based upon a knowledge of the chemical structure of the substance through which it is made manifest.

Proceeding from his conception of what constitutes life, Spencer defines natural death as a want of correspondence between the internal and external relations. Perfect correspondence would mean eternal existence.

If the organism could adapt itself to every change in its environment, old age and death would be impossible. It is difficult to understand the full significance of Spencer's language. Taken literally it seems to assert nothing more than that death is a cessation of life. It adds nothing at all to our knowledge of the causes leading to this cessation, nor does it indicate any fruitful line of investigation. If, however, Spencer means that the fatal want of correspondence may come from without; that is, from changes in environment to which no adequate adaptation can be made by the organism, and in many passages this seems to be implied, then his view is opposed to that accepted by most physiologists. They, the physiologists, believe in general that although the environment were perfect and unchangeable, yet by virtue of inherent changes in the organism itself the assimilative powers would inevitably grow weaker and finally cease with death, or as the same idea is expressed by Brown: "The causes of death are not to be found in the summation of many external injuries, but are already established within the organism itself, and death is simply the natural end of development." In want of a more exact knowledge of the structure of the living molecule and the changes in structure that come on in old age, the physiologist expresses his ideas of the general nature of these changes by similes and metaphors more or less apt. We may compare living matter to a clock, the mainspring of which is so constructed that in consequence of slowly developing molecular changes it suffers a gradual loss of elasticity. In such a mechanism there will come a time when "winding the clock up" will no longer make it run, since energy can no longer be stored in the spring. We may imagine this loss of elasticity to develop gradually, giving stages that may be roughly compared to the periods of life. To carry out the simile, it is the food we eat and the oxygen we breathe that take the place of the winding force. In consequence of a slowly developing molecular change in the organism, this energy is less efficiently utilized as the individual grows older. The clock runs more feebly and needs relatively more frequent winding, until at last the elasticity is gone, the power of assimilation is insufficient, and we have what we call natural death. In complex organisms like ourselves this failure of assimilation may come first to some one organ, such as the heart or the nervous system, and through its collapse the organism as a whole cease to exist. In the nature of the case natural death cannot come to every organ of the body at the same time, so that the death of a portion, perhaps from the standpoint of weight, the larger portion of the body, must always be accidental, as, for example, from a shutting off of the blood supply due to natural death of the heart. But this consideration does not affect the general conception of the liability of all the organs to a similar fate. Rightly or wrongly, it is, or has been, a wellnigh universal belief that every organism and every bit of living matter in an organism has only a limited duration of life, no matter how favorable the external conditions may be.

In striking opposition to this view, Weissmann, in a recent series of essays upon the duration of life, has attempted to demonstrate the essential immortality of living matter, or, in other words, to show that death is not an inherent necessity of life, but an acquisition or adaptation on the part of living things. These essays have aroused a widespread interest and discussion among biologists, and are probably the most important speculations of recent times upon the origin and meaning of death. Weissmann carries the problem back to the lowest forms of life, the unicellular organisms or protozoa. Whatever in this regard is true of them must be looked upon as being or as having been true for living things in general, since modern biological doctrines trace the evolution of life from these forms, and modern morphology has demonstrated that all complex forms of life are in fact mere colonies or collections of unicellular organisms. If we study one of the protozoa, the amœba, for instance, which has always been taken as the archetype of life, we find that it is a complete cell; that it feeds, and assimilates, and excretes; that it increases in size, and finally reproduces by simple fission, forming two new individuals, or daughter cells. In this last process we have the disappearance of one old individual and the formation of two new ones, nevertheless there is no death. To speak of the disappearance of the parent cell as an example of death, as some have done, is a mere figurative use of language. There is no death in such a change, because as Weissmann puts it, there is no corpse. If we consider the two daughter cells produced by the fission, we find not only that they are similar morphologically, but that each of them has possibilities of growth and reproduction equal to those shown by the parent form—there is apparently no reason why such a process should not go on indefinitely. Amœbæ, as we find them under the microscope, show no signs of old age; the daughter cells are not less capable of reproduction than is the parent cell. It is permissible to suppose that if a single amœba were given a favorable environment it would in time produce an infinite number of descendants, each of them possessing in turn the same unlimited possibilities of multiplication. This is precisely the hypothesis that Weissmann makes when he says that living matter is potentially immortal. It is an alternative hypothesis to the one usually adopted, and Weissmann's contribution to the subject comes not so much from his adoption of this view as from the application he makes of it in considering the higher forms of life in which death is an indisputable reality. Weissmann's theory of the origin of death among the metazoa is developed directly from his hypothesis that living matter was originally incapable of natural death. His direct statement that the simplest unicellular forms of life to-day probably retain this primitive constitution of protoplasm has not, however, passed unchallenged. Maupas has made an experimental test of the statement in some very interesting observations. He set himself to observe, throughout an extended period, certain unicellular animals when placed under the most favorable conditions for growth and multiplication. The infusoria were chosen for experiment. After making careful observations upon the best conditions of temperature and food, an individual was selected, placed upon a microscopic slide in a suitable moist chamber, and kept under the most favorable conditions possible for propagation. A faithful record was kept each day of the increase in number, through multiplication by division, of the specimen chosen for study. After the increase had reached some hundreds of individuals, one of them was again isolated and allowed to multiply, and so on until unmistakable signs of what he calls a senile degeneration became apparent in the offspring. His experiments lasted for a variable time. In no case were the observations carried over less than fourteen days, and in the case of stylonichia pustulata, upon which the most careful experiments were made, the successive progeny were cultivated for nearly five months.

