Inherent Death.

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LET us now parenthetically inquire as to this inherent cause of death—this something in the organism which, more clearly than the other structures and properties of the organisms, limits life. We say, "more clearly," for it is impossible to regard what was ascribed to "external agencies," without remembering that they have their correlatives in the organism itself.

How is it that absolute potential longevity is made to have a limit by heredity? How is it that natural decay is hereditary as to time and effect? The whole subject of the hereditary transmission of specific characters has been recently treated of by Mr. Darwin in his volumes on "Animals and Plants under Domestication," and the ingenious theory of Pangenesis started to explain and collect all these phenomena under one head. Though Mr. Darwin does not allude especially to senility, he mentions at length periodic developments agreeing as to the time of their appearance in both parent and offspring. The theory of Pangenesis is thus stated: "I assume that cells before their conversion into completely passive or 'formed material,' throw off minute granules or atoms, which circulate freely throughout the system, and when *supplied with proper nutriment multiply* by self-division, subsequently becoming developed into cells like those from which they were derived. They are supposed to be transmitted from the parents to the offspring, and are generally developed in the generation which immediately succeeds, but are often transmitted in a dormant state during many generations, and are then developed. Their development is supposed to depend on their union with other partially developed cells or gemmules which precede them in the regular course of growth. Gemmules are supposed to be thrown off by every cell or unit, not only during the adult state, but during all the stages of development." (Darwin, loc. cit. vol. ii, p. 374.)

We may use this theory to explain the hereditary character of senility. The gemmules, "when supplied with proper nutriment, multiply." As long as there is nutriment for them they will continue to be produced, but when the superabundance of nutriment ceases, which, as we shall see, is soon after growth is quite completed, their production ceases; they are thus limited in number, and, being called upon in repair and reproduction, are gradually exhausted. But it is not necessary to have recourse to the pangenetic gemmules, which are only considered by Mr. Darwin as provisional hypotheses. The physiological units of Mr. Herbert Spencer, which he describes as follows,* will suffice as an assumption; or, indeed, we need go no further in explicitness than is involved in the assumption of "a matter of life." What we have to explain is why Mr. Spencer's units, or the "matter of life," should be limited in quantity in various organisms, so that life terminates at different periods, even when two species compared appear to have been subjected to the same external agencies. The old writers distinguished the "*vires in posse*" and the "*vires in actu*." The aged, they said, had not, as the young, this under-stratum of "*vires in posse*" to call upon in cases of exhaustion. "We must never forget to insist," says M. Reveillé Parise, "upon this fundamental principle, that the unknown force of life, *vis abdita quædam*, diminishes more and more with the progress of age." "*Ex viribus vivimus*," said Galen. A young man is commonly said to overtax his strength and to injure his *constitution* by great expenditure of force when young. The common idea expressed in these various statements of opinion is that a store of life-force or life-material exists, which the young accumulate, which increases up to a certain amount, but which ceases to do so at some period, and thenceforward dwindles. Professor Huxley has well expressed this in terms of life-material, in a lecture delivered at Edinburgh in January, 1869. "At any rate," says Professor Huxley, "the matter of life is a veritable *peau de chagrin*, and for

* Mr. Spencer, after describing the organic "polarity" seen in the phenomena of repair and development, says, "If then this organic polarity can be possessed neither by the chemical units nor the morphological units, we must conceive it as possessed by certain intermediate units, which we may term *physiological*. There seems no alternative but to suppose that the chemical units combine into units immensely more complex than themselves, complex as they are; and that in each organism, the psychological units produced by this further compounding of highly compound atoms, have a more or less distinctive character. We must conclude that in each case some slight difference in their mutual play of forces produces a difference in the form which the aggregate of them assumes"

