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## Original Articles.

### METHODS OF RESEARCH AND IMPORTANCE OF CELLULAR PSYCHOLOGY.

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#### *What is a cell?*

All living things are either unicellular organisms, or coherent, functionally connected, groups of cells. A cell is the simplest known form of a living thing, and it consists of a small mass of matter a fraction of a millimetre in diameter, having a denser central portion called a nucleus, which is surrounded by a larger and more motile and more fluid mass of cytoplasm, whose surface by contact with the medium of the environment has acquired a more or less changed chemical and physical character so as to constitute for the cytoplasm an enveloping membrane or cell-wall. The cell is not such a simple, structureless affair as was formerly supposed—it is indeed astonishingly complex. The cytoplasm has a foam-like structure, which has been pretty successfully imitated by Bütschli's microscopic foams made out of emulsions of oil and alkaline waters, and the nucleus, which is the centre for all reproductive changes, is wonderfully complex. Different methods of staining reveal not only a variety of tissues in both the nucleus and cytoplasm, but a variety of chemical compounds, which vary with the degree of development and specialization which the cell has attained. The typical cell consists of a nucleus surrounded by cytoplasm, and neither of these parts can live

independent of the other, but the true character of the cell seems to be mostly centered within the nucleus. All cells must live within a liquid medium from which to absorb food.

In its simplest form, the cell, as the lowest known living creature, consists of a mass of protoplasm capable of assimilating foods, of moving, of responding to stimuli, and of growing and reproducing its kind. It consists of many organic compounds between which survival of the fittest has taken place, and the simplest organic unit is doubtless some small portion (somaucle) of the cell-mass, and there may be many kinds of somaucle. But the simplest form of this distinction between inorganic and organic or living matter is that of *automatic metabolism*, whereby foods are absorbed at the surface of the cytoplasm and are oxidized in such a manner as to create energy and supply new tissue, the waste products being at first absorbed or dissolved by the surrounding liquid medium, and in later evolutionary stages disposed of through special channels. The ability to maintain a temperature slightly above that of the surrounding medium, and to renew its substance and add thereto interstitially, and also to store up a surplus quantity of energy for movement of its parts is characteristic of living bodies as distinguished from inanimate bodies; this living or vital capacity is an *adaptive* functioning by which the organism adjusts its internal movements and relations to external movements and relations, which is a mental characteristic. The protoplasmic mass *feels* an appropriate stimulus and responsively *adapts* itself to the new condition—and this *feeling* as well as the *responson*

is a quality of mind. For these and many other reasons the distinction between lifeless and living matter is, that in living matter there exists a functioning of the kind known as mental, and hence its vital quality is a mentative phenomenon. A cell is a *living* creature.

*Where should psychologic studies begin?*

The study of living things must therefore begin with cellular organisms, and the psychology of the cell constitutes the basis of all higher psychology; just as by multiplication the cells up-build the mass of the higher vertebrate, so by concomitant division of labor the combined mentative activities of the cells constitute the mental life of the multi-cellular community composing an animal. Cells combine into groups of cells, and these groups in their turn into larger groups amongst which division of labor (mental activity) has taken place—some groups supplying soluble nutriment to the interior portions of the mass, and other groups removing the debris, and still other groups attending to movement, or to responson to certain stimuli, and finally, a number of such groups combine under the control of a ganglion. Various ganglia combine into an "organ," and the ganglia of various organs at length become united by a common nerve-tract, and so on, each such stage of development representing a higher degree of mind-embodiment. It is evident that the degree of mind-embodied by the organism is the true taxonomic basis in biology, and that whilst morphology and genetic relationships will continue to constitute important data in the determination of the degree of mind achieved by the organism, it is evident that a direct study of the mental phenomena of the organism will in the future form the most important factor in classification and nomenclature. The coming biologic taxonomy will be psychologic! And so will its terminology! A living creature is a mind-organism.

In the human organism all lower groups of ganglionated organs are united into a

common "person" by the cerebral cortical activities, or more properly speaking, by the complexes of organic and cosmic functionings localized therein. Lower ganglia than that of the cerebrum in the human individual have their own mentative activities and memories necessary for the performance of their specific functions in the economy of the organism, but their own consciousness and mental life constitute the sub-conscious processes out of which arise the consciousnesses of waking life. The mind of a man is the result of multitudinous mentations of which he never becomes directly aware, and these mentations are the combined adaptive functionings of myriads of cells, and the functioning of each cell is the product of its own individual activities *plus* the interaction of cosmos of which that cell is a functional part.

