Some Statistics of Evolution and Geographical Distribution in Plants and Animals, and their Significance.

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IN a paper read at the Linnean Society under the above title on February 2, the statistical methods long employed in "Age and Area" were pushed to their final conclusion. Age and area (review in *Ann. of Bot.*, October, 1921, p. 493) is the name given to a principle gradually discovered in many years of work upon the flora of Ceylon, which, in brief, affirms that if one take groups of not less than ten allied species and compare them with similar groups allied to the first, the relative total areas occupied in a given country, or in the world, will be more or less proportional (whether directly or not we do not yet know) to their relative total ages, within that country or absolutely, as the case may be. The longer a group has existed the more area will it occupy. Tens are compared in order to eliminate chance differences as much as possible, and allied groups to avoid as far as may be the complications introduced by different ecological habit, etc. Herbs, for example, probably spread much more rapidly than trees, but both will obey Age and Area. It is of course obvious that age of itself cannot effect dispersal, but inasmuch as predictions as to distribution of species, occurrence of endemics, etc., can be successfully made upon the basis of age *alone*, it is clear that the average rate of spreading of a given species, and still more of a group of allied species, is very uniform, and therefore affords a measure of age. The result of the work is to show that in general the species (and genera) of smallest areas are the youngest, and are descended from the more widespread species that usually occur beside them.

To Age and Area must be added, as will be shown in a forthcoming book, the twin principle of "Size and Space," which affirms that within any circle of affinity the total of areas occupied by any group of ten genera will go with the total number of species, being large when that is large. The monotypic genera, like the species of small area, must in general be young beginners, and descended from larger genera. Putting these two principles together, it is clear that age, area (or space), and size go together, and as age (representing the resultant of the active factors) is the only working factor of the three, whatever phenomena are shown by size should be similar to those shown by space. But size of genera represents evolution, and area or space represents geographical distribution. These two phenomena should therefore show similar expressions.

But the characteristic feature of geographical distribution, as indicated in all the work upon Age and Area, is that species, whether of endemic or of non-endemic genera, are arranged, as regards their areas of dispersal, in "hollow curves."[1] They show (*cf.* last curve of Fig. 1) many on the smallest area (here one island), fewer on the area next larger (here two islands), and a tail of a few on areas larger again. This type of distribution is practically universal; if one take, for example, a large and widely distributed genus like Cyrtandra, one finds 145 species on small areas, twenty on areas of moderate size, and two on very large areas. If one take the Hawaiian Islands alone, one finds that this genus has twenty-four on single islands, two on two, two on three, and one on four.