The rate of growth in some of the species was incredibly fast. Maupas estimates that in six and one-half days a single stylonichia, at a temperature of 25° to 26° C., might produce by repeated fissions a body of protoplasm weighing 1 kgm., and in thirty days a mass of protoplasm a million times larger than the sun. He was able to observe that after a certain number of generations the progeny began to show signs of a physiological decline. The new animals formed were smaller than normal, seemed weaker, were not so well provided with cilia, and the nuclei contained within them gave microscopical evidence of pathological changes. Maupas looks upon this result as proof of a genuine senility which would have resulted—had the process of isolation been continued sufficiently long—in the natural death of all the descendants, despite the most favorable conditions for living.

After a colony began to show signs of old age he found that if one of the animals was taken out and mixed with another lot having a different ancestry, conjugation took place. The weakened infusorian united sexually with one of the more youthful forms, and rejuvenescence was thereby secured. The descendants of this pair multiplied again with the original vigor and gave rise to normal healthy offspring. Weissmann takes exception to these experiments. The infusoria are the most highly developed of the unicellular animals, showing a marked degee of specialization of structure. Furthermore, they are known to conjugate at certain periods in their life history. A pair will come together and exchange a portion of their nuclear material, after which each begins to multiply by simple fission with renewed vigor for a certain undetermined period. It may be that in so highly a differentiated form the primitive reproductive power of protoplasm has been specialized in a particular structure of the cell, as in the higher animals it has been reserved only to the germ cells; so that in this regard the infusoria might be classed with the metazoa rather than with the protozoa. Moreover, it may be doubted whether Maupas really kept his captive infusoria under perfectly normal conditions. Outside the mere question of food the possibility of not retaining a perfectly normal balance in the inorganic constituents of the medium suggests itself at once. In some more recent experiments of the same character reported by Joukowsky results more favorable to Weissmann's views were obtained. Joukowsky used several species of infusoria. His method was to isolate an individual in a moist chamber and feed it carefully. After several days this individual by fission had given rise to a colony of perhaps sixty to one hundred offspring. One of these was then isolated, treated in the same way, and this process was kept up in some cases for many months. His most striking results were obtained with pleurotrichia lanceolata, which he observed during eight months and through four hundred and fifty-eight generations. During this time no conjugations were seen, and no signs of degeneration or senescence, such as Maupas described, were noticed. Granting, however, that no exception can be taken to the experiments as made by Maupas, and that his results are correct, Weissmann contends that in the more primitive forms, in which reproduction is always by simple fission and anything approximating sexual conjugation is unknown, his fundamental hypothesis must still be true—death can occur only by accident, and not by natural decay. In the amœbæ, bacteria, and similar forms of life no conjugation has been discovered. While the conditions of life are favorable, growth and multiplication go steadily on. When the conditions of life are unfavorable—*e.g.*, when moisture is withdrawn—forms like the amœba may become encysted and cease to show the properties of living matter until more favorable conditions prevail. Götte has seized upon this process of encystment as the equivalent of death, but we shall speak of the theory of this author after Weissmann's theory has been stated.