*The cell and cosmos.*

A cell is not only a part of the universe and a direct product of the activities of the universe, but is itself an independent source of reactions with the universe; it is one of the factors which must be considered in computing the reactions taking place within the universe. It is a *material* part of the universe, and as such exerts its own mechanical series of reactions upon cosmos. It is *dynamically* part of the total energy of cosmos, and as a coherent system of motions exerts its own modifications upon the total system of motions in space and time. But by means of its capacity to adaptively respond to stimuli it introduces into the universe a system of activities modified by mentation. Through mentation the cell commences to be regulated by conditions of truth more general than the sum of its individual experiences, and thus the cell lays hold upon the universal, and not merely local possibilities of cosmos. The cell is a *very little* affair in size and can affect the universe but little, but the universe is *very big* and can exert an infinite action upon the cell through the mind which it has commenced to embody.

*A bio-psychologic method of studying cell-mentation.*

The study of cellular psychology belongs partly to the domain of biologic psychology. By experimentally varying the environments of cells these lowly creatures are caused to exhibit different adaptive activities or mentations, and by these means we can correlate given mentations of cells with given environmental conditions and given structural conditions of the cell. By selective propagation these organisms can be rapidly evolved to higher forms or retrogressed to lower forms, and as new structures and morphologies arise the accompanying mentations can be studied and correlated with given cellular structures. By these means we study environment and cell-structure to determine the nature of their corresponding mentations: we vary the factor of structure and environment (which includes not merely the immediate neighborhood, but cosmos) to determine what changes take place in the factor of mentation; and we thus discover the causal relation between organic structure in reaction with the environment and the mentative phenomena which arise, without fully attempting to define what those mental phenomena are, except to state that the mentation requires as an essential condition certain structures on the part of the organism (the mentations varying with the structures), and certain interactions with the cosmic environment (the mentations varying with the environmental conditions. As to what else the mind may be, biological psychology does not reveal to us—this science does not deny that mind *may* be much else—it simply asserts that whatever else the mind may be, it at least consists of such phenomena as those mentioned.

*When this method was first used.*

The variation of the environment of cellular organisms, and the study of the concomitant mentations as a *method of psychologic* research was, I believe, first invented by myself some years ago (in 1882), and first publicly taught about 1890.

I do not mean that I was the first one to experiment on organisms by making changes in the environment, but that I was the first to use this as a *method of psychologic* research by systematically varying environmental conditions, and systematically recording the cellular activities minutely as arising out of each definite environmental change so as to correlate mentative changes with environmental changes in a given organism. It is a fruitful field, and demands much further investigation by students specially trained for these particular lines of work and thought.

*Another bio-psychologic method.*

At the same date I first invented and taught, as a method of psychologic research, the experimental variation of organic structures by rapid artificial evolution by means of a systematically regulated selective propagation. I was not the first to apply selective propagation to animals and plants and cells, but, so far as I know, I was first to apply selective propagation to the making, or experimental varying, of organic structures as a *method of psychologic research* so as to determine what mentative phenomena belong to varied organic structures and morphologies. Cells subjected to a given environmental condition, let us say a gradually augmented cold or heat or series of concussion, are slowly modified in their chemical constitution and morphology and size. By augmenting the intensity of the concussions or the heat gradually, so as to kill off all the individuals of a large colony of cells except one or two, we leave those best adapted to renew the colony. As soon as a large colony of millions of cells has again been acquired they are again subjected to a gradually increased intensity of concussion or temperature or chemical solution, until all are killed off except one or two most capable of withstanding the condition. If the unfavorable condition of environment were not *gradually* augmented all of the cells might be killed and the experiment lost, or some might survive which where not best ad-

apted to the conditions owing to the quickness of the change, and in that case would reproduce their kind and render more slow the evolution of the organism. As new creatures thus arise, with new chemical constituents in the cell-mass and new structures, the accompanying mentations or adaptive activities are carefully recorded and correlated with the structures. It does not require mutilations to make new structures by this method. Low organisms can thus be rapidly evolved to higher organisms with new and more complex structures, or retrogressed to lower organisms with less complexity of structure; and as new structures arise or pass away, it is interesting to note what concomitant mentations also arise or pass away. By this method of research much that is new has been discovered regarding the relation between structure and mentation, and much that is new yet remains to be discovered.

These two new methods of psychologic research make the scope of biologic psychology a very large and important one. These methods are applicable to higher organisms as well as to cells and protozoa, but these applications will elsewhere be described.

*These methods applicable to medicine.*

The methods are applicable also to the study of the cells within the vertebrate organisms, with applications to hygiene and therapy. The antitoxin and serum experiments of recent dates by Pasteur, Koch, Roux, and their followers, and the nuclein experiments of Aulde and Vaughan, have demonstrated that by changed conditions of environment, gradually brought about, the cells of the human organism can be rendered immune to hitherto dangerous diseases; and much further progress along these lines will result when by the new methods of research just described the psychology of the cells of the human organism are made the basis of therapy. This method applied to groups of cells constitutes a form of cellular socio-psychology.

