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MEMORY AS A GENERAL FUNCTION OF ORGANISED MATTER.*

WHEN a scientist leaves behind him his own special province of inquiry, to make an excursion into the realm of philosophy, he may cherish the hope of solving the great problem which underlies the minor questions to which he has devoted his life, but he must be prepared for being secretly discredited with those of his colleagues who still remain quietly at work with the subjects of their specialty, and at the same time must expect the mistrust of the rightful representatives of the empire of speculation. He runs the risk of losing his reputation with the former and of gaining nothing with the latter.

The subject for which I ask your attention on this occasion is a most alluring one; but in accordance with what I have just said, it is not my intention to abandon the domain of natural science to which my studies have been devoted, but only to attempt to reach

*An address delivered before the Imperial Academy of Sciences, at Vienna, May 30, 1870.

a higher ground from which we may enjoy a freer and more general survey.

It will seem in the course of this paper as though I am not always faithful to this purpose; for I shall often have occasion to tarry in the province of psychology. Consequently, for my own justification, allow me to point out the extent to which psychological inquiries form, not only an allowable, but also an indispensable accompaniment of physiological research.

The animal human organism with its material mechanism is the subject of physiology. But consciousness is a simultaneous datum. Besides the moving of the atoms of the brain according to certain laws, the inner life of our soul is woven of sensations and conceptions, of feeling and will.

Everyone experiences this in himself; and it is a fact also which beams forth from the faces of his fellow-beings. It breathes in the life of all higher organised animals, and even the simplest creatures bear some vestiges of it. Who can fix the limit of empsychosis in the empire of organic nature?

In the face of such a dual aspect of organic life what can physiology best do? Shall science be blindfolded on the one side, in order the better to comprehend the other?

As long as a physiologist is a mere physicist—and I use the word physicist now in its most comprehensive sense—his method of inquiring into organic nature is altogether one-sided. But it is justly so. As a crystal

is to the mineralogist, so to the physiologist of this class is a man or an animal—a mere lump of matter. An animal feels, of course, pleasure and pain, and with the material phenomena of the human body mental emotions are connected; but that is no reason why a physicist should take a different view of the corporeal existence of man, who to him remains a compound of matter subject to the same irrefragable laws as stones and plants; like a machine, his motions are causally connected with each other and dependent upon their surroundings.

Neither sensation nor conception nor conscious will can form a link in the chain of the material processes of which the physical life of organisms consists. When I answer a question, the initial material process is conducted from the organ of hearing by sensory nerve-fibres to the brain, and must pass through it as a material process in order to reach the motor nerves of the organ of speech. It cannot, after having arrived at a certain spot in the brain, enter into something immaterial, in order to be re-transformed, in some other place of the brain, into another material process. A caravan in the desert might just as well enter the oasis of a mirage, to return thence after a refreshing rest into the actual desert.

Such is the physiologist, so far as he is a physicist. He stands behind the stage and carefully observes the working of the machinery and the movements of the actors, but he misses the meaning of the action, which

a spectator readily understands. Now, should a physiologist never be allowed to change his point of view?

True, his object is not to understand a world of concepts, but a world of realities. Nevertheless, if now and then he changes his point of observation and looks at things from the other side, or at least accepts from trustworthy observers the results of their experience, he will derive much benefit from such an attitude and will better comprehend both the apparatus he is studying and its methods of working.

For this very reason psychology is an indispensable auxiliary of physiology. If the latter science has hitherto not made much use of the former, it has not been wholly the fault of physiology. Psychology has only lately worked her fields with the plough of induction, and it is only in such a soil that the fruits can be raised for which the physiologist has most need.

The neurologist is thus placed between the physicist and the psychologist. The physicist regards the causal continuity of material processes as the basis of his inquiry; the thoughtful psychologist seeks for the laws of conscious life: and in so doing works according to the rules of inductive methods, assuming the validity of an inalterable order. Now, if the physiologist learns from simple self-observation that conscious life is dependent upon his bodily functions, and *vice versa* that his body to some extent is subject to his will, he has only to assume that *this interdependence of mind and body is arranged according to certain laws* and the link

is found which connects the science of matter with the science of consciousness.

Thus considered, phenomena of consciousness appear to be functions of material changes of organised substance, and *vice versa.* As I wish to avoid all misconceptions, let me mention (although it is included in the term function) that the converse of this assertion means that material processes of the cerebral substance also appear to be functions of the phenomena of consciousness. For if two variables are dependent upon each other, according to certain laws, a change of the one demanding a change of the other, and *vice versa,* the one is called a function of the other.

This does not mean that the two variables, matter and consciousness, are connected with each other as cause and effect ; for we do not know anything about that. Materialism explains consciousness as the outcome of matter, idealism takes the opposite view, and a third position might postulate the identity of spirit and matter. The physiologist, as such, should not meddle with such questions.

Aided by this hypothesis of a functional connexion between spiritual and material facts, modern physiology is enabled to bring the phenomena of consciousness within the domain of its inquiry, without leaving the *terra firma* of scientific method. The physiologist, as a physicist, observes how a beam of light, a wave of sound, or a vibration of heat affects the organs of sensation ; how they enter the nerves, are trans-

formed into an irritation of the nerve-fibres and conducted to the brain-cells. Here he loses all trace of them. On the other hand, he observes a spoken word coming from the mouth of a speaking person ; he sees the person move his limbs, and finds these movements are caused by muscular contractions produced through motor nerves irritated by the nerve-cells of the central organs. Here again he is at his wit's end. The bridge which should lead him from the irritated sensory nerve to the irritated motor nerve, is indicated in the labyrinthian connexions of the nerve-cells, but he lacks a clue to the infinitely involved processes which are interposed in this place. It is here the physiologist successfully changes his point of view. Here matter no longer reveals the secret to his inquiring glance ; but he finds it in the mirror of consciousness, not directly, but indirectly and figuratively—yet in lawful connexion with what he inquires into. Here, in observing how one idea replaces another, how from sensations conception rises, and how from conceptions *Will* starts, how emotions and thoughts interweave, he will suppose that there is a corresponding series of interconnected material processes accompanying the whole action of conscious life according to the law of the functional interdependence of matter and consciousness.

