SPECIAL ARTICLES

PROGRESS REPORT ON POSSIBILITIES IN PROGENY-TEST BREEDING

THE extent to which plants and animals can be gradually modified by selective breeding over a series of generations in some predetermined direction, such as more rapid growth or increased yields—to mention only two examples from a very long list—as contrasted with the preservation of haphazard but inheritable modifications, known as "mutations," is evidently of significance to the theory of evolution by means of natural selection, because if man can change the character of a population by suitable methods of selective breeding to a sufficient extent in some desired direction, it is not unlikely that the same amount of change can be made by natural selection, even if the rate of change is too small to be measured in a human lifetime. Men's views on the effectiveness of artificial selection have passed from belief in its power to produce very extensive, indeed almost unlimited, modification to skepticism so great that twenty years ago biologists practically abandoned active work in this field. This change of opinion arose from lack of success in continuing the modification beyond nearby limits, thus leading to the conclusion that the amount of modification is so restricted that further work along this line would be of little value.

However, new efforts lead to renewed hope that larger changes can be made in quantitative characters than was indicated by the earlier efforts. The renewed efforts are merely a beginning—a very small beginning, it is true. And though it would be very unwise to conclude from what has already been accomplished, that the present rate of progress will be maintained indefinitely, nevertheless, the change already made in velocity of growth processes indicates that we may perhaps accomplish with sufficient time these larger changes which the men who followed Darwin thought could be accomplished by purely phenotypic selection. At any rate, ambitious young men with great capacity for lifetime application to a single task have an opportunity to devote their energies to a field of work which promises abundant returns from their time and attention.

This report deals with an experiment in increasing the body weight of mice, first reported in the *Journal of Heredity* for February, 1938. Using the progeny-test methods there described, it has proceeded from the fourteen chronological groups[1] of that paper through twenty-eight, thus doubling the number of groups during which the average weight of the mice has increased. The average weight of each of the fourteen new groups, added to the fourteen previously reported, is shown in Fig. 1.

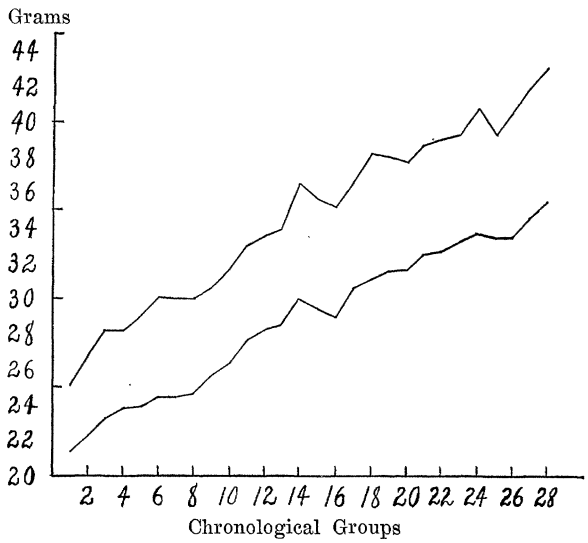

FIG. 1. The upper line shows the average weight of the mice arranged chronologically by groups of five hundred male numbers. The lower line shows female averages, but since females are more numerous than males, each female group, in order to synchronize with the corresponding male group, as a rule contains more than five hundred females. Since counts of the number of generations in the pedigrees of the mice of the last group correspond closely with the number of groups, a group may be taken as a generation, although the first group includes the first four generations and part of the fifth. Chronological groups are used because the number of generations in the ancestry of any individual mouse is not the same in the various possible ancestral lines.

An increase in the weight of the heaviest animals has also occurred. Thus the heaviest male in the last group weighs 54.3 grams as compared to 48.1 of the fourteenth group and 34.2 of the first group. The corresponding females' weights are 49.7, 41.0 and 28.6 grams, respectively (equivalent, on the average ratio of male and female weights, to males of 60.1, 49.6 and 34.6 grams, respectively), these weights being taken at the standard age of two months. Males weighing as much as 35.5 grams at one month of age—the weight of very large, full-grown albino males of the ordinary sort—have been recorded, and aged females have reached 87.5 grams. Thus the heaviest mice

[1] See the description of Fig. 1.

weigh nearly twice as much as the heaviest individuals of most strains of laboratory albino mice.