*The psycho-biologic method of studying cell-mentation.*

The study of cellular psychology belongs also partly to another domain—that of psychologic biology. In this domain the methods of biologic psychology are reversed. Instead of varying structure and environment, the factor that is varied is that of the mentations or adaptive activities of the cells. As the mentations are varied a record is made of the new structures and environmental changes that arise.

*When first discovered.*

This method was first used, as far as I know, by myself, in 1882, and was first publicly taught in 1890. It consists in experimentally varying the mentations of cellular organisms by artificially regulated means, and then in recording the structural and environmental effects of such mentations. Thus the creature is caused to react or respond to a given stimulus, such as light, or pressure, or sound, or chemical irritants, and this activity is kept up almost constantly during the life of the cell and even during the life of many succeeding generations of those cells. That is, the cell is caused to exercise that particular kind of mentation in excess of all other kinds of activity, and the corresponding structural changes noted. Activity produces growth in the functioning structures, and excessive activity of a definite kind, such as frequent responses to light, soon produces a growth of a definite kind in excess of that possessed by other organisms of its kind. Mental activity thus creates new structures. The mentations of the organism build the structures of the organism, and every structure represents embodied mind-activity. An organism is therefore a mind-organism, and psychology teaches us the meaning of life by revealing the fact that organisms are transforming-mechanisms interacting with cosmos for the manifestation or production of *mind*. Vitality is mentality, and biology is a psychological science.

When a protozoan organism is allowed

to multiply, generation after generation, under precisely similar conditions of environment and activity, there is no observable change in structure or activity; but as soon as these organisms are compelled to exercise some one form of activity more than the others there soon arises an observable chemical and structural change. The activity is, under these strict conditions, the cause of the change; and as the *response* to the stimulus which caused this excessive activity is a mental phenomenon it follows that mentation causes structure, and that the structure so formed is the embodiment of that form of mentation. This psycho-biological method of studying cellular phenomena is applicable not only to individual unicellular creatures, but to groups of societies of cells, as Zoogloeia and Volvox, and also to such functionally-integrated groups of cells as the metazoan organism. When applied to groups of cells we have a form of cellular psychologic sociology.

*Mentation affects environment.*

The activities of cells affect, not only the structures of the organism, but the environment also. Just as changes in the environment produce changes in the mentations of a creature, so changes in the mentations of a creature produce definite changes in the environment. Thus the creature may directly appropriate some of the environment to itself, creating a totality outside of itself which is a different totality than before this matter was appropriated; or it may by its movements differently distribute certain particles of the environment, or produce wave-motions of a molar kind in its surrounding medium (such as sound-waves), or of a molecular kind (such as heat-convection and heat-conduction), or of an etheric kind (such as heat-rays or color-rays), or it may throw off the products of a different metabolism thus altering the chemical character of its immediate environment.

*The three new methods of research in cellular psychology.*

Hence there are three new methods of

experimental research in the domain of cellular psychology:

1st. The method of experimentally varying the environmental conditions, one (or more) at a time, and studying the concomitant mentations so as to correlate environmental conditions which have been definitely known and regulated with the mentations that arise under these conditions. This method belongs to biological psychology.

2nd. The method of experimentally varying the structures of an organism by progressive or retrogressive evolution through graded selective propagation, and studying the concomitant mentations so as to correlate structural conditions which have been definitely known and regulated with the mentations that arise under these conditions. This method belongs to the realm of biologic psychology.

These two methods have for the known factors the experimentally established and maintained environmental and structural conditions, and the unknown factors are the mentations which arise out of these conditions. Mind is interpreted in the terms of structure and environment. Both the molar and molecular conditions of the environment and organic structure are subjected to experimental variation, and so are the various radiative forces which may be incident upon an organism.

3rd. The method of experimentally varying the mentative activities of an organism, and studying the structural and environmental changes which arise so as to correlate mentations which have been definitely known and maintained with structural and environmental changes which were the unknown factors until they arose under the experimental conditions. Two distinct sets of observations must be made when the mentations have thus been varied, (1) the structural changes in the organism must be noted and correlated with the mentative conditions, and (2) the environmental changes must be noted and correlated with the mentations. This method belongs to psycho-

logic biology. Organic structure and environmental conditions are interpreted in the terms of *mind*. Biology, and all the products of mentation, such as the sciences, arts, and the products of art, are to be studied and interpreted as mentative phenomena.