After this introduction I may venture to combine under one point of view a long series of phenomena which are apparently widely separated and belong

partly to the conscious, partly to the unconscious life, of organic nature: these we shall consider, comprehensively, as the results (*Aeusserungen*) of one and the same faculty of organised matter, viz., memory, or the faculty of reproduction.

Memory, as generally understood, is merely the faculty of voluntarily reproducing ideas or a series of ideas. But if faces and events of past days appear, uncalled for, and take possession of our consciousness, should we not also call this, with the same right, remembering? We are justly entitled to include in the concept of memory all involuntary reproductions of sensations, conceptions, emotions, and aspirations. In doing so, memory becomes an original faculty, being at once the source and unification of all conscious life.

It is well known that sensuous perceptions, if constantly repeated for a time, are impressed into what we call the memory of the senses, in such a way that often after hours, and even after we have been busy with a hundred other things, they suddenly return into consciousness in the full sensuous vivacity of their original perception. We thus experience how whole groups of sensations, properly regulated in their spatial and and temporal connexions, are so vividly reproduced as to be like reality itself. This clearly shows that after the extinction of conscious sensations, some material vestiges still remain in our nervous system, implying a change of its molecular and atomic structure, by which the nervous substance is enabled to reproduce

such physical processes as are connected with the corresponding psychical processes of sensations and perceptions.

Every one can observe in his daily and hourly experience such phenomena of sense-memory, although in fainter forms. Consciousness produces legions of more or less faded memory-pictures (*Erinnerungsbilder*) of former sensuous perceptions. They are partly called in voluntarily, and they partly crowd in spontaneously. Faces of absent persons come and go as pale and volatile shadows, and sounds of melodies which have long died away haunt us, if not audibly, yet perceptibly.

Of many things and events, especially if they have been perceived only once or very superficially, merely single, unusually striking qualities are reproducible; of other things only those qualities are reproducible which have been remarked on former occasions, our brain being in this way prepared for their reception. Such are responded to more strongly and enter consciousness more easily and energetically. Thus their ability of being reproduced increases. In this way, what is common to many things and hence has been most frequently perceived, will by and by be so reproducible as to be easily called forth by a slight internal impulse, without any exterior and real stimulus. Such a sensation, which is, as it were, produced internally, for instance, the idea of white, is not of the same vivacity as the sensation of white color externally produced by white light. But it is, after all, essentially the same,

being a weak repetition of the same material brain-process and of the same conscious sensation. Thus the idea of white is an almost imperceptibly weak perception.

In this way the qualities which are common to many things are, as it were, separated from them in entering our memory. They attain an independent existence in consciousness as concepts or ideas, and the whole rich world of our concepts and ideas is constructed of these materials of memory.

It is easily seen that memory is not so much a faculty of conscious as of unconscious life. What was conscious to me yesterday and again becomes conscious to me to-day, where has it been in the *interim*? It did not exist as a fact of consciousness, and yet it returned. Our concepts appear on the stage of consciousness only transiently; they quickly disappear behind the scenes, to make place for others. Only on the stage are they conceptions, as an actor is king only on the stage. As what do they remain behind the scenes? For that they exist somehow we know; a cue only is needed to make them reappear. They do not continue as conceptions, but as certain dispositions of the nervous substance (*Stimmung der Nervensubstanz*) by virtue of which the same sound that was produced yesterday can again be evoked to-day.

Innumerable reproductions of organic processes in our cerebral substance constantly combine with each other, according to certain laws, each in its turn stimu-

lating another. But the phenomenon of consciousness is not necessarily joined with each link of such a series of processes. Accordingly, chains of conceptions sometimes seem to lack proper connexions, when conveyed to the cerebral substance through processes unaccompanied by consciousness. Therefore, also, a long series of ideas may follow the correct logical order and have a proper organic structure, although the different premises that are indispensable to such combination do not become conscious at all. Some ideas emerge from unconscious life into consciousness, without being connected with any conscious conception whatever; others sink into unconsciousness without ever having been connected with conscious ideas.

Between what I am to-day and what I was yesterday, a gap of unconsciousness lies, the nocturnal sleep; and it is only memory which spans a bridge between my *to-day* and my *yesterday*. Who can hope to unravel the manifold and intricately intertwined tissues of the inner life by simply following the threads of consciousness? You may as well gather your information about the rich organic life of the oceanic world from those few forms which now and then emerge from the surface of the sea merely to disappear again into the depths of the ocean.

Thus the cause which produces the unity of all single phenomena of consciousness must be looked for in unconscious life. As we do not know anything of this except what we know from our investigations of

matter, and since in a purely empirical consideration, matter and the unconscious must be regarded as identical, the physiologist may justly define memory in a wider sense to be a faculty of the brain, the results of which, to a great extent, belong to both consciousness and unconsciousness.

Every perception of an object in space is a highly complicated process. For instance, a white ball suddenly looms up before my eyes. It is necessary, not only to convey the perception of white to consciousness, but also the circular periphery of the visible ball; moreover, its globular form, as it is recognised from the distributions of light and shade; then the exact distance from my eyes must be considered, and from this we form an estimate concerning its size. What an apparatus of sensations, perceptions, and conclusions is apparently necessary for accomplishing all this! And yet the actual perception of the sphere is performed in a few seconds, without my becoming conscious of the single processes which construct the whole; the result enters my consciousness complete.

The nervous substance faithfully preserves the records of processes often performed. All functions necessary for correct perception, which at first operated slowly and with difficulty with the constant help of consciousness, are afterward reproduced summarily and without an intensity sufficient to push each single link of the chain beyond the threshold of consciousness. Such chains of unconscious nerve-processes, which at

last end in a link accompanied with consciousness, have been called unconscious chains of perceptions, or unconscious conclusions; a name which is justifiable from the standpoint of psychology. For psychology might frequently lose sight of the soul, if unconscious states were not taken into consideration. To a physical consideration, however, unconscious and material mean the same, and a *physiology of the unconscious* is no *philosophy of the unconscious.**

Almost all movements which man performs are the result of long and difficult practice. The harmonious co-operation of the different muscles, the exactly gauged amount of work which each one must contribute to the common labor, must be learned for most movements with great trouble. How slowly a beginner at the piano finds the single notes, the eye directing his fingers to the different keys, and then how marvellous is the play of the virtuoso. With the swiftness of thought each note finds an easy passage through the eye to the finger, to be performed correspondingly. One quick glance at the music suffices to transform into sound a whole series of chords; and a melody which has been sufficiently practised may be played while the player's attention is directed to other subjects.

