

XVI.—*The Asymptotic Nature of Natural Selection.* By  
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I SUPPOSE all the members present understand what is meant by the term "asymptote" in mathematics. The best example of it is found in the case of the curve known as the "hyperbola," where two straight lines may be drawn such that the two branches of the curve continually approach but never touch them. The reason is that though the curve is continually approaching the lines, the rate of its approach is always getting slower, and it never reaches them. These lines are called the asymptotes of the curve, and the curve may be said to asymptotically approach them.

It has often struck me that in many branches of physical science an asymptotic law prevails. Take an example from our own science, geology. If we consider the case of a country acted on by the ordinary geological agencies—rains, rivers, frost, wind, etc.—it is usually allowed that if their action be continued without interruption for a sufficient length of time the country will be reduced to a nearly level plain, rising little, if at all, above the surrounding ocean. But the most extreme uniformitarian will not deny that the erosion will take place faster at first when the land is high and mountainous, and will get slower in proportion as the hills are worn away and the violence of the torrents decrease. Thus the longer the land is exposed to these ordinary geological agencies the less powerfully and rapidly do they act upon it. The process of erosion in such a case is therefore an asymptotic one, for, as the eroding power of these natural agents depends on the elevation and contour of the ground, their effect must continually lessen as the land wastes away. Any one examining the erosion of the country, and trying to estimate its rate, would very much underestimate the time required to complete it, if he chanced to make his examination near the beginning; while if he paid his visit when the erosion was far advanced he would correspondingly overestimate the time required to bring a mountainous country into such a condition as he would see. This point is very clearly brought out in Dr Arch. Geikie's recently published Text Book, where he says, after giving statistics of the denuding power of certain rivers, "It is of course obvious that as the level of the land is lowered the rate of subaerial denudation decreases, so that on the supposition that no subterranean movements took place to aid

or retard the denudation, the last stages in the demolition of a continent must be enormously slower than during earlier periods." ("Text-Book of Geology," page 445.)

To take another instance. If we consider a lake that is being filled up by sand, gravel, &c., brought into it by streams, it is evident that as the lake grows smaller and shallower through this silting up process, less sediment falls to the bottom, and a larger proportion of the whole is carried away by the effluent stream. Of course this latter part of the sediment may, by increasing the scouring power of the river, lower the exit level, and thus drain the lake; but, nevertheless, the filling up part of the process is asymptotic, for, if not interfered with, it gets slower as it goes on, and would never be completed. These examples will suffice to show the manner in which this mathematical expression may be applied to natural phenomena. Many others will occur to any thinking geologist.

This principle appears no doubt a mere conceit or useless play upon words in the examples given above. It becomes, however, valuable as a test or as a clue when investigating that great theory of evolution called by Darwin, "Natural Selection." For the basis of this theory is that a species of animal or plant may improve—that is to say, may become better suited to its habitat; and that this improvement takes place by those individuals who have been born with slight variations tending to make them better suited to their habitat, having the best chance of surviving and of leaving offspring which will inherit and transmit the favourable variations. Now, it was long ago pointed out that though an individual may be a little better fitted for the battle of life than his fellows of the same species, yet this by no means ensures his survival, for the odds, to begin with, are very heavy against any one particular individual living to a mature age, owing to the great overproduction in each species. But this chance of survival is greater the less developed the species is—that is, the less they are in harmony with their surroundings. For if all the members of a species are very well suited to their habitat, very well furnished for the battle of life, then the extra advantages possessed by those individuals born with favourable developments count for little; while if the species be far from perfect, any slight advantages will give the favoured individual a heavy pull over his fellows, and greatly increase his chance of survival. Moreover, these so-called chance variations do not take place without a cause, and to carry out the theory consistently we must look for the cause in the surrounding circumstances; and here again it is evident that as the species gets more in harmony with its surroundings, the impelling force causing these variations will get weaker, the variations will get



fewer or less marked, and the whole process of development slower.\*

But natural selection is not only concerned with the growth and development of any single species, it takes account of the struggle for existence among the various species inhabiting a country. Darwin applies the same general laws here, merely putting the species in the place of the individual above, and therefore the ultimate result will be the same. Whatever local and temporary changes may take place, the general course of development of the inhabitants of a country must get slower as time goes on, and they become more nearly perfect. Darwin in his books on natural selection is rather trying to prove and elaborate the manner in which natural selection acts, than looking to the results which follow if natural selection be taken as a fundamental fact, and the course of development be considered as a whole. But let us now consider what this general result is, assuming in the meantime that natural selection has full and uninterrupted sway, and that no great climatic changes take place.