*Allular psychology is of fundamental importance.*

But there is further evidence of the fundamental character of cellular psychology as the basis for the understanding of the more highly evolved mental operations of the human organism. The entire vertebrate body (and for that matter, the bodies of all metazoa) is the result of the functionings first embodied in an ovum, nay, in the *nucleus* of the ovum. The human organism is the result of the segmentations, cell-multiplications, and functional specializations of an ovum or egg-cell. The nucleus first subdivides, and the resultant subdivisions grow in size as they continue to subdivide until all the organs of the fully developed being have been formed—the whole organism being the product of the activities of the cells. Cell-metabolism underlies all the motor, nutritive, and reproductive changes of the animal organism, and as metabolism is directly connected with mentation, nay, as automatic metabolism in the first and simplest form of mentation or adaptive activity, it follows that cellular psychology is of fundamental importance in the study of life in all of its aspects.

Unicellular organisms possess all of the different forms of activity to be found in the higher animals. Thus the simplest cell can transform food into tissue and other metabolic products, and this is the basis of all of the nutritive activities and processes of the higher animals; the cell can move parts of itself and is capable of locomotion, and this is the basis of all movement in the higher animals brought about by bones and muscles; the cell can feel a stimulus and respond, and this is the basis of the sensory faculties of the higher animals; the cell can reproduce itself by

segmentation, and this is the basis of reproduction in the higher animals; the cell on dividing inherits the actual qualities of its parent mass, and this is the basis of heredity; in short, the cell contains in simplest form all of the activities to be found in man. In the phylogenetic and ontogenetic history of the individual animal these cells in undergoing multiplication also undergo specialisation of function by having some one of these fundamental functions accentuated or emphasized until a new cell is produced that differs in each case as much as a liver-cell differs from a muscle-cell or a fat-cell or a brain-cell. Now, fundamental in all of these physiological activities of a cell is a form of functioning out of which all of these special functions of the cell developed, and that fundamental activity is that which distinguishes inanimate from living matter, namely automatic metabolism.

The *aggregate* of chemical organic inanimate compounds which compose a dead cell lacks at least one thing to make it *alive*, namely the power to adapt its internal molecular movements and relations to the environmental molecular movements and relations—it lacks adaptive reaction to cosmic stimuli. The maintenance of tissue-waste and growth by the chemical assimilation of foods, and the storage of surplus energy for movements, and the capacity to feel or respond to stimuli,—and to do this automatically, is automatic metabolism, and it is this which distinguishes dead from living matter;—there may be still other unknown distinctions, but these, which have been specified, are some of the essentials. A crystal (or any known form of inorganic matter) does not take into its body foods and chemically transform them into substances of its own kind and eliminate the residues in such a manner as to store up energy to be used in effecting movements of its parts in response to stimuli, and in such a manner as to produce growth interstitially.

Inorganic matter has not the power of locomotion—of self-initiated movement.

Light may decompose an inorganic compound, or may warm an inorganic body, but such a body makes no attempt to move towards the light or to move away from a hot needle. It cannot adapt itself to its surroundings, and without any resistance of a responsive character suffers itself to be destroyed bit by bit. There is no taking in of chemical substances and transforming them into other compounds and eliminating the useless products—no changing of substances from a higher energy-potential to a lower one—the crystal grows by accretion of molecules of its own kind, and has no such a series of adaptive reactions to cosmos as automatic metabolism. Automatic metabolism is a self-maintaining series of chemical adaptive reactions to the environment, and when such a living mass grows to the limit of its size it subdivides into two nearly equal parts, each part inheriting the characteristics of the parent mass. Those masses most favorably situated for growth and activity will of course transmit to their descendants these favorable cocharacteristics, and therein lies the beginning of organic evolution—favorable variations are preserved. But are characteristics acquired during the lifetime of the cell transmitted to the offspring? This question, at present so hotly disputed, can be definitely settled by the third method of research before-mentioned—the psycho-biologic method. Excessive activity of the cell in any one definite kind of mentation, such as persistently repeated responses to some one stimulus, soon produces excess of growth in some definite portions of the cell and these acquired growths are transmitted to the offspring, because, without killing off those individuals which do not respond as readily as some others, there is a gradual change in structure and activity noticeable after a number of generations. And this brings us to the fourth new method of research in cellular psychology; but I will, before describing this method, make a few more remarks about metabolism.

Automatic metabolism is not merely an equilibrium between the system of molecular motions within the cell and the molar and molecular motions of the environment—there is more than an equilibrium; there is such an equilibrium in an inorganic compound; but in the animate mass there is an accumulation of material specially prepared by the cell, a storage of surplus energy and a utilization of energy in maintaining a temperature slightly above that of the surrounding medium, and in performing molar motions of the parts of the mass. The cell is a transformer of chemical energy into the energy required to maintain automatic metabolism. The cell does work upon its environment—it is a machine which burns fuel—a transformer through which energy flows from a higher potential to a lower potential—and this accumulated energy enables the cell to maintain its existence against the antagonisms of certain conditions of the environment.

