more and the leaving current the upper part of the nerve more. The nerve commotion passes along the nerve as undulations, but in order to preserve the undulations and prevent their combination, there must be an intervening period between each stimulus of about 1-100th of a second. If this interval is not preserved they will combine, resulting in tetanus. By preserving this interval the united results may be summed up, forming a summation of stimuli in connection with the nerve, resulting in a summation of muscle contractions. In regard to the speed of nerve conductivity, Helmholtz says that the speed of impulses in the motor nerves of frogs is about 86.6 feet per second, later researches in connection with the pendulum myograph gave about 89.6. Under changes of temperature in the case of the human subject a speed of 98 to 300 feet per second may be obtained. In the case of the sensory nerves the speed is placed at 98 to 130, the speed depending upon the temperature, nerve length and the electrotonic nerve condition. In the spinal cord and brain the speed is much slower than in the nerves on account of the increased complexity of the organs and the number of side paths along which impulses may pass. In the cord the rate of sensory impulses is placed at 26 1-2 feet, and the motor from 36 to 49 feet per second. The tactile sensations arise sooner than pain sensations as in the case of a burning hand, the former being about 89 to 160 feet, and the latter 26 to 48 feet per second. The slightest interference with neural integrity, as in the case of a section, even when the divided ends are kept close together interferes with the neural integrity of conductivity. The neural impulses cannot leap over spaces, so that to preserve the conductivity there must be neural integrity. In the spinal cord and brain we must remember that the same continuity may not be necessary as in a nerve, because in passing through the cells considerable modification of impulses takes place and several paths are open for them.

THE CENTRAL NERVOUS SYSTEM. Reflex action arises when one nerve is stimulated secondarily through a center by a primary stimulation in the case of another nerve. Where the primary stimulation originates in a center the action is automatic. Of this action we know nothing and the

term simply indicates want of knowledge on the subject. As distinguished from these we have the voluntary action associated with the exercise of will. There may exist various kinds of reflex actions—co-motor reflex in which two motor nerves are united through a center; reflex-sensory where an impulse originating in a motor nerve may be communicated to a sensory path; co-sensory reflex exists where one sensory nerve is united with another sensory nerve through a central organ, as for example, the influence of light on looking at the sun producing the irritation resulting in sneezing. The most common is the sensory motor in which the sensory represents the primary stimulation and the motor the secondary through the center. The spinal cord is particularly adapted to perform the function of reflex centers. In connection with the brainless frog we have a reflex nerve machine, the spinal cord being preserved alive but entirely severed from the brain below the medulla. By irritating the side of the frog in this condition there will result muscular movements. The same experiments have been made in connection with brainless mamimals, the difference being that immediately after the removal of the brain the responses are very feeble, whereas if the animal is kept alive the reflexes become strong. The age, sex and training of the animal also influence the response. If stimuli are applied suddenly a much readier response is given than if applied slowly and the repetition of stimuli gives the most effective response. The nature of the response depends on the condition of the spinal cord and also upon the local area to which the stimulus is applied. The stimulation of a sensory nerve with a slight degree of stimulation produces reflex movements originating on the same side of the cord as the sensory stimulation takes place; if the stimulation is increased reflex movements may originate from the opposite side; while a still further increase in stimulation may produce response on both sides. The neural impulse when it passes into the cord is diffused among the cells and fibers at the point of entrance, then it passes to the other side and finally it is found on both sides.

The spinal cord gives origin to certain automatic impulses such as those associated with muscular tonicity. This is questioned, however, as all the muscles are not affected at the same time and in the same way, certain sensory impulses in connection with the skin, even in the brainless frog, produce the tonic action reflexly. In some regions of the cord the motor and sensory tracts are more closely connected than in others, these regions being called the reflex centers, being dependent largely upon individual habits and specific functions of the animal as well as the individual eccentricites and the previous functional use of the cord, such as the vaso-motor, micturition, defaecation, etc., centers. The spinal cord gives a quicker response than when the stimulation takes place through the brain, because the connection of the cord with the brain in-

volves the inhibitory function of the brain. For example the heat center is in the upper cervical region, whereas inhibitory and acceleratory centers are in the brain, the cord function being inhibited or augmented in connection with the brain centers. While therefore the cord has its own in dependent functional powers it is regulated by the higher brain centers. This is involved in the fact that in most of the ordinary activities of life there are involved, spinal reflexes, motor reflexes that imply brain action in connection with the sense organs and the special modifications that arise from the distinctly conscious acts of volition.

In the brain the complexity of function is greatly increased, the brain in the human subject being so complex and complicated. Despite the difficulties arising from the difficulty of experimenting on the human brain much progress has been made through pathology, clincal observations and surgical experiments in cerebral localization. It is here that the relations between the body and the mind bring us closely to the localized areas of the brain. The brain may be divided into (1) a sensitive area, including all above the cord and below the cerebral hemispheres, and (2) a conscious area in the cerebral hemispheres.

(1) In the sensitive area we find next above the spinal cord the medulla whose functioning represents the vegetative and lower animal life. The reflex motor functions of the cord are extended into the medulla, especially in connection with the heart, vaso-motion, respiration, deglutition, etc. Automatic impulses originate in the medulla in connection with the blood circulation regulating breathing, heart rhythm and blood circulation. This minute substance is full of centers, the respiratory and vaso-motor being the most important along with the cardio-inhibitory center. Associated with the medulla are the functions of co-ordination the upper portion being closely connected with the gray matter of the third ventricle and the semi-circular canals in connection with body equilibrium and the co-ordination of muscle movements. Hence its reflex character is of greater importance than its capacity to do under voluntary control, all of the centers being more or less associated together. Above the medulla and below the cerebral hemispheres we find a number of varying brain portions that are of considerable importance. By the removal of the cerebral hemispheres in the case of a frog or pigeon interesting results have been obtained. It is aound that the rnimal deprived of these hemispheres is more or less mindless, while it does not appreciate magnitude or relation to other bodies except through contact with these bodies, having no fear and showing no power of recognition. The psychic qualities seem to be entirely absent. All of the intermediate parts between the medulla and cerebrum are related in function. They act independently to a certain extent, and in certain cases they can perform each other's functions' having largely the same sensory and motor connections. They are all united in

the formation of the central part of the nervous mechanism which acts as co-ordinating centers in connection with the impulses of the special senses and govern the motor mechanism. In the processes of adjustment and readjustment in connection with the animal body they play a very important part. The cerebellum seems to be concerned in the adjustment of the opposite sides of the body so as to produce equilibrium, the sense impulses of sight and touch furnishing the external stimuli that notify the brain of the body position and relations. The semi-circular canals are intimately associated with the cerebellum in discharging this function. The corpora quadrigemina are united with the cerebellum, pons and medulla in promoting equilibrium and sustaining the normal body movements, particularly in connection with visual sensations. The optic thalami seem to be associated with the corpora quadrigemina in the adjustment of body movements in connection with visual sensations and according to Ferrier with muscle movements in connection with tactile sensations. The corpora striata have some special function to discharge in the co-ordination of motor impulses as these originate in the cerebrum and cerebellum, while Ott regards them as heat centers, or regulators of the temperature of the body. The nervous matter on the floor and walls of the third ventricle has something to do with the equipoise of the body in ordinating motor impulses and sensory impluses especially of touch, and of sound in conjunction with the semi-circular canals, as well as of impulses that arise from visual changes. Thus all these intermediate organs between the medulla and the cerebrum have some special and general functions in connection with co-ordination as between the impulses originating in the special sense organs and the muscle movements.

Normally all these functions are subordinate to the cerebrum. The individual organs represent parts of an inter-related whole which corresponds with the psychic phenomena of motion resulting from the sensory impulses. Even in the lower animals when the cerebrum is absent, although these intermediate parts perform their functions independently, they do it unintelligently indicating that the psychic qualities of intelligence, feeling and volition can be mediated through these lower regions, but only do they possess psychic qualities when they sustain their normal relations to the cerebral hemispheres. Hence these have an important psychic bearing upon the phenomena of consciousness and not incorrectly did we distingush between the sensitive and the conscious functions in connection with the lower and upper brain.

(2). The Cerebral Hemispheres.—We know that the conscious phenomena are very intimately related to the body organism. This we gather from the fact that injuries to certain parts of that body organism involve mental conditions that are abnormal. It is more difficult to localize these changes in connection with nervous matter. We cannot judge directly

regarding the nervous system, but must depend on indirect indications of changes taking place in the nervous mechanism. In the normal condition of the nervous system there is no tension but everything seems to run smoothly, so that it is only when we find abnormal conditions we have any means of localiziug the varying sensations. In the case of the central nervous system it is beyond ordinary experience and observation so that we are unable to gain any direct knowledge of the action of the brain. In the ordinary life there is nothing to indicate the importance of the central system. Among the ancients very little significance was attached to the brain. Alcmaeon spoke of it as the general rendezvous of the senses within the body, while Aristotle regarded it as simply a lubricating reservoir for the eyes. We suppose that there exist in connection with the brain certain of the conscious phenomena intimatcly associated with the thinking processes. Attention is attended with a strain upon the eyes and the other sensations arising from the special senses are localized in connection with the brain. When thought or attention is concentrated the feeling is identified with the head, indicated by the attitudes of thought, meditation, and anxious consideration. The different senses are popularly associated with a brain center in such a definite way that the brain is popularly looked on as the seat of the most intricate processes of the psychic experience. It is this that led to the idea that the soul is seated in the brain and the particularly neurotic character of the modern individuality gives added force to this conception. These however, are very indefinite indications of what physiological researches have tried to unravel, namely, the localization of the cerebral functions. There is no doubt that the brain is of the highest importance, not only to the psychic but even to the ordinary physiological life. The human brain has a powerful influence upon human consciousness. Without the normal blood circulation with its abundant supply of O the central system could not discharge its normal functions. Hence the amount of blood that is utilized in the brain represents about 12 per cent of the entire blood of the body while the weight of the brain would not amount to more than 2 1-4 per cent of the body. If the blood circulating in the brain is impure, especially if certain chemical substances are present, the conscious activity is greatly interfered with. To increase the rapidity of the circulation by the use of stimulants has a decisive effect upon the rapidity of thought. Changes in the temperature of the brain are associated with mental changes, the changes in temperature during wakefulness being accompanied by psychic activity. Even without sensory impulses psychic activity developes a changed temperature. It has been found that where strong impressions reach the brain there is a variation of temperature represented by rise and fall in connection with the different areas of the brain, so that there is a localization of these variations. In the occipital region it is found that the greatest rise in the temperature exists, increasing more in the case of emotional excitement than in purely sense stimulation. This seems to indicate the localization of functions and areas in the brain. It is found that where psychic activity is great there is an accompanying increase in the amount of waste matter thrown off; indicating the metabolism of nervous tissue in the conversion of potential into kinetic energy. This means that increased psychic activity represents an increase in the cerebral cell activity in connection with the use of the phosphoric compounds. Thus the brain mass becomes more or less altered during the psychic activity.

A comparison of the structure and size of the brain in different animals indicates the relation of the brain substance to mental action. This indicates the place of the species in the scale of intelligence. Great variations are found in the size and structure of the brain so that no general principles can be laid down. There is a rapid development of the brain during the first years of the child life. At the period of birth the brain weight to the body weight, is in the male according to Tiedman, 1 to 5.85, and in the female 1 to 6.5. At the beginning of the third year the ratio is 1 to 14, and one year later 1 to 18. There is a gradual increase till about 25 or 30 years, after which it begins to decrease till old age, about the rate of 1 ounce for every decade of life. Much interesting work has been done in comparing the weights of the brain in the different races. The European and North American brain varies in the male from 44 to 55 ozs., and in the female from 40 to 44 ozs. The sexual distinction is not simply one of size in comparison with the body weight, the male being about 10 per cent heavier. Considerable variation above and below these averages is found in actual experience, without any indication of unusual mentality or exceptional inferiority. Brains below 30 ozs. are usually associated with imbecility, accompanying the mental weakness being a body weakness. Maudsley says the superiority of the human subject mentally over the animals, is connected essentially with man's capacity for a greater variety of muscular activity. To such an extent does he think this is so that if man with a normal brain were deprived of all the movements of face, hands and limbs, he would fall into idiocy. This brings out the close relation between mind and body in strength and weakness. Insanity on the other hand is not necessarily associated with an altered size of brain, although there is often an abnormally large brain found in the insane. We must remember, however, that weight is not an absolute test. More reliable results are obtained by comparing the development of the cerebral hemispheres in man with that in the lower animals, particularly in regard to the cerebral convolutions. As the convolutions become more numerous and complex, we reach a higher degree of mental life. In the development of the human brain from the

embryo, we find a correspondence between the embryonic form and the forms of fishes, birds, etc. Among the fishes there is a small cerebellum and cerebrum; among the amphibia the cerebral hemispheres become more developed; while in birds the hemispheres have developed their characteristic mantle form over the lower brain. In the higher mammals we find occipital development very complete and frontal development more perfect, with an increasing complexity of convolution development. As the mantle development becomes more perfect it spreads out over the intermediate ganglia, the cerebrum leaving behind and decreasing the importance of these ganglia, indicating the great importance of the cerebral hemispheres in the higher intelligence. Meynert suggests that the entire cortex cerebri represents a field of projection upon which all the sensory impulses are arranged as they come from the periphery, forming the physical basis for the distribution of these impulses in connection with the motor tracts. It cannot be said that the cerebral convolutions correspond with the intelligence displayed by all the scales of animal life, so that we are unable to say that the less civilized races have less development in the cerebral hemispheres. In the imbecile there is poverty of convolutions. Meynert thinks that in the peduncles we have two parts, the one tegmentum in direct relation with the optic thalami and the corpora quadrigemina and the other crusta in relation with the cerebrum through the corpora striata. As the cerebrum becomes greater compared with the corpora quadrigemina, the latter part of the crura must be larger than the former so that the crusta represents the measure of psychic development; and as this more fully developed in man than in any other animals, Meynert regards this as the index of mentality.

Here we find at least the importance attaching to the cerebral hemispheres from the standpoint of psychic activity. The neural impulses pass from the periphery along the nervous tracts to the brain; and in so far as these are converted into motion they represent ideation and conation. In this way physiology points out the convolutions of the brain as the ultimate physical basis of both the psychic and physiological life of man, the sensory and motor impulses finding a general meeting ground in this cortex cerebri. As this is cut off from the periphery, sensory and motor impulses are likewise cut off so that the psychic and physical life are divorced from each other. In the brainless frog a number of reflexes are possible, but without psychic relations; if the intermediate brain ganglia are left there is a definite psychic element in activity. This has led to the suggestion that consciousness and its purposive features are associated with the spinal cord and brain ganglia, but many of the purposive actions of the human life, such as walking, eating, breathing, are not necessarily connected with conscious mental states. The cerebral hemispheres in

man represent the only parts of the neural mechanism associated directly with consciousness. Any localization then of conscious activities must be in connection with the cerebrum. Below the hemispheres the nervous system is not capable of forming a physical basis for psychic activities. To say that certain phenomena manifesting purpose may be exhibited after decapitation does not import into the spinal cord the element of mentality. The action of these parts of the nervous mechanism depends upon the relations established between the different parts of the system by habit. In the case of the lower animals we know little of the relations of consciousness to the physical life, all that we know being the application of our own conscious experience to their actions. If we judge from the human life, however, many of the vital phenomena are not distinctly conscious. As the cerebrum in animals develops, there is a greater influence developed in connection with all the physical activities. Hence as the cerebrum becomes more developed it is more closely related to the entire physical and psychic life, so that if it is lost, it represents a greater loss than if the cerebral development had been less complete. Hence a frog, brainless, can do without its brain more than a dog could do deprived of its brain, and so on as we advance in the scale of intelligence. The more complex the relations established and the more complete the cerebral control, the greater is the loss of it. As the functions become coordinated in man, on a lower or a higher scale, the psychic activity is more or less intimately connected with these functions, so that habit which is psychic becomes physiological. Hence, the tendency to explain the more complex body activities on a purely physiological basis. The chief result of the destruction of the cerebral hemispheres is the elmination of the psychic element from the life, at least in the higher mammals including man, so that the real physical basis of mentality is in the cerebrum, or rather in the cerebrum as it forms the ultimate crown of the entire neural mechanism and muscular organism. The cerebrum which represents the most advanced development of the neuro-muscular mechanism is not simple but complex. It consists of different parts characterized by want of homogeneity, consisting of multifarious forms and relations established among the different parts. The question is, can we localize these parts functionally?

On general physiological principles there seems to be an a priori presumption in favor of localization of functions. In the cerebrum we find the same neural elements as are found in the rest of the nervous mechanism. The combinations and associations may be different, and this may result in differences of functions, but the substance is essentially the same. As we have seen localization is carried out in the intermediate parts of the brain, and this suggests the possibility of localization in the cerebrum. The doctrines of localization are not yet a quarter of a cen-

tury old. Older attempts met with no success, and the fact that large parts of the brain could be lost without any appreciable loss of sensory or motor functions assisted in discrediting any attempts to localize. The great physiologists of the first half of this century decided against localization, claiming that the different parts perform their functions in relation to the entire brain. Broca was the first to suggest localization in connection with articulation associated with the frontal lobe. Meynert claimed that the anatomy and physiology of the brain suggest that the anterior part of the cerebrum is motor and the posterior sensory in function. The experiments of Hitzig and Fritsch mark the first positive advance in the science of localization. They experimented upon the dog by electricity, finding that the cortex cerebri is subject to electrical irritation, that the motor parts are found on the anterior portion and the non-motor on the posterior part of the cortex. The stimulation electrically of the motor areas produced muscle contractions on the opposite side of the body. They indicated five motor areas, for the neck muscles, for the extension of the front limb, for the rotation of the fore limb, for the hind limbs and the muscles of the face. Ferrier followed out these experiments in connection with the monkey.

We do not have a physiology of the cerebral hemispheres, because of the fact that they are so much hidden from observation and so closely connected with every other function of the body that they cannot be discussed separately or subjected to observation. Investigation seems almost impossible in connection with the physics and chemistry of the brain, so that the physical and psychic facts that are available in discussing the localization of areas are most complicated. The evidence has been classified under three heads, experiment, pathological, and anatomical. In connection with experiments there are available, stimulation and destruction of the parts. By stimulation the attempt is made to associate certain muscles with certain definite areas, but this only indicates a relation between the muscles and the localized area, and does not prove that these areas are solely concerned in muscular actions. The stimulus commonly used is electricity and objections have been taken that electrical diffusion takes place so that we are unable to say that the effect is limited to any definite area. Hence, it is claimed that by stimulating certain cortical regions, these regions act simply as conductors of the impulse to other regions of the brain, particularly in the basal part. Ferrier answers this by saying the stimulation of the basal ganglia can be carefully estimated, so that the effect of stimulating these ganglia and the cortical regions can be compared.

By administering anæsthetics it is found that cortical excitability is lessened or lost. This in addition to the fact that if the gray matter on the surface is removed, the stimulus requires to be stronger in order to

excite motivity, seems to prove that somehow the cortical substance is connected with muscular phenomena. By the removal of certain parts of the brain, it is found that there is an interference with or loss of motion on the part of certain muscles. This seems to indicate the relation of these parts to the muscles involved. This cannot be applied absolutely, because we do not know the effect upon the brain substance itself produced by extirpation, nor can we follow the changes taking place in the brain as a result of extirpation. The fact that these experiments are made upon the lower animals lessens their value in application to man, as there is not an absolute correspondence between the brain areas in man and these lower animals, and the psychic experience of man does not correspond with that of the animal so far as known to us. The pathological evidence is of great value because here it bears upon the human brain when accident, disease and even the hand of suicide and murder open up for examination the different brain areas. Difficulties arise because the accidents do not often secure clean cut portions, and the lesions involved do not always represent complete conditions as to the relation between sensory and motor disturbances and the brain area involved. Post-mortem pathology is not yet scientific enough to enable the psychologist to get clear and definite cases. Hence the evidence is conflicting. With the advance of modern surgical science this is being remedied, because in large numbers of cases, with the present imperfect knowledge of localization, surgery is skillfully relieving many brain conditions and thus demonstrating its ability to reason from the disturbance, which is a symptom, to the lesion that is the cause. Physiology and psychology will profit by these discoveries.

Anatomy can aid only in a general way in the work of localization by pointing out the increasing complexity of the human brain areas in comparison with animals. Comparative anatomy can trace out the increasing complex areas in the ascending scale of animal life until it comes close to man. Histology expands this evidence by tracing out the relations of different parts of the brain. Microscopy and micro-photography lend a helpful hand to histology in following up the course of the nerve tracts into the cerebrum. These fields of investigation have presented a confused mass of evidence which requires to be carefully analyzed, compared and classified in order to gain any definite results, and only when all of these evidences unite with more or less unanimity do we get certain results. The first general conclusion reached is, that the cerebral hemispheres do not represent a single mass that plays a part in every psychic function, but that they represent a large number of psychic organs, every one of which has a psychic functioning with a more or less intimate relation to the physiological functions of parts or organs of the body. The second general principle is that in the attempts to localize cerebral areas

much of the cerebral hemisphere remains as yet unrelated to sensory or motor activities. There may be the removal of considerably large parts of the cortical substance without interfering with any of the normal body functions. The American crowbar case, in which a bar of iron, 3 feet 7 inches long and 1 1-4 inches in diameter, passed through the brain of a young man, entering at the left angle of the jaw and passing out at the top of the head without interfering with sensory or motor activity, may be taken as an illustration of this point from the pathology of the subject. This suggests the fact that all the defenders of localization lay emphasis solely on cases that favor their theories of localization without attempting to consider these negative cases that oppose their theories. This does not, however, destroy the work done in localizing such regions. It has already borne fruit in modern surgical cases, for in a number of cases lesions have been removed by the aid of our imperfect knowledge of localization. This indicates the possibility of laying down certain positive results while we await further developments.

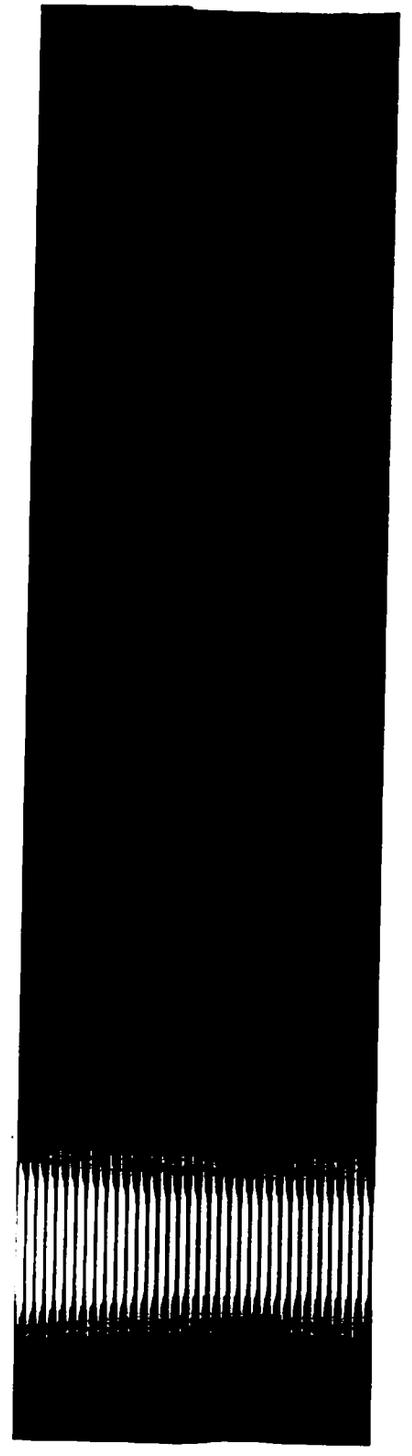
Recent experiments have increased rather than lessened the difficulties that arise in connection with the cases in which large portions of the brain substance have been destroyed without interfering seriously either with physiological or mental functioning. Yet the evidence amassed in connection with the three sources of evidence seems to present a basis for a more or less consistent theory of localization. This theory is most definite in regard to the areas associated with the motor functions. This renion is found around the Rolandic fissure, taking in the anterior and posterior gyri centrales and their extension on the median brain surface in connection with the lobulus paracentralis. In the first experiments conducted by Fritsch and Hitzig we find the localization of five areas in connection with the cerebrum of the dog, the stimulation of which resulted in certain movements. These are, areas for the muscles of the neck, at the middle of the praefrontal gyrus at the beginning of its declivity; for the extensor and the adductor muscles of the fore limb at the extremity of the post-frontal gyrus close to the frontal fissure; for the flexing and rotation of the fore limb back of the last; for the hind limb in the post-frontal gyrus nearer the median line than the two preceding; and the center for the face in the median part of the gyrus above the Sylvian fissure. Ferrier, by the use of electrical stimulation in connection with the monkey, found the centers of motion in connection with the gyri centrales and in the adjacent part about the Rolandic fissnre. Recent experiments in connection with electrical stimulation have confirmed most of these general results. It is claimed by some that some of the smaller areas become irritable after stimulation for a time while others lose their excitability after stimulation. In the case of the larger areas found in connection with muscle groups it is claimed that certain small portions of the cerebral hemispheres correspond with the origin of the nerve fibers controlling the muscle groups. Thus as Exner has pointed out there is an absolute and a relative field for the motor actions so that the fibers which originate at minute cerebral spots proceed to the lower portions of the brain.