Let us assume that Weissmann is right in his fundamental hypothesis, and that the first forms of life were potentially immortal, as the simplest forms of life are to-day. What, then, has become of that immortality in organisms like ourselves? What was the origin of death? Weissmann makes the supposition that in the higher animals we have two kinds of living matter, one composing the mass of the body, which unquestionably is subject to a natural death, and one composing the reproductive cells, which is evidently possessed of potential immortality, since if fertilized and kept under proper conditions it will give rise to an infinite number of descendants. The former, the mortal, he speaks of as somatoplasm, the latter, the immortal, as germ plasm. Furthermore, he supposes that the germ plasm, constituting the reproductive cells in any individual, is directly derived from the fertilized ovum from which that individual developed. The fertilized ovum is a single cell; by cell division it multiples a billion-fold and more to make the body. Of this infinite number of cells those which make up the muscles, skin, etc., although directly derived from the ovum, have become specialized physiologically as well as morphologically to fit them for the performance of their special functions, and at the same time they have lost the potential power of immortality which characterized the germ plasm of the ovum. But among this infinite number of cells there are always certain ones that do not undergo specialization; they remain like the ovum from which they were formed; they retain a portion of the germ plasm with its powers of immortality, and these cells become the ova and spermatozoa from which new organisms may be developed in turn. If we carry back this conception through the line of ancestral forms from which man has been developed, it involves the idea that the germ plasm has been actually continuous throughout the history of living things, and that it represents the immortal protoplasm of the unicellular forms from which the metazoa were evolved. This is the doctrine that goes by the name of the "continuity of the germ plasm," and in the form in which it is presented makes one of the most original contributions given to biology within recent years. The question as we have it before us now may be stated in this way: The unicellular forms are potentially immortal; the many-celled animals contain an immortal germ plasm and a mortal somatoplasm, and yet the many-celled animals have been directly derived from the unicellular forms. In the first many-celled animals produced, the different cells must have had similar properties; they must all have been equivalent to reproductive cells. But subsequently, after specialization of structure and physiological division of labor had become established, it happened that the vast majority of the cells of the body, all those in fact that had undergone differentiation in structure and function, lost the power of perfect nutrition, and became subject to old age and death. Upon what biological grounds can we explain this variation? Weissmann refers it to the operation of the law of natural selection, and states his theory briefly in saying that death is an adaptation, acquired because of its utility to the race on the one hand, and, on the other hand, because, after the beginning of a differentiation in function among the cells, the possession of immortality by all the cells was no longer of any value to the race, and therefore was not brought under the preserving influence of natural selection.