The aggregation of a metabolic mass from organic compounds is a cosmical process—the functioning of the environment produces, let us suppose, certain higher colloids; and further functioning of the cosmos transforms these colloids into a piece of protoplasm. It does not matter at present how this is done, or what unknown processes enter into the creation of a piece of protoplasm, the fact which I desire to emphasize at present is, that cosmical activity or functioning *precedes* the creation of the protoplasmic structure and creates it. Born of the universe this cell is still part of its mother—materially and dynamically and functionally a part of the cosmic whole, and its activities are the result of its own metabolism in *interaction* with the cosmic totality;—the forces, etheric and molecular, which make metabolism possible, are cosmic; the very medium in which it exists is cosmic, and each molecular movement and chemical change is directly connected with the etheric inter-atomic medium which forms the frame work, as it were, of the universe.

Every locomotion requires the direct reaction of the universe to move the cell forward—just as much as the cell by its pseudopodia pushes in a certain direction to move itself forward just that much does the universe push in the opposite direction upon the cell—action and reaction are equal and opposite. Every action of the cell upon its environment must necessarily be accompanied, as the very condition of the possibility of that action, by an equal reaction on the part of the universe upon that cell. Every stimulus is a cosmical activity upon the cell, and every response from the cell is a functional reaction of the cell with the cosmic whole. Mentation is, therefore, the result of two factors—the activity of the cell and the activity of the universe.

The cell is an independent factor—it is not only born out of the universe, but it is one of the actual portions of the universe and helps to make the universe what it is. The universe is composed of bodies, and this cell is one of those bodies;—it is a differentiated portion of the universe, and in being thus differentiated it has taken with itself a portion of the matter and energy of the universe, and hereafter the universe must reckon with the system of activities which that cell has embodied—the cell becomes an independent source of reactions upon the universe. Just as cosmical functioning preceded and created the cell, so the cell's functionings inherit the creative power of the cosmos, or some of it, at least, and the activities of the cell create its own structural growths. Under the definition of mentation as an adaptation of internal motions and relations to external motions and relations, it follows that automatic metabolism is mentation, and hence mentation is the causative factor of organic progress.

An animate body differs from an inanimate body because, among other things, it is capable of adaptive activities—it adjusts acts to ends—it feels stimuli and adaptively reacts—this is a mental characteristic. The mentation of the

highest animal does not differ in *kind* from that of automatic metabolism, for both are reactive adaptations of the internal systems of motion to the external systems of motion—the adjustment of activities to feelings or ends—and all this is a prerogative of mind.

I have dwelt on these aspects of the question, because metabolism is of fundamental importance as being the most simple known form of mentation—the most primitive kind of adaptive reaction which distinguishes animate from inanimate bodies. And out of automatic metabolism has arisen specialized functionings by variation and by the creative action of mentative functionings. Metabolism supplies the cell with food and one of the fundamental adaptations must necessarily have been of a chemical character—to absorb the right kinds of pabulum and reject the wrong—and out of this food-sense arose the senses of taste and smell. The *molecular* activities lie at the basis of cell-life, and hence the fundamental responses to stimuli are molecular, such as taste, smell, temperature, senses, and seeing. Out of the chemical reactions of foods arose the taste and smell of higher animals; out of temperature reactions arose the two temperature senses; out of effects of light upon chemical compounds arose the sense of sight; and out of pressures affecting the metabolism arose the senses of touch and hearing.

Molar movements of the cell-mass are the results of metabolism, and in higher animals the muscular fibers contract in response to stimuli by means of molecular movements which take place within the cell-substances enclosed within the sarcolemma which surrounds the fibril. Nerve cells have their functionings based in metabolic changes of the nucleus and cytoplasm, and my experiments, elsewhere described, have abundantly proved that every form of higher mentation is accompanied by a characteristic metabolism.

All of the higher forms of mentation are modifications of activities found in a



fundamental form in specific automatic metabolism, and it is in the metabolism of the cell that we must expect to find the bridge which connects mind and matter—if any such bridge exists! Or, shall we rather expect to find that the terms matter and mind are but names that conceal some fundamental verity and unity which contains no chasm that needs bridging! Just as the ideas of matter and motion are reducible to the conception of energy, so the ideas of structure and environment as connected with our ideas of mentation may ultimately be reduced to some form of unity.

These conceptions may lead us to a better understanding of the relation of cellular psychology to all forms of higher psychological investigation. When a man withdraws his hand from a too close contact with a hot stove he does nothing different in *kind* from that of the activity of a cell that moves away from a heated needle or a chemical irritant. When a man seeks food he does nothing different in *kind* from that of an unicellular organism seeking nutriment.