By the destruction of those regions in connection with which muscular movements can be stimulated it is found that there results an interference with the muscle movements. Hitzig and Fritsch made use of extirpation as a means of confirming the stimulation experiments. Munk experimented very carefully upon dogs, extirpating circular layers of brain substance 3-5 of an inch in diameter and 1-12 of an inch thick in connection with the surfaces of the parietal, occipital and temporal lobes. He concluded that by drawing a line from the sylvian fissure terminal in a vertical direction towards the sickel like falx between the cerebral lobes it will define an anterior and posterior sphere corresponding with a motor and a sensory region. His general experiments indicated that destruction of portions anterior and posterior to this line resulted respectively in motor and sensory disturbances. The definite areas he discovered correspond generally with the conclusions of Hitzig ond Ferrier, three of his regions, for the head, the arm and the leg being identical with the others discovered before. By extirpating the area of the fore limb he found abnormal conditions in connection with the limb so that stimulation applied to the limb even strongly will not call forth any response, or only a reflex result, so that according to Munk there is no cerebral action in connection with this limb. Munk rejects the theory that these cerebral regions are distinct motor areas, that is having the function of moving in connection with volition but he regards them as feeling areas, because the motor action of higher centers depends on the feelings arising in connection with the different tactile sensations. From this he concludes that the removal of the area mentioned before interferes with the sense of feeling and may be repaired as soon as restitution from injury takes place. Iu this he is supported by Schiff who claims that the loss of motion arises in this case from the absence of the tactile sensations. This he claims is proved by the non-sensibility of the limb on its cutaneous surface to stimulation. Goltz claims that extirpating the cerebral substance in the frontal lobe produces an indifferent activity in the limbs on the opposite side of the body accompanied by diminished tactile sensation while the muscular sense is destroyed, so that there is not any permanent loss of motivity in the muscles. His idea is that the greater influence is exerted on the psychic element by a removal of a part of the brain substance. Bechterew claims that on extirpating any extensive part of the motor areas the motivity is not lost but the adaptive movement is lost in the extremities so that they

cannnot be used as hands or feet, indicating the idea that there is a separation of these movements from the purposive force of the will. More recently Horsley and Schaefer have continued the investigations in connection with localization their conclusions being the most advanced in this new science.

It is difficult to attempt to frame a theory upon such seemingly indefiniteand contradictory results. It would seem that we may takeit assettled, however, that there is a region that may be called motor, any interference with this region producing a muscular disturbance, the loss being rather that of the psychic or intelligent power of adaptation in the use of the muscles. Associated with the loss of a large portion of the cerebral substance we find the loss of the tactile and muscular sensations that are necessary to the localization of everything external to the mind, including the body and external objects, so that movements cannot be adjusted. In other words there is a loss of voluntary expression in connection with movements and a more or less complete interference with sensation, perception and volition. Several explanations have been offered in regard to the effect of this loss of sensory-motor capacity. Some claim that the areas extirpated are purely mator, so that there is an impairment of the relations between the cerebral substance and the projection fibers. Others like Goltz claim that the loss is sensory, the motor disturbance being a manifestation of this sensory loss, so that the animal can nolonger use its extremities on account of loss of sensibility. It may be explained from a psychic standpoint, due to the impossibility of keeping before the mind the mental picture of the body and external objects so as to localize them definitely, involving an interference with the association fibers. Thus it is claimed that by removing the association fibers without impairing the projection fibers, theloss of motivity is quite as complete, indicating that any disturbance whether sensory or motor interferes with the cerebral psychic activity, so preventing its control of the muscles. In fact Goltz claims that any interference with the brain substance that is extensive interferes with this psychic control and therefore diminishes but does not destroy the sensory and motor functions. Thus certain areas of the brain are of special significance in the muscle movements, these areas being found in the region around the Rolandic fissure and in the paracentral lobule. In connection with this region there is an anterior region and a posterior, the former being motor and the later sensory. This general region is divided into local areas which are localized in connection with pathology because the experiments in connection with the lower animals cannot be transferred absolutely to the human subject. There is a difference in the brain development in the lower animals and in man and exact localization seems to depend to a large extent upon the intelligence development, the forward development guiding and determining the localized areas. Pathology thus steps in to mark out the application of the general principles brought out by experiment in connection with the lower animals to the human subject.

Here we have no more careful or thorough examination of pathological data than that furnished by the work of Exner. Out of thousands of cases consulted he selected 169 cases that were test cases, perfectly reliable and well authenticated. In analyzing the cases he divided them into three classes, mapping out those he called (1) negative cases, (2) positive cases, (3) percentage cases. In the first he found out the regions of the cerebrum not associated with sensory or motor functions. The second class of cases indicated direct lesions in particular regions and the disturbances associated with them. The third class of cases indicated the degree of probability arising from the discovery of certain disturbances associated with diseases or lesionsin certain specified areas, this probability depending on the result of the majority of cases bearing on the particular area. As a result of his analytical researches he found 20 cases in which no disturbance followed existing lesions, while there were 67 lesions in the right and 101 in the left hemisphere, indicating that his cases presupposed a larger latent field on the right hemisphere. The result is that on the right hemisphere only the two central gyri, the paracentral lobule and small parts of the inferior and concave surfaces of the occipital lobe represent an active field. This is in line with clinical observations which point out the possibility of large lesions in the frontal, temporaland occipital lobes without any interference with sensory or motor activity. It also confirms the experimental evidence from the lower animals that the region around the fissure of Rolandois the motor area of the cerebrum. Exner divided the active fields into two classes, (1) absolute in which whenever a lesion occurred there was found a disturbance of functions; (2) relative in which in more than 50 per cent of the lesions there was an accompanying disturbance. In connection with the upper extremities he found that the absolute field for the left arm is in the paracentral, anterior central and the upper part of the posterior central gyri and for the right arm in the upper parietal lobe and in part of the median surface of the occipital lobe. It must be remembered the cerebral regions and the corresponding extremities are on opposite sides. The relative field for the left arm he found to include in addition to the absolute field, the posterior part of the three frontal convolutions and the anterior part of the parietal lobe together with adjacent median surface, and for the right arm in addition to the absolute field the larger part of the parietal and occipital lobes. This is in line with the fact that righthandedness is normal in man and that a larger cerebral area is devoted to the activity associated with the delicate and intelligent movements of the right arm. In connection with the lower extremities he found the absolute field for the left leg in the



paracentral lobule, the upper part of the anterior central, the corresponding parts of the posterior central convolutions and part of the quadrate lobule, and for the right leg the paracentral lobule, the upper part of the posterior central convolutions and the upper part of the parietal lobe. For the relative field of the left leg he found the lower parts of the central and the posterior parts of the frontal gyri with the upper parts of the occipital lobe and the parietal lobules, and for the right leg in addition to the absolute field he designates the parietal lobe, the median surface of the quadrate lobule and the cuneate convolution. This indicates that cerebration is less perfect in connection with the lower extremities, indicating the fact that less psychic effort is devoted to the lower extremities, and that the upper extremities represent a greater and more intelligent development. According to this the great motor area is around the Rolandic fissure and in the paracentaal lobule. In these regions and the adjacent areas are localized the centers of more minute activites, for example the facial area in the lower parts of the anterior central and posterior central convolutions; the lingual area is at the junction of the middle and lower frontal and anterior convolutions; the muscles of the head and neck in the central convolutions. Other experimenters have confirmed the general conclusions of Exner, Charcot claiming that the cerebrum may be divided into a motor and a non-motor zone, the former being limited to the ascending frontal and parietal gyri and the paracentral lobule. Added to this is more recent surgical experience which is aiding in definite localization. Horsley has divided the arm region into four areas, uppermost the shoulder, next the elbow, then the wrist and last the thumb. Meynert claims that the sensory paths go more in the direction of the occipital region and the motor paths towards the frontal region of the cerebral hemispheres, this being based largely on the greater size of the motor cells on the analogy of the motor paths in the cord.

The question is raised, does not the motor area correspond with the area of tactile and muscular sensations? It would seem from the analogy of the spinal cord and the lower parts of the brain, that the sensory and motor apparati are closely connected. In connection with conscious sensations it would seem that a close relation exists between the delicacy of the sensations experienced and the delicacy of the motor activity depending on the will. Pathology it is claimed negatives this idea because many examples of motor interference exist without any sensory disturbance. Exner claims that the tactile sensations have no absolutely definite cortical field, the whole relative field of motor activity being included in the field of tactile and muscular sensations. Hence, he claims that the cortical fields for sensation and motion are the same, although the right hemisphere is the predominant sensory area, as the left is the prevailing motor area. This is in line with the fact that motor disturbances are more generally associated with the lesions in the left hemisphere. Thus the central convolutions with the paracentral lobule and the adjacent parts represent the cortical field for the sensory functions, these representing the central areas of the sensory impulses originating in the muscles and cutaneous surfaces of the limbs corresponding with the motor areas. In connection with the interferences with sensory and motor relations there is involved a complicated psychic condition, which renders it difficult to separate the sensory motor disturbances from one another. It is certain that a very close relation exists between the two. It is probable they are not identical and also that the sensory region extends more posteriorly than the motor, possibly including the motor, certainly closely related to the motor, and taking in the gyrus fornicatus and hippocampi, with the quadrate lobe and the posterior parietal convolutions.

The sensory localization is more difficult because of complicated psychic relations and physical mechanisms. The experiments on the lower animals are of little value here because we have no knowledge of the facts of consciousness in these animals. It is possible, however, to apply the results of experimentation in connection with the facts discovered in human pathology. Particularly the experiments of Munk are so careful that they form the basis of application to the human sensory impressions. Ferrier has localized the visual centers in the gyrus angularis and the occipital lobes. Munk localizes the sight area in the occipital lobes in the upper and posterior part, claiming that the gyrus angularis is associated with the tactile sensations of vision. According to Munk the extirpation of the sight center in the dog produces psychic blindness, that is, it is not able to transform the visual impressions into mental pictures. It does not lose sight; as it can regulate its movements by sight but it has no psychic capacity to associate external objects or beings with its former actions. If this extirpation takes place in both hemispheres the psychic blindness is permanent. From this he concludes that the sight center is associated with visual pictures, the occipital lobules being associated with sight perceptions. Pathology seems to get from these experiments the fact that on the convex surface of the occipital lobes and possibly on adjacent parts of the lobe and the cuneate lobe are to be found the visual regions. According to Exner the upper part of the first occipital convolution is the most important visual area, the rest of the occipital convolutions, the cuneate and quadrate lobules being less important. It would seem that the sight areas are largely and widely distributed over the cortex, so that a different points the sight impulses may be cut off producing psychic blindness. This may arise from interference with the connection of the visual perception and the other psychic perceptions or an interference with the visual perception alone so that there may be a corresponding cerebral disturbance in the regions representing the projection

and association fibers. In this case a large area of the brain in the occipital, parietal and frontal lobes is associated with vision. The attempts to subdivide this large area are based largely on histology. In the human subject the optic nerve has two systems of fibers, the one crossing to the opposite side, possibly in connection with the optic chiasm and the other remaining without crossing on the same side, so that the retina of each eye has cortical relations in both cerebral hemispheres. The two areas on either side of the median line are united so that we have a large area in the two hemispheres connected with each retina, but as to the minute divisions of that area we are unable to say anything definite.

In regard to the other sensory areas much speculation has been indulged in and attempts have been made to localize in unassigned areas the centers of the mental phenomena associated with taste, smell and hearing. Ferrier localizes taste and smell together in connection with the subiculum of the gyri of the temporal lobe and adjacent regions, and the touch area in the gyrus hippocampi, in which Munk localizes smell. Ferrier localizes the area of audition in the upper convolution of the temporal lobe, but recent experiments indicate that it may be entirely extirpated without permanently interfering with hearing. Luciani says that it includes the entire temporo-sphenoidal lobe and the cornu of Ammon. In connection with articulation all the cerebral functions are more or less intimately associated together, Broca, despite this fact, claimed that the area of articulate language is in the lower frontal convolution. In aphasic conditions there is an interference with cerebral functions. Great variations are found in this condition from the entire loss of speech to mere inattention. In some cases there is an entire absence of speech although there is the capacity to use written language; in other cases there may be the inability to express thought in written form; in other cases there is incapacity to associate spoken language with intelligent perceptions, called word deafness; sometimes there is a connected disturbance of vision and speech, indicating the connection of the visual areas with association fibers connected with the speech areas in the temporal and frontal convolutions. Exner distinguishes, (1) cases in which the words are not understood; (2) cases in which ideas cannot be put into language; (3) cases in which the ideas and words cannot be brought together by association. These may be combined in different ways, the cerebral hemispheres or the lower brain regions being affected. All true aphasic conditions however, involve an interference in connection with the cerebrum which prevents the association of ideas and articulate expression. Can we localize in the cerebral cortex any special region where this association takes place? It is claimed that in the majority of cases where cerebral interference is found there is a lesion in the posterior part of the third frontal convolution and the adjacent regions around the Sylvian fissure, in the parietal and temporal lobes. In Exner's cases 30 out 31 aphasic cases represented lesions in the left hemisphere and Seguin out of 260 found 243 associated with lesions on the left side. This has led to the theory that in normal individuals, speech is left brained, while in the case of left handed people it is right brained. In the left hemisphere the anterior central gyrus and the contiguous convolutions in the posterior frontal lobe represent according to the cases the points of aphasic lesions.

In the scheme of localization the theory has been carried out by applying the same principles to the frontal region. It seems as if localization is to be carried out there must be found some cerebral region for the mental activities including perception, memory, volition and emotion. The anatomical significance of the frontal lobes, and the fact that the increase of intelligence is marked as we rise higher among animal existences by frontal development, seems to confirm this. Experiments upon some animals have indicated that on the removal of the forebrain there is a lapse into imbecility. Despite these facts, there is no part of the brain that can sustain with less disadvantage the loss of a large part of the substance. In addition it is found that injuries in the other regions, parietal, occipital and temporal, involve loss of mentality to a greater or less degree so that intelligence can not be said to be confined to the frontal area.

Undoubtedly mentality is associated with the activities of the sensory and motor regions. The loss of mentality does not mean the loss of power in the intelligence center but may be due to the fact that no support is furnished to mentation in connection with such processes as audition, vision and touch. Hence all mentation represents an intelligence that has a basic foundation in sensations and volitions. This precludes the idea of restricting the intelligence to the frontal or any other brain region. Goltz has demonstrated that there is no loss of mentality accompanying the loss of a large part of the brain substance from one side only, but if the loss is extensive from both sides, either in the frontal, posterior or temporal regions, it involves a loss of function amounting to lack of intelligence. In this way there is an interference with all the senses and with the mental activity that is at the basis of these senses. Hence, in the lower animals idiocy is increased as the amount of cerebral substance lost increases.

Even where the cerebral functions are only temporarily interfered with there is a tendency to imbecility. Hence Goltz says that by gradual removal of cerebral substance it is possible to reduce an animal to a simple reflex mechanism so that as the gradual lapse takes place to idocy no area or areas can be localized as intelligence, feeling, emotion, volition and sensation, but these are associated with all parts of the cerebrum. Goltz

is not opposed to all localization, because he admits that extirpation of the parietal lobes interferes permanently with feeling and the occipital lobes with sight, in fact the removal of the posterior parts of the brain has a more depressing effect than the removal of part of the frontal portions. His theory is against the minute area localization. On this principle it is altogether impossible to follow out or define the local areas that are associated with the physical basis of the mental activities in the sense of restricting sensation, feeling, intellection and volition to certain local regions.

Ladd has summarized the conclusions in connection with localization in three principles. (1) The principle of use and wont in connection with habit. In the nervous mechanism the individual parts can perform their functions only when in proper relation to each other, and when these relations are properly established by use. This implies an important psychic law that of functional differentiation and the law of habit which underlies differentiation. Individual functioning is not independent, but dependent on relations to such an extent that the association and projection fibers form the fundamental basis of all activity. This forms the basis of the education of the individual elements in the nervous mechanism so that functioning becomes more specific by use and in this way they are better adapted for their purpose. By habitual exercise there is developed a facility among the cerebral areas to perform their parts with ease. Following from this we find (2) the special localization of function. According to the division of labor the neural elements have their individual functions, but in the combination of individual elements the groups of elements become also specialized. In the spinal cord and lower brain we find localized area functions and in the cerebrum the same principle holds good. The areas or centers are not so specialized, however, that extension cannot take place; hence we find differences among the different individuals in the same species due to individual peculiarities. These areas are therefore not absolutely the same for all individuals, but are capable of individual variation depending upon their use and association with other areas more or less complete. (3) It is possible that when an area becomes incapable of performing its proper functions another area may be substituted for it. The only essential of such substitution is the established relation between the substituting and substituted areas. Hence in cases where certain parts of the brain are lost or removed, there is a restoration of the lost power. It is on this principle that the absolute and relative fields of Exner have been built up and on this theory Goltz has strenuously opposed the minute localization theories that have been defended in modern times, because, as he claims, the principle of substitution may take place to such an extent as to change in particular cases the localized areas.

PART II.

The Correlations Between the Physiological and Psychic Phenomena.

We have considered the individual parts of the neural mechanism leading up to and finding their culmination in the brain. Taking the mechanism as a whole we find that it consists of afferent, association and efferent nerve tracts all of which have a physiological connection with the psychic phenomena. The cortex cerebri contains those elements which form the basis of psychic activity. In it we find the meeting place of the sensory organ fibers so as to form the basis of perception as it takes place in the brain. What we know of these sensory paths is indefinite. The sensory impulses pass into the spinal cord through the posterior roots, passing along the cerebral tract in the posterior column to the restiform body into the cerebellum; or after decussation in the cord through the posterior part of the pons into the tegmentum cruris, into the posterior portion of the internal capsule. Thereafter some fibers enter the optic thalamus, others entering the white matter of the cerebrum. As to the more exact distribution of impulses and their paths, great difference of opinion exists, and it is fruitless to attempt to follow the difference of opinion. So far it has been impossible to localize accurately the areas representing different portions of the body.

Ferrier claims that because centers have been localized in connection with sight, hearing, smell and taste there must be definite areas connected with all the various elements of sensibility, including touch, contact, pressure and temperature. He claims that there is an exact differentiation of sensory and motor paths up to the point where radiation takes place into the cortex. So that theoretically there must be such a differentiation also in the cortex. The sensory and motor tracts are distinct in the spinal cord, in the pons and in the crura as well as in the internal capsule. Ferrier claims that when cutaneous sensibility is abolished, the muscular sense is also abolished and that the paths representing the muscular sense are quite distinct from those of volition. Ferrier concludes that the centers of touch and of pain are identical, the latter representing simply the excessive activity of the former. Hence, he concludes that the falciform lobe taken as a whole represents the center of tactile sensation for the opposite side of the body. This center is connected with the motor centers by association fibers, this association forming the basis of the muscular-sensory localization. The center of sight has been localized in the angular gyrus round about the posterior portion of the parallel sulcus, and in the occipital lobe. By the removal of both of these, hemiopia for the opposite field of vision results; and if the angular gyrus on one side only is removed total blindness in the opposite eye results. Ferrier

thinks that each hemisphere is related to the corresponding half of the two retinæ and that the semi-decussation of the optic tracts is maintained in the cortical centers and that the angular gyrus is the center of clear vision for the opposite eye. The nerve of audition represents not only hearing but also has a share in body equilibrium on account of its relation to the semi-circular canals. It springs from two roots, a large anterior root from which the vestibular nerve arises and a small posterior root from which the cochlear nerve proceeds, each of these roots arising from a median and lateral nucleus. The cerebellar fibers are connected with equilibrium. The chief part of the cochlear nerve fibres crosses and enters the corpora quadrigemina, the internal geniculatum and passes to the temporo-sphenoidal convolution. Munk says that total destruction of this region produces deafness in the opposite ear, while partial destruction produces incomplete deafness, which is psychic or word deafness. The auditory centers are found to be most perfectly developed in the left hemisphere, but complete deafness will not result without destrcution of the centers on both hemispheres. The center of smell is localized in the anterior portion of the temporo-sphenoidal lobe, Ferrier finding that destruction of this part produces loss of the sense of smell on the same side. The olfactory bulb and tract represent parts of the cerebrum, triangular in shape, consisting of white matter enclosing a gray neuroglia matter. It is found in the olfactory sulcus parallel to the longitudinal median fissure. On the anterior it is continuous with the olfactory bulb and receives the olfactory nerves. Posteriorly it is found to divide into two roots, the mesial and lateral, which diverge from each other as they go backwards; the mesial root subdividing into two branches whose course is unknown. The taste center is localized beside the smell center, according to Ferrier, in the lower extremity of the temporo-sphenoidal lobes. The taste tract crosses in the posterior portion of the internal capsule. Gower says that taste impulses reach the brain solely through the roots of the fifth nerve and not at all in connection with the glosso-pharyngeal, although he admits that the taste nerves to the posterior part of the tongue are distributed along with the glosso-pharyngeal through the otic ganglion.

The motor tracts concerned in mechanical movements pass from the motor cortical areas through the white matter of the cerebrum to the internal capsule; in connection with the fibers of the face and tongue are found in the knee of the capsule, the arm fibers in the anterior third of the posterior limb, those for the leg in the middle third. Crossing under the optic thalamus to the crusta of the crura they enter the middle third, the face fibers being found close to the median line, next the arm fibers and then the leg fibers.. They then pass to the pons on the same side where the face and tongue fibers cross to the nuclei of the facial and hypoglossal

nerves of the opposite side, the arm and leg fibers passing to the medulla in connection with the anterior pyramids, the greater number crossing in connection with the formation of the crossed pyramidal tracts. The pyramidal fibers are related to the multipolar nerve cells in the gray matter of the spinal cord, from which the anterior roots of the spinal nerves originate. The motor cranial nerves take a similar course, and after passing from the internal capsule and crusta they cross the nuclei on the opposite side from which the fibers pass to the muscles that are supplied by these nuclei.

