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Whither Poultry Genetics?*

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One advantage in being a comparatively old man is that most elderly people have accumulated a wealth of experience and are therefore sometimes better qualified to peer into the future than are the enthusiastic youngsters of the day. I should like to think this is why I have been invited to share with you some of my ideas on the future for poultry genetics.

As I have been in the chicken business for some 56 years, and a student of genetics for over four decades, there is, perhaps, some justification for my pondering what lies ahead for the combination of those interests. Like old Ulysses, I can say:

Yet all experience is an arch, wherethro'
Gleams that untravell'd world, whose margin fades
Forever and forever when I move.

Before speculating about the future of poultry genetics, let us consider briefly whence we have come, and how far we have got. For the first 15 years of this century one of the chief responsibilities of poultry departments in North American colleges was to breed strains of improved stock for distribution to farmers. There were few specialized poultry farms. In the 1920's, resulting, perhaps, from Record of Performance programmes in Canada and the United States, there were enough private breeders producing good stock that they could view the state-supported institutions as unfair competition. It was a good thing for the colleges when they were forced out of the poultry-breeding business, and thus enabled to work on problems which the private breeders were unwilling, unable, or unqualified to handle.

During the 1930's the pattern changed again. Hatcheries that had thrived more on volume of business than on quality were squeezed out. Good breeders got better and bigger. Eventually competition

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forced small breeders to recognize that the facilities necessary to produce superior strains were far greater than they had supposed, and the number of small-scale, breeder-hatchery combinations steadily diminished. Out of the competition there emerged the big breeding farms that we know today, with their networks of associated hatcheries stretching, not only from coast to coast, but even to the farthest corners of the earth.

An important factor contributing to the evolution of the big breeder was the recognition that levels of productivity in the best pure strains (whether measured in eggs produced or rate of growth) could be raised significantly higher by the hybrid vigor that frequently results when suitable strains are crossed. To find what crosses yielded the maximum increment in hybrid vigour, extensive testing programmes were essential and, for these, only the big breeder could afford the necessary facilities.

Finally, the old laying contests in which a baker's dozen of carefully selected young hopefuls carried their owners' banners were replaced about 1950 by the random-sample trials. These are far better than their predecessors, not only because they test random samples and bigger ones, but also because they provide better measures of viability and of some other desirable traits. They also provide show windows on which the sun shines from many angles, and in which almost every breeder with a good advertising manager can find some distinction for his stock.

While all this was evolving during half a century, so was the field of poultry genetics. William Bateson started it off in December, 1901, with his report to the Evolution Committee of the Royal Society of London that dominant white, rose comb, and pea comb segregated as simple Mendelian characters. This provided the first evidence that Mendel's laws apply to the animal kingdom.

Over the next four decades, most of the characters that distinguish breeds of the fowl were genetically analyzed by Bateson, Punnett, Davenport and their successors, and a substantial body of facts was accumulated. The mysteries of secondary sex characters, of hen-feathered cocks, and of the celebrated "hen that Crew" were all elucidated.

Following much trial and error, the number of the fowl's chromosomes is established as 39 pairs and the sex chromosome is identified. In fact, since Spillman's demonstration in 1908 that the gene for barring lies in that sex chromosome, at least 14 other sex-linked genes have been discovered, and for 13 of these the approximate loci in the chromosome were shown in a map published four years ago.

Unfortunately, knowledge about quantitative characters is much less precise. We can hardly blame Pearl, Goodale, and other pioneers who tried to fit genetic variations in egg production, size of egg, age at first egg, and other economically important traits into the Procrustean limits of simple Mendelian classes. We can still say only that the number of genes affecting such polygenic traits is not known, nor is their distribution in the chromosomes.

Much has been learned about the inter-relationships of such traits, and we have all those hundreds of "estimates of heritability" waiting so patiently for someone to find any good use to which they might some day be put, but, in breeding to improve important things like egg production and viability, we must still fall back on the progeny test.

The rapid expansion of the science of genetics, and the convincing demonstrations by plant breeders of what its principles could contribute to the improvement of cultivated crops, led to the acquisition of trained geneticists by many poultry departments. Pioneers in this field were Lippincott, Goodale, Asmundson, Warren and others.

A course in poultry breeding, or poultry genetics, became essential for undergraduate students specializing in poultry husbandry, and the field also attracted an increasing number of post-graduate students.