Put briefly, it is as follows. The development of the inhabitants of a country seems to depend, at first sight, mainly on the mutual action of the various races and individuals on each other; but in this action there is no supply to keep up the continuous development. Hence, though the immediate action of natural selection is a struggle betwixt different races and individuals, yet the start and source of power of development is in the external circumstances of the country in question, that is, using the word in its widest sense, in the climate. The power of the climate to cause (directly or indirectly) variations will get less and less as the inhabitants get better suited to it, and the rate of development must fall off. If these statements are correct the rate of evolution of the various inhabitants of a country will follow the same asymptotic law that the rate of denudation does. It will get slower as time goes on, just as the erosion of a country gets slower as its hills are worn away, and its mountain torrents turn into peaceable lowland rivers. Any small spurt that may take place in the development of one particular species or genus will be merely a temporary irregularity, akin to a sudden increase of erosion caused by a landslide or other local phenomenon.

All this is, however, on the assumption that the conditions under which the action is going on do not change—in the case

\* If the Darwinian principle be pushed to its extremest range, in order that evolution may get a starting point, we are driven to speculate on the probability of the ultimate particles or molecules of the universe being not quite in harmony with *their* surroundings. But this is a matter that may be left to the chemical or physical investigator; it does not directly concern geology.

of the land under erosion no upheavals or subsidences; in the case of the animals and plants no change in the conditions of life. But we find in every country signs of disturbance of level, of upheaval, of volcanic agencies altering the surface contours of the ground, and so giving this asymptotic process of erosion a fresh start. Similarly, if there is to be any great and continuous development of the inhabitants of a land, great, and, from the evolutionist's point of view, tolerably rapid changes in the climate of the land, that is, in the conditions of life, are necessary. In any one country these changes may be caused by local alterations of the positions of land and sea, of the great ocean currents, prevalent winds, &c.; but if we are to seek for a cause affecting the whole world we must look to some such great cosmical causes of change as Dr Croll brings forward in his book, "Climate and Time." He supposes from certain moderately well-authenticated data concerning the variations in the eccentricity of the earth's orbit that the climates of the northern and southern hemispheres will at times get into an unstable state, such that the changes induced by the precession of the equinoxes (that is, by changes in the direction of the earth's polar axis) will cause alternate warm and cold periods of sufficient intensity to give a temperate climate at the poles, or to bury the temperate zones in sheets of ice resembling those which at present surround the southern pole. The period of the precession of the equinoxes is about 20,000 years, and if his calculations are correct, we should have every now and then a period of some 200,000 years or more, in which the climate and conditions of life are completely altered every 10,000 years. The eccentricity is at present small, and is very slowly decreasing, thus we have no great difference between the climates of the northern and southern hemispheres; and indeed the climate of the whole earth may be called *temperate* compared with what it is when the eccentricity is large. During these times (large eccentricity) natural selection will work in a far more rapid and thorough manner than we see it doing at present. When a country that has been long covered with ice and snow becomes in the course of a few thousand years a land with a tropical or sub-tropical climate, it may easily be seen that animals and plants entering and living in it are exposed to rapidly varying conditions of life. They will develop rapidly, every favourable change having great value. And because of the rapid alternations of climate the asymptotic process of natural selection never gets into its slower stages,—before the first stages of rapid development are over the climate has altered, and evolution has to start from a new basis and under new conditions. This effect of climate, it is to be carefully observed, is not a *direct* one.

The direct effects of change of climate on species are usually slight and transitory, a return to the original conditions obliterating all the results of the change. But in this case climate acts through natural selection, and the results have all the widely varying and lasting character that that process stamps on its subjects.

So powerful does this climatic action appear to some that we ourselves—the genus *Homo*—have been put down as a product of the last Glacial Epoch!

On the other hand, species that live under very uniform conditions of life do not develop rapidly. Thus we know that certain species of *Singula* have come down to us almost unchanged from Silurian times; they have probably lived all the time in water of a tolerably uniform character as regards temperature, &c.

Be this as it may, the fact which I wish to call the attention of the Society to is, that when we find any natural process going on, it is not enough, and it is not correct, to measure its present rate of progress, and then assume that it has proceeded uniformly since its commencement: we must first examine and see if the process, whatever it may be, has been uninterrupted, and then if it has, we must assume, not that it goes on uniformly, but that it goes on at a continually diminishing rate. There are, no doubt, exceptions to this rule, but when thought over, they will be found to be wonderfully few, and to consist mostly of cases where only a part of the whole process is considered, and the general scope and result not taken account of.