According to Meynert there are three projection systems. (1) Those fibers that connect upward and downward with the cortex cerebri, radiating through the corona radiata, some passing through the basal ganglia and others being connected with the central gray matter. Connecting the two hemispheres are the commissural fibers and also the associating fibers uniting the different regions of the same hemisphere together. In the corona there are fibers from the corpus striatum, the lenticular nucleus, the optic thalamus and the corpora quadrigemina. (2) Fibers that pass longitudinally down to the central gray canal, some of the fibers terminating in the gray matter and others descending to the lowest spinal nerves. Here we have fibers from the caudate and lenticular nuclei passing to the medulla and pons through the crusta, from the optic thalamus and corpora quadrigemina to the spinal cord through the tegmentum. (3) Fibers that include the sensory and motor peripheral nerves. According to Meynert in connection with the medulla three fiber systems are found, the projection, commissural and association. The projection fibers represcent elongations of the cerebral cell axis cylinders. The commissural fibers represent the transverse fibers of the corpus callosum and the anterior commissure, the former arising from the cortical cells either directly or indirectly, the different parts of the two hemispheres being united by diffused fibers through the commissure. The anterior commissural fibers unite the temporal lobes of the two hemispheres and the olfactory and hippocampal areas on opposite sides. There is considerable variation in the association fibers. According to Meynert the short fibers unite contiguous convolutions, the long fibers are united in bundles, forming connections between the frontal and occipital lobes, the front and exterior of the temporal lobe, the temporal and occipital lobes, the frontal and temporal lobes, the hippocampal and callosal convolutions, the inferior parietal and the fusiform lobules. In this way there is established a close connection in the nerve mechanism.

In the application of localization to the mental functions it is claimed by some that every nerve cell in the gray matter represents a psychic element so that the cell becomes the psychic unit. In opposition to this minute localization others claim that the

brain must be taken as the unit. In the same sense in which the mind is in the body, the mind is in the brain. The brain represents a necessary medium in the correspondence between mental phenomena and peripheral changes, and it also forms the physical basis in connection with which ideation and volition take place. If a limb is amputated there is still a feeling of its movement indicating that the ideas and feelings are not localized in the limb. It is claimed that the existence of a certain amount of purposive adaptation in the lower centers indicates that intelligence cannot be limited to the higher centers. This led Ferrier to conclude that there is not an essential distinction between the simple reflexes of these lower centers and the highest psychic centers, the difference being one of degree. But in the case of man there is less of this adaptative action than in lower animals, besides in man consciousness does not extend to the impressions of the sense organs, so that conscious activities may be regarded as limited to the cerebral hemispheres. The mental functions seem to be connected with the cerebral hemispheres, at least from the standpoint of the motor execution of them. We have no data on which to localize the mind in any one area or in some areas of the brain as there may be a loss of considerable parts of the cerebral lobes without mental impairment. The cerebral hemispheres therefore, seem to operate and co-operate as a unity in the exercise of the mental functions. According to some psychologists the consciousness represent simply the sum total of individual sensations in a successive series, so that the individual nerve elements supply their quota to the whole conscious experience. But this sacrifices psychic unity. The mental processes coincide with cerebral processes, and so consciousness cannot be bound up in any single cerebral area. Meynert claims that when we consider the intricate meshwork of fibers in the grey matter we must admit that there is a possibility of independence of function. The cortical distribution of the grey matter renders it possible according to him, that cortical regions may act independently. Waller indeed claims that the distinction of sensory and metor regions is false, claiming that every center must be really sensori-motor so that as he says, "between centripetal and centrifugal impulses I see a single psychical process, one and indivisible. All that I can recognize in a center is an organ of elaboration receiving and giving out impulses," Hence he claims that a central process is not properly sensory or motor but senso-motor. Meynert really coincides with this view, although he expresses it differently. According to him there is no real motor capacity either in the nerve cells or fibers. The cerebral hemisphere is wound up by the sensory keys resulting in the activity of the muscular mechanism through the cerebral mechanism. Hence he claims that "sensitiveness is the only specific property of brain cells."

It would seem from the experimental evidence already referred to that the removal or injury of certain regions involves the loss of sensori-motor functions, but this may refer simply to an objective loss and does not necessarily involve the loss of the subjective psychic activity. At the same time the fact that adaptiveness characterizes movements or actions, does not of necessity involve psychic guidance or conscious control. From these two standpoints, therefore, we may conclude that the sensori-motor localization does not involve the proof of their relation or correlation to the psychic element of consciousness. The cerebral processes have been explained on the principle of reflex action. But this does not seem to explain why some of these processes involve consciousness while others do not. Jackson has attempted an explanation by claiming that the sensori-motor mechanism of the cerebral hemispheres is subject to the control of a higher re-representative area. According to him the mental processes represent the subjective correlate of the sensori-motor processes. There are numerous sensori-motor phenomena that have no correlate in consciousness. It may be that sensitiveness which characterizes the lower centers becomes more delicate as we ascend higher in the scale of centers. In paralysis there is an involvement of the sensori-motor apparatus without of necessity any psychic accompaniment. The same is true of sleep, epileptic and hypnotic conditions. Hence the consciousness of man seems to be placed above the most highly sensitive conditions of the purely physiological sensory motor processes, and as such cannot be localized in any one part of that sensori-motor cerebral apparatus, unless we localize it in a higher area. Ferrier contests this hopothesis because it has no experimental evidence. He regards the theory as valueless from the purely psychic standpoint. He claims that in the sensori-motor areas there is a physiological basis for sensory perception and ideation, and for the voluntary acts and emotions. He prefers the theory of higher and lower degrees of complexity in the sensory and motor areas. It is true we have found tracts along which stimuli may pass to these brain regions, but this of itself does not prove the existence of such areas as substrata of psychic actions. Spencer says that different parts of the cortex have different functions in the mental phenomena, but these different parts like all the rest of the organism are subordinate to mental activity, they subserve but do not serve. According to Spencer a perception can be localized in a nerve center, only diffusively, and the single fiber cannot produce consciousness; consciousness implying diffusion in connection with a plexus of nerve cells and fibers. Wundt repudiates the idea of localization of sensations in isolated areas of the sensori-motor regions, claiming that in the frontal region we find the organ of apperception, and not in the complicated mass of sensory and motor tracts. Waller vigorously opposes this idea on the ground that we have no evi-

dence of any such higher centers above the senso-motor. Really there is no proof on either side.

In the frontal region we find a non-excitable area, anterior to the region for the head and eyes. Most psychologists regard this as the special seat of the mentation processes. According to Meynert in the forebrain sensitiveness which characterizes the lower centers, is transformed into actual sensation. In it we find nerve tracts that carry all the impressions to this higher region converting them into the phenomena of sensation. Intelligence is limited to this forebrain so that it controls all the rest of the mechanism. By extirpating the forebrain, according to Goltz, there is a serious interference with intelligence resulting in idiocy. This is due according to Meynert to the fact that intelligence is based on perceptions arising in connection with the sensations of the nervous mechanism in which the forebrain is specially active. Hence the exercise of every part of the brain cortex depends on the activity of the forebrain, all the different parts of which are connected by means of association fibers not only to each other, but to the other parts of the brain. The Spencerian principle is really the most generally accepted along this line in connection with psycho-physiology, the ratiocination being dependent upon definite correlations. Hughlings-Jackson has propounded a theory that is interesting. Evolution represents the movement from the well organized centers up to the most highly developed centers, while at the same time it is from the lowest well organized up to the highest less organized, in other words, from well established relations to less organized relations. In this evolution there is a passage from the automatic to the voluntary. Thus in these highest centers which represent the culmination of nerve evolution constituting the physical basis of the mind we have three elements, the least organized, the most complex and the most voluntary and on the basis of these the upbuilding of the neural mind takes place. The lowest centers are found in the spinal cord and in the nuclei of the cranial motor nerves. They represent the lowest cerebral and cerebellar centers and any interference with them cuts off the motor system they represent from the higher central system. The next centers are the motor areas localized in the cerebral hemispheres and the ganglia below, representing larger body areas than the first centers. The highest centers represent motor areas anterior to the motor convolution regions the entire anterior portion of the brain being motor. These highest centers represent the most complex centers and yet they are least organized, representing the widest body regions. Hence from the lowest to the highest centers we have, (1) increasing complexity, and (2) this involves increasing representation so that the highest centers represent the co-ordination of all the movements of the body embraced in the lower centers. Hence the three may be called representative, re-representative, re-re-representative. In regard to the sensory centers, and their relation to the motor, he says (1) that the highest sensory centers in the sensory region and the highest motor regions represent the physical basis on which consciousness rests, and (2) that consciousness embraces the entire psychic field just as the physical basis of it includes the entire physical being, representing movements, impressions and sensations of the entire body. In other words, the highest centers are representative of the entire person physical and psychic.

Meynert has attempted to establish a sequence in the development of association, the intensity of associations established depending upon their frequent reiteration in consciousness. Hence the difference between accidental association and this association based upon causation in which the recurrence of external stimulation establishes a permanent cerebral association. In the development of the association, imitation is an important principle as one individual may grow through the imitation of psychic association in others, but before development can take place it must become an individual association of ideas. Hence in the individual projection and association represent the two principles of cerebral activity, and these form the basis not only of the purely receptive capacity of the brain but also of its creative capacity. The association fibers are said to be connected at the two ends with the cortical cells, the projection fibers being found in connection with the corona radiata diffusing therefrom into the forebrain leading into the cortex the impressions of external stimulation and dividing them among the sensory centers. Here is the physiological basis of the correlation of the physiological and the psychic. Waller has tried to show that all neural processes are similar if not identical, so that the neural process includes within it from the centripetal standpoint and in the order of sequence impression, sensation and perception; the impression here exists external to consciousness, the sensation being a conscious impression and perception the conscious result of a conscious impression. All that is claimed for it is that this sequence represents the possible elements in a neural process and hence the basis of a neural induction.

The objection to this inductive method of viewing the mental operation is that the physiological organism is made to subserve what seems to be primarily psychic activities without attempting to prove that the correlation on this basis is real. It is true that the objective phenomena form the data upon which the neural processes are based, but whether we are justified in regarding both the presentations and representations in consciousness as correlates to the purely physiological activities, we have not yet determined. From the physiological side we have definite activities associated with excitations and reflex actions; on the psychic side we have certain elements in consciousness which form the premises of

mental activities; to complete the chain we must say that the sum of the physiological activities passes into the conscious experience as the contents of consciousness, so that from the standpoint of consciousness the conscious subject views these contents which are psychic and not the physiological activities. In this way the nervous mechanism is brought into close relation to the contents of consciousness. When this takes place there is, or seems to be, a subjective ego which considers all of these conscious phenomena, unifying the diversified experiences but in what way we cannot tell. The central nervous system therefore can receive and distribute determinate neural commotions, exercising some modifying influence over its own neural activity. How this is accomplished is unknown and may be left to metaphysics to discuss.

Schaefer by separating the praefrontal lobes from the rest of the brain showed that no appreciable mental changes took place in the case of monkeys, disproving as he claimed, the older conclusions of Ferrier, who found following extirpation conditions of apathy and idiocy at least temporarily. Schaefer claims that the frontal lobe is not essential to the mental life. The pathological evidence seems to show that injured or diseased conditions of the frontal region do not impair the sensory or motor functions, so that this region cannot be regarded as necessary to the sensory and motor phenomena of consciousness. This implies that if the functions of these regions which are said to subserve consciousness are preserved, then injuries involving the region that is said directly to serve consciousness do not impair the mentality. Ferrier cites the case of a man who died from a brain condition in the full possession of all mental capacities, the post mortem examination of his brain showing the entire absence of the right hemisphere from suppuration. As we said before the attempts to explain conditions of the brain affecting the use of language seem to indicate that the entire cortex is associated in some way with language. Similarly in the case of insanity it would seem that the entire cortex seems to be influenced more or less in insane conditions, indicating that the mental and conscious influences are distributed over the entire cortex. All we can say is that the mind is correlated with the external world through the medium of the neural mechanism and injured or diseased conditions of that mechanism either impair or interfere with the correlation. The view of Meynert seems to be be the most reasonble, that the highest centers simply represent arranging mechanisms for the representation of impressions coming in from below and for the connecting of the different mechanisms in connection with this process of arranging. The idea of James is in line with this, that impressions arrive from the organs of sense arousing certain arrangements, these in turn arousing others, until the motor mechanism is stimulated, all of these processes being in consciousness. But this does not describe or analyze the mind.

It would seem then that sensations represent states of consciousness the brain representing the medium through which stimuli reach the mind.

An attempt has been made to identify different elements of the mental operation with definite localities in the cortex. This has been done chiefly in aphasic conditions, but the observations made may simply indicate an interference with the physiological substrata and not with the psychic. Mental activities are complex so that it is difficult, if not impossible, to identity distinct parts of the neural mechanism with the definite mental factors of an operation of the mind. Kirchhoff thinks that consciousness includes all the internal processes, so that no individual elements of consciousness can be identified; and that the entire nerve mechanism, not simply the cortex, is engaged in these processes. While this is true we must remember that there is a more direct relation of the brain cortex with mental processes than that of any other part of the mechanism. James thinks that there is a form of consciousness in the cortex that may be regarded as the sole consciousness of man, any consciousness in the lower centers being directly subservient to the self consciousness of the cortex. Jackson seems to confirm this view from his evolutionary standpoint, in which he claims that every part of the organism must have representation in connection with any unit of the cortex, this representation taking place undoubtedly in consciousness. Meynert and Munk seem to oppose this idea in claiming that sensitiveness is the common property of the individual cells. As the cells possess this specific energy, so soon as there is a neural sensation, we have the conscious intelligence everywhere in the cortex, so that conscious movement may originate from any point. Hence, according to Meynert, memory represents a common characteristic of all cortical cells. This does not explain and seems to take no account of the unity of consciousness. It does not tell how cell activity, which is fundamentally chemical and physical action can give us the phenomena of consciousness. Hence we may conclude that the external world of objects and the physiological neural mechanism are both necessary to our conscious states; that the physiological and psychic represent each a universe within itself, so that we cannot make the two convertible; at the same time the correlations are so close that the psychic actiity is manifested only through the physiological.

Cabanis concludes that the brain secretes thought just as the liver secretes the bile. Here of course the analogy is rudely original and uncouth, although there is a certain element of truth in it. The mind considered as a natural force cannot be subjected to observation, but can be understood only from the manifestations of its activity in and through matter. There are no doubt correlative changes in the material substratum corresponding with the mental activities. Every mental phenomenon is in some sense the result of certain changes taking place in connection

with the neural elements. The mind does not represent simply the material products of cerebral activity, but that wonderful degree of energy that cannot be brought nnder observation. The results of the activity of the brain as these can be observed in passing from the brain in connection with the blood for future processes of assimilation and excretion do not represent the mind. The question of the consumption of the nerve cell in the mental processes is not definitely settled because it may be simply in the matters furnished to the cells by the blood that the changes take place. If this latter were the case why does the performance of a certain function imply the impression made upon the neural substance in such a way that there is a predisposition to perform the same function again. This cannot be explained unless on the basis of some neural decomposition which is renewed by the process of nutrition. Among the older writers the vital spirits were supposed to be secreted in the brain in connection with the blood so that these became exhausted by frequent or continued use. There is no doubt that the nerve substance is nourished in connection with the blood, a secretory process furnishing to the nerve cells the nutritive materials and that in this process of nutrition the elements are exhausted and waste matters are thrown off. It is quite possible that in connection with the nerve cell there is a permanent and a transitory element, the former representing the essential structure while the latter represents what is used up in functional activity. To cut off a nerve cell from its nutrition would mean its destruction, so that its functional use depends upon its established relations with the blood and in this sense the blood is essential to mentation.

Popularly mind represents an abstraction, although it is a generalization based upon the abstract idea gathered from the mental phenomena. We observe the mental phenomena and then by abstractions from general conceptions of mind in connection with these phenomena. It does not follow however that because we have this general idea of the mind that it is capable of an independent existence apart from the brain and the brain nutrition by the blood. The human mind, however, tends to translate the idea into real form and hence the mind which originally arose from an abstraction becomes an entity. Into this entity is infused life and spirituality so that popularly it is regarded as having an independent existence. There is no doubt that mind depends on the brain and the entire nervous mechanism in order to secure its manifestation, the brain being the organ in connection with which mental existence and activity are displayed. The power of the mind must be regarded as something that is matured in connection with the progressive development of the neural mechanism. It differs from the organs like the heart in the fact that at its birth period it is incapable of any of the highly organized functions of brain life. It certainly has organic capacity even from an embryonic condition of controlling

the organism as a whole, but its specialization as the organ of the higher life of man depends upon education. This educational development applies not alone to the individual, but has a bearing upon the race as a whole. The acquirements of preceding generations form the inheritance of the brain and mind, and these are brought to bear upon the mental development in such a way as to train up the child mind in the very sphere of acquired experience, so that the individual subjected to environmental experiences may be able to make the most of his individual life. The very form of education, including its language and the appliances it uses, represents the embodiment of numberless stages in historic progress brought to bear upon the individual life. The brain development therefore is something that takes place after birth, and as the brain becomes differentiated it is correlative with the development of the intelligence. And yet the mental activity cannot be separated from the nerve structure and its proper nutrition in connection with the blood. Here we have the primary correlation between brain existence and nutrition and mental existence and development that forms the fundamental basis of all the other correlations found in a mental science. The nervous system consists of myriad cells localized in the brain and these form the initial foundation of the brain activity. Out from this region we find ganglionic masses of cells which form the centers of functional activity on the part of the internal organs of the body. They do not represent exhaustless centers of generating force for their capacity depends upon what supports their cell life. Hence in the cell there takes place a transformation of potential matter into kinetic force, the nerve cell becoming the center of the correlation of matter and energy, the resultant being the manifestation of the highest degree of vital force. Thus to preserve this correlation represents the necessary condition upon which the existence of thinking and thought depends so that it involves the two forms of thought, (a) statical thought which is dependent on nerve cell maintenance; and (b) dynamic thought which manifests itself through the changes that take place in connection with the metabolism of nerve tissue and the changes that are involved in the response of nerve tissue to stimulation.

From this standpoint, therefore, in establishing a correlation between mental phenomena and neural mechanism certain preliminary principles may be laid down as the basis of those correlations. (1) In connection with the origin of thought there must of necessity be a correlative variation in the gray substance of the brain. No thought can sustain any relation to the body mechanism without this correlation. (2) This brain alteration represents a variation that falls under the physical principle of motion. According to Unzer these brain movements represent material ideas, of which there are two kinds, the object presentative and the object representative, the former originating externally and the latter in-

ternally. When originated the direction is determined by the nerve tracts in the relation of nerve cell and fiber. (3) These motions taking place in connection with the neural substance may be interrupted by the interference with nerve continuity arising either from mechanical pressure or injury to the nerve tissue or from an interrupted or abnormal blood supply, or from the accumulation of waste products that produce exhaustion. Thus the essential movements associated with mental and brain activities depend upon normal physiological conditions. (4) These motions require time, representing the time relations that are established in connection with the neural and mental processes. The question that comes up for discussion is not that of the functional relation of mind to brain, but rather those conditioning processes involved in cell activity and the bearing of these processes on the mental phenomena, If we consider the lowest forms of animal life in which nerve tissue manifests itself it will be evident that the conditions of neural activity are very simple; whereas in ascending the scale of existence we find increasing complexity in the action of these nerve cells, indicating that side by side with increasingly complex neural activities we find increasingly complex mental activities.

In the entire realm of nature there is not found any deep chasm between nature's productions; so in the realm of animal life one form passes into another on a gradually ascending scale from the lowest up to the highest. This same principle is applicable to the development of individual man from the embryonic to the adult condition. Man, as he develops, is found to progress through stages found in the lower vertebrate animals, the difference being that the permanent stages which mark the highest development in the lower animals form the transitional stages in the human evolution. He represents not only the climax of all lower development, but in miniature we find in his progress the steps in the march upwards among the lower animals, so that man unites in himself the perfect forms of development, himself the ideal. The human ovum is not distinguishable from the ovum of one of the lowest animals and its stages of embryonic development are also similar. What is true of the body evolution is equally true of the brain. At the fifth or sixth week the human brain in the foetus is found in the form of a series of small sacs, the anterior one divided into two parts representing the cerebrum the posterior one being larger and representing the cerebellum. Anterior to the cerebellar vesicle is the vesicle representing the corpora quadrigemina, another vesicle being found between this and the frontal one corresponding with the optic thalami. Here the foetal brain is comparable to the fish brain, on account of the lack of cerebral development and of the convolutions. Five or six weeks later the foetal brain is comparable to the brain of the bird, on account of the increased cerebral development, the mid-brain vesicles being partially concealed by the cerebral hemispheres, although as

yet the convolutions are lacking, with an anterior commissure. Shortly after this the foetal brain is marked by the still further cerebral development with the commissural development in connection with the corpus callosum, although limited to the anterior part of the hemispheres and so comparable to the stage of growth found in the Marsupialia. About the seventeenth week in the foetal brain the middle vesicles are developed posteriorly concealing the corpora quadrigemina, the posterior lobes developing also backward over the cerebellum. At the same time as the development of the posterior lobes is taking place the frontal lobes are being enlarged towards the forehead until we find the highest animal human condition of the brain. It is easy to see that if the development is arrested at any stage, the brain may be left in the condition of a purely animal brain; in line with this it is found that in congenital idiocy there is an arrest of brain development represented by the lower animal condition.

Man is thus in his development a "compendium of animal nature," "paralleling nature in the cosmography of himself," as Brown putsit. In this way we can discover in the human being the activities of all the different forms of nerve potentiality as they are found in the animals. Hence we have the scattered ganglion cell activity of the sympathetic system which represents the simplest mode of neural activity in man; thus we have co-ordination of the different tissue and organ elements under the sympathetic ganglia cells. Then we have the ganglionic nerve cells of the cord so combined as to form independent centers in connection with the most important and complex body movements. Next we have the sensory ganglia in which are found large numbers of the differentiated nerve cells combined together in the brain. Lastly we have the cerebral hemispheres in which specialization is most perfect. Thus in the human brain we have the synthesis of the best brain conditions in the lower animals, the combination representing a harmony of functions which constitute brain and also mental vitality in man. From this standpoint of correlations there are therefore in the human subject four centers that require to be taken account of, (1) the primary centers found in connection with the gray matter of the cerebral convolutions, associated with ideation; (2) in subordination to these we find the secondary centers in gray matter between the pyramidal decussation and the floors of the lateral ventricles, associated with sensation; (3) in subordination to these higher centers we find the tertiary centers in the gray matter of the spinal cord, associated with reflex actions; (4) Subordinate to all the higher centers we find the organic centers associated with the ganglia of the sympathetic system, in the ganglionic cells in the region of the viscera with established connections by communicating fibers with the cerebrospinal system. In this chain of centers there is the subordination on the

part of the lower to the higher centers, although each class of centers has its own independent function. All of them are in subordination to the primary centers especially in unfolding the consciousness of the will that marks the most perfect co-ordination of the functions of the body and the greatest manifestation of the principle of individual activity. The sympathetic cells in co-ordinating the activities of the different organic elements mark the simplest form of this individual activity; this sympathetic co-ordination is transferred to the cerebro-spinal system in which the vital organization of the lesser elements take place. When we remember this close relation established among the different centers of animal and organic life we are not surprised to find psychic factors all through the entire organic life of man.

In this connection then mind becomes the most perfect development of a harmonized physiological life or vital force and to its existence and vitality all the lower natural forces contribute, while this vital force is dependent upon all the lower forces that contribute to vitalizing energy. Setting aside all the purely abstract definitions of mind, such as, "that which thinks, reasons, wills," physiology answers that it is associated with the brain substance. As we study mental phenomana we become convinced that mind is to our knowledge at least non-existent apart from the brain, because all we know of its phenomena in connection with the brain. From this standpoint mind simply represents the highest functioning of the brain associated with consciousness, this functioning assuming the forms of intellection, emotion and conation. The human brain represents a living organ with functions higher and more perfect than those of any other body organ, the nature of whose existence and operations we only know through the manifestations given us in the mental phenomena of life.