This experiment was designed in the first place to throw light on the amount of improvement which might be made in the productive qualities of farm animals. When it is realized that the number of parent mice—some 1,200 males and 6,000 females—in the entire twenty-eight generations is very small compared to the hundreds of thousands or even millions of each kind of farm animal mated every year in the United States of America, it would seem that by adding a small amount, perhaps one per cent., to the labor now required to maintain these animals, their productivity can be changed from a level suited to medieval times to a level befitting the twentieth century. If the attained increase in the average weight of the mice is taken as a guide in estimating possible improvement, average milk yield could be increased 70 per cent., horses could be 70 per cent. stronger or speedier, pigs grow 70 per cent. faster, with a corresponding amount of improvement in other animals.[2] We may even wonder what the world would be like if the brain power of the human race were to be increased in like proportion.

Progeny-test breeding of the kind used with the mice may also be applied to plants in numerous ways, such as the development of races adapted to conditions of life to which the parent race is ill adapted, more rapid growth or less rapid growth, indeed to any continuously varying character—not that it will replace other methods of breeding, such as hybridization, which are so effective for some purposes, but that it can be used for purposes to which other methods of breeding are inapplicable, with good prospects of making progress in the desired direction.

The bearing of this work on evolution by means of natural selection is not found in the amount of change, which, after all, is not very large, or in the method of breeding, which does not occur in nature in so far as known, but in providing evidence that organisms may be modified at a rate and to an extent that makes further studies along this line worth the necessary time and effort. The means seem to be at hand for accelerating the rate of change which Darwin and his followers supposed occurred in nature at a very slow rate—too slow, indeed, to be observed in short periods of time. Progeny-test breeding, by accelerating the rate of change, offers a means of studying this aspect of evolution experimentally.

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2 Progeny-test breeding of poultry, under well-controlled conditions, by increasing egg yield by similar amounts, is another demonstration of the possibilities in progeny-test breeding.

ENZYMES IN ONTOGENESIS (ORTHOPTERA). XVII. THE IMPORTANCE OF COPPER FOR PROTYROSINASE[1]

AN inactive tyrosinase or protyrosinase yields a tyrosinase which can be poisoned by carbon monoxide, cyanide and diethyldithiocarbamate. The occurrence of copper in this protyrosinase is thus a reasonable expectation. The purpose of this paper is to test the effects on protyrosinase of the removal and subsequent addition of copper.

Protyrosinase was extracted from eggs of a grasshopper, *Melanoplus differentialis* (Thomas), according to a previously described method.[2] Its tyrosinase activity was measured in a Warburg apparatus. Aerosol, a commercially available synthetic detergent, was added in such excess that any protyrosinase was activated or converted into tyrosinase.

The procedure employed for removing copper from the protyrosinase was similar to that used by Kubowitz in studies of polyphenol oxidase.[3] An excess of potassium cyanide, 5 cc of .01 M KCN, was mixed with 20 cc of the protyrosinase extract. After a half hour 100 cc of saturated ammonium sulfate was added. The precipitate was centrifuged down, washed with 25 cc of saturated ammonium sulfate 0.05 M with respect to potassium cyanide, and dissolved in 0.9 per cent. sodium chloride. This solution was removed to a Cellophane tube and dialyzed against 0.9 per cent. sodium chloride for 50 hours at 0° C. A similar volume of protyrosinase extract received the identical treatment except that sodium chloride was substituted for potassium cyanide. The latter solution served as a control for the extraction of copper. After dialysis the volume of each of the two solutions was brought to 28 cc.

The copper content was estimated by means of a recently described method.[4, 5] A solution of copper sulfate in 0.9 per cent. sodium chloride was used as a source of copper. The total concentration of copper in the Warburg vessels is expressed in terms of moles per liter of reaction fluid (volume equals 3.0 cc).

The results of the treatment with potassium cyanide can be compared in terms of the change in amount of copper. During precipitation and dialysis the control protyrosinase preparation must have lost very little copper, since its 4.7×10^{-6} M represents a 98 per cent. recovery. Only one fifth as much, 0.9×10^{-6} M, remained in the extract treated with cyanide.

1 Aided by a grant from the Rockefeller Foundation for research in cellular physiology.

2 T. H. Allen and J. H. Bodine, *Proc. Nat. Acad. Sci.* (in press), 1941.

3 F. Kubowitz, *Biochem, Zeitschr.*, 299: 32, 1938.

4 A. Eden and H. H. Green, *Biochem. Jour.*, 34: 1202, 1940.

5 The analyses were performed by E. B. Newell.