Between 1950 and 1960, demand from the big breeders for qualified poultry geneticists was greater than the supply. More than one fledgling Ph.D., happily clutching his hard-earned sheepskin, went straight to a poultry farm at a salary far exceeding that of the professor under whom he had trained.

Now, in 1964, matters are different. Because of the demise of the small breeders, undergraduates in agriculture—even those from poultry farms— are no longer interested in poultry genetics, and post-graduate students in that field are scarce. This last is not too serious because the record shows that zoologists trained in genetics can become poultry geneticists after a little indoctrination and experience. They can even learn how to hold a hen.

One risk is that the administrators, ever alert to find money for new ventures, may decide that courses in poultry genetics are passé, just as are the courses in incubation once so indispensable in the curriculum of poultry departments, but now seldom offered. If poultry genetics is no longer an essential course, perhaps those who teach that subject are equally expendable. Can we leave the whole business to the big breeders who have unwittingly brought about these changes?

The question is particularly important now because of the trend toward consolidation of separate college departments into divisions of animal science. In such divisions, some specialists deal less with specific animals like chickens, turkeys, pigs or dairy cattle than with specific sciences like genetics, nutrition, physiology, etc., which are applicable to all domestic animals. This trend is not to be deplored. We shall still need other specialists in the management or husbandry of each important domestic animal.

I hope that the need will also be recognized for geneticists who are interested primarily in exploring operations of the genes in domestic birds. Admittedly, we do not need such a specialist at every agricultural college in the land. Perhaps co-operative arrangements can be made among states or provinces so that one poultry geneticist could serve a large area as a source of information, as a leader in research, and perhaps as tutor for disciples in his field.

Certainly, there is almost unlimited scope for further research in the field of poultry genetics. This is neither time nor place for listing problems still unsolved, but it is not inappropriate to mention a few areas which seem to offer interesting opportunities. Most of them would entail the co-operation of geneticists with investigators in other sciences, such as physiology, biochemistry, pathology, etc.

To begin with, there is the unsolved riddle of hybrid vigour. The big breeders are concerned about this, too, but their interest is chiefly how to get the most of it with the least expense. The geneticist would like to know what causes it. How does it work? What are its limitations? Can we select to increase it, as the proponents of reciprocal recurrent selection have been telling us (without any evidence) for 15 years? Or is the increment from hybrid vigour superimposed on the mid-parental mean? If so, then we should select continuously to improve the parent strains that are to be crossed. There is some evidence from silkworms in Japan and from Leghorns at Cornell that this procedure is effective.

Perhaps the answers to some of our questions about hybrid vigour will be found by some cellular physiologist working in his secluded laboratory with Paramœcium or Neurospora, but the workings and utilization of hybrid vigour in domestic animals will still have to be studied with domestic animals. Among these none is more suitable than the fowl.

Enough genetic differences in blood antigens, hemoglobins, and albumens have been found to warrant further extensive research in this field. There are good indications that some of them affect physiological efficiency, and even economic value. Good research in this area has been carried out by some of the big breeders, but is to be hoped that the colleges will not leave them to bear the chief responsibility for it.

Our poultry geneticist of the future will undoubtedly try to raise still higher the productivity of fowls, turkeys, ducks and other domestic birds. I hope that his interest in that field may be directed less toward squeezing another 10 eggs from hens that now lay 300 of them than to the question why some members of even the best families can lay only 150 eggs or fewer. Why are these defaulters substandard? The differences between the leaders and the laggards are often far too great to be explained by simple segregation of polygenes affecting egg production. They suggest, rather, the operation of a few genes that impose great handicaps.

I believe that the search for such genetic defects in physiology, and elucidation of their operations, will prove to be a fascinating field for any geneticist interested in domestic animals. To work efficiently, he will be one member of a research team that includes biochemists and physiologists, perhaps a pathologist as well. Such teams have already found in our own species enough genetic abnormalities in the metabolism of proteins, fats, and carbohydrates to suggest that similar defects must be widespread in other animals.

For example, a deficiency of the enzyme phenylalanine hydroxylase causes the condition called phenylketonuria, and there are at least three other genetic blocks in the catabolism of the amino acids phenylalanine and tyrosine, all resulting from deficiencies of specific enzymes. Deficiencies of other enzymes cause in one case, excessive accumulation of glucose in the liver, and, in another, a galactosemia that is fatal if uncorrected. So many other hereditary defects of metabolism in man are now known that new books about them are appearing almost every year.