Many of the reflex actions associated with the spinal cord play a most important part in the human activity and therefore form the basis upon which psychic functions rest. In the spinal cord we find the power of retention corresponding with memory in the higher centers, in virtue of which an action done once becomes easier afterwards because of the power imparted to the second action from the first. In this way by the principle of association certain movements may be so closely connected in the nerve centers as to render it impossible to separate them. Hence, the reflex acts of the spinal cord represent the acts of an organized mechanism so that whatever tendencies have been inherited in the system predispose the actions in a definite direction. On a higher scale in the sensory ganglia we find the capacity to respond to stimulation by adaptive movements apart from consciousness, conciousness not being brought into play unless at the same time as we have the sensation or subsequent to it there is a perception; in this latter case the stimulation has passed beyond the sensory and into the higher cerebral spheres. The sensory

centers lie intermediate between the spinal and higher cerebral centers and thus manifest not only the reflex functioning but also exhibit the rudimentary elements of those functions that attain their climax of development in the cerebral convolutions. In this sense they represent more complex actions than the spinal centers, particularly connected with the reception and co-ordination of impulses, in which they manifest the germinal evidences of a higher intelligence. But it is in the countless nerve cells in the gray matter of the cerebral hemispheres that we find the centers of ideation. These two hemispheres represent two large ganglion masses superadded to the sensory and motor areas bound together by numerous fibers for the purpose of translating sensory impressions into ideation. In the evolution of the human intelligence the mind of man has undergone vast changes before attaining the climax of development, the principle of specialization associated with the increasing complexity of the brain mechanism being at the basis of this correlation. In this ideational development there is also the emotional and volitional progression. Phrenology has long attempted to localize the different mental functions, mapping out the cerebral surface into well defined areas, assigning to each area a mental function. But these attempts although aided by the genius of the ancient Greeks and fostered by the philosophic enterprise of men like Comte have been entirely discredited because they have no foundation in anatomy or pathological observations. The localization of the motor-sensori areas is quite a different matter. It is certain that the frontal portion is associated with the movements and sensations, from which we get our sensori-motor intuitions, and that the posterior part of these same convolutions is associated with the purely sensory from which arise the sensory factors in ideation. This gives us the reflex arc in psychic acts. Activity aroused in the sensory area passes to the senso-motor area from which it receives intelligent expression in movements, language, etc. This represents the most simple form of psychic activity. This represents the ideo-motor are as distinguished from the purely senso-motor arc, representing the climax of and containing within itself the potentialities of all the neural arc processes. In this highest reflex the afferent impulse is represented by an idea or perception and the efferent by a perceptive movement of volition. Within the cerebral hemispheres we find an innumerable number of these reflexes all bound together by internuntiant connections so that numerous plexuses are formed, the basis of numerous complicated mental processes. In the development of the brain and mind correlatively there is not only an income of sensation corresponding with every outgoing of motion, but in the progress of experience perception becomes capitalized so that the out going of motor impulses represents not merely the present and transitory sensory impulses but an accumulation of such ideo-senso-motor experiences.

According to Haller ideas are traced upon the brain as actual impressions; but according to Bonnet the ideas represent molecular changes transmitted as vibrations along the nerve paths. It is on this principle that when a vibration has passed along a path once a modification is supposed to take place in the nerve substance which renders it very responsive to similar changes in the future, something being retained that disposes it to the same functional activity, forming the basis of differentiation of function. In its rewal again if in consciousness it embodies recollection, if not in consciousness it is simply a neural predisposition. Hence there is retention not only in consciousness, but also in unconsciousness, the nerve process being its psychic correlate in both.

This principle of retention lies behind memory, in fact behind every psychic function as the physiological basis of these functions. Here we have the distinction of Unzer, ideas of presentation and representation, those presented by the former being stronger than the latter, because aroused in connection with the accustomed external stimulation so that the sensory and motor elements are both strong. On the other hand when they are brought to the internal attention their activity may be intensified, even to the extent of reacting upon the sensory medium so as to produce an illusion or hallucination. In connection with the preception we have the grouping of several sensations in connection with a single idea. When this organization has taken place any of the sensations that produced the idea may arouse it to mental activity. From this standpoint the perceptions represent symbols which depend upon the different senses, the impression received from these different senses forming the basis of our idea of the object. Hence the idea is organized as a mental object, but it does not have any correlate in a single external object. To us then psychically the idea is not presentative, but representative of various objects introduced to us through sensations. The ideo-motor or perceptive centers then idealize what comes to us through the sensory or senso-motor channels so that there is a subjective field of ineation in some sense correlative with the objective field of sensation, although different from it because mentally constructed from objectively perceived phenomena. Ideation has its progressive evolution on the basis differentiation and integration, differentiaong those elements that are uniike and synthetizing those that are alike. In this development of ideation the progress is marked by increasing complexity towards the abstract, parallel with the increasing complexity of the brain; so that in the uncivilized we find a lower stage of psychic development in which abstraction is almost entirely absent, while in the highly civilized abstraction becomes more perfect. Hence in analyzing abstract conceptions we must trace back the devolution process to the concrete through the less abstract, this representing the true process of analytical thought. Hence we fink

from this standpoint the absurdity of innate ideas, except in the sense that an individual born in civilization inherits certain predispositions found embodied in cerebral conditions that are awaiting to be called into functional activity. Hence in man we find in the cerebral convolution development the cerebral substrata which represents from the physiological side the capacity psychically to acquire ideas that are impossible in lower animals that do not possess the same cerebral convolutions.

In regard to the mechanism of ideation we only know it hypothetically. It is supposed to consist of a neural circuit in which certain cells are united so that in the passage of a molecular variation through this circuit perception takes place by the stimulation of the points which mark the perceptive centers. This stimulation can only take place at the cell junctions in the circuit, and hence, any sensation that was engaged in forming the perception can arouse it. In passing from the percept to the concept or from the abstract idea formed in connection with the sensations to the abstract idea formed in connection with the perceptions by their comparison and differentiation, we must increase the complexity of this nerve circuit. This is accounted for on the physiological basis of complexity found in connection with the cerebral hemispheres. In connection with ideo-motion we find a sensory impression, a motor result and a cerebral process along a cerebral circuit, this entire process being essential to the formation of the idea, so that the correlate of the mental idea is the whole process. This may be modified by development so that when complete organization has taken place in the cerebral substrata any part of the neural process may result in ideation, just as the mind emphasizes the sensory or motor part of the process. The idea, however, is really correlative with the entire neural excito-motor process. Thus we find in the central system a neural substratum capable of great native capacity and developed adaptation, on the basis of which harmony is established between the internal functions and the external surroundings, this harmony forming the basis of the correlation of all the physiological and psychic phenomena.

1. Analytical Correlations from the Standpoint of the Neuro-Mental Processes. In the world of experience we find a great number of things which come to be known by us on account of their possessing certain characteristic properties. These objects are perceived by us in their common properties and they are apperceived under time, space and action relations. In the ordinary life the attention is fixed on certain things but even then the attention is diverted from the objective things in themselves to the sensations aroused in us in virtue of the relations of these things to us through the senses. The unrelated sensations come to be classified primarily in connection with the senses through which these come to be related to us. Hence the fivefold classification of sensations in connection

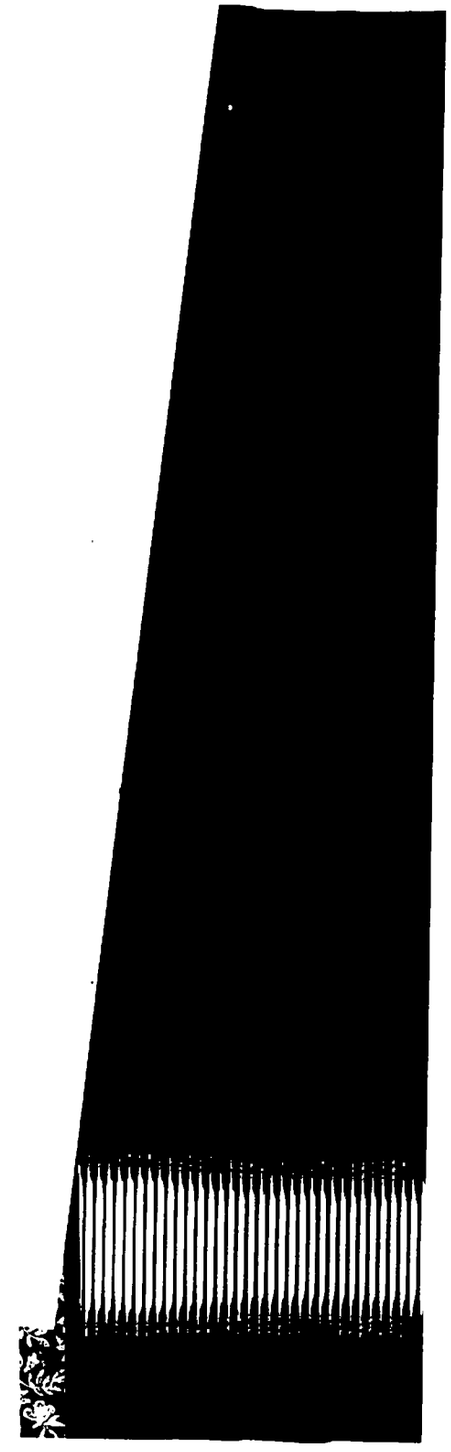
with smell, taste, hearing, sight and touch. There is a sub-classification made among the sensations that belong to a particular sense but this classification is not particularly important. The sensations are found to be of different degrees and they are always regarded from the standpoint of time and space, as well as depending upon the different modes of stimulation and having associated with them certain molecular, chemical and other processes which form the basis of the special forms that they assume. In order to have a scientific account of this field of sensation we must, (1) separate simple sensations from the complicated objective experience that alone forms the basis of popular conciousness; (2) distinguish the varying quality and quantity of sensations so as to form some idea of the principles which determine the relation of stimulation and resulting sensation; (3) trace out the transformation of sensations into sense presentations in accordance with the psychic conditions of time, space and action; (4) trace out the relations of the higher psychic activities to these sensations and sense presentations and find out if they are subject to the same principles. Modern psychology along these lines has done almost all its work and has gained an insight into human experience impossible under the old psychology. It is here that analytical investigation has been very carefully made to discriminate between the ideal and the real and to separate one form of sensation from another so as to form a purely physiological foundation for all sensations.

In the starting of this investigation is is necessary to distinguish simple sensations from sense presentations including the complicated objective experience that really depends upon synthetic psychic processes. The simple sensation is unreal from the standpoint of developed experience. They cannot be examined independently and yet they are important elements in the sense presentations. Any sensation that is incapable of analysis in respect of qualitative distinctions and which from this standpoint does not consist of more simple parts is a simple sensation. A sensation represents an important element in connection with an external object as related to us. Hence every sensation is a mental affection which we associate with some extra self object or subject in connnection with our own sense activity. The simple sensations therefore are the simple elements of sensations from which our sense presentations are built. Our knowledge of the objective world of experience therefore represents the association of the simple elements on the basis of definite space relations. In discussing the quality of sensations Ladd says four questions arise, (1) in regard to the localization of the particular sensations in connection with the body organism; (2) in regard to the nature of the stimulus and how it produces a specific form of sensation in connection with the special senses; (3) as to the difference of the concious sensations produced by these different kinds of stimulation; and (4) the principles underlying the

sensations in relation to the producing stimuli. These questions cannot be fully answered, because of the complicated physiological and psychological processes associated with the production of all sensations.

One law is taken for granted in these discussions, namely, the law of specific nerve energy. The nerves undoubtedly possess certain common functions; yet the sensations involve in their characteristic distinctions distinct neural elements in order to furnish the basis for the qualitative difference of sensations. This differentiation is based essentially on characteristic properties of the end organs and the nerves, at least in their neural relations with the nerve centers. What forms the basis of this differentiation is not known.

(a) SMELL. The smell sensations are farthest removed from psychic conditions and are much more difficult to consider scientifically than the other sensations. The portion of the mucous membrane spoken of as regioolfactoria embodies the smell end organs. The olfactory nerve is diffused in this region. This organ can be stimulated only by substances carried upon the air. In order to act on this organ the stimulation must be gaseous, as substances without any odor like arsenic when acted upon by heat produce the smell sensation.s Weber claims that the pouring ofa fluid into the nasal cavities does not siimulate the olfaction, probably because the fluid prevents stimulation by contact, preventing the odorous substances from stimulating the organ. Some claim that in fishes olfaction can be produced by pouring into the nostrils camphor solutions. It is claimed by others that mechanical stimulation can arouse the sense of smell, such as is found in the case of extended sneezing. Ritter claimed that by thrusting pieces of graphite or zinc into the nose the sense of smell could be excited. Similarly the placing of the positive pole in the nose produced an ammonia odor and the negative pole a sour odor. It is probable that in these cases other senses like the tactile and feeling senses are aroused. We have no evidence that heat stimuli will produce any sensations of smell. There is no direct evidence that the injection of odorous substances into the blood will arouse the sense of smell. Pathology furnishes evidence that tumors pressing upon the nerve of olfaction may give rise to odor sensations and undoubtedly in some cases of insanity there arise subjective smells in connection with the diseased conditions of the nervous system, especially of the brain. We do not know of any special property that must be possessed by substances in order to excite this sensation, as we find in plants some odorous during the day, others during the night. The principal element seems to be capacity of vaporization and readiness to diffuse in the air. All bodies that have an odor have the capacity, particularly when in contact with a moist medium, to arouse motivity in the medium so as to produce diffusion in the air. The sensations of smell must be carefully distinguished from the

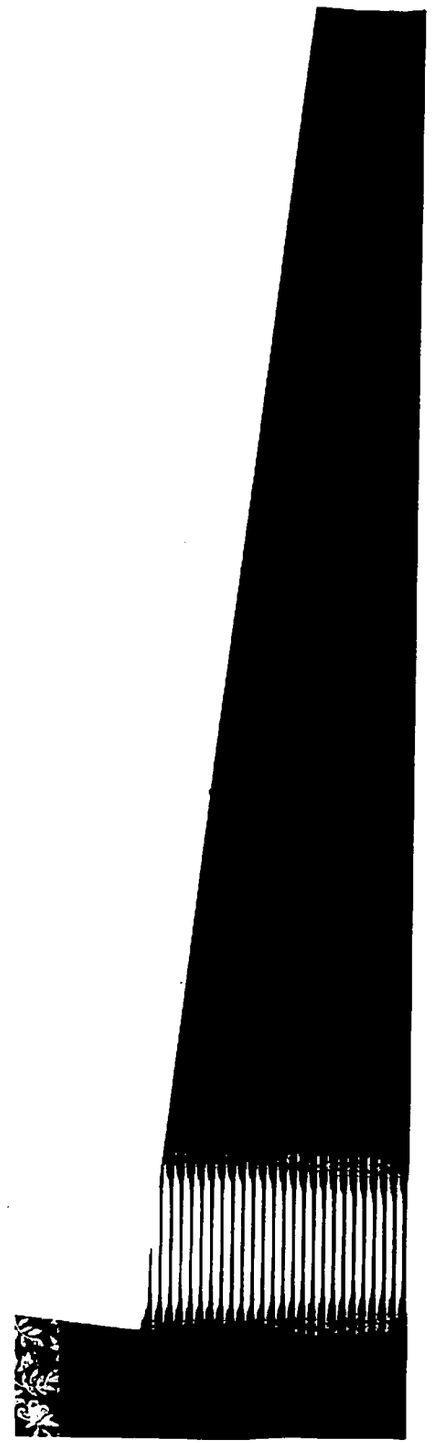


sensations of taste, for example ammonia acts upon both the trigeminal and olfactory nerves arousing the feeling sensations. No successful classifications have been made of smell sensations.

(b) TASTE. Our knowledge of taste sensations and their stimulation is very indefinite. The stimulus necessary is a tastable substance and it must act on the end organs under definite conditions. The substance must be liquid or soluble in liquid as substances that are insoluble are tasteless. This may arise from the hidden position of the internal cells of the taste bulbs which can be reached only by soluble substances. Not all soluble substances have taste and no law can be laid down to distinguish between tasteless and tastable. It is disputed whether the gases can directly stimulate the end organs. A stream of CO_2 allowed to act on the tongue if in a dry condition has a sweetish taste mingled with sourness. It is difficult to state whether a tastable substance excites all parts of the organ of taste. The general conclusion is that the tip of the tongue is the region of sweetness and sourness and the roots of the tongue of bitterness and alkalinity of taste. It has been found that some sugar derivatives produce bitter sensations at the root of the tongue and sweet at the tip of the tongue. Here there are undoubtedly individual peculiarities which make it difficult to limit the area of stimulation. It is questionable if the sense of taste can be stimulated mechanically. Some regard these sensations as associated with the general feeling accompanying mechanical pressure of the tongue surface. Electricity is found to be the excitant of taste sensations. Rosenthal found that if the tongues of two persons are in contact while one holds the positive and the other the negative electrode of a battery there will be developed in connection with the one an acid and the other an alkaline taste. In regard to the production of taste sensations there seems to be some chemical relation between the stimulating substance and sensation. It is claimed that the simplest form of this relation is found in the case of acid substances. The compounds of carbon seem to have the taste of sourness and the soluble chlorides the salt taste while many of the alcoholic substances have a sweet taste. It is claimed that tastable substances are carried in a vibrating medium the vibration arousing a sensation in connection with the senstiive organs, the vibration determining the quality of the sensation. Certain compounds vibrating in a particular way produce certain sensations, the variations being caused partly by the inability of the tongue to analyze directly the compound result. It is usual to classify taste sensations under the four heads of sour, sweet, salt and bitter. Wundt adds to these other two, the metallic and alkaline, all the other tastes being compounds of these simple tastes. It is questionable if this classification can be made to conform with experience, because many of the sensations of taste cannot be analyzed into these simple sensations, and the relation of taste sensations to

those of smell and touch is such that it is very difficult to clearly differentiate them.

(c) CUTANEOUS AND MUSCULAR SENSES. The sensations of temperature and pressure are localized in the skin. Other sensations supposed to be localized in the skin, called the common sensations, including pain, pleasure and the delicate forms of tactile sensations, all are more or less closely related to pressure and temperature. Some of these are undoubtedly to be localized in the cerebrum arising from the combination of a variety of sensory impulses, the combination taking place cerebrally. The pressure sensations are aroused by the stimulation of the sensory cutaneous nerves. If the main trunk of these nerves is stimulated painful sensations result but these are distinct from the localized sensations. The normal stimulation consists of compression or extension through contact with something external, the degree of the stimulation depending upon the nature of the pressure and its continuance. There is really no scientific classification of these sensations, although sometimes they are distinguished as simple touch and pressure or weight. This distinction however is one simply of degree. The pressure sensations arise in connection with the stimulation of small pressure areas, which are found in chains radiating from a central point, being found most abundant in the skin where it is extremely sensitive to pressure. Two quite different sensations are distinguished in connection with pressure. If a very delicate pointed instrument touches the skin it will arouse a sensation only at special points, resulting in a gentle prickling sensation. If the pressure is increased the sensations are altered, so that the feeling produced is that of a solid substance pressing against the skin. If the intervening points between the pressure spots are stimulated only an indefinite and characterless sensation results. In quality sensations of pressure cannot be classified, the complex as distinguished from the simple sensations involving, muscular and articulation sensations, the difference being in the intensification of the complex as compared with the simple. Some have identified the simple pressure sensations with those of temperatnre, cold substances in contact with the skin having the feeling of a heavier weight than warmer substances. It is claimed that a silver dollar at 25° F is as heavy as two dollars at 98° to 100° F. Certain minute areas and those only are subject to irritation of a kind to result in sensations of heat and cold. It has been found that small wood discs at 122° F have the feeling of a greater weight than larger discs quite cold. The fact that the pressure spots and the temperature spots may be stimulated by the same excitation does not prove that they are identical. Hence the temperature sensations are quite distinct from the pressure sensations and are aroused only in connection with minute cold and heat spots. These minute spots of sensation are distinguishable from one another on the cutaneous



surface. Their localization is not symmetrical on the different parts of the body and they are found to be different indifferent individuals. They are found in radiating chains of spots radiating around the roots of the hairs. The cold spots are more abundant than the heat points. Some spots are aroused by a temperature that would not affect others. When the spots have become aroused the sensations become specific, the sensations having, it is claimed, a certain dependence on the temperature of the stimulus. Hering claims that when the stimulus at a point in the skin has a temperature higher than its own zero-point there is a heat sensation, and vice versa a cold sensation. The zero point of the skin applies to the temperature which will not produce a sensation of either cold or heat, differing for the different cutaneous parts. Hence the tip of the nose represents a cold part because there is in connection with it a loss of its own heat by radiation. Hence there is a mechanism of adjustment regulated mainly by the blood supply and the principle of evaporation. Hence heat may be induced, by checking the radiation, being in contact with a higher temperature and the passage of heat from the interior of the exterior of the body; cold may be induced by promoting radiation from the skin, by contact wite a lower temperature and by diminishing the internal temperature of the body. It is almost impossible to reconcile the psychic principles of temperature sensations and the physical principles of physical heat and cold at the basis of which is motion. The psychic principles have a great deal to do in determining the character of the sensations. The sensations of temperature depend on the temperature of the stimulus, the rise and fall of temperature and the principle of nerve fatigue, particularly applicable to the terminal organs, bring out many of the phenomena of sensation. Weber thinks that wherever there is a rise in the skin temperature the feeling of heat results and vice versa. Goldscheider however proves that by holding the hand for ten seconds in water at 104° F and then placing both hands in cold water the hand that is cool will feel the cold water more distinctly than the warmed one. The perception of variations of temperature is keener for a temperature close to the normal, although we do not know why it is so. It is possible that certain chemical changes or electrical variations take place on the basis of heat changes in connection with stimulation. It is certain that sensitiveness to heat continues after the cold sensitiveness is lost.

It is much disputed whether excitation of the sensory nerves in connection with the muscles gives raise to muscular sensations. We localize in connection with the muscles certain sensations particularly in connection with movements and the vision. This is clearly observed in lifting weights and changing body positions in which muscles are brought into play that are not used normally in ordinary movements. There are undoubtedly muscular sensations in connection with the conscious mind,

these muscular sensations supplying the sensations of pressure in connection with the skin with greater definiteness as the basis of movements. It is impossible to account for delicate muscle movements on any other basis. In cases of locomotor ataxia there is often a little absent, but these muscular sensations. There may be a loss of skin sensibility without interfering with the power of lifting weights and distinguishing their masses. It is not known how the muscular sensations arise, possibly it may consist of some chemical or mechanical stimulation. It is impossible to analyze and classify these sensations because to the conscious subject they are complicated processes associated with pressure and temperature sensations and also with the sensations of sight. These muscular sensations differ in quantity rather than in quality from each other. In connection with the body we also find articulation sensations particularly valuable in body movements. It has been found by experimenting in connection with the index finger that sensations arise in connection with the joints that determine our perception of movements. It has been found that manifold cutaneous sensations exist over the surface of the body, great variations being found at different points, when a uniform current of electiricity is passed over the surface, indicating the variety of the forms assumed by sensations in connection with the body surface, all of these bewildering sensations being analyzed and combined in consciousness.

