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MULTIPLE FACTORS VS. "GOLDEN MEAN" IN SIZE INHERITANCE

GROTH's preliminary note on the "golden mean" in the inheritance of sizes in SCIENCE of April 17, 1914, pp. 581–584, deserves the attention of geneticists. Its publication is of such recent date that I need only call attention to one or two points that seem to me of particular moment.

In brief, Groth's hypothesis is that the mode of inheritance in F_1 not only of surfaces and volumes, but also of linear dimensions is to be expressed by $\sqrt{ab}$ rather than by $a+b/2$ where a and b are parent sizes. The hypothesis is based upon measurements of a large number of tomato fruits of parental and F_1 plants. It will certainly be worth determining whether Groth's expression fits size characters in other plants. A hurried examination of data, both published and unpublished, derived from my own studies of seed size in beans and maize, indicates that F_1 sizes are nearer the average than the geometric mean of the parent sizes. But my object now is not to lay stress upon any possible agreement or disagreement between my results and those of Groth. It is rather with the relation of Groth's hypothesis to the idea of multiple factors that I am here concerned.

That Groth's hypothesis is essentially Mendelian is shown by the fact that his size factors are assumed to segregate in equal numbers in the gametes of F_1 plants. That he regards his hypothesis as entirely unlike

the multiple factor hypothesis is indicated clearly by these statements:

> We know that size characters do segregate in the F_2, but we admit that with them the simple Mendelian ratio of 1:2:1 is never realized, though in large populations the parental sizes may reappear. Mendelians commonly try to account for the complicated ratios by assuming the presence of multiple factors; non-Mendelians point to the same ratios as quasi-evidence against Mendelian inheritance. I offer a different explanation.

By way of conclusion, Groth further remarks:

> The finding in the F_2 or later generations of lines which breed true to size characters is thus not proof of the presence of multiple size factors in the original parents.

It is evident, however, notwithstanding Groth's disavowal, that his hypothesis is distinctly a multiple factor one. His suggestions as to how spherical fruited parent races, the dimensions of whose fruits are $4 \times 4 \times 4$ and $9 \times 9 \times 9$ respectively, might combine to produce F_1 fruits of dimensions $6 \times 6 \times 6$ is rightly regarded as having a bearing "beyond furnishing an explanation of partial dominance in F_1." It might seem at first that he regards volumes as the inherited units and that volume, together with a shape factor, controls linear dimensions. This is evidently not, however, his idea. In the cross noted above for illustration, a gamete bearing a length factor 9, a breadth factor 9 and a thickness factor 9 differs from a gamete bearing a length factor 9, a breadth factor 4, and a thickness factor 9 or 4 with respect to its effect not only upon the volume of the resulting fruits but also upon the length of those fruits. The postulated spherical shape factor, which is common to all gametes, but which modifies the common length factor 9 only in case the breadth or thickness factors are other than 9 and does not modify it in case these breadth and thickness factors are 9, is certainly somewhat confusing. But to say that a length factor 9 produces an effect equal to 9 in length when the breadth and thickness factors are also 9 and produces some other effect on length when the breadth and thickness factors are other than 9 is merely the equivalent of saying that the breadth and the thickness factors have an effect upon length and are thereby length factors. This makes three factors for length—a typical multiple-factor hypothesis.

Again, if the presence of the somewhat fanciful shape factor be insisted upon, we are still dealing with multiple factors. In his illustration, Groth assumes two length factors, 4 and 9 and a shape factor that modifies them under certain conditions. This makes three factors affecting length. We can not limit the length factors to the two, 4 and 9, and say that the third factor assumed to modify length is nevertheless not a real length factor merely because we have chosen to call it a shape factor. Genetic factors for any character are the inherited units that have an effect upon the development of that character. The fact that some of them may also be concerned in the development of other characters, while really important, is immaterial in this connection.

It was said above that a shape factor affecting length, plus the two length factors 4 and 9, make a complex of three multiple factors for length. As a matter of fact there are more than three such factors, if we hold to the shape factor. The shape factor was shown to modify length only in certain cases, namely, when the breadth or the thickness factor is not of the same value as the length factor. In other words, the ability of a shape factor to modify length is influenced by the presence of breadth and thickness factors and the latter thereby become at least indirect length factors. But who, in the present state of our knowledge, can say that the assumed primary length factors 4 and 9 are less indirect in their effect than are the other factors influencing length?

I do not wish to appear too critical of Groth's suggestions. It is only by a careful analysis of such novel suggestions that we can hope to gain a better understanding of how genetic factors behave. My purpose is merely to aid in such an analysis.

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