With reference to the first of these reasons, the utility of death to the race, it must be borne in mind that the operation of the law of natural selection is directed entirely toward the perpetuation of the species. Anything that endangers this perpetuity will be discarded, and the duration of life of the individual is a point worth fighting for, or against, only in so far as it influences the struggle for existence of the species. If natural death had not appeared, and creatures could have been destroyed only by fatally adverse changes in their environment, then we may imagine that every species would have been burdened in its fight for existence by individuals whose physical value had been impaired by previous minor accidents, such as loss of limbs, etc. There would have been, from the pitiless standpoint of natural selection, many useless mouths to feed. Weissmann was inclined in his first essays to lay great stress upon this point, but in later years he emphasized chiefly the second of the reasons given above, namely, that immortality was lost to the non-reproductive cells because, being of no direct value in the perpetuation of the species, it was not acted upon and preserved by natural selection. The tendency of structures to retrograde and disappear when their value to the species becomes *nil*, even though they may not be actively injurious or burdensome, because natural selection no longer acts to preserve them, is something of a new idea in biology. Weissmann attaches great importance to it, and has coined for it the term panmixia. A simple example of its action is seen in the absence of eyes in the cave-inhabiting animals. Many of the crustacea living in the dark caves have lost their eyes—by panmixia, Weissmann would say; that is, in their peculiar environment their eyes are no longer of use, and they have therefore degenerated and disappeared, in the course of generations, by the lack of the direct preservative influence of natural selection. So Weissmann thinks that the original immortality of living matter became lost to the non-reproductive cells in the many-celled animals because, being of no value to the species, indeed, on the contrary, threatening the species with an unnecessary burden, natural selection let it alone. To the writer's mind this kind of argument, indeed, the whole idea of panmixia, seems to be very incomplete, it lacks all suggestion of a specific cause. In physiology we are familiar with many examples of retrogression of structure following upon disuse. A muscle or gland thrown out of function by severance of its motor nerve, or a nerve cell cut off from its normal connections, atrophies from disuse. But the explanation given is specific to the extent that it refers the atrophy to an altered metabolism. Functional activity in specialized tissues seems to be necessary for their normal metabolism, and lack of activity, as in the paralyzed muscle, is followed by a perverted metabolism that results in the destruction of the tissue. In the same way the loss of perfect nutrition in the somatoplasm might readily be referred, as in Weissmann's first explanation, to an altered metabolism that, arising spontaneously, was subsequently preserved by natural selection, because it proved advantageous to the species.

Many eminent biologists have found a logical difficulty in understanding how from cells originally immortal cells that were mortal could have been derived by differentiation of any kind. They hold that natural selection can operate only upon a structure that exists, it cannot create a thing outright. If living matter was all originally immortal, how could natural selection, by negative or positive action, produce mortality, if in some degree this latter property was not already inherent in living matter. As one of the objectors (St. George Mivart) puts it, the difficulty is to understand the first step, the beginning of something from nothing. Objections of this kind are of course fallacious; it is curious that they should have been seriously made by eminent men. The words mortality and immortality do not stand for definite things; they are not substances or entities, or whatever term of this kind one may choose to use. On the contrary, they are in this case merely convenient phrases to express the kind of nutrition going on in living things, whether it is self-perpetuating or self-limiting. They are properties that are connected with the physical or chemical structure of living matter, and this latter is a thing that does exist and may be acted upon and modified by natural selection in many ways. Weissmann's conception of an early differentiation in the developing embryo of a somatoplasm and a germ plasm has not seemed to meet with favor in the eyes of many competent biologists. These have claimed that in the early segmentation of the ovum the separate cells that are formed are essentially equivalent; that a complete embryo may be formed from a half or quarter of the egg, and that the nuclei first arising may be changed about experimentally "like a heap of billiard balls" without altering the course of development. In thus denying that the orderly course of development is controlled entirely from within, by a system of differentiating divisions of the ovum, these authors are led to lay more stress upon what may be called external forces. As Hertwig expresses it: "I regard the divergent differentiation of cells as a reaction of the organic material to unlike impelling forces." This point of view would seem to be incompatible with the conception of a continuity of the germ plasm, and it has been said with much force that the truth of this latter hypothesis has not been actually demonstrated. However, those who oppose Weissmann's views become involved themselves in numerous undemonstrated assumptions, and seem often to miss the physiological truism that continuity of living matter does not imply an unchanging organization, but rather a perpetuity of nutrition, a perfect metabolism whereby waste is completely repaired, senescence is made impossible, and death is conceivable only as the result of accidental causes.