(d) SOUND. In connection with these sound sensations many investigations have been carried on since the time of Helmholtz. It has not yet been definitely settled where the stimulation takes place in connection with the neural mechanism nor in what way. Sound implies vibration and this vibration in some way produces a stimulation that affects consciousness through the nervous mechanism, involving the excitation of the auditory nerve and the cerebral auditory apparatus. Psychologically sound is therefore purely subjective although the ear possesses the capacity of analyzing sound as perceived, but this does not give us any means of analyzing the process of audition or the way in which vibration excites it. Sounds are divided into two classes, noises and musical notes. In the former is the lack of periodicity in stimulation such as we find in the latter. It is true that in all tones there is an element of noise and even in the most ungainly noises a trained ear could detect musical notes. According to Helmholtz noises are characterized by rapid and alternate vibrations in different sounds. According to Hensen there are three classes of noises, beats that interrupt musical tones; crackling and hissing sounds. The musical notes differ in quality and also in quantity depending on the extent of the vibrations causing them. In regard to quality they are either simple or complex as they are produced by one set or more sets of periodic vibrations. In the complex sound there is not such absolute blending of

simple sounds as to be incapable of analysis on a simple basis. The complicated sound produced by this blending of simple sounds in contrast with one another is termed clang. From the standpoint of simple sensations we have the pitch which represents the quality of the sounds, the pitch varying as we give our sensations a particular place in consciousness and compare them objectively from the standpoint of the number of vibrations producing them. The complex tones of our experience also vary in quality, this variation being called the timbre which depends on the pitch, the number and intensity of the simple tones of which it is composed. The pitch of the tone produced by the voice or the piano is the same, but its timbre is different depending on overtones that are associated with it in connection with the fundamental tone. The pitch is determined in the case of a simple musical tone by the position we give it in the scale, so that the pitch is either high or low. The pitch, however, depends on the rate of the periodic vibrations producing the notes or the length of the sounds waves. Vibrations that are beyond or below a certain limit of vibration per second give no musical sounds or at least sensations of them. The pitch is regulated by the measurement of the number of vibrations required to produce some fundamental sound which is taken as a keynote, the other sounds being determined in relation to this one. The German scale fixes its key at 440 vibrations per second, the French scale 435 and the English 512. It is difficult to determine the limits of sounds that produce sensations on account of individual idiosyncrasies. Helmholtz considered that the sound begins to die if the vibration is below 34 per second, while Preyer could hear sounds at 16 and also at 40,000. For normal ears the limits may be set at from 28 to 22,000, although variations may be admitted from 20 to 50,000 vibrations per second. The normal ear would be capable of hearing a little over 9 octaves of pitch.

Great differences are found in the sensitiveness of individual ears to differences of pitch, some being entirely deaf to differences in pitch. Those who are not sensitive to a difference of a half tone are said to be incapable of distinguishing one note from another. Sensitiveness can be cultivated very extensively and to such a high degree that variations may be detected of one-third of a simple vibration. There is also great difference in individuals in the power of discriminating the intervals between notes. The delicacy of the sensations of sound may be illustrated in the fact that the discrimination between two notes from the standpoint of pitch is independent of everything outside of the sensations produced by them. Hence, the mind must possess the power of immediately discriminating between differences in pitch, although training may considerably intensify this power of judgment. This training may be aided by the delicacy of the muscular sensations which arise in connection with the larynx in the act of singing. These sensations, however, of themselves

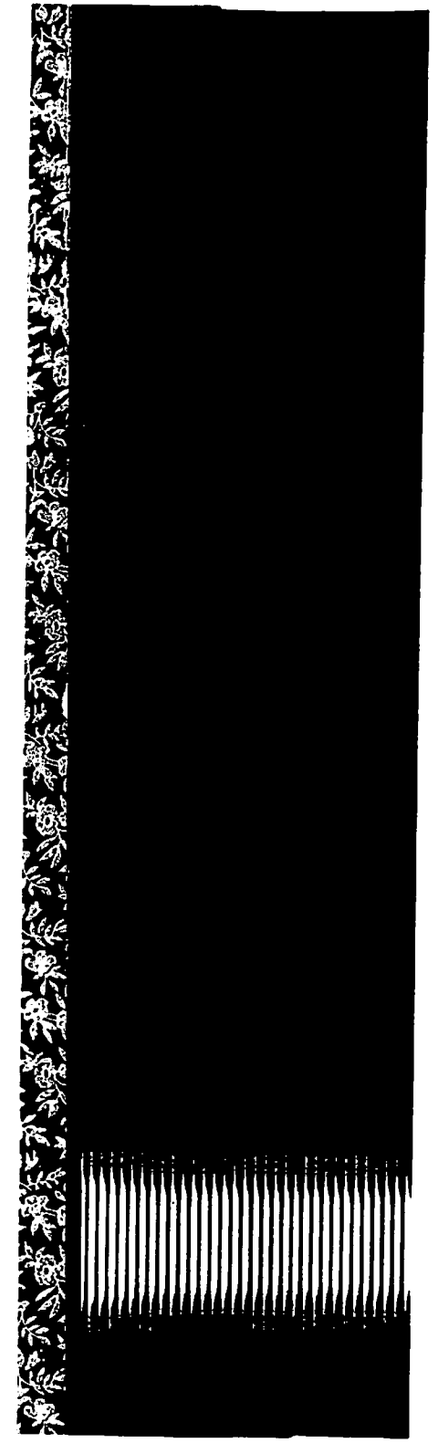
could not supply the basis of judgment, the variations in the quality of the musical tones supplying the means for bringing them together in a series called a scale. The symbolism made use of in connection with varying positions in a straight line depends on sensations arising in connection with touch, vision and the muscular sense, on the basis of which we call the sounds high or low and designate certain intervals between the notes. In the lower tones the sound is produced in connection with depressed vocal organs, in the higher tones the vocal organs are elevated. Hence, lower notes in connection with consciousness impress the mind with ideas of breadth and gravity, more time being necessary for their entrance into and passing from consciousness. By sounding a note in connection with the voice or an instrument there is a clang, producing by the summation of the simple note qualities in connection with consciousness a sensation which is complex, the result of a complex undulation sound. Hence, the clang represents the blending in consciousness of the simple tones found in a complex wave. When simple tones by their vibrations are related to one another they produce in consciousness the pleasing sensation accompanying a harmony; if the combinations however are related in an unharmonic relation they produce the unpleasant sensations caused by noises. If several clangs are sounded at the same time a complex sensation follows, which may represent consonance or the complex fusion of pleasant sensations, and may also represent dissonance or the complex fusion of unpleasant sensations. Thus we have complex sensations psychically corresponding with the cords and discords of sound. Helmholtz thinks this depends on the fact that beats are present or absent, consonance resulting from the absence of beats. To this is added the idea that consonance involves pleasure because of the "recognition of relations." In other words consciousness recognizes the relation of the sound to a fundamental note and also recognizes in the consonant notes a harmonious action arising in connection with the notes themselves. From this we may infer that the ear as the organ of hearing represents the most acute and analytical of all the senses to appreciate these minute auditory differences.

(e) SIGHT. The sensations of sight are the most complicated of all the sensations. There is really a two-fold sensation involved in sight, that of light and color; and as there exist different shades of color and many varieties of light sensations, the sensation of sight comes to be very complex. Qualitative changes depend upon a number of causes that are indistinguisnable in conciousness. The quality of the sensations also depends upon the quantity of the white light that is brought to bear on the eye in connection with any specific color. Limiting the investigation, however, we enquire into the sensations arising in connection with the stimulation of a small part of the central portion of the retina when the

light is normal. This will give us the normal visual sensations. Light is the normal stimulus, but the same results may be produced by electrical or mechanical stimulation. The retina is said to be continuously active and thus possesses its own characteristic light which varies considerably in quality and degree. As it is preserved in a tonic condition of stimulation, this depends upon the blood supply and the chemical changes taking place in the terminal organs and the brain in connection with the blood supply. It is in connection with the rods and cones that the light sensations are produced. This retinal layer consists of a large number of distinct elements each of which is sensitive, the one side of which is stimulated and the other responds in connection with the sensations of light and color. There must be the irritation of two contiguous retinal elements in order that two visual sensations may be seen separated from each other, so that stimulation must take place over a retinal surface equivalent to the distance between two such retinal elements. The trained eye can attain a degree of accuracy according to the size of the retinal elements ,so that in distinguishing two objects there requires to be a separation of 60 to 70 seconds, the angle represented by this distance being about the size of one of the retinal elements. If on a dark surface white lines are drawn so as to come closer to each other than this retinal limit to the vision they will appear distorted. This arises from the effect produced by the stimulus in connection with the rods and cones.

In connection with sight sensations we require to consider the wave lengths that are associated with the different kinds of colored light and the component elements of the colored light in connection with white and colored light. There is a marked difference in color tones, light being the normal stimulus upon the end organs of vision. In the case of the rods and cones the real stimulus is the photc-chemical changes taking place in connection with the light. These changes producing sight sensations may be aroused by mechanical pressure or by electrical stimulation, while in some cases a sound heard by the ear produces the sensation of a particular colar. Color tone is spoken of as pure in case it is not mixed with the other color tones, this distinction of pure color tone being obtained only in connection with the spectrum. In the use of it the compound white light may be analyzed into its component color tones, so that the compound of sunlight rays in connection with the stimulation of sight sensations consists of several consituent elements which represent vibrations of certain magnitude varying from 370 to 900 billions per second. According Frauenhofer light rays consisting of less than 450 billion oscillations per second, give rise to the sensations of red, varying slightly in quality up to 470 billions; after 470 billion is reached we have orange yellow varying up to 526 billions when the characteristic yellow is produced; above this the green sensations originate until 589 billions is reached, when the

sensations begin to become blue varying in quality to 640 billions; from this up to 722 billions the variation of blue to violet takes place above which there is the characteristic violet. There is a gradual variation from the red to the violet so that no sharp distinction can be drawn between the spectral colors. In the ultra red the rays do not excite retinal action. In the ultra violet Helmholtz discovered the lavender grayish color, and in more recent times the X radiance represents the ultra violet color. The sight sensation represents an image of external things which comes into consciousness through the optic avenue of the brain. Hence all the sensations coming from vibrations must be purely psychylogical. Light reveals wonders of the universe and yet it is itself the greatest wonder. The eye is not as expansive as the solar universe of radiation. Hence we find in the ultra violet spectra of color unknown to vision. Stokes points out ten variations of color ultra violet and Muller has pointed out two ultra red, these representing a fluorescence created so as to render the light visible. Hence Tyndal claims "beyond the extreme violet of the spectrum there is a vast efflux of rays which are totally useless as regards our present powers of vision." Lenard regards the cathode rays as essentially of the same nature as the ordinary light rays and Hertz has proved that the cathode rays pass through the delicate metal sheets inside the tubes, passing through substances opaque to ordinary light. Hence in this ethereal medium we find the perfect adjustment of molecular relations. In the X radiance we have an anti-cathodic ray of light arising from the spot of fluorescence on the glass surface opposite the cathode plate. The light cannot be utilized by any ordinary vision without the aid of a phosphorescent medium, demonstrating the existence of other media for the transmission of light waves to the end organs of light sensations than simply the retinal rods and cones. The color sensations originating in connection with the green-yellow of the spectrum are brighter than the other color sensations this being generally acknowledged to be due to the retinal structure and its sensitiveness to these color rays. We find also different degrees of sensitiveness in the retina to different and very slight variations in the quality of the color tones. The sensations of color are not simple but complicated and the analysis of these complex sensations is impossible, because they retain in consciousness the characteristics of the color tones. When only slight variations exist in the wave lengths of two colors the variations can be recognized as shadings of colors. There is not a difference in the color impressions resulting from a mixture of the colors, the character of the color impressions depending on the spectral position from which the color tones are taken and on the intensity of these color tones. According to Newton an octave of seven colors is distinguishable by vision, red, orange, yellow, green, blue, indigo and violet, but there is no foundation for the analysis, because some of



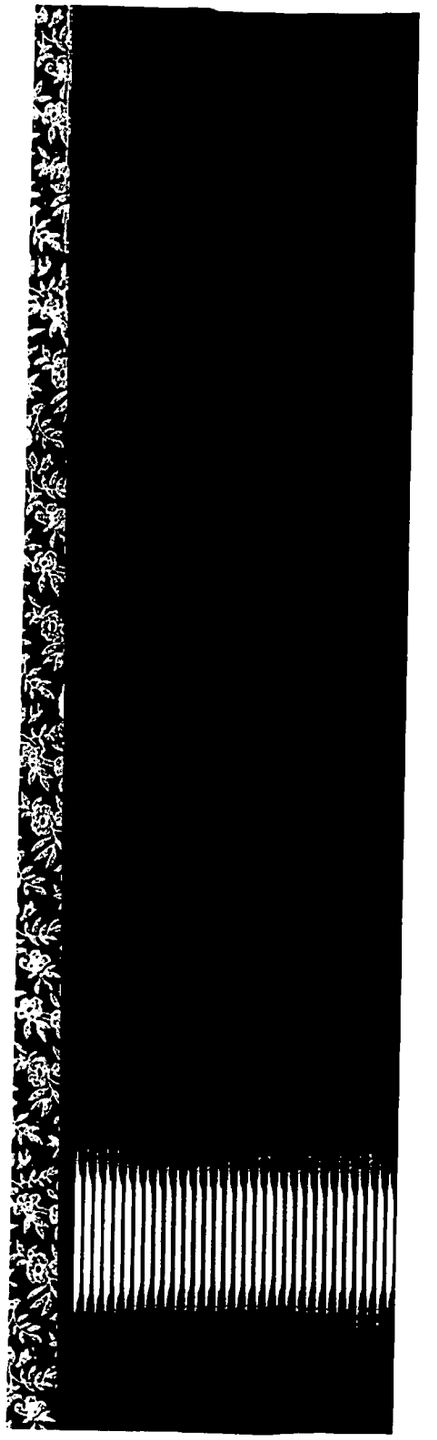
them like indigo and orange really represent semi-color tones and not color tones. A great number of color tones are discernable in vision so that if all differences are considered many thousand color tones may be distinguished. By uniting certain color tones on the retina there is a resulting color sensation quite different from the sensations of the two separate; the former sensation is called white and the separate sensations complementary. The mixture may take place by placing one spectral ray upon another, by the fusion of the reflected images of two colored wafers or by the fusion of colors in connection with a revolving cylinder.

If the light intensity approximates to the highest or lowest point there is an important variation in the quality of the sensations that does not depend on the changes in the wave lengths. When the stimulus reaches its maximum there is an entire loss of color tone, the sensation being that of white light, before the maximal point is attained red and green tones become yellow; when the stimulus is at its minimum all the color tones except red cease to possess color, if upon a dark background. There are color tone variations when the period of the stimulation of the retina by the light falls to its lowest point. A certain duration of time is necessary for the light sensations. If the color is saturated sensations may arise from an instantaneous spark, but if the light intensity decreases a longer period is necessary. The quality of the sensation also varies with the part of the retina which receives the light or color stimulation. The whole retinal field is divided into three areas called central, middle and outer. The same stimulation may produce sensations varying in quality and intensity. The retinal sensitiveness is intensified towards the outer part, the lower portion being less sensitive than the upper part, possibly because the rodlike structures mirror the light.

In some individuals defective vision is found. the whole retina being found to be similar to the outer portion of the retina, and hence imperfect in retinal function. Among some persons the retina is either partially or wholly non-sensitive to the red rays, confusion being found between the red and the yellow or green. Among others the retina is either partially or wholly non-sensitive also to the various shades of green. Hence, according to Kries color blindness exists either in regard to red or green. The eye vision may be modified in connection with the retinal condition either as found before or during the time when the rays of light fall upon the eye. In these cases there is usually a brain condition behind this abnormal variation in the sensation that is itself abnormal, although it is claimed by some that it depends on the chemical nature of the stimulation. By fixing the eye on an object particularly if bright colored and then closing the eyes there is still kept before the eyes a picture of the object, called a positive after image, which only gradually fades from the vision. By a continued consideration of this image the colors are changed, white

becoming greenish blue, then indigo blue and then a deep violet color. If the eye is fixed for a length of time on a green object and then changed to a white object, the color of vision becomes red. This image is called the negative after image and depends on the law, that the color of the image is the complementary color of the object, that the blending of the colors of the image and the object would produce white. These after images are said to depend upon fatigue of the nerve elements so that when the color is prolonged in its relation to the retina the retina becomes insensitive to that color until the exhaustion is removed. If a bright object is surrounded by a darker medium, it appears brighter and vice versa. This depends on the principle of contrast. If colored light takes the place of white light then the complemental colors are found. The explanation of these facts seems to depend on the physiological principle that when one point of the retina is stimulated there is a radiation of excitation to neighboring parts of the retina, while at the same time any one point on the retina is modified by the surrounding retinal parts. In addition to this there is undoubtedly an influence exerted by the cerebral centers in connection with the optic connection.

On account of the complication involved in the visual sensations it is difficult to find a theory that will take in all the phenomena. There are many facts that require to be explained, for example the principles upon which the primitive colors can be built up into color tones; the relation of the color tones to the light intensity; the relation of complementary colors to white light and the phenomena of after images and comparison. Among the theories propounded the most interesting is that known as the Young-Helmholtz theory. It originates from the fact that a mixture of certain primitive colors produces all the other color tones. According to this there are three primitive colors, green, red and violet and according to Fick blue. On this basis it is claimed that three nerve elements are found associated with every part of the sensitive retina, so that the stimulation of any of these elements singly would produce a primitive color tone, so that in the retina we find the green, red and violet color elements producing corresponding sensations. In every visual sensation we find a complexity of elements so that the complex sensation depends upon the relative intensity of the constituent nerve elements. In this theory we find a very plausible explanation of the visual sensations, particularly in connection with the mixture of colors. The greatest difficulty arises in the attempt to explain color blindness which according to some is irreconcileable with this theory. It is claimed that the lacking colors do not correspond with any of the fundamental colors, as persons who are red blind ought to see the white color tone as green-violet. According to Hering who rejects this theory, the variations in the sensations of gray color from white to black correspond with the quality of sensations produced



by the eye looking upon the different color tones that shade into each other. Hering claims that we have three double primitive colors the mixture of which produces all the color tones, black and white, blue and yellow, green and red. According to him a constructive process produces the first color tone of the pairs, black blue and green; while a destructive process produces the second color tones of the pairs, white, yellow and red. Hence, he bases the double color tones in each pair on the principle of antithesis. According to Wundt the processes differ rather than the primitive elements of the retina. According to him the retina is continually in a condition of stimulation or tonic contraction, corresponding with the sensation of darkness or the color tone of black. When this is modified by an external stimulation there are two processes found in connection with the retina, the one a chromatic or color process, the other an achromatic or colorless process, both of them depending on the length of the waves, while the latter varies only in intensity. The colorless process retains throughout the same character, being photo-chemical, yellow representing the maximum and the two ends of the spectrum variations towards a minimum. The color process is also photo-chemical and varies with the wave lengths. When the stimulation takes place in connection with a stimulus, the stimulation stops before its effects cease in connection with the irritation of the nerve elements and continues the irritation until the nerve elements are exhausted in connection with this form of excitation. Contrast is explained according to Wundt on the basis of relation in connection with the activity of the cerebral elements, the positive and negative after images depending on the continuance of the retinal stimulation and the retinal exhaustion. According to Kries the visual sensations are photo-chemical and this prevents us from regarding the changes as Wundt does as simply qualitative. There are certain components at the basis of all color sensations and the proper combination of these components gives the color-tone. This adjustment takes place in connection with the central system, but in what way we cannot tell.

Many attempts have been made to invent a scheme for the purpose of visualizing the colors so as to represent them to the eye. Among these we have the color triangle and the color wheel; in the former the color tones are represented as lying around a curved line ranging from the one end of the spectrum to the other; in the latter case the color tones are represented by two concentric circles, the complementary circles being contiguous in the corresponding arcs of the two circles. These symbolic representations, however, are of little value from a psychological standpoint.

THE QUANTITY OF SENSATIONS. Not only de we find variations in quality in sensations but also in quantity. The sensations when they appear in consciousness not only differ as to their production but also in the

degree in which they absorb the conscious attention. When a sound is heard like that of a church bell as we come near to or move away from it, we perceive variations in the intensity. The same element of quantity in sensations is found associated with touch, pressure, temperature, etc. These quantitative changes depend upon changes in the specific character of the sensations. The measurement of these varying quantities in sensations cannot be exact, even when the comparison is limited to variations in the sensations of the same sense.

There is an inter-dependence of quantity and quality which makes it more difficult to make such a measurement but this does not abolish the scientific analysis of the elements of our sensations in the ordinary experience. Experience, however, analyzes these sensations in a very inexact way; we may be able to say that one sound is louder than another, but precisely what the variation is it is difficult to determine. This complication is increased when we consider the variations in quality and the comparative intensities of the sensations of different senses. It is only in musical tones that we can analyze and compare the quality and quantity variations. If sensations are quantitative, however, they must admit of some degree of measurement. The sensations, however, represent not objects but modes of mental action that are aroused in connection with nerve activity. In connection with the quantity of sensations we must find out the limitation imposed upon variations in connection with the sensations as they belong characteristically to the special senses; and inside these limits there must be certain principles regulative of the variations in sensations. The sensations, although they cannot be measured by the physical yardstick, are yet the result of certain stimuli that are brought to bear on the nervous mechanism, the variations in sensations corresponding within certain limits to the intensity of the stimulation. The changes of stimuli can be measured, and the resulting sensation changes can also be measured by discriminating the intensities of the sensations. We must, in order to solve this problem, (1) determine the maximum and minimum stimulation that will occasion the maximum and minimum sensation, in order to settle the limits of variation in sensations; (2) try to find a principle that will determine the relations of stimuli and resulting sensations. Here of course great difficulty is met with because it is difficult to measure subjectively the sensations in intensity and objectively the quality of the stimulus. It is possible to determine in the case of two sensations of the same quality produced by a quantitative stimulus that is the same or nearly alike in both cases, the resulting intensities of the two sensations in consciousness, so as to determine what is called the minimum of observable difference. This is taken to be the great question of quantitative analysis of sensations, namely, the observation of the minimum observable difference in quantity for the different

kinds of sensations. This minimum of observable difference is itself an ideality and must be regarded as such in its bearing upon mental processes. In determining the minimum of stimulus necessary to produce a sensation, a stimulus that is slightly stronger than that necessary in the production of a sensation may be applied, gradually lessening the stimulus till the point is discovered where the stimulus produces no sensation; on the other hand a stimulus may be applied that produces a sensation and we may increase it gradually to the point of producing a sensation. In determining the maximum stimulus which produces a sensation, we meet with the difficulties associated with fatigue and over-exertion, as well as the elements of paid that make it impossible by experiment to determine the higher limit.

In connection with the determination of the minimum of observable difference in sensations, Ladd mentions three methods. (1) According to Wundt there are two ways of applying the method of least observable difference, either by the formation of a gradation series of stimuli with intervals of time corresponding with the intervals between the sensations, so as to determine the variation of stimulus necessary to divide the interval of time in two, continuing this process of division until the least observable difference is found; or we may construct a scale of stimuli with varying intensities just sufficient to give a variation in the resulting sensations. (2) The average error method first determines a standard sensation produced by a definitely known stimulus after which an attempt is made to determine another stimulus that will give a sensation of exactly similar intensity. By making an average of these combinations determination is made of the least observable difference. (3) A given stimulus is taken with a resulting sensation, slight additions and subtractions are made so as to vary the stimulus, with the view of guessing at the result associated with the changing stimuli. All these methods attempt to measure the mental sensitiveness to small variations in the sensations corresponding with variations in the stimuli, without taking account of the other elements aside from purely objective changes that determine the sensitiveness of the mind. Weber has formulated a law based upon many experiments and Fechner has enlarged and corroborated it. This represents the only scientific statement we have on this subject, namely, that our consciousness of the differences quantitatively between two sensations is not in direct proportion to the difference of stimuli, because the intensity of the stimulus increases more rapidly than the resulting sensation. If the minimum observable difference is regarded as constant, then in order to get an increase or decrease of sensation, there is required the addition or subtraction of a larger amount of stimulus in the upper than in the lower scales. The law of Weber attempts to measure the difference. It claims that "the difference of any two stimuli is experienced as of equal magnitude in case of the mathematical relation of these stimuli remains unaltered;" "if the intensity of the sensations is to increase by equal absolute magnitudes, then the relative increase of the stimulus must remain constant, the strength of the stimulus must ascend in a geometrical proportion in case the strength of the sensation is to increase in an arithmetical proportion." The law seems to be applicable to a certain field in the scale of sensations, but inapplicable to the larger portion of the field in connection with the higher and lower limits of sensations.