every vital act it is somewhat the smaller. All work implies waste, and the work of life results directly or indirectly in the waste of protoplasm." Is there any direct evidence of the existence of such a store of force or material as is evidently usually supposed to exist in organisms? If we look at the question from the point of view of force it makes little difference, for force implies matter in a particular condition. It could not be maintained that one organism might possess a greater store of vital force or life-power than another, without there being some *material* representative of that force. Hence we must—whether taking force or matter as our text—look for some matter in the young which disappears in the old. Protoplasm, the physiological basis of life, which no doubt is the same thing as that which Dr. Beale terms "germinal matter," is a matter which by its increase or accumulation in an organism must increase its power—in fact, its amount of life; and, conversely, when diminished, the amount of life must be diminished. It is from the changes of this germinal matter that the formed tissues result, that repair is effected, force evolved, nutriment elaborated, secretion manufactured; and it is a matter of observation that this germinal matter is more abundant in young than it is in aged organisms. The numerous preparations of tissues, and their description by Dr. Beale, the result of his carmine process, clearly demonstrate this, and it is on all hands admitted. The quotation which follows from Mr. Paget is a fair description of that diminution of repairing power to which we shall have to refer, while Dr. Marshall Hall has largely detailed the decline of the vital powers in old age:

"Some people, as they grow old, seem only to wither and dry up; sharp-featured, shriveled, and spinous old folk, yet withal wiry and tough, clinging to life, and letting death have them, as it were, by small instalments slowly paid. Such are the 'lean and slippered pantaloons,' and their 'shrunk shanks' declare the pervading atrophy. Others, women more often than men, as old and as ill-nourished as these, yet make a far different appearance. With these the first sign of old age is that they grow fat; and this abides with them till, it may be, in a last illness, sharper than old age, they are robbed even of their fat. These too, when old age sets in, become pursy, short-winded, pot-bellied, pale, and flabby; their skin hangs not in wrinkles but in rolls; and their voice, instead of rising 'towards childish treble,' becomes gruff and husky."

The germinal matter which abounds more in youth than age, obviously embraces Mr. Spencer's physiological units, thus accounting for and correlating its power of general and special repair. It also must include Mr. Darwin's gemmules, and must be immensely called upon therefore in reproduction, far more largely, perhaps, than is represented by the mere bulk of the generative products. Mr. Spencer recognizes this, and alludes to the shrinking and diminution of the germinal matter in advancing life in the following passage: "Protoplasm, which has become specialized tissue, can not be again generalized and afterward transformed into something else, and hence the progress of structure in an organism, by diminishing the unstructured part, diminishes the amount available for making offspring; or, we may add, for carrying on the work of life. This same store of living matter is called upon and reduced in cases of great expenditure of force, such as are greater than the contemporaneous power of assimilation can supply; and it seems not improbable that this germinal matter may be the store from which Professor Parkes supposed a muscle to draw a supply of nitrogenous aliment in the absence of nitrogenous food, and when only carbo-hydrates and hydro-carbons had been supplied. This is consistent with what is known of the great danger of excessive exertion, especially in the absence of abundant nutriment.

The ovum is composed, in its very earliest stages, of nothing but this protoplasm. As development and growth advance it gives rise to the formed tissues, increasing itself also in bulk. But the germinal matter never increases at the same rate as the whole organism; it is always diminishing relatively to the whole, though increasing absolutely as long as growth continues. This gives us some insight into the way in which the change in the vitality of youth and age occurs.