In such a case the *will* no longer directs each single finger to produce the desired movements, and no close attention is needed to watch the whole execution

* Refers to Von Hartmann's *Philosophy of the Unconscious.*—*Tr.*

carefully. Will is only commander-in-chief. Will issues an order, and all the muscles act accordingly. They continue to work as long as they move in their customary tracks, till a slight hint of the will prescribes some other direction.

This would be impossible, if those parts of the central nervous system which bring about the movement, were not capable of reproducing entire series of states of irritation. When they have been previously practised, under a constant accompaniment of consciousness, they can be called forth, as it were, independently, on the slightest impulse of consciousness, being executed more quickly and more perfectly, the oftener the reproductions have been repeated. All this is possible only if they remember what they *did* before. Our perceptive faculty would forever remain in its lowest stage, if we should consciously construct every single perception from the given single materials of sensation. Our voluntary motions would never surpass the awkwardness of a child, if in every case we should reincite with conscious will the different single impulses and reproduce over again all our single conceptions; or, to state it briefly, if the nervous motor system were not endowed with memory, viz., an unconscious memory. What is called force of habit, is the strength of this memory.

It is to memory that we owe all we *are* and *have*. Ideas and concepts are products of it; each perception, each thought, each motion is carried by it.

Memory unites all the innumerable single phenomena of consciousness into one entirety; and as our body would be dispersed into myriads of atoms, if it were not held together by the attraction of matter, so, but for the binding power of memory, consciousness would be dissolved into as many fragments as there are moments.

We have seen that only a part of the reproductions of organic processes, as effected by the memory of nervous substance, enters our consciousness; no less unimportant parts remain unconscious. And the same may be proved by numerous facts relating to parts of the nervous system which are exclusively subservient to the unconscious processes of life. For the memory or reproductive faculty of the so-called sympathetic nervous system is by no means weaker than that of the brain and the spinal cord. Medical art, to a great extent, makes good use of this.

In concluding this part of my investigation, let me leave the subject of nervous substance for a moment in order to take a cursory view of other organic matter, where we meet with the same reproductive faculty, but in a simpler form.

Daily experience teaches us that muscles grow stronger the oftener they are used. Muscle-fibre, which in the beginning but feebly responded to the irritation of a motor nerve, works with more energy the oftener it is irritated, after proper intervals of rest. After each single action it becomes more capable of action; it

grows fitter for the repetition of the same work and better adapted to the reproduction of the same organic process. *Pari passu*, its size increases, because it assimilates more than in a state of constant rest.

This is the very same faculty of reproduction whose action in nervous substance is so complicated; here it is observable in its simplest form, and easier understood as a physical process. And what is more accurately known of muscle-substance, is more or less clearly demonstrable of the substances of all other organs. Everywhere we find an increased activity with adequate pauses of rest accompanied by an increased strength of action; and organs which are used oftener in the animal economy also grow in size by increased assimilation. But this increase of mass not only means an aggrandisement and growth of the single cells or fibres of which the organ is composed, but also an augmentation of their number. A cell grown to a certain size divides into filial cells, which inherit, in a greater or less degree, the qualities of the parental cell, and accordingly represent repetitions of it. This growth and augmentation of cells is one of the different functions which are characteristic of organised matter. These functions are not only interior phenomena of the cell-substance, not only certain changes or motions of its molecular structure, but they also become externally visible as a modification of form, an aggrandisement of size or a division of the cell. Thus the reproductive function of a cell is manifested also as

a reproduction of the cell itself. This is most obvious in plants; the chief function of their cells is the work of growth, while in animal organisms other functions are predominant.

Now, let me finally consider the phenomena in which the power of memory in organised matter is most striking.

On the basis of numerous facts, we may justly assume that even such qualities of an organism can be transferred to its posterity as have not been inherited but have been acquired under peculiar circumstances of life. Thus, every organic being endows its germs with some small inheritance which has been acquired during the individual life of the parental organism and is added to the total legacy of the race.

Considering that properties are inherited which have been developed in different organs of the parental being, it has appeared highly enigmatic to investigators how these same organs could have influenced a germ developed in a distant place. So it has happened that as a solution of this problem mystic views have often been propounded.

The subject may be best comprehended from a physiological standpoint, in this way.

The nervous system, in spite of its being a compound of many thousands of cells and fibres, nevertheless forms one coherent entirety. It is in communication with all organs; according to recent histological researches, it is believed that it is connected with

every cell of the more important organs, either directly or at least indirectly through a living, irritable, and therefore conducting cell-substance. Through this connexion, all organs are more or less interdependent, so that the destinies of the one are re-echoed in the others; and any irritation effected in any one, is transfused, be it ever so feebly, to the remotest parts of the body. In addition to this delicate connexion of all parts by the nervous tissue, another, but slower and more sluggish, connexion is effected by means of the circulating fluids.

We notice further that the developmental process of the germs destined to attain independent existence, exercises a powerful reaction on both the conscious and unconscious life of the whole organism. And this is a hint that the organ of germination is in a closer and more momentous connexion with the other parts, especially with the nervous system, than any other organ. Conversely, the conscious and unconscious destinies of the whole organism, it is probable, find a stronger echo in the germinal vessels than elsewhere.

This, it must be recognised, is the path on which we have to look for the material link between the acquired properties of an organism and those elements of a germ that redevelop the parental qualities.