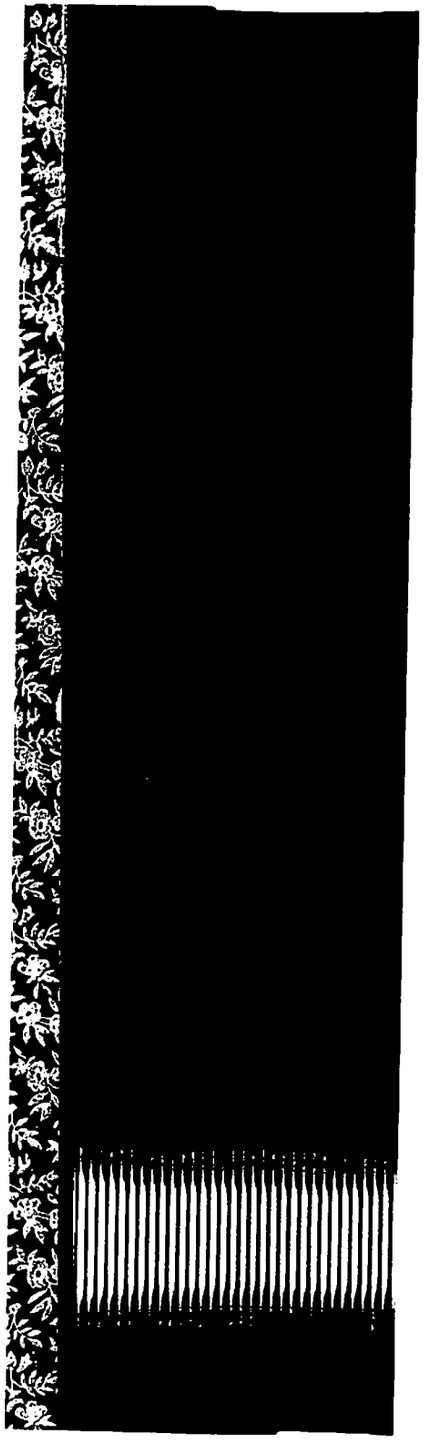
In regard to the tactile sensations of pressure the minimum of observable difference is subject to much variation, including the effects of the muscular and temperature sensations the region of the application of the stimulus and the time intervening between the stimulus and the sensation. Experiments indicate that the sensitive quotient for pressure sensations depends upon the absolute weight values that are made use of. As the weights increase the quotient varies and the observable difference varies with the rapidity of the rise of the weight. The differences of sensitiveness in the different parts of the skin depend on sensitiveness of the nerve elements, skin thickness, skin tension, etc. In regard to the temperature sensations it is almost impossible to find out what is to be measured, the zero point of the skin varying so much. It seems that greater sensitiveness exists in the skin close to the zero point, the least observable difference being found slightly above and below the zero point. Temperature sensitiveness depends on the extent of the surface irritation and its localization on the body surface. The differing degrees of sensitiveness can be mapped out in connection with the cold and hot spots. Hence the intensity of sensitiveness is great to cold on the forehead and on the back, intense to heat on the chest except the sternum, equally intense to cold and heat on the hands. In regard to the sound sensations the variations in the sensations do not correspond directly with the changes of stimuli, otherwise delicately shaded musical sounds would be impossible. If the intensity of a sound is increased the timbre is modified. The Weber law does not seem to be generally applicable, as in the upper and lower limit it fails altogether. Aural sensitiveness for minute tone variations is much greater than for noise changes. The minimum of observable difference in sound depends on the condition of the medium, so that if almost absolute stillness prevails very minute variations may be detected. The psychic element of habit explains the fact that some sounds fail of detection that would otherwise attract attention. In regard to sight sensation the astronomers early pointed out that the minimum of observable difference in connection with two sight sensations is less for those that possess the minimum of intensity. The fact that the retina has its own light and that qualitative variations tend to hide the quantitative variations makes it difficult to measnre the sight sensations. The back ground in

connection with which the color tones are exhibited also is very important. According to the early application of the Weber law the minimum of observable differences is .01, more recent experiments indicating a variation from .015 to .005. In regard to the light and color sensations Weber's law may be said to apply generally when the stimuli are in the middle of the scale and inapplicable in the upper and lower limits. In connection with the taste sensations such variations are found in the stimuli conditions and the individual element is so strong that nothing definite can be stated in regard to the minimum observable difference. In the sensations of smell very minute differences can be detected, so minute as to indicate almost inappreciable points of discrimination, the element of quantity in the stimulus being capable of very fine differentiation.

According to the Weber-Fechner law there is a variation in the quantity of sensations arithmetically and in the quantity of the stimuli geometrically. This represents only one principle that may apply within certain sensation ranges when no external disturbing elements are found Fechner applies this law to interpret the relations of the bodily and spiritual activities, making this the foundation of many of the relations of mind and matter; others apply it as a physiological statement of a neuro-physical relationship between stimulation applied to the body and the neural commotion resulting from stimulation. Undoubtedly the organism is excitable and this would represent one of the modes of stimulating the organic elements to activity. In addition to this there is a psychic side, because all of the mental states are definitely correlated, so that the value of one mental state can be determined only by considering this correlation. The mind appreciates the variation in sensations but so many elements of a psychic nature are involved, including attention, judgment, habit, that it is difficult to reduce it to an arithmetical form. The relation of the internal and external variations undoubtedly exists, but we cannot as yet at least formulate it in precise language. Where interruptions exist between these or abnormal conditions are found in the correlations of mind and body such as we find in insanity, we have here a physiological basis for Osteopathic education applied to the organism with the view of the re-establishment of the normal correlations that are at the basis of sane life.

SENSE PERCEPTION. The sensations and their interpretation imply very different things. The sensations imply the consciousness of the affection of the nervous system. But the affecting objects are considered as real things and hence are said to possess objective existence. Hence, sensations represent psychic conditions which have no space form, but the objects giving rise to these sensations are regarded as having a space form. The mind is subjected to the influence of certain stimuli and it interprets these stimuli by giving to them certain qualities as objects of perception. The perception of such objects is not native to the mind but the result of certain educative process involving a knowledge of time and space relations. In order to mental perception there requires to be a constructive process for things can only be perceived when formally constructed. This construction process is not individual only but hereditary and racial. It is impossible to formulate a theory of perception that will account for all the processes associated with our knowledge of the external world, because it is impossible to analyze all the complex processes by which the individual has constructed this world of experience. Hence the contents of consciousness cannot all be traced to their genesis. We must try to find if any physical basis can be found for this constructive process by which psychically the field of perception assumes its spatial form.

Sense perception involves so many complex processes that its analysis is impossible. When the eye looks on a scene there is the consciousness of something being impressed upon us mentally that has an exact counterpart outside of us. Commonly these external factors in experience are adjudged the only basis of mental perception. These external things and beings, however, do not explain psychic perceptions, but only furnish stimuli that may or may not affect us. This affection takes place in connection with the nervous system, but there must be in addition certain psychic activities to construct the mental perceptions. The old theory of spiritualized or ethereal transformations of the external passing through the senses and forming the basis of psychic perception has no foundation. The conditions and processes of the body itself cannot furnish any adequate explanation of the perceptions. The physiological theory according to which the physiological changes produce the psychic changes is also inadequate. The retinal image for example is a physiological condition of perception, but it is not a picture for the mind itself. Psychic pictures cannot be constructed out of physical or physiological elements. Similarly it is inadequate to localize space in connection with the peripheral sensory nerves in connection with the external stimulus, because in this case the mind must be regarded as diffused over the entire body area. Hence the space form is not perceived in connection with the localization of space through the fibers or skin areas. The true theory of perception must be characteristically psychic, because no process can translate the physical into the psychic. Hence sensations both simple and complex must be regarded as mental factors. The constructive process is therefore a psychic one and depends upon mental evolution. Whatever qualities are found to inhere in the presentations of sense are associated with the object by a mental action bringing the object into relation with the mind through the nervous system. Hence the objects



of perception have space relations, these being the mental stroma into which the sensations are fitted as these arise in experience.

In connection with the theory of perception we must recognize, that there takes place a synthetic combination or association of two or more sensations differing in quality. Hence in the existence of the different senses we have the basis of those qualitatively different sensations which give us perception. When a series of sensations are found in connection with the mind arising from the stimulation of different parts of the sense organ we have the spatial series. Such arise in connection with vision and the muscular sensations, while others like the sensations of smell do not give rise to any spatial idea. In the sense organs we find locally different parts giving rise to different psychic sensations, so that the difference in location gives rise to a difference in the mental representation. Hence in the variation of the part to which stimulation is applied to the end organ we have the basis of the local calibre of the sensation, giving us a complex of sensations, differing from one another, the difference arising from the local signs of the organ.

Perception is an educative process, not one that is native or instinctive. In the construction of the field of vision and of touch we have the education of the mind and the senses in harmony with each other to construct such a united field. In connection with the educative process we find that there is, first the tendency to localize at different points in connection with the body organ the production of the sensation and to render objective the sensations by giving to them an objective existence as related to the body. In the educative perception process the mind is constantly active, localizing certain sensations as belonging to particular parts of the body, and projecting the body external to itself in the localization of pure extra-bodily objects. The mind is thus active in constructing or synthetizing in connection with the sensations originating from the stimulation of certain organs or parts of organs, so that the physical basis of such psychic construction exists in the physiological stimulation. Hence there must be in perception a psychic as distinguished from a purely physiological element. It is not correct to speak of the purely neural and physical processes as if these were the exhaustive elements of the mind. To say what mind is it is impossible; it is better to recognize the psychic reality as shrouded in mystery, because here is the limitation of all science even exact physical sciences which cannot relieve themselves of the burden of the unknowable.

The theories of perception have been classified as two-fold, the nativistic and the empiristic. The differences arise in regard to the self-reality of the nativistic school emphasizing the primitive and intuitive characistics, while the empirical repudiates native intuition depending upon the experiential elements that are introduced into the mind through the

stimulations of the neural mechanism in connection with the external world. According to the genetic school the space form represents a native framework into which experience is fitted, while the empirical regards it as the product of inter-relations between the mind and the external world through the nervous system. In both theories we find an element of truth. Our sense perceptions are not simple native elements, but very complex products, implying not only native capacity, but the experience involved in the exercise of memory, association and judgment. Yet the most simple sensations must be regarded as involving an intuitive capacity on the part of the mind and its organ the nervous system to be stimulated. Hence the complex perceptions must involve the synthetic action of the mind and the action of the nervous mechanism as the basis of stimulation.

We must first of all find out the difference in the quality of sensations which adapt them to become the basis of perceptions in connection with mental synthesis. It is not sufficient to say that sensations must originate from the stimulation of the contiguous parts of the sense organ. In the case of the eye, for example, there are double organs of vision, the retinal elements being found in the two eyes. The cerebral action must take place in order to unite the elements of the picture so that it is not necessary that the different parts of the sense organs stimulated are related to each other on a definite space basis. In order that this unity may be found in the sense perception it is necessary that the elemental sensations be capable of combination into a series in the formation of complex sensations, in other words the single sensation must have the characteristics of the space series. In order to this the sensations in the space series must be similar in qnality and must be capable of repetition in an order different from that fouud in any single series. In the case of the eye and the skin we find this capacity of variation with rapidity and precision such as will give the spacial series, slight variations being possible, sufficient to give varying combinations of the series of sensations. In the case of the muscular sensations we find the same peripheral mechanism capable of giving a series of repeated sensations. Taste and smell do not give such a series of sensations that can be repeated. In the case of hearing the ear does not represent an organ whose surface can be accommodated to an external stimulation and the normal aural sensations do not consist of a series that shade into each other, capable of repetition, so that hearing is not a geometrical sense. In addition to the different series of space sensations must be capable of comparison with one another and associated together. Hence in the use of the eye there are simultaneous sensations associated with the muscles, skin, etc., so that the qualities possessed by the one series of sensations may be compared with those aroused by the other series of sensations. In connection with this the tactile sensations the contact of the body with foreign bodies at different points

gives the idea of contact, the idea of contact giving the spatial sensation.

These sensations associated on the basis of space relations are differentiated by means of symbolism. When stimulation takes place at a particular part of the organ there is a similarity in the sensations arising from the common local origin, this local origin, according to Lotze, furnishing certain local signs. According to this it seems necessary that each minute area in connection with the sense organs, like the eye or skin, possess peculiar shadings in virtue of which, when stimulated, certain graded sensations arise. Hence, the stimulation of different elements in connection with the organs of sense seem to produce a grading of sensations depending on quality relatively to the point of the organ stimulated. When such stimulation takes place it involves the simultaneous stimulation of several parts, resulting in complex sensations that differ according to the number of local points stimulated. According to Bain, all these local signs simply represent symbolic differences arising in connection with the muscular sense, simply symbolizing signs of things. This would make them really illusory. In connection with these local shadings there are various forms of mixed sensations depending on the specific energy of the nerve elements aroused by active stimulation. Hence, the location of visual image depends on the retinal image and also on the impression made upon the skin head etc. the image depending on the sensation in its complexity originating from all of these combined. Hence the local sign will give to the complex sensation its peculiar shading and it arises in connection with the complicated activities of various nerve elements stimulated by different organs and at different points. This is provided for in the almost infinite variety of the nerve elements producing in consciousness an almost infinite variety of shadings of sensations. In connection with our complex experience we find the complication of the processes that are involved both sensational and perceptual. In the transformation out of sensations into perceptions we have seen that this is done chiefly by localization and objectification, the former being limited to the body according to which we get a knowledge of our body and the latter giving us the knowledge of our own body in relation to the external objects. Hence, the process of perception depends on very complicated psychic processes, involving the combination of a number of sensations on the basis of mental principles independent of the physical laws of objects external to ourselves and even laws of our own physiological being as found in the organs of sense. Hence, perception is purely subjective and relates to the field of existence that subjectively exist, not being concerned with the material things and beings of the external world, except in so far as the sense data are furnished from an external world and brought to consciousnes in connection with the stimulation of the organs of sense, arousing the activity of the nervous system.

Our perceptive knowledge arises in connection with the special senses and to this perceptive knowledge we must turn. (1) In connection with smell there are no qualitative space ideas. Localization cannot take place in connection with the olfactory sensations alone, the localization of such sensations taking place in connection with the tactile and muscular sensations. (2) In connection with taste there is no localization limited to taste sensations, hence, they have no local qualities. These taste sensations are so closely allied to touch that the tactile sensations give localization to tastes. (3) In regard to perceptions of hearing there is not a direct localization of the acoustic sensations, the localization taking place in connection with the other senses of vision and touch. Acoustic sounds that originate in or near the ear are transmitted by the tympanum and the perceptions are formed by means of judgment in connection with other sensations. In some cases the power to discriminate between these internal and other external sounds is lost. There are great differences among individuals in the power to localize sounds in relation to the body, these differences depending on the sensitiveness of the external meatus and the tympanum and the position of the semi-circular canals. The nervous connection of the ampulla possibly has something to do with localization of sounds. Rayleigh proved that if a tuning fork is sounded before or behind it could not be so distinctly localized as if held to the right or left. Our perception of distance in reference to sounds depends on the quantity and quality of the sounds. Our perceptions of sound then depend upon complicated processes associated with the sensations of vision and touch as interpretations of the sound sensations.

(4) In regard to the perceptions of touch there is the construction of a tactile field on the basis of mental activity in relation to the tactile sensations. Weber mapped out the body surface into localized areas by means of the delicate points of the compass. He took it that the minimum distance at which two localized sensations could be felt represented the standard of sensitiveness in connection with the different areas. He estimates it for the tip of the tongue 1 mm, for the volar side of the last finger phalanx 2, for the red part of the lips 5, white of the lips 9, back of the hand 31, forearm and foreleg 40, skin in the middle of the back 68. These areas represent sensation circles or ellipses, with a long axis up and down. Our knowledge of the field of touch depends upon these sensation ellipses. By dividing the two compass points less than is required to give the minimum at a certain part of the body and then gradually moving the compass with the same separation to a more sensitive part, the points of the compass will be felt to become separate more than on a less sensitive part. Hence, it is inferred that the mental picture of the sensitiveness is inversely proportional to the size of the sensation ellipses. Different individuals have different degrees of sensitiveness and this may

be cultivated by practice, as in the case of blind persons, who have a very fine space perception by means of touch. The explanation of the difference between the sensitiveness of one part of the skin and another part depends upon the fact, as Weber points out, that each of the ellipses contains a number of isolated nerve fibers, one at least being sensitive and several unexcited. It also depends upon the fact already referred to that there is a minimum of observable difference in regard to sensations, so that there must be an observable difference in the coloring of sensations. The differences found in the tactile perceptions depending on different parts of the body depend on the nature of the skin, the nerve supply, the relations of the cuticle to the underlying tissue or bone and the tension of the skin, as well as upon habit in cultivating fineness of perceptive appreciation. Functional activity and mobility are also said to determine the delicacy of perception as in the case of the arm it is said to increase from the shoulder towards the finger tips. According to Goldscheider the delicacy of discrimination in connection with the skin depends on the pressure spots. Hence, it is only when two such spots are excited by the two compass points that the two points are localized, and the perception of two such points is more acute if the two points belong to different chains of pressure points. In the use of the compass a number of these pressure spots are touched, arousing a number of complex sensations, the variation in perception following the variation in the pressure spots upon the skin, depending upon the distribution of the nerve fibers.

Associated with this perception of space in connection with the skin is the perception of motion, depending upon the successive stimulation of a part of the body so as to produce sufficient variation in the local coloring of the sensations, these sensations passing into each other. Hence, the perception of motion is keener than that of simple space. The sensibility to motion differs over the body surface and does not correspond with the sensation ellipses. Hall says that when a metal point 12 mm. in diameter moves over the skin at a velocity of 2 mm. per sec. in order to discrimination of direction it must move over .2 mm. on the forehead, .44 on the forearm, and .85 on the back. The motion can be reduced to such a slow movement that no discrimination of direction takes place. This is in line with the theory of localized signs so that perception of motion depends on complex sensations differing in quality, degree and rate of mobility. Associated with sensations of pressure and motion we find the temperature sensations, the cold and hot spots forming the basis of this perception. Both the cold and warm sensations are localized as points on the surface of the skin. All of these sensations aid in the forming of perceptions in the regard to the position of the body. In a condition of skin in sensibility it is difficult if not impossible if the eyes are closed to localize the position of the parts of the body. In addition

to these tactile sensations we must take account of articulation sensations in connection with joints and tendons, the movements associated with these materially helping in localization of the body in space relations.

The muscular sensation also represent an important complex of sensations in connectien with peripheral body localization in contact with external objects. Some claim that such purely muscular sensations do not exist; Wundt claims that these as far as they differ from tactile sensations are simply cerebral feelings; while others like Weber and Ladd claim there are specific sensations dependent on neuro-muscular apparati that determine the perceptions of body relations to a large extent. The sensations arising from the muscular sense depend upon the mass of muscles called into activity. Hence the sensations that depend upon the skin and the joints are supplemented by muscular sensations, these depending upon the extent to which the muscles are moved in exploring the object. In the case of lifting a weight, if the eyes are closed our knowledge of the weight becomes more definite is it is lifted quickly so that the muscles become cognizant of the sensation. Direction seems to be determined also largely by complex sensation arising in connection with the semi-circular canals, giving us perception of the body relations to space. There is a difference between the sensations arising while the body is at rest and those arising when the body is moved as in the movement of the head or body certain changes are found in the endolymph. In this way the mind synthetizes the qualitatively different sensations in the construction of a field of tactile perception. In the normal individual the tactile and muscular sensations give rise to a complex of perceptions that enable us to localize the body in its space relations, but these are dependent to a large extent upon the leadership and discrimination of the sense of vision, which with precision and rapidity moves over the entire field of sensation and by delicate discrimination localizes the space relations of the body.

(5) The Visual Perceptions. The eye represents the most complex organ associated with perception. It is naturally provided with a very delicate mechanism for furnishing to the mind the data of sense presentation so that very minute discrimination is possible both in relation to quantity and quality. The eye is endowed with native capacities at a very early period of life and its psychic relations are established very early in life. Many changes and variations take place in connection with the eye and these variable experiences form the basis of a complexity of psychic interpretations. There are also tactile and muscular sensations associated with the eye movements that give rise to certain judgments which aid the vision. If there is a local color tone arising in connection with the retinal nerve elements, then there must be local signs in connection with the visual sensations at the basis of the visual space perceptions. The question is raised, at what point in the perception process of vision does the

visual sensation posess extension as distinguished from intension. In order to have the most primary visual perception there must be sensations of light color; these must be different in quality and intensity, but must exist in consciousness in relation to one another and at the same time; these must be related to each other on the basis of local signs in connection with the retina and brought into relation with other sensations arising from tactile and muscular senses.

The increased complexity of the visual perceptions depends upon the fact that the eyes are double, although the double organs represent but one sense. Although there are two sets of retinal signs, retinal images and retinal motions, yet they act together in such a way that the one is constantly influencing the other whether normal or abnormal. Experience has involved in such complexity the visual perception that we must analyze experience in order to attain the elements out of which to construct a theory. We must follow nature from the most simple case to the more cemplex visual experience. According to Wundt we have three stages leading up to a complex visual perception, (1) while the eye is resting we have a retinal image involving complex sensations; (2) as one eye move certain variations are found corresponding with this single motion; (3) when the two eyes unite in common action there are still further variations. In connection with these three stages we find the three visual fields the retinal, monocular and binocular, which give us the perception based (1) on the arrangement of the sensations of light and color arising in connection with the retina and its nerve elements; (2) on the sensations associated with a single eye, and (3) on the sensations associated with two eyes. The retinal and monocular visual fields are imaginary and are of value only as a basis for analyzing the sensations in the field of binocular vision. If both eyes are covered and kept perfectly still, there will be perceived an extensive mass of light and color sensations, depending upon feeling rather than vision. The points of distinct color may be localized, but there is no definite localization, unless in so far as these depend upon past experience. By moving the face upward the extent of the visual sensations moves above us and by moving the face downward, the extent of the sensations passes down towards the feet. This apparent depth is due to the variations in the color tone of the minute field elements. Even this perception depends on experience of tactile and muscular sensations. While the eyes are closed, if pressure is made upon the eyeball, then there is a change in the visual field. By opening one eye then the field of retinal vision passes into the field of vision of the single eye. If strong pressure, however, is made upon the closed eye so as to produce phosphenes the field of monocular vision is absorbed in the retinal field. The retinal field depends upon the muscular sensations that arise in connection with the accommodation and movement of the two eyes. In order to

perceive position and localizeg areas there must be even in the retinal visual field the recalling of former experience of muscular, tactile and visual sensations. This would seem to indicate that the peaceptive value of the visual sensations depends upon experience. Hence in the child there is no knowledge of space qualities or relations intuitively. As against the empiristic view it would seem that the retina possesses a native perceptive capacity in regard to space; but this depends upon the fact that when each part of nerve elements is irritated there is a local sign in consciousness. Added to this is the fact that spatial judgment is limited by the definite limits of the retina. This seems to indicate that the perception of space from the standpoint of vision is native to the eye, as it represents the mental organ, the mind synthetizing the sensations that are qualitatively different as they originate from the stimulation of the different retinal elements.