In accepting or refusing Weissmann's theory of the origin of death, everything seems to depend upon the validity of his fundamental hypothesis with regard to the absence of natural death among the primitive forms of life. If we admit that there are simple organisms, such as the bacteria or the amœbæ, that do not propagate by conjugation or by any method of multiplication other than simple fission, it would seem logically impossible for such a species to be perpetuated unless its protoplasm is exempt from senility. If we do not accept this solution, then we must suppose either that there is some kind of sexual rejuvenation that has not yet been discovered in these particular forms, or that there is some process of molecular rejuvenation occurring at periods in the life history of such forms that brings the living substance back to its primitive constitution and nutritive vigor. Götte has clearly recognized this necessity, and has proposed a theory that is logically acceptable. According to Götte, death is a necessity immanent in life. As regards the unicellular forms of life, he avoids the difficulty that has just been described by assuming that the process of encystment is the death of the old individual and the beginning of a new one. Encystment, of course, is known to occur among the unicellular forms. During the process the visible evidences of life, such as movement, come to an end, to be renewed again after a certain period, or under more favorable conditions. Götte believes that during the encystment a change of molecular structure takes place. There is first a dissociation or dissolution, which is an actual death, inasmuch as the properties of living matter are lost. This, however, is succeeded by a stage of reconstruction with the formation of new protoplasm possessed of the primitive powers of assimilation, and capable of developing and multiplying for a certain period. This is obviously an hypothesis that it is practically impossible to test by chemical investigations. To the physiologist it will probably not be acceptable on theoretical grounds because of the difficulty of conceiving how matter once in the dead form can again pass into the living form, as the result of spontaneous molecular activities, and without the aid of an exciting or liberating force. Dead matter, as we know it, is converted into the living form only by the process of assimilation on the part of matter already living, whereas the hypothesis of Götte calls upon us to believe that the transition may take place by virtue of the intermolecular movements in the dead matter itself. Encystment, then, according to the theory of Götte, represents at the same time the primitive form of natural death and the primitive method of reproduction. As the metazoa have been derived from the unicellular forms, he further assumes that among the former both natural death and reproduction have been acquired by direct inheritance. As in the protozoa reproduction and death stand in a causal relationship, so in the simpler forms of metazoa, *e.g.*, in the orthonectidæ, this connection is still maintained, inasmuch as the liberation of the ova results in the death of the individual. Among the higher forms the relationship between reproduction and death is not so evident, though the theory demands always a causal connection between the two processes.

It will be evident from this brief statement of Götte's views that he differs from Weissmann, not only in his belief of the necessity and universality of death, but also in respect of the discontinuity of life. Among the protozoa, that propagate by encystment, his theory denies that the new individual is directly sprung from the living substance of the parent cell. On the other hand, the general belief has been that in some way the continuity of life is maintained. Darwin's theory of pangenesis, which was formulated to explain the phenomena of heredity, implies a continuity of living matter between parent and child. It will be remembered that in this theory the ova and spermatozoa are supposed to contain minute germs, gemmules, thrown off from the different cells of the body and collected in the germ cells. Under

the proper physiological stimulation, the gemmules develop into organs like those from which they were derived. The gemmules must be regarded as living matter; hence the theory implies a direct carrying over of living substance from parent to child, a continuity of living matter at least. In contrast with this the theory of Weissmann supposes a direct continuity of germ plasm, the essential part of the germ cells of the child being an actual portion of the germ protoplasm of the reproductive cells of the parents. The immortality of the germ plasm and the direct continuity of the germ plasm are, then, the fundamental parts of Weissmann's theory, and his hypothesis of the origin of death as regards the somatoplasm follows naturally if we accept these premises. It will be observed, however, that Darwin's pangenesis theory may also be regarded as implying the essential immortality of the material composing the germ cells, although neither Darwin himself nor those who have made use of his theory have ever made a specific statement of this kind.

In the older treatises upon the nature of death a distinction was often made between molecular death and somatic death. The former term was meant to include those changes of disassimilation or katabolism, to use a more modern word, which are supposed to be in play in every bit of living matter, and to lead to the formation of dead waste material, such as urea, carbon dioxide, and water. Somatic death was used, as it is at the present time, to describe the final cessation of all vital activities in the body at large. It was supposed that we had here the production of dead from living matter by two entirely different methods. The term molecular death is obviously an unhappy one, and has fallen into disuse, although it is possible that it is an accurate statement of what takes place. The essential nature of the physiological oxidations which lead to the formation of the products of disassimilation is at present a subject of discussion, and will probably remain so for a long time. Treating the subject in the most general way, it seems evident that in disassimilation one of two things may take place. If, for the sake of simplicity, we confine our attention to a single cell, then it is possible, on the one hand, that the formation of the wastes of nutrition is brought about by the actual death and disintegration of portions of the cytoplasm, their places being supplied by new living material formed in other parts of the cytoplasm or in the nucleoplasm. Or, on the other hand, it is equally possible that in normal disassimilation no single living molecule undergoes total destruction. The process of dissociation may be such that only a portion of the molecule is split off, and lost from the cell as dead material, while the remainder of the molecule reconstructs itself from the food material of the cell juices into the originally complex molecule of living matter. This, in fact, is the hypothesis of physiological oxidation which has been proposed by Pflüger with special reference to the metabolisms of muscle during functional activity. His theoretical views have much to recommend them, and some account of them is usually given in the text-books of physiology.

