

Mutations

Und was in schwankender Erscheinung schwebt,
Befestiget mit dauernden Gedanken.¹

GOETHE

'JUMP-LIKE' MUTATIONS — THE WORKING-
GROUND OF NATURAL SELECTION

The general facts which we have just put forward in evidence of the durability claimed for the gene structure, are perhaps too familiar to us to be striking or to be regarded as convincing. Here, for once, the common saying that exceptions prove the rule is actually true. If there were no exceptions to the likeness between children and parents, we should have been deprived not only of all those beautiful experiments which have revealed to us the detailed mechanism of heredity, but also of that grand, million-fold experiment of Nature, which forges the species by natural selection and survival of the fittest.

Let me take this last important subject as the starting-point for presenting the relevant facts — again with an apology and a reminder that I am not a biologist:

We know definitely, today, that Darwin was mistaken in regarding the small, continuous, accidental variations, that are bound to occur even in the most homogeneous population, as the material on which natural selection works. For it has been proved that they are not inherited. The fact is important enough to be illustrated briefly. If you take a crop of

¹And what in fluctuating appearance hovers,
Ye shall fix by lasting thoughts.

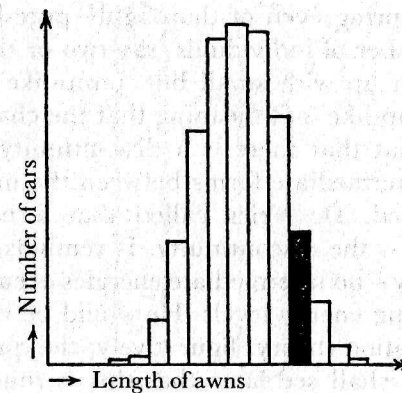


Fig. 7. Statistics of length of awns in a pure-bred crop. The black group is to be selected for sowing. (The details are not from an actual experiment, but are just set up for illustration.)

pure-strain barley, and measure, ear by ear, the length of its awns and plot the result of your statistics, you will get a bell-shaped curve as shown in Fig. 7, where the number of ears with a definite length of awn is plotted against the length. In other words: a definite medium length prevails, and deviations in either direction occur with certain frequencies. Now pick out a group of ears (as indicated by blackening) with awns noticeably beyond the average, but sufficient in number to be sown in a field by themselves and give a new crop. In making the same statistics for this, Darwin would have expected to find the corresponding curve shifted to the right. In other words, he would have expected to produce by selection an increase of the average length of the awns. That is not the case, if a truly pure-bred strain of barley has been used. The new statistical curve, obtained from the selected crop, is identical with the first one, and the same would be the case if ears with particularly short awns had been selected for seed. Selection has no effect — because the small, continuous variations are not inherited. They are obviously not based on the structure of the hereditary substance, they are accidental. But about forty years ago the Dutchman de Vries discovered

that in the offspring even of thoroughly pure-bred stocks, a very small number of individuals, say two or three in tens of thousands, turn up with small but 'jump-like' changes, the expression 'jump-like' not meaning that the change is so very considerable, but that there is a discontinuity inasmuch as there are no intermediate forms between the unchanged and the few changed. De Vries called that a mutation. The significant fact is the discontinuity. It reminds a physicist of quantum theory – no intermediate energies occurring between two neighbouring energy levels. He would be inclined to call de Vries's mutation theory, figuratively, the quantum theory of biology. We shall see later that this is much more than figurative. The mutations are actually due to quantum jumps in the gene molecule. But quantum theory was but two years old when de Vries first published his discovery, in 1902. Small wonder that it took another generation to discover the intimate connection!

THEY BREED TRUE, THAT IS, THEY ARE
PERFECTLY INHERITED

Mutations are inherited as perfectly as the original, unchanged characters were. To give an example, in the first crop of barley considered above a few ears might turn up with awns considerably outside the range of variability shown in Fig. 7, say with no awns at all. They might represent a de Vries mutation and would then breed perfectly true, that is to say, all their descendants would be equally awnless.

Hence a mutation is definitely a change in the hereditary treasure and has to be accounted for by some change in the hereditary substance. Actually most of the important breeding experiments, which have revealed to us the mechanism of heredity, consisted in a careful analysis of the offspring obtained by crossing, according to a preconceived plan, mutated (or, in many cases, multiply mutated) with non-mutated or with differently mutated individuals. On the other hand, by virtue of their breeding true, mutations are a suitable material on which natural selection may work and produce

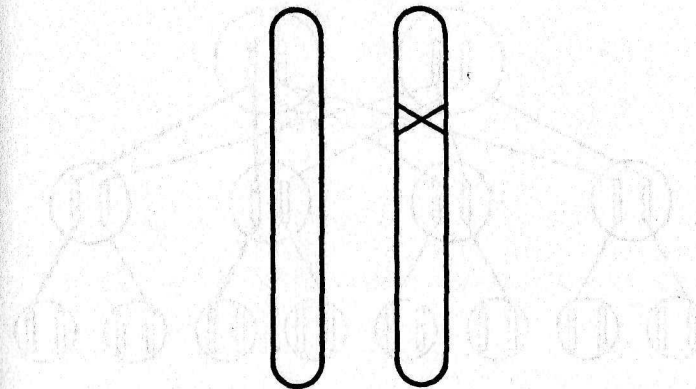


Fig. 8. Heterozygous mutant. The cross marks the mutated gene.

the species as described by Darwin, by eliminating the unfit and letting the fittest survive. In Darwin's theory, you just have to substitute 'mutations' for his 'slight accidental variations' (just as quantum theory substitutes 'quantum jump' for 'continuous transfer of energy'). In all other respects little change was necessary in Darwin's theory, that is, if I am correctly interpreting the view held by the majority of biologists.¹

LOCALIZATION. RECESSIVITY AND DOMINANCE

We must now review some other fundamental facts and notions about mutations, again in a slightly dogmatic manner, without showing directly how they spring, one by one, from experimental evidence.

We should expect a definite observed mutation to be caused by a change in a definite region in one of the chromosomes.

¹Ample discussion has been given to the question, whether natural selection be aided (if not superseded) by a marked inclination of mutations to take place in a useful or favourable direction. My personal view about this is of no moment; but it is necessary to state that the eventuality of 'directed mutations' has been disregarded in all the following. Moreover, I cannot enter here on the interplay of 'switch' genes and 'polygenes', however important it be for the actual mechanism of selection and evolution.