The sensations aroused by simultaneous irritation of the retinal elements assume spatial form in the mental interpretation, at least in the normal adults the mind being natively active in the synthetizing process. This involves experience in the movement of the eyes in the simplest case. In order to have a clear vision of an object, the image requires to be fixed in connection with the fovea centralis, the point of the object that corresponds with the image point falling on this central point being called the regard point, this point being constantly changed in order to get a clear vision of the object. In order to accomplish this the eye requires to be rotated around a central point, these rotations representing changing axes. This center of rotation has been fixed as 1.24 to 1.77 mm. posterior to the middle of the optical axes. The six eye muscles rotate the eye around three axes, the antero-posterior, the vertical and the transverse. If a line is drawn from the point of regard to the center of rotation it is called the line of regard, each eye having its own line of regard, so that the plane of regard is represented by a line passing through the two regard lines. The primary position of the eye is found in the erect position of the head and the lines of regard are horizontal. In eye movement without torsion there is a rotation of the eye on the vertical and transverse axes. When the rotation on the antero-lateral axis is combined with vertical displacements, the eye assumes an oblique position and is in a condition of torsion. Helmholtz gives the law regulating these torsion movements, "when the line of regard passes from its primary position into any other position, the torsion of the eye, as measured by the angle of torsion, in the second position is the same as if the eyes were turned about a fixed axis standing perpendicular to both the first and second positions of the line of regard." The details of the movements of the eye in vision belong to physical optics rather than physiological psychology. It is of importance to remember that in constructing the field of vision the

eye wanders over the object surveyed, the point of regard representing this movement, while the mind interprets and synthetically constructs a visual field out of the different sensations. The field of vision in its general form and the relation of different objects in it to one another depend upon and are determined by the eye movements. Only objects seen by direct vision are seen in the actual position they occupy, the objects of indirect vision are seen at the place in which they would be found by transferring the retinal images corresponding with the object to the point of regard. Hence, the retinal image lines do not correspond to the objective lines, but are constructed by the eye in connection with a number of sensations that have local signs and in connection with certain muscular sensations aroused by the different eye movements. The muscular sensations that originate from the movements of the eye in accommodation to distance when harmonized with tactile sensations form an important element in visual perception. In connection with binocular vision we must take account of the fact that we have two retinal images in relation to one another and determined by the eye movements. Normally the two eyes are in activity so that two images are present; while each eye is an independent instrument in combined action they represent a unity. Hence, the two eyes move and act as a unit. If we found in the two eyes perfect symmetry then the elements might be regarded as two perfectly similar retinas upon which identical images could be formed. Perfect symmetry however is not found, and other points than those called primary are brought into common actions these points being called corresponding rather than identical points on the two retinas. These corresponding points upon which the two images of a point in an object fall act together in the visual perception, so that each separate image covers the other image. In some cases points that do not correspond act together, these points covering each other so that here substitution takes place among the different points of the two retinas. If the regard lines are parallel in the horizontal meridian plane of the two retinas, there is no correspondence in the vertical meridians. This produces unsymmetry in the eyes. When an object is imaged upon corresponding points of the two retinas, the object is seen as a single object, although double in the retinas. By fixing the eyes on a distant object and pointing the finger at the same object, there will be noticed two pictures very transparent of the finger, indicating the double vision of a single object. If the eyes become changed from their primary position, there is a change in the two images. By converging the eyes on an object, the images cast on the central partf of the retinas exactly correspond, so that the vision of the object is single. But the points that lie close to the central spots are also seen to be single, because they represent corresponding points which have been accustomed to act together in binocular vision. All other points away from this

point of visual fixation however give double vison of objects, because they do not fall upon corresponding retinal points. The sum of all the points seen single by the two retinas while the fixation point remains the same represents the horopter. Much speculative discussion has taken place in regard to what it is, but it cannot be determined, because it is a psychic matter and depends on experience, so that it cannot be reduced to mathemathical or physical precision. When the eyes are fixed In the primary position, the horopter is found in a plane perpendicular to the median line of vision. In the case of all points nearer in the primary plane it is found in a line that inclines towards the person observing, the inclination being towards the plane of vision. If the visual plane is turned upward or downward, tne inclination of the horopter increases or decreases In the act of fixing the point of regard in binocular vision of a near object, the visual lines must converge on the object the eyes rotating in this convergence on the axis in opposite directions. In looking on distant objects the visual plane is raised, the lines of regard diverging to the parallel position. The convergence is symmetrical where the two lines of regard turn in at equal angles, the point of regard being fixed in the median visual plane; it is not symmetrical where the point of regard lies outside the median plane, the eyes being turned inward at unequal angles, or the one in and the other out at an acute angle. Accompanying these variations are variations in accommodation, these changes furnishing complex sensations of great importance in the space perceptions. In connection with convergence attention is necessary. If the attention is arrested the two eyes are combined as a single optical apparatus, the sensations aroused by the nervous stimulation of the muscles in connection with convergence forming the basis of feelings of innervation which are cerebrally associated with the initiation of motor impulses originated in the central system. Some claim that there is an equality in the innervation of the two eyes even when the eye movements are unequal. Even so the psychic representation of the different movements has an important bearing on perception.

In these ways the eyes are capable of stereoscopic vision, that is of combining rays of light that furnish two pictures in such a way as to form a single image. If the two eyes were not active such a result would not be possible. From this standpoint binocular vision is the only normal vision and monocular vision may be taken to represent simply a plane of vision, without any perception or at least direct perception of depth. In the normal condition of the eye it is true in the adult by a single eye such stereoscopic vision takes place but this depends upon experience, and in addition to experience certain means are used, such as variations in intensity of light, for the purpose of establishing relations to form the basis of complex sensations. From this standpoint the solidity of objects is

perceived and appreciated in connection with the two eyes, each eye having its own vision of the object, the right eye looking at it more towards the right and the left eye towards the left side. Hence, a series of partial images is perceived and in the fusion of these lies the possibility of the perception of solidity in an object. By the movement of the eyes there is a uniting and separating of a series of double images which enables us to localize objects. Eye movements are not necessary for the adult eyes in connection with stereoscopic vision. This is proved by the fact that a visual field can be constructed by the illumination of an electric spark which does not permit of any movements in the eyes in connection with convergence. But this depends upon past experience associated with the movements of the eyes. In connection with visual perception of the distance of objects and the solidity of objects, it is necessary to have two eyes in motion. In order to have such a perception Hering claims that, "all the lines or points whose images lie, with a given position of the point of regard, in the vertical horopter, appear clearly defined on a surface which is either plane or slightly cylindrical; and all the lines or points lying this side of the vertical horopter and whose images have a crossed disparateness appear in front of this surface; while those lying beyond the horopter and whose images have an uncrossed disparateness appear behind the surface on which whatever lies in the horopter is seen." This law implies that to interpret the images in connection with the eyes when at rest in the perception of distance and solidity there is a past experience of local signs in connection with the eyes in motion and accompanying tactile and muscular sensations. According to the older psychology the perception of distance and solidity depended upon muscular and tactile sensations of the body in conjunction with visual sensations, the former being necessary to such a perception. Newer psychology has demonstrated the possibility of perceiving distance and solidity by sight, in connection with the two eyes in movement.

In addition to the primary visual perception, the vision of distant objects depends upon secondary aids in the construction of the visual field. Such secondary vision is distinguished from primary vision by the added element of discrimination, although even in the immediate, primary perceptual vision there is also the element of judgment. The main distinction is found in the fact that in addition to what is associated with normal binocular vision, there is a judgment of space relations depending on the variations of position in more distant objects. The muscular sensations do not furnish sufficient variation if the objects of vision are over 30 or 40 feet distant from the eyes. Hence, the necessity of subsidiary aids in connection with stereoscopic vision. When the eye is in motion it sweeps over an object in different directions constructing certain lines of limitation in regard to the object, and these lines determine our perception of

distance and solidity. When these lines run counter to previous experience there is confusion in our perception, especially if the lower lines of limitation are obscured. These limiting lines determine the contour of an object and from this standpoint form an element in perception. In addition to this the mathematical angle of vision in connection with an object aids in its perception. This angle gives us the relative distance from the eye and also the size of the object. If the objects are quite remote from the eyes, then the light reflected from them requires to pass through an extended atmosphere, varying the contour of the objects and the color shading; with the result that if the air is clear the objects appear nearer, if dim and hazy more distant. When the shadows are increased, as in the case of a morning or evening light, objects appear to be more remote from vision, the distance being increased. Hence the relation of shadows of objects to one another gives an important aid to visual perception. In the movements of the eye there are called forth certain series of sensations that differ from each other, the number of these and their intensity furnishing a means of determining the size and form of objects. As the sensation series increases our perception of the object gives us an increase in its size; with the increasing intensity of the sensations there is an increase apparently in the size of the object, as it is seen when an object is looked at with tired eyes; as the length of time occupied in the perception increases there is also an increase in the size of the object. In adult vision memory furnishes important data, because when the eye furnishes an indistinct outline of an object memory-pictures fill up the lacunae. Attention to an object makes the object clearer in vision, so that by an effort of will the sweep of the eye can be determined and consequently by choice the mind interprets the data furnished in the visual sensations. Hence experience plays a very important part in perception. Psychic laws govern our perception of visual magnitude, so that our knowledge of visual lines and objects is relative, variations depending on the different positions of the eyes as well as the objects.

Ocular discrimination is more delicate in the case of horizontal than vertical distances, and is more accurate if the distances compared lie in the same direction. Hence, in deciding distances, the local retinal signs in conjunction with memory pictures and variations in muscular sensations depending on accommodation movements are most important. The apparant size of an object is judged from the visual angle of the image and the surface stimulated by the rays of light in connection with the reflection upon the retina. The real size is definitely determined by the standards fixed by the mind in connection with visual and tactile sensations. In connection with these there is the determination of the distance of the object from the eye, the distance being determined in interpreting the real size from the apparent size. Hence apparent and real size with

the distance of the object from the eye form the three necessary elements in the visual perception of an object.

These form the basis of our perceptions of motion in relation to its direction and velocity. There are certain perceptions that are primary, the elements of which cannot be consciously distinguished, whereas other perceptions are secondary, according to which there is consciousness of the elements of perception, the perception itself being inferential from movements of a body or object. In the judgment of motions of an object, some point is fixed, variations by movement from which, form the basis of our perception of motion. Perception of movement in objects may arise in one of two ways, (1) there may be a change in the object's position in the visual field, adjoining retinal areas being stimulated in succession so that all images formed are alike; (2) the same retinal areas may be successively excited, resulting in the production of different images. In all perception of movement the eyes follow the body in motion; if the eyes move so that the point of regard continues fixed on the object, our perception of motion depends on the muscular sensations of the eye movements; if there is a movement of the head or neck or both, there is added the muscular sensations arising from head or neck movements. The perception of bodies in motion implies the perception of bodies at rest and the complex sensations involved in eye movements. These complex sensations involve the construction of images, these images remaining as after images in the mind. In all of these perceptions there is more or less of discrimination and judgment and hence liability to error. In distinc vision we must always have psychic interpretation of complex sensations, hence, the presentations of sense are not exact copies of external objects of sense. These errors of visual perception may arise from mistaken perception of the relation of the double images, depending on whether the two retinal images correspond or not; from the mistaken or obscure perception of lines, surfaces and angles in connection with the object; from the mistaken perception of the different elements found in the visual field; from the liability to synthetize the different sensations in a manner already familiar in connection with memory images, habit or imagination. These may arise from confusion in regard to physiological conditions or psychological principles in connection with the activity of the brain centers. Hence, psychologically complicated processes are involved that are not as yet understood.

Visual space involves the existence of complex sensations of light and color, arranged and synthetized by the mind. This arrangement and syntheis involves the inherent activity of the mind in conjunction with the activity of the body organism. It also implies psychic development especially in connection with experience. Visual perception is developed in connection with the synthetization of sensations which are aroused in

relation to the activity of the organs of vision. The visual field is purely subjective and perception depends on the formation of the retinal image, the formation of the retinal image depending on the reflection of the light rays from an object. Hence, we have the connection established between the mind and the object, the spatial form of all perception being purely psychic, so that the visual field is subjective.

THE TIME ELEMENT IN SENSATION AND PERCEPTION. The sensations not only have their special relations, but also a time element or form. It is not possible either physiologically or psychologically to explain time because even when the order and relations in time of the sensations have been grasped we are unable to interpret the meaning of these relations. Hence, in explaining the order of succession we simply take for granted the idea of succession. Many experiments have been made in this field of psychometrical calculations in connection with delicate instruments to find out the periods of time necessary for nervous and mental processes. No general principles can be laid down aside from the fact that time is essential to all the processes of mind and body and that the amount of time required is determined by the complexity of the object, the nature of the sensation and the condition of the bodily and mental mechanism. The experiments all aim to establish the same point, namely, the amount of time occupied from the period of stimulation in connection with an end organ of sense to a consequent movement. The electrical current is used to determine the exact periods when the stimulation and motion take place. Hence, in the case of a spark of electric light or the sounding of a bell we have the stimulation, and in the giving of a signal, the motion of a finger or a foot or the utterance of a vocal sound we may have the resulting movement. By the repetition of these experiments in connection with the same or different persons a great variety of conditions and circumstances may be found modifying the results. The value of these experiments, dissociated from particular circumstances rests in the indications given of the complex psychic and psycho-physical processes involved. The starting point in all such experiments is the determination of the reaction time, which includes the period elapsing between the stimulation and the resulting movement. This reaction time is found to be simple in the case of a single sensation resulting in a single movement. Even here, however, the period of reaction is complicated by the stimulation of the peripheral organ, the nerve conductivity, the spinal conductivity, co-ordination in the lower part of the brain, transference from the sensory to motor, efferent conduction and liberation of the efferent impulses in motivity. In connection with psychology the most important of these changes is the transformation from the sensory to the motor process in the cerebrum, the time occupied in this process being psycho-phychical. According to Wundt it consists of three elements, (1)

its passage into the conscious field resulting in perception; (2) its passage into the attentive field, resulting in apperception; (3) the stimulation of the will which gives rise to a voluntary impulse in the cerebral organ that produces movement. Time is necessary for each of these factors; and in the time relations we find both physiological and psychic elements or processes, so that the physiological question according to Wundt is to differentiate the perception, apperception and will time-periods and the corresponding physiological and psychic processes involved.

Preliminary to the determination of the psychic periods and fundamental to their existence is the activity of the nervous system. In the nervous system we find different elements, hence, time is necessary not only for the stimulation, but also for the production of definite effects in connection with the stimulation. In regard to latency we do not find the necessity for the same period as in the case of the muscles, but in the case of the neuro-muscular terminal organ certain definite stimuli are required and also definite time relations in these stimuli in order to produce the desired effect, the terminal organs differing on the basis of the special senses. If these time relations are not of a particular kind there is a fusion of the closely related and successive stimuli. Experiments have been made for the different senses to determine the minimum interval of time. For the visual sensations it is found that the interval is greater. It is found that the light sensations are capable of being separated as stimuli at an interval of .025 of a second. In the case of a stimulus falling on the fovea centralis and another on a retinal point 6 mm. distant the minimum interval is about .075 a second. In connection with color perception it is found that very slight variations exist in regard to the minimum interval of time. The recent researches indicate that the time required for color to act on the retina in order to produce a visual sensation is increased in arithmetrical proportion as the light intensity diminishes in geometrical proportion. In the tactile sensations it is found that the minimum interval between two or more sensations differs considerably under different conditions from 500 to 700 being distinguishable as appreciable stimulations per second. In the case of auditory sensations it is found that the number of sounds discernable in a second is about 500, these sensations being capable of separation. The period necessary to distinguish different successive stimulation in the case of the different senses is very difficult to determine. Much depends on the intensity of the sensations themselves and on the senses that are discriminated. In the comparison of sight and tactile sensations the minimum interval between two sensations is placed at .05 of a second; in the case of sensations of sight and undition .06 of a second, and sensation of sight and tactile impressions when the sensation of sight precedes .16. The first determination is the the reaction time, but this is subject to variation in different individuals

and even in the case of the same individual. In connection with experiments the period occupied by the cerebral process is brought as close as possible to zero and in this way the purely mechanical action of the processes is determined. In connection with various experiments it is found that the reaction time varies from about 1-10 to 2-10 of a second. If the stimulus is increased then the reaction time is diminished within certain limits. The same thing is true if, preceding the stimulation there is expectancy of the stimulus, on account of the fact that the cerebral centers are aroused to sensitiveness awaiting the stimulation, so that very prompt action takes place in connection with the response. If, on the other hand, the attention is overstrained, there is an excessive amount of stimulation sufficient to counteract the effect of expectancy. If the nature of the impression expected is known, but intensity is not known there is a tendency to increase the period of reaction. The same thing is true if the psychic condition of inattention exists, because time is required to concentrate attention and this increases the reaction period.

Many attempts have been made experimentally to find out the rapidity of the psychic processes in connection with perception. It is necessary to determine the reaction time in the case of apperception and then deduct from this the simple reaction time. If an image of a special color is permitted to fall on the retina and then the image of a bright object is permitted to fall on the retina after a brief period, if the period intervening is too short then the first perception is lost in the second and no comparison takes place to form apperception. Hence the apperception time depends on the complicated or simple character of the actions involved. This does not enable us to determine the time of apperception because no account is taken of the time occupied during the process of nerve conduction.

Other experimenters have tried to find out the time occupied between the stimulation and the consciousness of the stimulation in connection with a definite action or determination not to act. These investigators took it for granted that the will time was not involved, but that by finding out the entire reaction time and deducting from it the simple reaction time, the balance represented the apperception time. Hence, in connection with the apperception of sound it was found that .015 to .070 of a second was necessaary. It must be remembered, however, that we are simply finding out or trying to find out the time necessary to enable us to connect a sensation with a definite movement on the basis of habit. On this basis the psychic process becomes simply apperception with the discriminative process eliminated. This eliminates the will time altogether and to reach a decision in regard to reaction there is necessary the exercise of volition. Hence, another method is suggested by Friedrich. Preintimation is given of stimulation in connection with a number

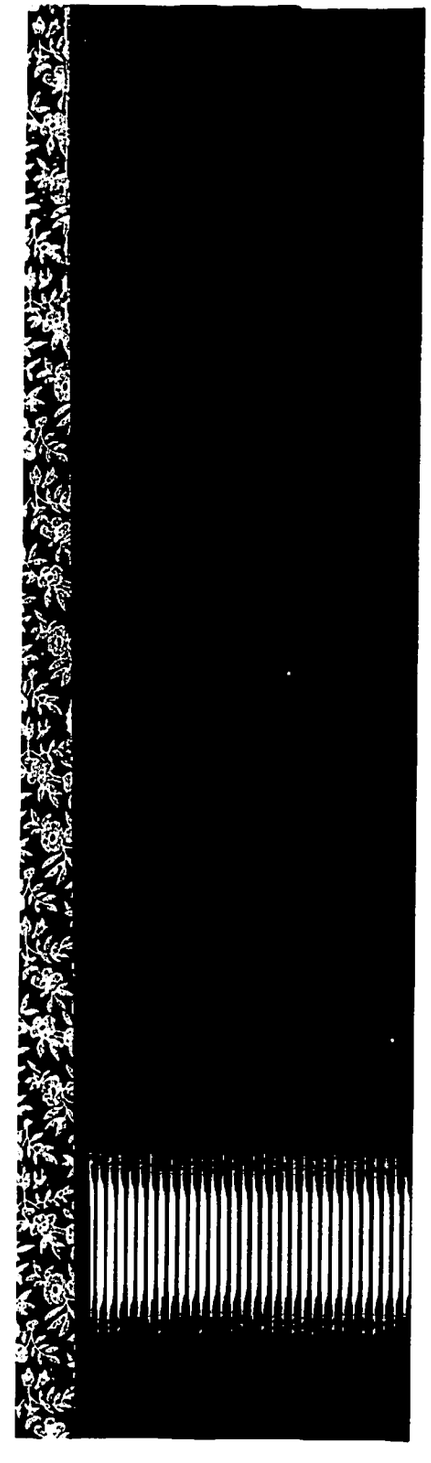
of colors without the definite knowledge of what color is to be expected. In this case the determination of the color is a matter for individual judgment and the individual is required to signal the moment of apperception. When the complete reaction time is obtained the simple reaction time is deducted and the balance is said to represent apperception time. A mean apperception time is deduced from a number of experiments in connection with different colors varying from .047 to .086 of a second. Thus we find that the apperception time varies with the conditions involved in the simple or complex circumstances the variation of time being from .03 to .08 of a second. In order to distinguish the intensity associated with different sensations a longer process is necessary. If, for example, reaction is required in the case of the more powerful of two tactile sensations, time is required to discriminate intensity and time to determine the reaction. In connection with the finding out of apperception time we must consider whether the element of expectancy is associated with the action and to what extent this expectancy exists, for if the attention is divided between the expectation of a particular sensation and the readiness to reach them there is a difference in the time involved. In the case of several objects there is also necessary a longer time than in the case of a single object. This depends on habits in association and comparison of a number of objects.

According to Donders the time occupied by the will in connection with the solution of a complicated problem is shorter than that involved in the apperception period. Having determined the simple reaction time Merkel inquires, what length of time is necessary to liberate a voluntary impulse. According to him following apperception there is a will period whether longer or shorter. First of all the simple reaction time is determined; secondly the time required to compare two impressions and give the result of the comparison is found; and lastly there is a determination of the time of reaction in the case of the exercise of will involving choice in regard to reaction and the nature of the reaction. From these experiments it was found in the case of ten persons that the reaction time in the case of choice of two alternative courses was .024 to .015 of a second. By the increase of the alternative courses there is an increase of the time of reaction. It is found that there is an inceasedepending upon the individual characteristics, these increasing as the choice is increased to five and decreased from five to ten.

We are not able on the basis of existing experimental knowledge to speak of the psycho-physiological time with any degree of definiteness or to analyze its elements. According to Wundt there is an appreciable period occupied in apperception and willing; but according to recent experiments it seems possible so to arrange conditions as to make the entire period including apperception and will time very little if any longer than the

simple reaction time. This means that habit or practice can appreciably lessen the psycho-physiological time, as we become able to perform the most complicated and discriminating movements without almost any cerebral deliberation. According to Donders apperception time is almost equal to will-time, the former being represented by .039 and the latter .036 of a second. This indicates that the discriminative and voluntary actions occupy about the same periods of time, but in cases of the succession of discriminative and voluntary actions the former are capable of very great acceleration over the latter. Attempts have been made to compare our subjective idea of time formed from the succession of subjective processes with the objective time standards. It has been found that the mind is able to appreciate in connection with a number of reaction intervals as small as one hundredth part of a second. The rapidity with which the impressions pass into consciousness, however, does not exactly correspond with the rate of external stimulation. In connection with sound for example, Wundt has proved, that in hearing a sound it is almost always heard either before or after the physical sound takes place. If there is a condition of mental expectancy the sound seems to be heard before it occurs. This is called the positive and negative lengthening or displacement. Great variation is found in the discrimination of minute intervals depending on the length of the intervals. It is found for example that minute differences are appreciated most accurately at intervals of seven or eight tenths of a second. The sensitiveness is diminished as the intervals become longer or shorter, so that at longer intervals the period is considered as too short and shorter intervals as too long. In the case of longer periods no definite principle can be laid down as individual peculiarities seem to form the necessary condition of such variations. The most accurate way of considering these variations is in connection with sensations in succession whose intervals are definite and can be definitely determined in connection with the chronoscope so as to be accurately counted. It is found that two clicks can be appreciated if the interval is .0523 of a second, while three or four can be appreciated if the interval is .0895. This seems to indicate that when the period between the sensations falls below the briefest period of reaction, some of the sensations will not enter consciousness.

In connection with the more complicated mental actions involving the association of ideas and memory in reproducing mental pictures it is found that these processes form the fundamental basis of all such discrimination as is involved in apperception. Time to necessary for the process of association, the association depending upon habitual connection or else natural association of objects on the basis of internal relations of quality or property. In the apprehension of single words it is found that the reaction time varies from .05 to .17 of a second. The association time



varies according to the nature of the association involved, the order in which the ideas are presented and the amount of mental action preceding the association. Very great differences are found in different individuals these depending on the time that is required for the exercise of memory, for completing the chain of association, etc. In regard to the number of impressions that may be found in the conscious field of perception at the same time, some claim that only a single object can be before the mind at any moment of time, while others regard it as certain on account of the relativity of knowledge that at least two impressions must be in consciousness in order to the possession of such a knowledge. Experiments have been made to determine how many successive impressions of sound may be formed into a single picture so as to form a distinct series. It is found that all states of consciousness are relative and that the elements in these states are relative, so that a close and inseparable relation exists among the different elements. It is possible thus to name isolated letters or words if a number of letters or words occupy the field of consciousness at the same time. It has been supposed that the unity of the mind precludes it from having before it at the same time more than a single object. Experience however proves that the mind can perceive a number of objects and even give attention to those objects at the same time. Different persons are capable of attending to a varying number of objects, the most favorable circumstances permitting of attention to about 10 or 15 impressions in the conscious field.