You may object that an immaterial something cannot be determinative of the future development of germs so like each other; it must rather be the peculiar character of its material composition. But I answer:

The curves and planes which a mathematician imagines, or accepts as imaginable, are more numerous and manifold than the shapes of the organic world. But if we imagine infinitely small portions of all these possible curves, they will bear a closer resemblance to each other than germs do. Nevertheless, the whole curve is latent in each portion of it and if a mathematician extends it in its proper directions, it will grow into the peculiar curve which was determined by the form of its small fragmentary part.

Therefore it is erroneous to declare that we cannot imagine such minute differences in germs as must here be assumed by physiology.

An infinitely minute dislodgment of a point or a complex of points in one part of a curve will alter the law of its entire course. Exactly so, an evanescent influence of the parental organism upon the molecular structure of its germ is sufficient to predetermine its whole future development.

Accordingly, the reappearance of properties of the parental organism in the full grown filial organism can be nothing else than the reproduction of such processes of organised matter as the germ when still in the germinal vessels had taken part in; the filial organism remembers, so to say, those processes, and as soon as a same or similar irritation is offered, a reaction takes place in it just as formerly in the parental organism, of which it was then a part, and whose destinies influenced it.

If in a parental organism by long habit or constant practice something grows to be second nature, so as to permeate, be it ever so feebly, its germinal cells, and if the germinal cells commence an independent life, they aggrandise and grow till they form a new being, but their single parts still remain the substance of the parental being, they are bones of its bones, and flesh of its flesh. If, then, the filial organisms reproduce what they experienced as a smaller part of a greater whole, this fact is marvellous indeed, but no more so than when an old man is surprised by reminiscences of his earliest childhood. Whether it still be the very same organised substance which reproduces old experiences, or whether it be its descendant and offspring, a part of itself, which in the meantime expanded and grew, is a difference which, apparently, is one of degree, not of kind. But, is it not strange that we are engaged in considerations of how trifling inheritances of the parental organism can be reproduced in the filial being, as if we had forgotten that the filial organism is nothing but one great reproduction of the parental organism, even in its minutest details? This is because we are so accustomed to accept their similarity as granted, that we are astonished at finding a child who is to some degree not quite like its mother, and yet the fact of its being in so many thousand ways like its parent is much more wonderful!

If the substance of a germ is able to reproduce what the parental organism has acquired during its

individual life, how much more will it be able to reproduce what is innate in the parental organism and has been repeated through innumerable generations in the same organised matter of which the germ of to-day, after all, is, and remains, but a part. Is it then to be wondered at, that the things which organised matter has experienced on numberless occasions are impressed more strongly into the memory of a germ than the incidents of a single life? Every organic being which lives to-day, is the latest link of an immeasurable series of organic beings, of which one rose into existence from the other, and one inherited part of the acquired properties of the other. The beginnings of this series, it must be assumed, are organisms of extremest simplicity, like those which are known to us as organic germ-cells. In consideration of this, the whole series of such beings appears as the work of the *reproductive faculty* which was inherent in the substance of the first organic form with which the whole development started. When this first germ divided, it bequeathed to its descendants its properties; the immediate descendants added new properties and every new germ reproduced to a great extent the *modi operandi* of its ancestors; part of which grew feebler, because under altered circumstances their reproduction was no longer elicited.

Thus every organised being of our present time is the product of the unconscious memory of organised matter. Constantly increasing and dividing, constantly

assimilating new and excreting waste matter, constantly recording new experiences in its memories, to be reproduced again and again, each has taken richer and more perfect shape the longer it has lived.

The whole history of individual development, as observed in higher organised animals, is, from this point of view, a continuous chain of reminiscences of the evolution of all the beings which form the ancestral series of the animal. A complicated perception takes place by means of a volatile, and, as it were, superficial reproduction of cerebral processes which have been long and carefully practised; exactly so a growing germ passes quickly and summarily through a series of phases which were developed and fixed, step by step, in the memory of organised matter in the series of its ancestral beings, during a life of incalculable duration. This view was repeatedly foreshadowed; it took shape in several theories; but was only rightly understood by a scientist of recent times. For truth hides in different shapes before the eyes of its inquisitors, until it is revealed to the elect.

A body, an organ, or a cell, reproduces simultaneously with its interior and exterior shape, also its functions. A chick which creeps out of its shell at once runs about, as did its mother, when she, as a chick, broke her shell. Think how extraordinarily complicated are the motions and sensations of such acts! Only consider the difficulty involved in the equipoising of its body in running, and it will be conceded

that the supposition of an innate reproductive faculty alone, can serve as an explanation of these intricate performances. The execution of a motion that is exercised during the greater part of an individual life becomes second nature, and the actions of a whole race, repeated over and over again by each member of the race, must also become second nature.

The chick is not only endowed with an inborn skill over its motions, but possesses, also, a strongly developed perceptive faculty. Without hesitation it picks up the grains which are thrown to it. This implies that it sees them, and that it correctly judges their position and their distance; moreover, it has to move its head and other limbs with great precision. All these things could not be learned in the egg-shell; they were learned by the many thousands of beings which lived before this chick, and of which it is the direct offspring.

The memory of organised matter is strikingly recognisable in this instance. Such a feeble irritation as the rays produce which proceed from a grain and fall upon the retina of the chicken form the occasion of the reproduction of a complicated series of sensations, perceptions, and motions, which in this individual have never as yet been combined, and which, nevertheless, from the beginning were adjusted with accuracy and precision, as if the animal itself had practised them thousands of times. Such surprising performances of animals are generally called instincts; and

some philosophers have indulged in mystic explanations of instincts. If instinct is regarded as the result of memory, or of the reproductive faculty of organised matter, if we assume that also the race is endowed with memory, instinct is understood at once; and the physiologist is enabled to correlate and connect instinct with the great series of facts found to be phenomena of the reproductive faculty. In this way we have not yet gained, but we have certainly approached, a physical explanation of the problem.

If, for instance, a caterpillar changes into a chrysalis, or if a bird builds a nest, or a bee constructs a cell, such animals, in obeying their instincts, act with consciousness, and are not unconscious machines. They know to some extent how to adapt their actions to changed circumstances and are liable to err; they feel pleasure if their work proceeds, and displeasure if they meet obstacles. They learn by working, it must be assumed, and birds, no doubt, build their nests better a second time than the first. But if animals so easily find the most practical means of attaining their ends the very first time, if their motions are so excellently and perfectly adapted to their purposes, it is due to the inherited disposition of the memory of their nervous substance, which only awaits an occasion to work in full conformity with the situation, and remembers just what is necessary for that occasion.