It is in the activities of the cells of the human organism that we are to find a solution of the mysteries of the activities of that organism, and the highly specialized cells of the animal body can best be understood by first studying the activities of isolated unicellular organisms. The study of these one-celled creatures is reduced primarily to a study of automatic metabolism in reaction with cosmos, and the three methods of investigation which have been described open new domains of research in cellular psychology.

*A fourth method of research in cellular psychology.*

The fourth method of research in cellular psychology is a modification of the third. It consists in experimentally regulating the activities of cellular organisms in such a manner that in a given species of cells one group shall be subjected to a persistent repetition of some one activity while another group shall not be compell-

ed to use that particular activity any more frequently than before, and during these experiments to maintain a constant environmental condition in all other respects for both groups, and to continue the same conditions of environment and excessive activity of one group for many generations. The group subjected to excessive activity of one faculty is allowed to continue without killing off those which do not respond to the stimulus with equal readiness. That is, survival of the fittest is not allowed to play any part with reference to this one activity—those cells which do not respond well are allowed to live just as freely as those which by favorable variation respond most readily, and as far as possible, select for the continuation of the propagation of the group under training those which by variation respond least readily to the particular stimulus. Under these conditions those which respond least readily to the stimulus are not killed off in the struggle for existence as in Nature, and hence the Darwinian factor is excluded. If under these conditions there is a ready growth of those cellular structures which are concerned in that particular kind of functional activity, and if this characteristic increases, generation after generation, even when the favorable variations are destroyed each generation, then we must conclude that acquired characters are transmitted. My experiments lead me to conclude that *acquired characters are transmitted*, and that it is *mental activity which produces an acquired character*. This method is applicable to metazoa as well as to protozoa—to monkeys and men as well as to monera. It seems to me that this is the first experimental method which directly approaches the problem which is at present giving the neo-Darwinians some trouble.

A unicellular organism that produces its kind by simple subdivision transmits to its descendants all of its characteristics, and if it acquires any characteristic during its lifetime it must of mechanical ne-

cessity transmit that acquired character to its offspring. Now, as a matter of experiment, such a cell can be caused to acquire a staining, which staining will be transmitted to its offspring. So far we have a very simple case of transmission of acquired character. If we steal from the cell a portion of its cytoplasm the offspring will be smaller than otherwise; and if we subject the cell to intense cold, but not enough to kill it, its offspring will partake of the acquired lethargy and will not, after getting warmed, grow as rapidly as some "control" cells which have not been cooled. It seems to me that even in these simple cases we have some direct hints of the method and possibility of the transmission of acquired characters. But the new method of research, just described as the fourth, seems to supply all the test conditions for the settling of this important problem. The basis of the transmission of acquired characters is automatic metabolism, and the cause of such an acquisition is mental activity. The fact that mentation is a causatory factor in organic progress does not remove from organic evolution the effect of favorable variations and their preservation in the struggle for existence, but emphasizes its importance in the lower orders of life and minimizes it the higher the degree of mind-embodiment. The higher the animal the more it comes under the influence of the transmission of acquired characters; and the advent of the possibility to directly make more brains and more mind by an art of brain-building would at once give the human race a new mode of progress; and the power of using the mind scientifically in systematic mentation would systematize the transmission of acquired characters and lay the basis for an art of eugenics.

The conclusions to be derived from this fourth method of research corroborate the former statements as to the importance of a knowledge of cellular psychology.

*All cells feed from a liquid medium.*

Cells must be fed from a liquid medium.

This is true not only of all unicellular organisms, but also of cells in the animal body. In the later case, the surfaces of the cells must be exposed to a fluid, such as the blood, carrying nutrient material. In the animal organism blood-vessels permeate the masses of cells and carry this nutrient fluid to their cellular surfaces. The greater the activity of a cell the more food will it need and the more waste products will there be, hence vasculature of an organ is an indication of the relative amount of metabolism in an organ. Those parts of the human brain which are most used are most vascular, and those parts which are not so much used contain a relatively smaller amount of blood and lymph channels. Sending more blood to a part will not necessarily cause that part to grow—there must be *cellular activity* in that part, that is, metabolism, that is, mentation, to cause the cells to need food before increase of blood to the part will cause growth. Hence the whole vasomotor and nutrient system is a modification of the metabolic process. Each cell selects from the blood what it needs and rejects what it does not need—it adjusts acts to ends—it mentates, and this mentation is ever accompanied by metabolism and metabolism is ever accompanied by mentation. It follows that severe mental labor should be carried on only when good blood can be supplied to the brain cells, and it follows also that increased activity in any group of cells will be followed by increased flow of blood to those parts, and if this habit is kept up regularly there will be a habit of activity and blood-flow established in those parts, rendering that class of functionings more intense and efficient. A dominancy can thus be artificially created, and when such a dominancy comprises a definite kind of memory-activities a *personality-dominancy* results, and a certain kind of character arises which differs morally and intellectually and conatively according to the classes of activities which have been rendered dominantly and systematically

active by the teacher who has essayed to build a character in a pupil according to a pre-established plan of mental or cerebral dominancies. This art of character-building will be elsewhere described and from another standpoint, and it will include the curing of abnormal affective and emotive states.