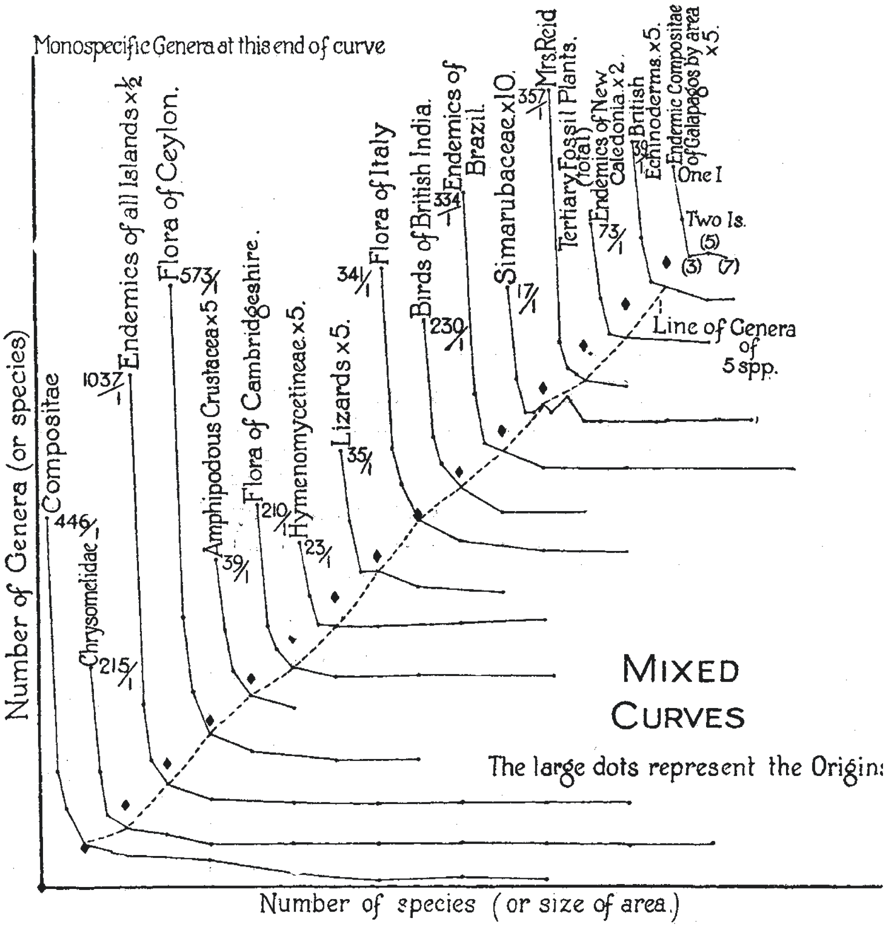

FIG. 1.—Mixed hollow curves. The numbers (thus 446/1) at the beginning of each are the numbers of monotypes.

Now evolution, as expressed in the sizes of genera, shows exactly similar phenomena, and if one group together genera that are associated in any way, systematically, ecologically, or in a given local flora, one gets just the same type of hollow curve, as

[1] By a hollow curve is meant the curve obtained by plotting graphically a series of numbers of which the first is much the largest, while there is a considerable drop to the second and again to the third, and then a gradual falling off to the end. The first two make up about half the total. For instance, a hollow curve will be obtained by plotting 40/1 (40 of one species), 15/2, 8/3, 6/4, 5/5, 3/10, 2/20, 1/30. Many examples are given in Fig. 1.

Fig. 1 shows. It begins with many genera of one species, fewer (but still many) of two, and tapers away in a tail to the larger genera, the tail being longer the larger the family or area dealt with (the tails in the figure are usually very incomplete: Compositæ, for example, run to 1450). A number of curves are plotted together in Fig. 1, and show that this type of curve holds not only for all the genera of the world, but also for all the individual families both of plants and animals, for endemic and for non-endemic genera, for local floras and faunas (as may be verified in an hour), and even for very local floras, such as that of Cambridgeshire; it holds even for Wicken Fen and other strictly local associations of plants. It obtains, too, as Mrs. Reid showed in a note read the same evening, for all the deposits of Tertiary fossils examined. For the first three numbers it shows very clearly, but as the numbers become smaller they tend to be irregular, though always diminishing towards the end. If one take only the tens, twenties, etc., one obtains a practically smooth curve.

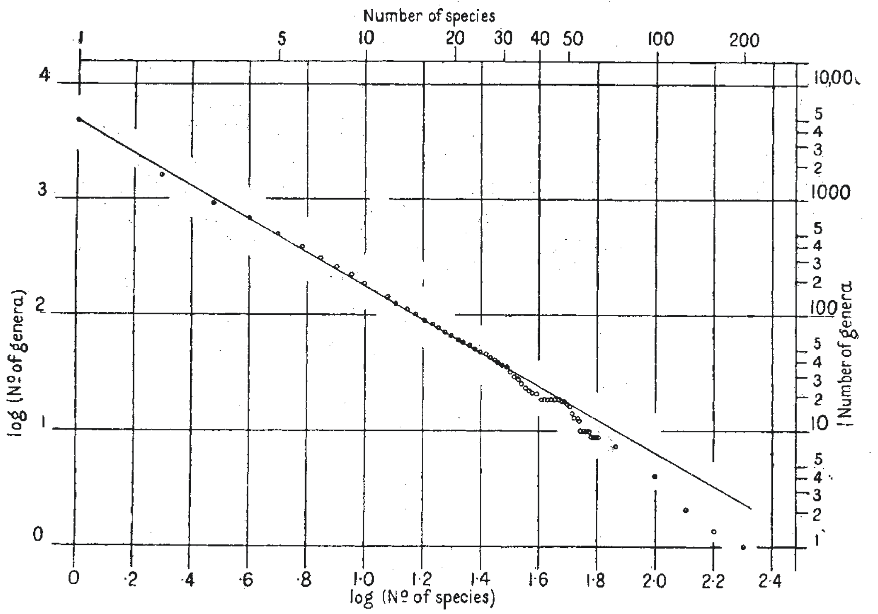

FIG. 2.—Log. curve for all flowering plants.