It is striking how easily dexterities are acquired, if sufficient limitation is exercised. Onesidedness pro-

duces virtuosity. He who admires a spider for spinning his web, should bear in mind how limited his other faculties are. Nor should he forget that the spider did not learn his art himself, but that it was acquired slowly by innumerable generations of spiders, and that this art is almost all they learned. Man takes to his bow and arrows if his nets fail to catch him food, but the spider must starve.

Thus the body, it is seen, and what is of greater import, the whole nervous system of a newborn animal, is predetermined and predisposed for intercourse with the world which it enters; it is prepared to respond to irritations and influences in the same way as this was done by its ancestors.

We cannot expect that the brain and nervous system of man should form an exception to this rule.

True, man learns with difficulty, while the animal from its very birth is, in instinct, matured. However, the human brain, at birth, is at a much greater distance from the acme of its development than the brain of an animal. Its growth not only takes a longer time, but is much more marked. The human brain, we may say, is much younger when it enters the world than the animal brain. The animal is born precocious, and at once behaves precociously. It is like a phenomenal child whose brain is overmatured and, as it were, too old, so that it is unable to develop as luxuriantly as another brain, which is less finished and inured to work, but fresher and more youthful. The scope for

individual development in the case of the human brain, and generally of the human body, is much larger, because a relatively great part of its development is relegated to the time subsequent to birth. It grows under the influences of its surroundings, which affect its senses, and acquires under such circumstances, in a more individual way, what an animal has received in the fixed formation of the race.

A far-reaching memory, or reproductive faculty, we must assume, is to be ascribed to the whole body, as well as particularly to the brain of a newborn man. By the help of this memory he is able to acquire the attainments which were developed in his ancestors some thousand times and are necessary for his life, much more quickly and easily. What appears as instinct in animals, in man appears, in a freer form, as a predisposition. True, ideas are not inborn in an infant, but the ability of ready and precise crystallisation of ideas from a complex mixture of sensations, is due, not to the labor of the child, but to the labor of innumerable ancestors.

Theories of individual consciousness, according to which it is assumed that each human soul starts life for itself and commences a development of its own, as if the thousands of generations before it had not been in existence, are in striking disagreement with the facts of daily experience.

The realm of those cerebral processes which elevate and distinguish man, it must be conceded, is not

of such antiquity as is the province of the more physical necessities. Hunger and the procreative impulse have stirred even the oldest and simplest forms of organic beings. Accordingly, organic substance has the most powerful memory for these stimuli, as well as for their satisfaction. The impulses and instincts rising from them take a firm hold even of the man of to-day with elemental power. Spiritual life grows slowly, and its most beautiful blossoms belong to the latest epochs of the evolutionary history of organised matter. It is not long that the nervous system has been adorned with the ornament of a rich and grand brain.

Oral and written traditions have been called the memory of mankind, and this conception is true. But beside it there is another memory, which is the reproductive faculty of the cerebral substance. Without it, all written and oral language would be empty and meaningless to later generations; for, if the loftiest ideas were recorded a thousand times in writings or in oral traditions, they would be nothing to brains not predisposed for them. They must not only be received, they must be reproduced. If increasing cerebral potency were not inherited simultaneously with inner and outer development of the brain, with the wealth of ideas which are inherited from generation to generation, if an increased faculty for the reproduction of thoughts did not devolve upon coming generations simultaneously with their oral and written traditions, scripts and languages would be useless.

The conscious memory of man dies with his death; but the unconscious memory of nature is faithful and indestructible. Whoever has succeeded in impressing the vestiges of his work upon it, will be remembered forever.

THE SPECIFIC ENERGIES OF THE NERVOUS SYSTEM.

JOHANNES MUELLER, the greatest physiologist of our century, in his essays on the senses, established a theory which is well known as "the theory of the specific energies of the sensory nerves." I cannot here recapitulate his doctrine in his own perspicuous language, which would be intelligible only to specialists. But a few sentences will suffice to explain the quintessence of his theory to any one whose occupation prevents him from bestowing more than that kindly interest upon physiology which this most fascinating science awakens in the mind of every educated man.

From the eye and from the ear, from the mucous membranes of the organs of taste and smell, and from the skin of the whole body—viz., the organ of touch and temperature—proceed thousands of delicate nerve-fibres. Gradually uniting, they coalesce into steadily enlarging bundles, which either lead directly to the brain, or are indirectly connected with it by the spinal cord. Through these nerve-fibres the sensory organs

communicate with the brain, that most wonderful living structure which is both the origin and the product of our consciousness.

When a vibration of ether irritates the nervous membrane of our eye (the retina), a process ensues, the real nature of which we do not yet understand. We only know that the irritation is at once transmitted to the fibres of the optic nerve, and in its further progress acts upon those cerebral parts into which the optic nerve enters. As the life of these brain-structures is in close connexion with our consciousness, it happens that when a ray of light enters the eye, it causes an irritation of the nervous fibres and of the cerebral cells; and thus we become conscious of the sensations of light and of color.

If, now, these same rays, which, when entering the eye, produced the sensation of light, fall upon the skin of the hand, and there irritate the delicate rootlets of the sensory nerves, this irritation is transmitted through the nerves and the spinal cord to the brain, and instead of light we are conscious of warmth. How is it that the same external agent in one case produces light, and in the other warmth?

Moreover, the sensation of light can be produced in a perfectly dark room by irritating the nerves of the eye by an electric current; and if we pass the electric current through the auditory nerve, we hear sounds and noises, though the deepest silence surround us. If we apply the current to the nerves of the skin, we

experience the sensation of heat or cold, although not in contact with any cold or warm object. And if, by the very same current, we excite the nerves of the tongue, gustatory sensations are produced. Accordingly, the nervous apparatus of each sensory organ responds to the same irritation with different sensations. And again we ask : How does precisely the same cause produce such a variety of effects ?