But there is a more important action than this. What is it that limits growth? what gives the limit to size? Mr. Herbert Spencer ("Principles of Biology," vol. i, p. 128) very fully enters into this matter, and clearly shows that *expenditure* (expenditure which uses the matter of life, and prevents its accumulation) increases more rapidly than growth; there is not a direct agreement between the increase of the one and of the other. This appears from the following considerations. It is demonstrable that the excess of absorbed over expended nutriment must, other things being equal, become less as the size of the animal becomes greater. In similarly shaped bodies the masses vary as the cubes of the dimensions, whereas the strengths vary as the squares of the dimensions. "Supposing a creature which a year ago was one foot high has now become two feet high, what are the necessary concomitant changes that have taken place in it? It is eight times as heavy, but the muscles and bones have increased their power only in proportion to the areas of their cross sections; hence they are severally but four times as strong as they were. Thus, while the creature has doubled in height, and while its ability to overcome forces has quadrupled, the forces it has to overcome have *grown eight times as great.* Hence, to raise its body through a given space its muscles have to be contracted with twice the intensity, at a double cost of matter expended." Mr. Spencer shows that the same relation is true for the absorbing surface, which has only increased fourfold, and for the circulation of nutriment, which has to be transmitted to an enlarged periphery. Thus, then, the period of growth must be limited; thus a period must be reached when the germinal or living matter is no longer accumulated but is destroyed; thus the inherent cause of death has a structural existence. The apparent absence of inherent decay in many trees, in fish, in some reptiles, is alluded to by Mr. Spencer. He attributes it, as we have done above, to their exceedingly small expenditure; trees and plants generally exhibiting no personal expenditure at all, while fish and cold-blooded inert reptiles show very little indeed. Mr. Spencer also remarks that a strict inductive confirmation of the law of increase of expenditure and of growth must not be expected, since the bodies compared, *e. g.* fish and mammal, are not of the same density or chemical constitution entirely.

Another circumstance coöperates with the arrival of a period of balance between the expenditure and the accumulation (and depends on that period) to influence the natural termination of life. The condition of equilibrium between expenditure and nutrition, growth having ceased, might be maintained for an indefinite time were it not that precisely at this period a new form of expenditure, involving a very severe tax, sets in—namely, reproduction. It is when a stationary condition has been reached that we may anticipate from general laws new adjustments of the whole aggregate; while the changes of the more adaptable state of *growth* were in course, while concrete shape was being built up, discrete shapes were less likely so to be; and hence it is, when growth has ceased, or nearly so, that reproduction sets in.

The effect of this additional tax is to start the organism more rapidly down the incline toward the termination of the road of life, the length of time occupied in the downward run depending no doubt on the height of the hill which has been mounted, and on the friction, inclination, and additional acceleration, if any, of the descending body. An accident on the way may bring the imaginary rider over some precipice to the bottom of the course at once, and it is little likely that he will succeed in avoiding the many dangerous corners and pitfalls, which increase toward the end of the road, and finally expend the full amount of impulse in traversing the whole course.

Some organisms may continue to grow and produce young throughout their life; but the earlier reproduction is commenced, and the more rapidly it is carried on the sooner must the increase of the organism's bulk be stopped, and so waste and death ensue. Fish, mollusks, and trees are the extreme cases of this protracted period, which was explained as due to small personal expenditure. A test of the superabundance of the matter of life is seen in the reproduction of lost parts which Salamandroid Amphibians, and also Crustacea, exhibit during a considerable period of life, though it may be questioned if they possess it after their last moult, if they ever have a *last* moult. Salamanders and Crustacea belong to the same category as fish.

A second lot of organisms die at once upon the setting-in of reproduction by the rapid abstraction of the matter of life contained in the eggs and sperm. The Protozoa are typical of this group, for in them the formed matter of the organism is all that remains after reproduction, the entire mass of the germinal or living matter being used in reproduction. Hence there is no after-life, no down-hill run. It is the same with insects and with annual plants; so much of the living matter is taken that they have not power to recover the loss; even assimilation is stayed. The animals of the former group of small expenditure could recover their generative loss, not being called upon simultaneously in other directions.

A third group have the procreative subtraction coming on late. It checks growth and finally stops it, but it is so moderate as to leave the organism enough living matter to go on with, and life ceases only when the living matter is so far reduced as to be unable to keep the existing structures in adequate repair, or provide sufficient material for the necessary outlays of force. Such cases are presented by mammals, birds, and possibly some trees and shrubs.