When an evil class of memories of an intellectual, emotive and conative kind have become by experience dominantly active in a child it may be said to have an immoral or criminal disposition. Certain portions of its brain are active whenever these evil propensities are in the child's consciousness, and growth is then taking place in those parts. Its personality is characterized by that series of dominant memories. Now if the teacher who has learned the art proceeds systematically to register in those same parts of the brain the same classes of memories but of a pleasurable and moral kind, and keeps those morally-functioning activities in action a greater number of times per day than the evil memories can functionate, and keeps on enregistering new evil memories of that class until the morally-functioning memories far exceed in number the evilly functioning memories of the criminal dominancy, and if the teacher integrates these new and normal memories and keeps them periodically active a greater number of times per day than the evil memories are active, then growth takes place in those parts of the cells and in the those parts of the brain where the desirable functioning occurs, and the most blood goes habitually to those new parts, and by and by the old criminal dominancy is no longer dominant—the new dominancy sways consciousness and motive, and the old dominancy atrophies, and the child has its character physiologically and psychologically re-made by its own mentations, creating new mind-structures! I have mentioned the curing of immoralities and criminal propensities in this place to emphasize the fact that the seat and basis of

the change is in cell-substances, and that metabolism must be modified by mentative activity in order to cure an immoral dominancy or a criminal tendency; and to emphasize the fact that these brain-building processes are dependent upon the mentation, and that the mentation builds structures by regulating and varying cell-nutrition, which is metabolism. The importance of a knowledge of cellular psychology is again impressed upon us by these facts.

*Cell specialization a mental phenomena.*

Whenever any one of the activities of a cell becomes specialized the other activities are gradually lost—the accentuation of any one capacity of the cell diminishes all other capacities of the cell not needed to carry on that specialized function. A cell that has been specialized is said to be physiologically unbalanced and requires the co-operation of cells in which all of the other functions have been specialized. The older doctrine is, that by variation and survival of the fittest the specialization took place in the cell—those capacities not needed were dropped, and those which were useful were perpetuated. Now, it is significant that only those functions which had to be *used* were perpetuated, and is proven by the fourth method of research, that excessive use of any of the functions of a cell causes excessive nutrition of those parts by means of an excess of metabolism and hence an excess of that kind of structure. Cellular specialization is thus also brought about by differentiation of the mentative activities of the cell, and not alone by variation and survival of the fittest. Hence, to understand that wonderful system of specialized cells which constitute the animal body we must become acquainted with the psychology of the cell.

In the ontogenetic development of the vertebrate animal the cells formed by the segmentation of the fertilized ovum separate into two layers, the ectoderm and entoderm, and a little later into a third layer, the mesoderm. From the ectoderm,

or outer layer, as might be anticipated, arises during later development, the skin and nervous system; and from the inner layer, or entoderm, arises the alimentary tract; and from the middle layer, or mesoderm, arises the muscles, reproductive apparatus and circulatory system. The first subdivision of cellular activity in the specialization of cell-function, as indicated by this ontogenic history, is into nervous (ectoderm) and nutritive (entoderm) activities. The cell, first, is dominantly nutritive, then by the contacts with the stimuli of its environment its surface becomes not only a protective membrane, but is specialized in those parts to respond to stimuli. The cells which thus become dominantly nervous lose their other dominancies; and the cells which become dominantly nutritive lose their other capacities; hence another group of cells must become dominantly motile and reproductive. In all of these cell-specializations the metabolism of the nucleus is primarily concerned. Hence, to understand the functions of the organs and ganglia of the animal body, we must resort to a study of psychology of the cells which compose those organs.

This accentuation of some *one* of the functions of a cell to the detriment of the other functions of that cell is of highest import to the art of education and brain-building. It shows, in the first place, that in the cell there is a diverse series of capacities or faculties, and that consequently there must be an equally complex series of cellular structures—for functions do not exist apart from structures. It shows that excessive activity of any one of these functions produces excessive growth of the corresponding structures, and it does this by differently distributing the metabolism of the cell.

My experiments upon the higher animals have demonstrated that a variation of mental activity in some one kind of mental functioning produces a variation of structure and chemical constitution in some groups of brain-cells. Rabbits con-

finied in a room with only green light exhibited an occipital cortex containing brain-cells that stained differently with the same reagent (an iodide of rhodopsin) than the cortical cells from rabbits confined in a room with red light. In these cases the difference in the seeing-activities did not bring into play different classes of cells but different parts of the same cells.