Even by the aid of the microscope the anatomist has not been able to discover any essential difference between the various sensory nerves. For instance, that part of the brain which produces the visual sensations does not, in its ultimate structure, vary noticeably from those cerebral regions which produce sensations of sound or temperature. But (and this is the answer to the problem in question) this sameness of form is not accompanied by a sameness of nature. The diverse structures of the nervous system, the nerve-cells and the nerve-fibres, are internally different in spite of all external similarity, and the diversity of the sensations produced is a manifestation of such difference.

It is the nature of the nervous substance in the visual organ to produce sensations of light, and only such. It is the bell which sounds, and not its tongue ; and similarly it is not the vibration of ether, but the nerve, that produces light. No matter whether it be a ray of light,—whether it be a pressure or a blow upon the eye, an electric current, or any irritation whatever,—that affects the nervous apparatus, it invariably

manifests itself as light or color. In the same way, we become conscious of the irritations of the auditory organ in the form of sound or noise, no matter what their cause, which may be aërial vibrations or any morbid irritation of the inner ear, or an orgasm of the blood.

Johannes Müller named the inherent function of certain nerves to communicate certain sensations, which could not be produced otherwise, to our consciousness, the "specific energy" of those nerves. More than half a century has elapsed since this great physiologist developed his theory in bold and magnificent proportions; thus formulating, in scientific terms, an idea, the original germ of which lies buried in the distant past, as far back as Aristotle. Johannes Müller's doctrines were re-echoed in innumerable writings, but it cannot be said that the seed he sowed fell upon fertile soil, or that it was developed in any essential feature. A few partially successful attempts were made to promote Müller's theory of the sensations of color and of sound; but, aside from that, his doctrine bore little fruit. On the contrary, it was suppressed, even by Johannes Müller's own disciples. It again became customary to regard all nerve-fibres as having essentially the same nature, and to suppose that the same kind of irritation is transmitted in all fibres of the various nerves. The question why the nerves of the different sensory organs produce such various sensations was either entirely abandoned, or it was deemed suffi-

cient to say that the cause should be sought in the brain, although the same reasons which were thought to prove that all nerve-fibres are of the same nature, would hold good also in the case of the cerebral cells and fibres. Even in some writings of the present day we meet with authors who, confounding philosophy and physiology, declare that the theory of the specific energies is one of the great aberrations of physiology.

In consideration of this fact, permit me, as an enthusiastic follower, although no personal disciple, of the great scientist, to disclose and reveal the deep significance of the great master's doctrine, and to show that it is the application of a principle which has been, or surely will be, accepted in other provinces of biology.

The animal kingdom exhibits an inexhaustible multiplicity of form, and to a layman who is not initiated into the science of biology it seems almost incredible that living creatures, so manifoldly different in their forms and habits, should, as germs, in the first stage of their development, be so homomorphous! As a rule, even the most experienced eye, with the assistance of every means of scientific analysis, would not be able to recognise in a germ the animal into which it is going to develop. The fish as well as the bird, and the insect as well as man, so far as we can judge from external appearances, all begin their lives as very simple and microscopically small, spheroidal structures. Nor does this uniformity exist only for the eye;

for chemical analysis resolves them all into the same ultimate elements.

We ask, how is it possible that totally different forms can develop from apparently like germs; and the answer is, that this resemblance of the germs is merely external. By the aid of the most powerful microscopes we can barely discern the roughest outlines of their structures.

In the heavens whole systems of suns appear only as nebulæ, which even the most powerful telescopes cannot resolve into single stars. As observation is impossible, we can only surmise their structure. Similarly the ultimate and exquisitely delicate frameworks in the architecture of the living substance of germs is withdrawn from the observation of even the minutest research. Could we approach nearer and nearer to one of these nebulæ, one star after the other would emerge from the apparently homogeneous mass; we should see planets revolving around their suns, and satellites about the planets. Thus, if with our corporeal or intellectual eye we could penetrate the minutest internal structure of the substance of germs—if we could comprehend the arrangement and motion of the molecules and atoms—we should discover that the living germ-substance of each animal species has its specific properties, and the substance of each single germ has its individual properties by virtue of which, in a further evolution, a special and peculiar type must mechanically develop.

Whether these internal variations of the germs are chemical or physical, is, at present, immaterial; for the physical properties of a substance are conditioned by their chemical qualities, and when we inquire into the molecular and atomic structure of a substance, the dividing line between the domains of chemistry and physics entirely disappears. We cannot, in the immediate future, however, hope to find a chemical formula for the individual germ-substances. To reveal the delicate secret of living matter by the comparatively crude methods of chemistry, would be like trying to explain the mechanism of a watch by melting it in a crucible, and examining the molten mass with respect to its ingredients.

As we cannot at present solve the problem of the internal variation of the externally similar germ-substances, we must be satisfied with the statement that the germs of each animal species possess an inherent and innate faculty—viz., a specific energy, which directs its developments in a manner characteristic of this animal and of no other. Again, each single germ possesses an individual energy, which, in addition to the normal features of its species, secures an individual character to its future development.

Let us now approach our problem from another side. When the naked eye is not able to discern the more minute organisation and delicate structure of an organism, the anatomist employs the miscroscope, and a new world of discernible facts is revealed to him.

The apparently homogeneous form dissolves into innumerable distinct structures; millions of the minutest separately-existing beings, different in shape and internal structure, compose a systematically arranged aggregate, thus forming the diverse organs; and these beings, in spite of the complicated interdependence, lead quite separate lives, for each single being is an animated centre of activity. The human body does not receive the impulse of life like a machine from one point, but each single atom of the different organs bears its vitalising power in itself. The current of life does not emanate from one special part of the body, but all its minutest parts are themselves sources of life. The architecture of the human body, which consists of these elementary organisms, or cells, as they are called, has often been explained. The harmonious interaction and the division of labor among these innumerable particles has been compared to the judiciously adapted co-operation of the individual members of a well-regulated community. As in such a community, so also in the human organism, a special kind of work is assigned to each group of individuals; and, according to the various functions, the elementary organisms are differently formed; but those elements which possess the properly so-called vital power, in every respect exhibit the most striking resemblance, although it may be hidden by and interwoven with various less important solid or fluid ingredients.