It may not be out of place here briefly to state how death may be brought about by mechanical causes and external agencies in those organisms whose period of natural decay is very remote. There is of course the chance of accident, which is greater in a long life than a short one. But there are two examples of self-adjusting, or rather self-destroying tendency in the organism, to which allusion may be made. Trees, increasing in size as they grow older, expose a larger surface to the wind, while the roots can not penetrate beyond the limited soil; they thus are more liable to get blown over year by year. Again, increasing as they do, and being stationary in their position, they encroach on each other's area, and exhaust the limits of the soil and space by their united action, what is enough for one not being enough for five or six. In the case of animals, the same mechanical limit appears; where the food is diffused and taken in numerous but small mouthfuls (*i. e.* as in herbivorous and scavenger animals, not predaceous animals), five small mouths will be more efficient in supporting five pounds of an animal than one big one. It is thus that the Maori fly is expelled by the smaller European house-fly. It is thus that large fish, large mollusks, large crustacea of species with diffuse food receive a limit to their life. The greater danger of all kinds involved in increased *surface* also tends to limit life in such organisms.

We have yet to ask how the exact or approximate period of natural death comes to differ in various species by heredity. We have seen how it is possible for a limit to be inherited, but how does the period so limited come to be an hereditary quantity characterizing species? How is it that it varies in animals which commence life and carry it on under very much the same conditions? The specific accidents, actions, wear and tear to which different species are severally subjected are not sufficient alone to account for the fixity of the period, though their influence is important. There is something additional, some more direct cause than these, and we must look for it in the quantitative limitation of the germinal matter itself, varying in species. If it were not so, how can we account for the fact that a cow and a sheep, which start from ova so exactly identical in form and size, composed probably of equal amounts of germinal matter or protoplasm, subject as they develop to the same external influences, living perhaps side by side in the same field, yet differ in their inherited term of life, which appears to be, as nearly as can be guessed, about twenty years for the larger and twelve for the smaller ruminant? We have seen that the expenditure increases during growth more rapidly than the bulk, more rapidly *à fortiori* than the accumulation of germinal matter, which we saw did not increase even as rapidly as the bulk. We may regard this germinal matter as a sort of stock-in-trade with which the losing game of increasing profit or accumulation, but more rapidly increasing expenditure, has to be played. "The rate at which a man's wealth accumulates is measured by the surplus of income over expenditure, and this, save in exceptionally favorable cases, is determined by the capital *with which he begins business*." In the transactions of an organism we trace the same three elements. "There is the expenditure required for the obtainment and digestion of food, there is the gross return in the shape of nutriment assimilated or fit for assimilation, and there is the difference between this gross return of nutriment and the nutriment that was used up in the labor of securing it." As long as this is in excess we have an increase of living matter and an increase of structure, and clearly the larger the capacity of the animal to take in food, etc., on commencing life (individual life), the larger and the *longer* will be the accumulation of germinal matter by the increase of bulk (profit). Say that each year the profit doubles, while the expenditure trebles, with a capital at starting of six units, while the expenditure is a third of the capital, and the profit cent. per cent., or equal to the capital at starting. In the *fourth* year, with these figures, we shall find that the capital commences to diminish, the figures representing its condition in the same units being respectively for the four years, 7, 13, 19, and 13, while it descends to 1 in the fifth year. Now, for comparison, suppose nine units as the initial capital, and the same relations of expenditure and profit, we shall find that the diminution does not commence till the *fifth* year, the growth thus continuing a year longer, the figures being 15, 24, 35, 36, and 33 respectively.

These two cases, in which the quantities are of course merely arbitrarily chosen for example, and in which the ratio of expenditure and profit as to increase is exaggerated, suffice to demonstrate the principle, which may be applied to organisms. It is because the calf at birth is a much larger animal than the lamb, having been carried longer by its parent, who from her greater size could of course give to the offspring a greater proportionate amount of living matter to commence life with, that the cow lives longer than the sheep, or rather inherits a later natural limit to life. The quality of the germinal matter and many other conditions which have to be provided for in laying down such rules as this, by the expression "*cæteris paribus*," must always be taken into consideration.

We have, then, seen reason to think that the duration of life, after growth is completed or coming to an end, depends on the amount of living matter accumulated during growth, and that this depends on the size at birth, *cæteris paribus*. Thus it is that we trace the rationale of that connection between time of growth, time of gestation and potential longevity, which has been pointed out, though we can see no good reason why the number five or any other should express the ratio for the whole class of animals.