But now, if species of very limited area and genera of one species (which also have usually small areas) are, with comparatively few exceptions, the young beginners in the race of life, and are descended in general from the species of wider dispersal and the larger genera, and if the number of species in a genus is, broadly speaking, a measure of its age, the idea at once suggests itself that a given stock may be regarded as "throwing" generic variations much as it throws offspring, so that the number of genera descended from one prime ancestor may be expected to increase in geometric ratio or according to the law of compound interest. The number of species descended from one ancestor might be expected to follow the same form of law with a more rapid rate of growth. On such a very rough conception it is found that the form of frequency distribution for sizes of genera should follow the rule that the logarithm of the number of genera plotted to the logarithm of the number of species gives a straight line. Fig. 2 shows the results of this method of plotting for all the flowering plants of the world. The dots give the data, graduated; some process of graduation had to be used, as the statistics were based on the figures given in the "Dictionary of the Flowering Plants and Ferns," which are rounded off in doubtful cases to the nearest 5 or 10 (or greater number in the large genera). It will be seen that, up to genera of some thirty or forty species, there is an excellent fit to a straight line, though there is a marked deficiency of the larger genera—a point on which further investigation is required. Single families show precisely the same rule, the lines not differing very greatly in slope: Fig. 3 gives an illustration of the chart for the Rubiaceæ. Nor is the law one confined to plant life, as is shown by Fig. 4, for the family of Chrysomelidæ amongst the beetles.

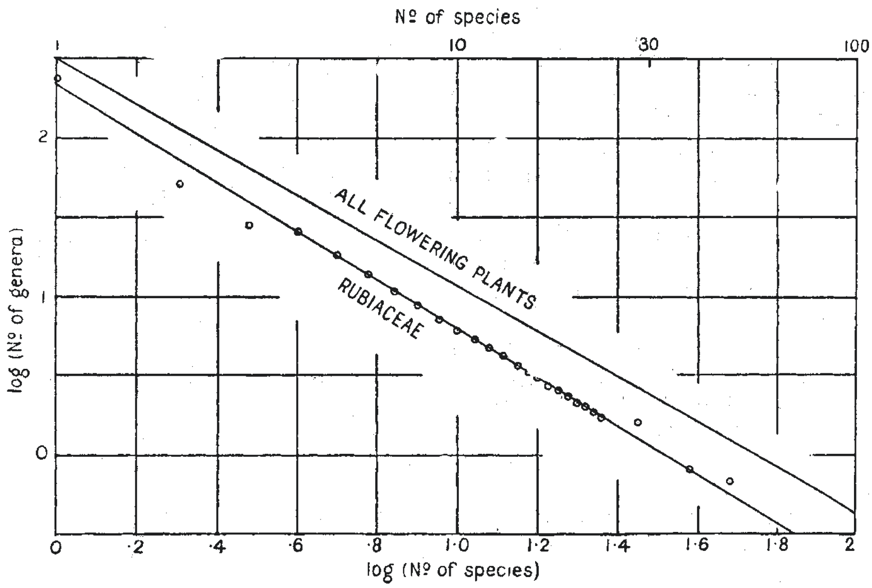

FIG. 3.—Log. curve for Rubiaceæ.

It follows from the conception stated that the excess of the slope of the line over unity should measure the ratio of the rate of increase of genera to that of species. The slope should always, therefore, lie between the limits 1 and 2, for a slope of less than unity would have no meaning, and a slope exceeding 2 would imply that generic variations were more frequent than specific variations. Hitherto no exception has been found to the required rule. One group of fungi tested (Hymenomycetineæ) gave a line with a slope very little exceeding unity (1·08), but the figures found for flowering plants lie between the narrow limits 1·38 and 1·64, with an average of about 1·43. Snakes and lizards both give a figure very near 1·50, and the Chrysomelidæ about 1·37.

The development of a more complete theory may in some degree modify conceptions and interpretations, but the results so far obtained suggest that the basic principle put forward is correct.