In all living cells and fibres of the different organs

we encounter the same colorless, almost fluid, soft, easily changeable substance, in the shape of highly delicate threads, nets, or drops. It is the properly vital element of the cell. There the enigma of life lies buried, for *it* is the moving and creating power in the elementary organism. *It* produces the contraction of muscular fibres and transmits the irritation in the nerve-fibre; *it* builds up the solid and strong mass of the supporting bone and the tough fibre of the tendon; *it* shapes the feathers of the bird, the scales of the fish, and the horns of the stag.

Yet it is everywhere apparently the same, and if it is isolated from its proper sphere and surroundings, and considered by itself, the most experienced eye cannot tell which of the different functions was performed by it.

Again we ask, how is it possible that apparently equal causes produce such different effects. And here no one will doubt that in spite of external similarity the living substance in the cells of the individual organs is internally different; and a difference of function necessarily results from this difference of internal structure. It is an innate function. The specific energy of the living substance in the liver produces bile, as the specific energy of the root of a hair builds up the horny mass of hair.

All the innumerable elementary beings or cells of an organism are the offspring of one single germ-cell, in which the development commenced. By division,

the first cell was split in two. Although both were intimately connected with each other, they were nevertheless, to a certain extent, independent cells. These two cells divided again and formed other cells, and so on. Thus, by a constantly renewed formation of more living substance the number of the elementary structures increases in almost inexhaustible multiplicity. But in the progress of multiplication also form and arrangement of the cells are changed. They separate into divers homogeneous groups, each of which differs from the others in character in so far as it performs a special function. The living substance is specialised in the process of development according to its function and destination. All the united different specific energies which later on will separately develop to full life in its descendants, lie concealed, although only potentially, in the substance of the germ.

In the light of these considerations the diversity of function in the nervous substance can no longer surprise us. Its external similarity prevents us from considering it as internally different, and from claiming for it specific energies, according to the doctrine of Johannes Müller.

The specific energies of the living substance in the different organs are characterised by their chemical or physical functions; while in the present state of science the energies of the nervous substance can be recognised only by the different sensations which they produce in our consciousness. Our sensations and all the

phenomena of consciousness are the psychological expressions of physiological processes or the irritations of our nerves,—especially of our brain. *Vice versa*, these irritations are the material expression of the processes in our soul.

The soul does not move unless, simultaneously, the brain moves. Whenever the same sensation or the same thought recurs, a certain physical process which belongs to this special sensation or thought is repeated ; for both are inseparably connected. They are conditioned by and productive of each other. Accordingly, from the course of our sensations we can draw inferences concerning the simultaneous and corresponding course of processes in the brain. The resolution of our sensations into their various elements is at the same time an analysis of the involved interactions of the various elementary cerebral functions or irritations.

For instance, let us suppose that the great variety of the sensations of light and color can be reduced to a few simple or elementary sensations, to those of the principal colors, which by combining in different proportions can produce innumerable different sensations. This fact, if proved, would justify the conclusion that different kinds of elementary irritations can take place also in the nervous substance of the visual organ. Each of them corresponds to one of the elementary sensations, and the elementary irritations can be arranged in a manner analogous to that of the elemen-

tary sensations. Or similarly, if we succeed in reducing all the many and various gustatory sensations to a few simple sensations, we may again justly infer that a corresponding number of elementary irritations can be produced in the nerve-substance of the tongue.

Consequently the analysis of our sensations leads us to recognise the fact that what Johannes Müller summarily called the specific energy of a sensory nerve may be resolved into a certain number of elementary irritations. But we need not assume that a distinct nerve-element is a medium for each simple irritation. The same nerve-cell can produce the sensation of heat or of cold according to the direction in which its specific energy is irritated. The same fibre of the visual organ can be irritated in different ways and thus convey correspondingly different sensations of color.

Each single kind of irritation, therefore, does not necessarily correspond to one and the same nervous substance. The specific energy of a certain nerve-element is not merely a simple property, it is not a faculty which causes only one kind of function, it is a multiform potency.

The power of specialising and individualising its functions is an inborn quality of living substance, and bears its richest and most wonderful fruit in the nervous system. In this respect the nervous system far surpasses all other organs.

One fibre of a muscle performs the same function as all its other fibres, and even the fibres of different

muscles possess essentially the very same energy. One liver-cell works as all the other liver-cells do, and it cannot work otherwise. The intensity of a function may be different in the different fibres or cells of such an organ, but the kind of function is common to all.

Not so in the nervous system. The various energies in the various groups of the nervous elements are innate. By an innate faculty the optic nerve of the new-born babe responds to the ray of light which enters the eye with a sensation of light, and the nerve of the skin responds to an increase of temperature with a sensation of warmth.

The specific energy of almost all other organs is definitely fixed at the time of birth and will change in the further development of life in degree only—but never in character.

The muscle-fibre of a babe contracts in the same way, and thus exhibits the same energy, as does the muscle-fibre of an adult person. The liver-cell of an old man produces bile just as the liver-cell of a child does. The muscle as well as the liver grows with the entire man, but the fibres and cells added can always perform only one and the same function. Some fibres and cells perish in the course of life, but those which take their place merely perform the functions of the replaced fibres and cells.

Thus the innate energy of almost all organs remains unchanged throughout life. The individual small cell-organisms of which the organs consist, come

and go, one generation follows another, in some organs more rapidly and in others more slowly. The living substance of each single element is consumed and then replaced by nutrition, but their faculty and activity always remain the same. In the nervous system all this is very different. Although, as a rule, the innate energies of many regions, especially in the peripheral nervous system, remain unchanged throughout life, there is in the nervous system of a new-born babe some living substance which is ready to be moulded for the performance of this or that function and for the development of this or that *individual* energy.