In connection with all these experiments in regard to time relations exercise increases the capacity and exhaustion diminishes the capacity of the mind rapidly to perceive and will. It has been found that exercise lessens the will time in the choice between two alternative motions one third. In the apperception time it is found that exercise diminishes the time even after the simple reaction time has entirely ceased. If the nervous system is exhausted the reaction time is increased. In the case of insanity and kindred conditions there is involved an increase in the reaction time. Alcohol is found to produce variations in the reaction time but these are not constant. The use of coffee is found generally to decrease the reaction time, indicating the beneficial effect it has upon strengthening and intensifying of the psychic processes. The results we have observed indicate that physiology and psychology are not able to explain our time relations. It is possible to describe the order of our ideas and their relations from the standpoint of time but it is impossible to explain what is meant by succession such as is found at the basis of time. Time is necessary for any and every sensation, for every act of will, so that in sensation and resulting motion we have a definite succession. Succession it is said is based upon association but how to classify the associations is still a problem unsettled psychologically.

THE LOWER AND HIGHER PSYCHIC FUNCTIONS. Here we are passing from the purely experimental stage of psychology into the more dogmatic field. In regard to the physical foundation of the higher psychic functions and the mental development opinion seems to be the principal guide. In regard to the psychology of feeling very little of a definite character is at present known because the phenomena of feeling are very changeable, depending on such variable changes in connection with the central nervous mechanism. The attempt to investigate feeling from the standpoint of self-conciousness and the attempt to condition the feelings by physiological processes do not yield any satsfactory results. Many very different opinions have been formulated in regard to the nature of feeling. The word feeling has been used in a very indifferent sense. In some cases it is used in the general sense of feeling as localized in conection with the skin, in regard to contact, pressure or temperature; at other times it is applied to complicated sensations, involving pleasure and pain, religious emotions and even moral duty. The theories formulated in regard to feelings may be classified as threefold, one laying the principal stress upon the original and primary nature of feeling, on account of which feeling is not definable, the attempt to define feeling resulting in idealizing it; the other theories regard feeling as derivative in character, the derivation being either purely psychic or purely physiological. These latter theories only differ in the point of view from which the derivative character of feeling is looked at, both of them being essentially ideal. From the physiological standpoint feeling is regarded as the consciousness of certain conditions associated with the nervous mechanism, In the activity of the different nerve elements we undoubtedly find the physical basis of many of the pleasurable and painful feelings, but this does not imply that all of the feelings can be reduced to physiological conditions. Lotze first attempted to distinguish feeling on the basis of psychic conditions involving pleasure or pain from those complex sensations which arise in connection with the indifferent elements of perception. The basis of pleasurable feeling is the agreement and of painful feeling the disagreement between the results of the stimulus and some conditions associated with the expression of physical or psychic life. According to him feeling represents "the measure of the partial and momentary concord between the effect of the stimulus and the conditions of vital activity." This principle however connot be applied in explanation of feelings because they cannot be explained as derived forms of consciousness.

In the case of any form of stimulation where the stimulus is excessive there results a painful feeling. This excessive stimulation involves something that is in opposition to the vital processes. This does not mean that the amount of danger to the organism can be measured by the degree of painful feeling. In the case of some persons any intensification

of the smell, taste or auditory sensations result in a disagreeable feeling. In the case of the higher class of disagreeable sensations associated with intellectual, moral or aesthetical feelings we cannot analyze these sensations into the consciousness of nervous stimulation in excess of what is advantageous to the vital activity, In some cases where this kind of stimulation is excessive it is pleasurable rather than painful, this being determined from a purely subjective standpoint by habit, association or will. In connection with sensation we are able to determine the relation of pleasure or pain to the degree of nerve stimulation. If the sensations are not excessive they are usually agreeable; after the sensations become painful on account of excessive stimulation we find the disagreeable feeling. The degree of disagreeable feeling does not correspond with the degree of sensation; on this principle Wundt claims that a felling becomes pleasurable to the maximum degree as the sensation ceases to increase in proportion to the increase of stimulation: If painful feeling depends on the consciousness of over stimulation of the nervous system, then there can be no painful feeling independent of the intensity of stimulation. This cannot be the case because to some persons all degrees of stimulation involve painful feelings. According to Bain pleasurable states depend on an increase and painful states on a decrease of the vital processes. According to Allen this theory should be modified to the extent that pleasure is associated with the healthy vitality of the body or its organs supplied by sensory nerves, provided the functional activity is limited to the recuperative capacity of the system and its organs. Here pleasure will depend on the normal activity, but necessarily simply vital, found in connection with the end organs of sense. Here there is a limit, because we cannot say that the slightest disagreeable feeling involves an intensity that is beyond the ordinary power of repair. Pain in a large number of cases is the signal of excessive stimulation but this does not cover all cases; for we are unable definitely to determine what amount of stimulation is necessary for and compatible with normal function.

Distinguished from and in opposition to the physiological school we find the school of psychic feelings. Nahlowsky distinguished between feeling and sensation. When sensations are pleasant or disagreeable they do not constitute or give us feelings but depend upon the effect of the stimulation upon the vital organic functions. Pain represents a sensation, not a feeling. Feelings represent those conditions that arise from the simultaneous existence of certain ideas in the mind; if these ideas harmonize, the feeling is agreeable; if they do not harmonize the feeling is disagreeable. Thus feelings are derivative, depending on ideas, feeling being the direct consciousness of the raising or depressing of individual psychic action among the mental ideas. Hence sympathy and love are feelings as distinguished from the purely physiological sensations of fatigue, hunger, thirst. In this sense we find the Herbartian idea of feeling that of the "immediate consciousness of the rising and falling of one's power of ideating." It is thus derivative, depending on the reciprocal relation of ideas; as distinguished from the consciousness of separate ideas, it involves the correlation of ideas to the extent of furthering ideation in case the feeling is pleasant and hindering ideation if it is disagreeable. This theory falls short of explaining agreeable and disagreeable sensations, and for this reason is unsatisfactory. In addition to this, feeling cannot be regarded as a derived activity. In the most primitive forms of child life feeling seems to be inseparably associated with the organism. Some feelings, such as desire and self-feeling are coeval with self-consciousness. The two theories therefore that we have considered, the one physiologicol and the other psychic, represent the two conditions, physiological and psychic, under which feelings exist, but they do not even when combined into one theory give us a satisfactory explanation of feeling.

As distinguished from these theories, the true theory is that feeling is primary and not derivative, representing a conscious activity of the mind. It is not capable of definition, because knowledge of feeling can be gained only from feeling itself, and as feeling is associated with all psychic activity, both from the standpoint of sensation and perception, it is complicated by its association with the psychic processes. Undoubtedly many of the feelings depend on the stimulation of nerve elements. We find special nerve elements that need to be stimulated to produce pain and the difference in the painful feelings depends on the stimulation. What produces the difference in the tone of the feeling in pleasure or pain we are unable to determine definitely. As we have seen there is not considered to be a special pain mechanism, the same mechanism that gives us the pressure and temperature sensations, under excessive stimulation, giving painful sensations. But recent researches seem to indicate that as pressure and temperature are quite distinct in the terminal organs, and as in some cases tactile sensation is not lost when the pain sensations are lost, there is a physiological distinction between the ordinary sensations and the sensations of pain. This seems to be closely related to the fact that feeling is primary rather than secondary. It is very difficult, if not impossible, to classify the feelings. In order that the feelings may be judged in consciousness there must be differences in the feelings themselves. There are so many variations in the phenomena and these are so closely inter-related to the physiological and psychic phenomena that their analysis is very difficult. In dividing feelings on the basis of pleasure and pain we require to settle the question of indifferent feelings; if we admit such indifferent feelings then we must determine the dividing line, while if we deny the existence of indifferent feelings, then we must recognize

almost numberless variations in the pleasure and pain feelings. These differences in feelings cannot be absolutely determined, because one shades into the other. It is difficult, for example, to say that purely ethical feelings are absolutely separated from physical conditions so that we are unable to state the difference between these two classes.

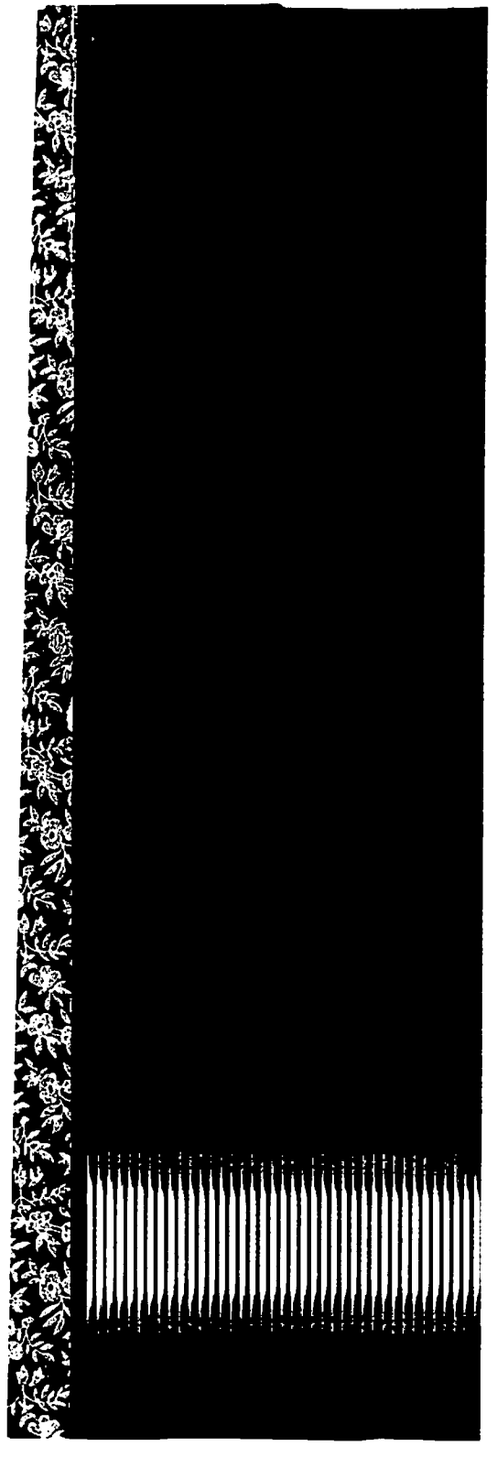
Feelings can be classified only, if at all, in connection with other psychic activities. According to the physiological theory feelings have been classified into (1) those associated with sensation, and (2) aesthetical feelings, if the end organs are, or are not, directly associated with vital functions. According to the psychic theory, feelings have been divided into (1) formal, depending on the form of the representation of ideas; and (2) material, depending on the content of the ideas. According to the theory of feeling as underived the feelings may best be classified on the basis of the psychic activities which they accompany. It is from this standpoint that we get the four-fold classification of feeling commonly given (1) sensuous, depending on sensations; (2) aesthetic, depending on the conscious forms associated with perception and imagination; (3) intellectual, depending on the higher thinking functions; and (4) moral, depending on the volition and desire. Depending on and arising from complex combinations of these simpler feelings we find (5) higher feelings depending on the complicated social relationships.

Among the different feelings we find variations depending on tone, rhythm, matter and intensity. Feelings are acknowledged by all to be either pleasant or painful and from this standpoint it is claimed that they can be classified in the pleasure-pain series, taking an ideal point to represent the point of indifference. So far as consciousness seems to indicate there are no feelings which do not possess in some degree the element of agreeable or disagreeable, so that the tone would represent some shading of these two qualities. Feelings have time relations like all other psychic phenomena and hence have rhythm, the rhythmic movement being determined by variations in the nerve conditions or the ideational elements. Some claim that feelings cannot be distinguished on the basis of content, as all feelings are determined by the quantity of pleasure or pain. This, however, is contradicted by our conscious experience. Feelings differ in quality and these qualitative differences depend on differences in the body organism or in the ideational elements of the mind, forming the basis of the differences in content. Feelings differ in strength, the strength of feeling often passing through rhythmic variations, the differences in strength being determined by the condition of the nervous mechanism and of the terminal organs, and the ideas of the mind.

(1) Some feelings are so closely connected with sensations that it is difficult to separate them. Yet sensations and feelings are distinct. There must be a stimulation of the terminal organ in order to produce a

sensation, the sensations representing the factors of perception. Feelings are in all probability different from sensations, at least to the extent of being pleasurable and painful, although it is possible some feelings may be neither characteristically agreeable nor disagreeable. There are constantly impulses passing from the peripheral parts of the body to the cerebral centers, some being too weak to arouse or pass into consciouness, while others excite consciousness; both of these classes of impulses give rise to feelings which are associated with the psychic life. It is difficult to tell where the sensuous feelings pass into the aesthetic feelings. The distinctive aesthetic feeling depends, however, on rising ourselves above the purely sensation basis, the true aesthetic feelings arising in connection with perception and imagination. These purely aesthetic feelings originate in connection with the application of space and time relations to the purely sensuous feelings. This takes place in connection with audition and vision. Audition represents the chief sense in connection with which the sensation feelings become aesthetic from the standpoint of time, and vision the chief sense in connection with which they become aesthetic from the standpoint of space. In connection with feelings there is the blending of certain intellectual elements, these elements determining the character of the feelings. Feeling is closely connected with all psychic activity, pleasure being associated with time relations of ideas that are not excessive and do not involve any strain upon attention; while painful feelings are associated with excessively slow or rapid mental activity involving a psychic strain. Feelings are largely dependent upon association, all the forms of feeling, sensuous, intellectual and aesthetical being governed by association. It is here that we are able to account for complex individual and natural eccentricities of feeling, as well as the higher feelings.

When feelings are accompanied by an increased intensity of consciousness they are associated with organic and functional body changes, these changes reacting on the feelings and modifiying the feelings to such an extent that the feelings are regulated by body changes. Affections and emotions represent such feelings subjected to intensification under the action and reaction of organic changes; passions represent states of feeling which are entirely dependent on some excited or abnormal condition of the organism or its parts. All the emotions and passions arise in impulse, experience associating the impulses with perception and psychic activity, this forming the basis of emotion or passion. These impulses are either those of attraction or repulsion, these two varieties of instinctive impulse forming the basis of the opposite emotions and passions. All the emotions are dependent on some sudden variation in the time relation of the ideas, involving an interference with the even and steady flow of ideas, and resulting in that abruptness that characterizes the emotions



and passions. This disturbance reacts on the psychic activity and introduces an element of interference into the conscious life, indicating a molecular disturbance of the body organism, an interference with the body processes and excitation of the sensory, motor and senso-ideo-motor centers of the brain. The emotions have been classified as they affect thedifferent parts of the organism, for example, fear or shame upon the blood circulation; anxiety and strong hatred affecting the secretory and nutritional actions. As a complex of these feelings and emotions we find mental moods when the general character of feeling, sensation and perception affects the psychic life. Moods are determined by the abnormal sensations arising from different parts of the organism, these being accentuated by cerebral action in connection with an abnormal train of ideas, abnormal feelings, etc.

(2) Closely connected with feelings are the feelings of innervation associated with the body position and the attitude of the different parts of the organism to the body and to one another. These feelings depend on development, arising primarily from complex sensations involving the muscles, tendons, joints, skin, etc. Thus the feelings associated with the body position seem to arise peripherally, being rather mixed sensations than feelings, localized under the strong influence of perception and association. In body movements we find the influence of conscious states in automatic or voluntary movements and the absence of consciousness in purely reflex movements. There is a constant tendency either into or away from consciousness, indicating that the peripheral processes which give rise to these movements either tend to pass into cerebral activities or tend to fall away from cerebral activities, There is thus a close relation between these movements and both feeling and ideation. The influence of feeling and ideation may be found in connection with the modification of innervation, emotion or ideation reacting upon the muscles and nerves through the cerebral centers. The same effect is found in connection with the association of sensations that are analogous, the combination of such sensations producing intensification of impulse to movements. By development certain particular movements come to be associated with special perceptions, these being illustrated perhaps best in the gesticulations and movements employed by dumb persons as signs of ideas.

In regard to the higher psychic functions very little satisfactory work has been done from the standpoint of psycho-physiology. In these fields the introspective method has yielded the best results, but when we try to apply the results to the brain processes we come to a standstill. We must accept the phenomena of consciousness on the evidence of consciousness itself, attempting thereafter to find a physiological basis for these facts in the cerebral hemispheres. Here the brain processes cannot be observed and therefore nothing definite can be formulated regarding them. In entering the higher psychic field we first meet with consciousness. We cannot define it but take it to represent the existence of a psychic life, which is represented by different particular states of consciousness. Hence, consciousness is not general but particular as applicable at a particular moment and in a particular state of the mental life. From the standpoint consciousness represents the condition implied in all our inner experience. When we are conscious we are conscious of possessing a certain form of psychic life and this must be distinguished from our consciousness of self-existence in which the conscious state is attributed to some existing ego. Thus self-consciousness represents a form of consciousness in which ihe ego bears the prominent place. The cerebral hemispheres are regarded as the seat of consciousness, but this simply implies that the cerebrum represents the center of those molecular and nervous processes which are associated with the phenomena of consciousness, so that changes taking place external to the brain become conscious to the brain centers by being represented in the brain changes themselves. Hence, the conditions of consciousness are associated with the blood supply to the brain and the normal activity of the brain substance.

Memory represents a psychic function which it is claimed has three different aspects, retention, reproduction and recognition. Retention and reproduction may be associated with recognition in order that they may be recognized as psychic processes. Retention does not represent a psychic activity, but rather depends upon either a brain movement or movements, a cerebral impression or a tendency to movement or impression in connection with the brain. It is difficult to distinguish between after images in the case of a sensory impression and the memory picture of this sensory impression. We have seen that some images of sensory impressions persist for a long time after the cessation of the impressions themselves. The nerve cells connected with psychic processes become permanently modified as a result of stimulation; this is the basis of all adaptations found in connection with the development of the complex neural mechanism. If we take it that this complex neural mechanism is subject at all times to this general biological principle, then as this modification becomes perpetuated under the influence of nutrition, molecular changes and heredity, we find the basis of retention in these modifications of the nervous system. In regard to the reproductive aspect of memory we must presume the existence of association in connection with the perpetuation of neural modifications. At the same time we must remember that all the molecular changes are not perpetuated, hence the forgetfulness of certain phenomena involves the dissolution of certain associations that might have been held fast. Memory cannot be localized in any one organ or part of an organ, like the cerebral areas. Hence Newman says,

"there are a hundred memories," each psychical function having its own definite association. Attempts have been made to formulate and explain the laws of association at the basis of the memory power of reproduction. Some claim that all laws of association may be reduced to a single principle like the laws of contiguity. From a physiological standpoint there is no foundation for such a supposition, because the mental processes are multiform and no single iron-clad principle regulates all these processes.

In regard to the will much discussion has taken place from a psychological and psycho-physiological standpoint as to its nature and action. Here we are apt to fall into the ethical and theological controversies. Will is used in the sense in which it is applied to the psychic phenomena which imply the conscious activity involved in body movement or mental action. Here the physiological basis is to be sought in the automatic action of the nerve cells in the central system, in virtue of which molecular changes are originated independent of the impulses derived from external stimulation. This automatic power is inherent in some sense in the cerebral centers, all of these centers capable of originating molecular changes having this independent will power. While the power of origination is is general, its exercise is particular. Hence, volition takes place only in connection with definite movements or definite mental activities. Hence the physiological basis of volition is found in the activity of these cerebral centers which are concerned in ideational activity. From the standpoint of psycho-physiology there is will of different degrees of freedom. There are acts of will in which there is the absence of consciousness of freedom of choice; on the other hand there are acts of will involving deliberation, freedom of choice and determination to act in a particular way. From this standpoint freedom of will depends on development, the physical basis of which is a brain passing through the different stages of evolution, capable of adapting itself to the developing conscious life and also capable of manifesting its activity in varying shades of reflex and automatic actions. Hence the act of will involves the blending of a number of physiological processes under the direction of the cerebral centers. All the lower elements, including sensation, perception, feeling, attention and memory contributing to and enforcing that choice which is essentially at the basis of will. Choice represents that element of the psychic activity without which will would not be possible, that climax of mental influence exerted over the body. We find certain conscious states determined by the will becoming the basis of certain molecular variations in the higher cerebral centers and here the physiological basis of volition is to be found. Choice is accompanied by the feeling that a strain has been removed, indicating the presence of conflict in the nerve commotions and the over-mastery of one of these. The choice represents something psychic that adjusts certain physiological conditions of the organism.

In regard to the nature of the mind it is difficult to state anything definite from a purely psycho-physiological standpoint. Mental reality and the nature of this psychic entity belong to metaphysics rather than to psychology. And yet in summing up the results of our investigations it is necessary to take some definite stand in regard to mental reality. Materialism denies that the mental phenomena can be attributed to a really existing mind, the material nerve substance forming the only basis of reality in connection with mental phenomena. The mental phenomena according to this represent phenomena of the brain substance. Here, however, we are attributing phenomena that are psychic to a physical substance and for this reason among others we are drawing a false conclusion. We must remember that although conscious states are associated with molecular changes in the brain substance we cannot identify these. Sensation, perception and ideation states are entirely different from chemical or physical changes in the nerve substance. Yet at the basis of all the psychic phenomena there are physiological changes. This does not mean that the mind is the product of brain changes, although the mental phenomena are in some way associated with variations in the centers and nerve fibers found in the nervous mechanism. All the changes in the centers depend upon previously existing conditions in those centers and in the neural and neuro-muscular parts of the body organism, the mental variations depending upon these changes and also to a certain extent at least governing these changes. Hence from a physiological standpoint we must take account of the existence and activity of a real mind, even although its existence requires to be demonstrated by metaphysics. The reality of the mind is undoubted. Materialism claims that the mind represents simply a series of phenomena associated with and produced by changes in the cerebral centers. It is true that all psychic life is based upon senso-motor activities, but these activities represent psychic as well as physiological changes. From the psychic standpoint it represents those elements of sensation, perception, apperception, etc., associated with all our knowledge and activity. There is as we have seen a close correlation between the physiological and the psychic activities, the nature, intensity and coloring of the psychic being determined by the nature, intensity and coloring of the physiological. But the correlations do not exhaust the description of the mind. We find mental phenomena that cannot be classed under the head of senso-motor activities, because these are purely psychic activities. Perception represents a knowledge of things and complex sensations do not give us a correct idea of things. To account for this there must be primarily a knowledge of the self and a recognition of the subjective activity of the mind. What applies to perception applies equally to the entire psychic life. Hence behind all the activities both psychic and physiological lies

the mind. It is true that in all science observation is the method of investigation, but in order to carry out this method there must be psychic activity.

In connection with the real mind there is a real mental development. It does not represent simply a series of complicated sensations, becoming more complex as the process of development progresses. There is a plan in the development and this plan has its history. In every form of development, even the physical, there are underlying psychic factors, which cannot be regarded as simply atoms of existence. The field of consciousness is being enlarged in connection with development, and every newly developed field of consciousness exists in relation to that self-consciousness that underlies all the states of consciousness. Hence development applied to mind is different from development applied to the organism or its organs, because we are dealing with psychic factors that cannot be limited by purely material progress. Hence the mental development represents the progressive manifestation of the inner self in consciousness, this inner self unfolding itself in the physiological activities associated with the body organism. This mental reality underlies all attempts to gain knowledge of the external world. Associated with this attempt to gain knowledge is the synthetizing function of the mind in virtue of which the mind unites all phenomena into a synthetic whole, perception and apperception unifying in this way the numberless phenomena of the sensitive life. This unit being depends upon self-consciousness and memory, underlying which we find the knowledge of self, this self being associated with differing states of consciousness, all of these states being unified in the self. If this unity is lost, then, memory, self-consciousness and reason no longer possess the power of self-development. Whatever unity is imparted to the external world is the subjective unity of the mind.

In regard to the origin, ultimate nature and final destiny of the mind we cannot enter into the discussion of these topics because physiological psychology throws no light upon them. It is evidently non-material and real, but whether this involves the further fact that mind is spiritual and to what extent it is purely spiritual the physiological and psychic processes give us no light.