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DEATH, SIGNS OF. See *Cadaver, Legal Status of.*

DECIDUA.—The decidua is the mucous membrane of the uterus, which, under the influence of pregnancy, has undergone marked changes to fit it for the implantation and nutrition of the ovum. It owes its name to the fact that it is cast off after labor. The older writers usually distinguished between the decidua of menstruation and that of pregnancy; but as the most recent work upon menstruation has shown that only a minimal portion, if any, of the endometrium is cast off at that time, the employment of the former term does not appear to be justified.

We are not able to state exactly when the decidual formation commences, but

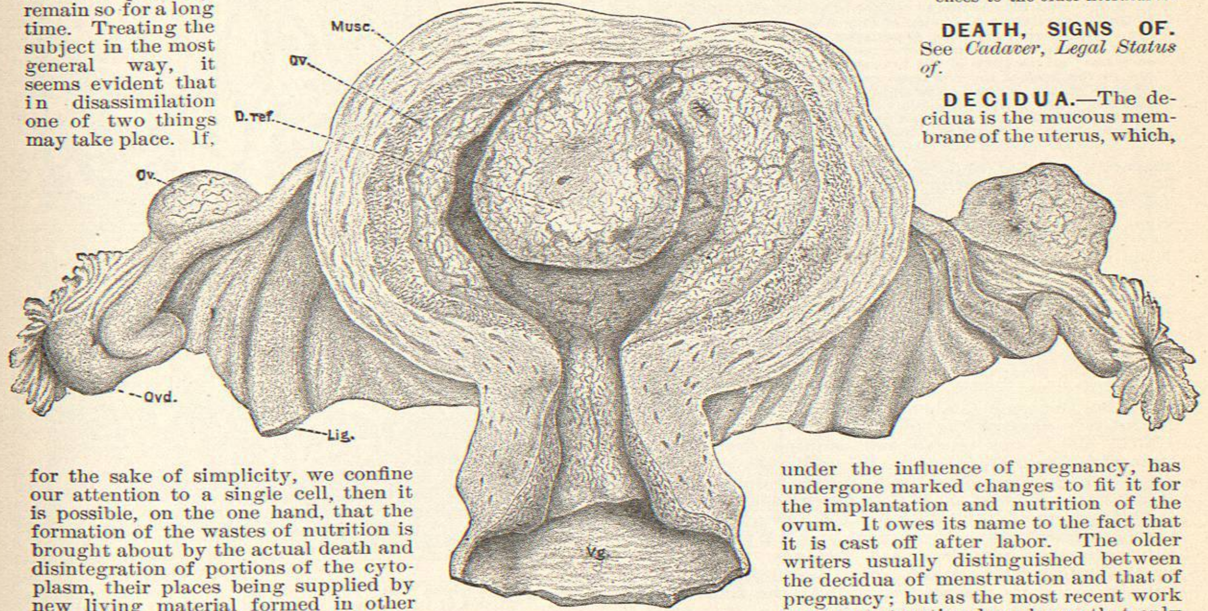

FIG. 1577.—Uterus about Forty Days Advanced in Pregnancy. (After Coste.) *Musc*, Muscularis; *Dv*, decidua vera; *D. ref*, decidua reflexa; *Ov*, ovary; *Ovd*, Fallopian tube; *Lig*, round ligament; *Vg*, vagina. The uterus has been opened by cutting through the anterior wall, and reflecting the sides.