Inasmuch as all families, both of plants and animals, show the same type of curve, whether graphic or logarithmic, it would appear that in general the manner in which evolution has unfolded itself has been relatively little affected by the various vital and other factors, these only causing deviations this way and that from the dominant plan. And since, assuming that genera "throw" other genera and species, it was predicted that the logarithmic curves would be straight lines, and it was then discovered that they actually were so, it is probable that the assumption was correct. But if this be so, then not only must evolution have been by mutation, but it must also have been, as one of us has contended for many years, by mutations that were at times of rank sufficient to give rise to Linnean species, genera, or even families. Not only so, but evolution must have proceeded on the lines of Guppy's theory of differentiation, the larger genera, and the species of larger area, being the parents of the smaller: *i.e.* it must have proceeded on the whole in the reverse direction to that postulated by the Darwinian theory, as one of us has long maintained.

Finally, it is clear that geographical distribution has been largely mechanical, the general effect of the many factors that are operative being to cause species to spread at a fairly regular speed (differing for each), so that spread forms a measure of age.

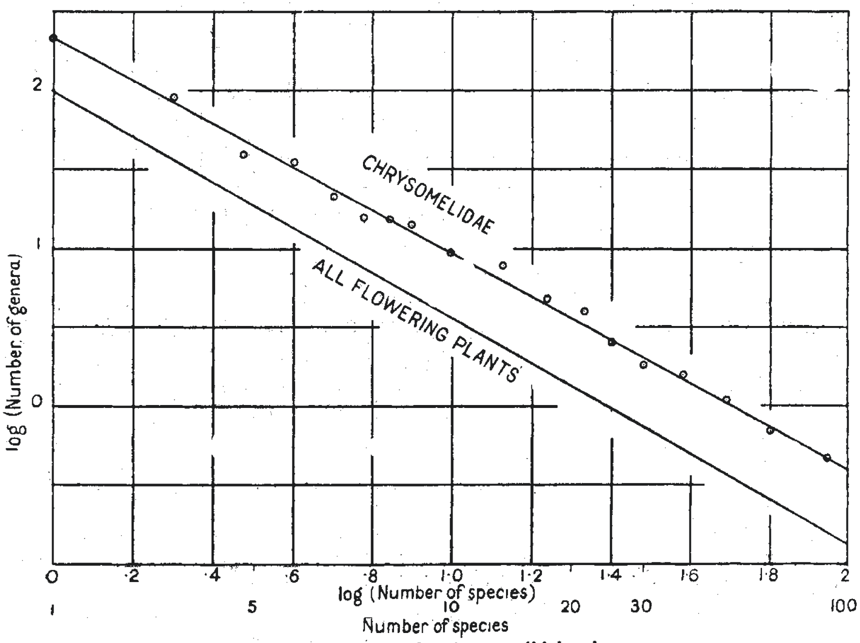

FIG. 4.—Log. curve for chrysomelid beetles.

Space does not permit of detailed argument, which must be left for forthcoming books; but a couple of hours' work at statistics of genera (by sizes) will suffice to make clear the general position taken up.

Some Problems of Long-distance Radio-telegraphy.[1]

By Dr. J. A. Fleming, F.R.S.

II.

ANOTHER cause operating to effect a separation of the positively and negatively charged dust is found in the viscosity of the atmosphere. Roughly speaking, the viscosity of a gas is that quality of it in virtue of which fine particles experience a resistance in moving through it. Maxwell showed long ago that the viscosity of a gas is independent of the pressure over wide limits. Crookes continued these researches and demonstrated that between atmospheric pressure and a pressure of about one ten-thousandth of an atmosphere the viscosity remains constant, but that when the pressure falls below this last figure the viscosity very rapidly decreases to zero. Again, both Maxwell and Crookes found that the viscosity of hydrogen is about half that of oxygen or nitrogen. The viscosity of air at 760 mm. is 0·00018 C.G.S. units.

Sir George Stokes proved that if a small sphere of diameter d and density σ is falling through a gas of density ρ and viscosity μ under the action of gravity it will attain a final velocity v such that

$$v=\frac{1}{18}\,\frac{d^2g}{\mu}(\sigma-\rho),$$

where g is the acceleration of gravity. This explains the extremely slow rate of fall of water particles constituting clouds, and also the very slow settlement of fine dust particles through air.

The positively-charged solar dust particles are probably larger than the negatively-charged particles, as the latter consist of electrons having condensed round them molecules of gases, probably hydrogen and helium, gathered from the solar chromosphere. Accordingly the negative ions will be brought to rest before the positively-charged particles and gas viscosity will assist the separation.

But Stokes's expressions apply to smooth spheres and not to irregularly shaped particles. Also, if the diameter of the particle is much less than the mean free path of a gas molecule, the expression

[1] Continued from p. 143.