Above all, the brain of a new-born babe is not a completed structure. It grows and develops; and if the externally visible growth has reached its limits, the internal process of formation continues. Up to the moment of birth the nervous system with the brain is developed according to its own inner law. Until then, neither light nor sound nor any other sensory irritation has affected the nerves and the brain has been asleep. After birth thousands of new incitations at once intrude from the external world upon the nervous system. The eye is opened to the vibrations of ether and sound-waves obtrude upon the ear, pressure and impact, cold and warmth affect the skin—thus placing the brain which heretofore was left to itself, under the influence and discipline of the external world.

Before birth the chemical processes of the nervous system, its change of matter and its growth, depended

upon internal conditions of life. After birth the incitations of the external world excite the brain and produce a more vigorous exchange of matter for further development and increase of the living substance. The further development, the inner formation and cultivation henceforth depend upon occurrences in the external world which the brain experiences.

All living substance, especially nerve-matter, has the peculiarity that every irritation produced in a limited region at once spreads to the adjoining parts. It continues spreading as long as it meets with any substance which is capable of being similarly irritated and which, so to speak, responds to such irritation.

The specific irritation awakened in the sensory nerves by external causes, is thus transmitted to the virgin parts of the brain. Here in the most youthful and most docile living substance, the irritation terminates, and here every kind of irritation finds its echo. For this substance which possesses no innate and definitely specialised energy, has not yet through the frequent repetition of a certain kind of irritation lost its susceptibility for all other irritations.

If the virgin substance of the brain is excited and internally agitated by an irritation which has been transmitted through the nerve-fibres of the sensory organs, an increased ability to reproduce the same kind of irritation is acquired by a permanent change of its internal structure. If the sensory nerve again transmits the same irritation, the cerebral substance re-

sponds to it more easily. The oftener it is repeated, the stronger will grow the inclination to reproduce just this kind of irritation. Through frequent repetition, one particular kind of function becomes, as it were, the second nature of a single cerebral cell, i. e., the cell acquires this special ability or energy. In this way the individual energies of the cerebral cells and fibres are developed by education on the basis of the inherited dispositions. Also the additional energy which the cells acquire during life, is transmitted by inheritance to the new-formed cells which are generated by partition. These new cells can in their turn develop, evolve, or modify the inherited energy.

The anatomical arrangement of the brain is such as to place (single) parts of the so-called gray substance into a particularly intimate relation with special sensory nerves. The irritation of a sensory nerve-fibre will necessarily seize upon and affect those cerebral cells first which are in closest connexion with it. But each cerebral cell is connected with other cerebral cells by a net-work of most delicate nerve-fibres.

The irritation which enters from the sensory nerve-fibres into the gray substance can advance (through those cerebral elements which are excited first) in all directions farther and farther into the labyrinth of the cerebral cells and fibres, until at last it dies out and ceases sooner or later, or in exchange, calls forth new irritations, which, starting from the brain, return to the peripheral nervous system.

Every cerebral element is subject to the educating influence of those sensory nerve-fibres with which it is anatomically connected and whose energies are most closely related to it. But these single cerebral elements can receive irritations, although in a weaker degree, also from the adjoining fibres of the same sensory nerve and even from those nerve-fibres which enter the gray substance in more remote parts, and which originate in other sensory organs.

In this way the cerebral substance is constantly permeated with many diverse irritations, which crowd upon it from all the sensory regions. The cerebral cell will be particularly educated for the qualities of these irritations, according to its opportunity of easily and repeatedly receiving irritation from this or that sensory organ and from such or such a sensory nerve-fibre. It will acquire the faculty of reproducing them vigorously, as often as an incitation, be it ever so weak, is offered.

Consequently, every single cerebral element, in the course of its development and under the influence of sensory experience, attains an individual character. And it may be asserted that not even two of the innumerable cerebral cells are alike in kind and degree of individual energy. If one cerebral cell is destroyed, there would of course be many others which possess in all essential points the same energy, and can by their functions compensate its loss, but no other cerebral element could do exactly the same work with ex-

actly the same individual ability, with the same ease and exactness; as no man can, in all respects, entirely replace another man.

Experience and practice rest upon this specialisation and individualisation of the functions in the different cerebral elements, and the energies of the nervous substance which are developed in the course of our life are the organic expression of our individual memory.

The nervous system, and above all the brain, is the grand tool-house of consciousness. Each one of the cerebral elements is a particular tool. Consciousness may be likened to a workingman whose tools gradually become so numerous, so various, and so specialised that he has for every detail of his work a tool which is specially adapted to perform just this kind of work most easily and accurately. If he loses one of his tools, he still possesses a thousand other tools to do the same work, although with more difficulty and loss of time. Should he lose these thousands also, he might retain hundreds, with which he can possibly do his work still, but the difficulty increases. He must have lost a very large number of his tools, if certain actions became absolutely impossible.

The knowledge of the tools alone does not suffice to ascertain what work is performed by the tools. The anatomist, therefore, will never understand the labyrinth of cerebral cells and fibres, and the physiologist will never comprehend the thousand-fold intertwined

actions of its irritations, unless they succeed in resolving the phenomena of consciousness into their elements in order to obtain from the kind and strength, from the progression and connexion of our perceptions, sensations, and conceptions, a clear idea about the kind and progression of the material processes in the brain. Without this clue the brain will always be a closed book to us.

We can indeed compare the brain to a book. A book is anatomically a number of rectangular white leaves, bound on one side, and marked on their pages with numerous black spots of different form and size. Under a microscope, the leaves will be seen to consist of delicate fibres, and the black spots of minute black granules. A chemical analysis will show that the leaves are cellulose, the spots carbon and resinous oil. If all this has been investigated and ascertained with the utmost accuracy, we do not know, in the least, why the black spots are arranged just in this and in no other way, why some spots are large and others small, why some occur frequently, others rarely, why the single leaves follow one another in this and in no other order, and altogether what the whole book really means.

Whoever wishes to know what the book signifies, must know what is the function of the specific energy of each single letter and of the individual energy of each single word—in short, he must know how to read.

Nothing can be fully explained by a simile, and it is perhaps dangerous to attempt to adorn the dry language of science with allegories.

But let the scientist wear his working apparel while ploughing the field of his science; and when, on a festal occasion he offers the fruits of his labor to others, he should be welcome in a festive garment.

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