Hence, mental activities are localized within the cells as well as within the cortex—there must be a topography of localized functions in the cell as well as in the cortex as a whole.

Perhaps few men have brain-cells of any one class as fully developed as they might be.

My future experiments, will, I hope, give me accurate data for the construction of a topography of functional localizations within the cell, not only of unicellular organisms but in the cells of metazoan organs.

I have now briefly described four new methods of research in cellular metabolism and cellular psychology, and the purpose of this paper has been accomplished if I have made plain that there is a cellular psychology and that it is of fundamental importance to the understanding of the psychology of complex groups of cells, such as those in the animal organism, and that there are four new and definite methods of scientific research in this domain which promise richest results to the competent investigator.

Special laboratories and apparatus are needed for the prosecution of these four lines of investigation. These researches have many practical bearings upon bacteriological, pathological, and medical studies.

These four methods of research are subdivisions of some of the six general new methods of psychologic research which I have elsewhere described.

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# THE AMERICAN THERAPIST.

*A Monthly Record of Modern Therapeutics,*

WITH PRACTICAL SUGGESTIONS RELATING TO THE  
CLINICAL APPLICATIONS OF DRUGS.

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## Editorial.

### THE MEDICAL RELATIONS OF CELLULAR PSYCHOLOGY.

In order to determine the medical relations of cellular psychology it is necessary that we should become familiar with what may be termed the fundamental laws governing cell-life. To do this successfully we must study cell-function under various conditions. Thus we may vary the environment; we may vary the structure; or the activities may be varied. With appropriate apparatus and suitable facilities, the effect of change in environment, change in structure, or change in activities may be studied in unicellular organisms. Experiments of this nature, repeated again and again and always with the same results, must prove especially useful to the physician who is constantly engaged in studying the effects of disease upon cell-function.

While the results of physiological experiments are still fresh in our minds, we must not forget that physiological experiment does not undertake to deal with unicellular organisms, but with complex and complicated organisms. Physiological investigation has done much for rational medicine by showing the immediate

and direct dangers from indiscriminate drugging, but so far the most approved methods of treatment have scarcely influenced the mortality rates, unless we except the hospital records of diphtheria. In the case of pneumonia, for example, the death-rate varies but little from that which obtained fifty years ago; and it is now generally admitted that insanity is increasing more rapidly than in former years, according to the population. In view of these facts, how important it is that the physician should become familiar with the effect of change of environment, change of structure or change of activities upon cell-life and cell-function.

In this connection, we desire to direct special attention to the communication of Prof. GATES in the current issue, outlining the methods of research in cellular psychology. Prof. GATES has given the subject a vast amount of thought, and while his demonstrations show the wide range of utilities embraced in this study, the results of his pains-taking industry for the past twenty years prove conclusively that it appeals especially to the medical profession. Our author is about to undertake a new line of work with a view to elaborate the medical applications of these methods of research. Thus, in varying the environment of an unicellular organism he not only changes the temperature, diet, pressure, light, electrostatic potential, etc., but he also proposes to introduce into their pabulum different chemicals and medicines, such as aconite, strychnine, nuclein, etc., to determine their influence upon the activities (metabolisms) of the cells. Special attention will also be given to a study of effects of pathogenic organisms, such as the cholera bacillus. Proving, *a la* HAHNEMANN, will also be undertaken, *not*, however, upon people, but upon unicellular organisms.

By these methods, it should be observed, we shall learn more of the principles underlying cellular therapy, because they will shed a flood of light upon cell-function and cell-life. But this line of investiga-

tion, systematically carried out, will do much more for the medical practice of the future than is implied in this observation, since it will teach us how to vary the chemical environment, the cellular structure, the mentative—specific automatic metabolism—of pathogenic germs for the purpose of arresting and curing disease. But there are diseases which do not, so far as known, bear an etiological relation to micro-organisms, diseases which arise from various unknown causes, but always associated with, or dependent upon, abnormal cellular activities. Experimentation, to be of practical value, should be confined to a study of the activities of isolated cellular structures rather than to complex and complicated organisms. By this means we shall learn how to control the activities of cells in the animal body; in addition, we shall be in a fair way to understand how we ought to proceed where our object is to restore normal cell-functioning. We must not lose sight of the fact that the regulation of cell-metabolism in an organ or in an organism is of first importance. Cell-metabolism is always an important factor, but since cell-medication is usually directed to restoration of function, it naturally occupies second place. Hence, the importance of studying the fundamental principles governing cell-metabolism.

Notwithstanding all that has been said, in the preceding paragraphs, we have but touched upon the probabilities in the future of the cellular psychology; but we commend the subject to our readers as offering the best promise of success, since it turns into account so completely the possibilities of cell function.