Some genetic abnormalities of human physiology have already been found in domestic animals. The hemophilias, A and B, occur in man and the dog; so does a deficiency of the enzyme catalase. The peculiar Chediak-Higashi syndrome, which causes dilution of pigment, an abnormality of leucocytes and subnormal viability, is apparently identical in man, in Hereford cattle, and in Aleutian minks.

Although none of these abnormalities of mammalian physiology has yet been found in domestic birds, one suspects that they must be widespread in our flocks. Man has no monopoly on what Dobzhansky has so aptly called "genetic junk". Such defects could be responsible for some of the poor reproduction, slow growth, mortality, and low productivity which depress average performance of large flocks.

For example, one breeder's average hatch of fertile eggs was consistently lowered by a few hens whose embryos all died during incubation. Studies by Maw revealed that those hens were homozygous for a recessive autosomal gene which prevented transfer from feed to egg of the riboflavin essential for normal development of chick embryos. Buss and his associates are now finding out how that gene operates, but the breeder has long since been told how to detect the defective hens and how to eliminate the gene responsible for them.

Nutritionists, no longer discarding as a non-conformist the recalcitrant chick that stubbornly thrives on the deficient diet, at long last are interested in the genes that make such rugged individualists different from their fellows. Apart from genetic differences in requirements of certain vitamins and of manganese that have been known for many years, similar genetic diversity in the utilization of amino acids has recently been discovered.

In Australia, McDonald's Leghorns differed from his Australorps in the utilization of methionine. Dr. Nesheim and I have found surprising genetic differences among strains of White Leghorns in the utilization of arginine. There are even significant differences in this respect among sire-families within strains, and, by selection within one stock, strains having high or low requirements of arginine have been quickly developed.

As these unsuspected differences were revealed only by special search for them, one wonders to what extent other unknown, latent, genetic differences in the utilization of nutrients might be responsible for the shortcomings of the sub-standard birds that seem to exist in every flock.

Those who know my special interests in poultry genetics may have been dreading, at this time, a long harangue about the importance of research on genetic resistance to disease. I shall surprise them (pleasantly, I fear) by saying only that there is much to be done, and that the work is interesting. Elsewhere I have emphasized the desirability of search for indicators of resistance to diseases, and of investigating the diverse mechanisms for it.

I hope that my poultry geneticist of the future will find time and facilities to carry along a few mutations for study. None can tell when the facts established from such studies may be useful, but any addition to knowledge is desirable, whether immediately useful or not.

When Bateson discovered how dominant white is inherited, he could have had no idea that half a century later a broiler industry wanting birds with white plumage would use his findings to put the gene for dominant white in every new synthetic male developed to sire those broilers. Spillman's sex-linked barring proved to be essential for one of the sex-linked crosses which permits identification of sex at hatching and which is still popular in some areas. The same applies to the gene for silver, long used for sex-linked crosses in Britain.

If it had not been found feasible to identify sexes of chicks at hatching by examination of the cloaca, sex-linked genes and auto-sexing breeds like Punnett's original Cambar would have been of almost inestimable value to the poultry industry. The *K-k* alleles, the only sex-linked genes that can be used thus far for sexing White Leghorn chicks, may yet prove of great value to the industry, but it is doubtful if any such possibility was ever envisioned by Serebrovsky, the Russian geneticist who discovered them 42 years ago.

Some of these simple Mendelian characters are now being found to have interesting pleiotropic effects. For example, the gene for rose comb was incriminated by Cochez as being responsible (in the homozygous state) for the subnormal fertility of Wyandotte males. This has now been confirmed by Crawford and Merritt. Search for pleiotropic effects of other genes is under way, and should be continued.

Somewhere in our great divisions of animal science, interesting careers await the cytogeneticists who will identify in domestic animals the abnormalities caused by aneuploidy—*i.e.* too few or too many chromosomes.

From what has been learned about such unfortunates in our own species, it is certain that our flocks and herds must carry counterparts of Klinefelter, Turner and other related syndromes, and that these are responsible for some of the poor reproduction so common in domestic animals. Others may lower physiological efficiency, and, as the Mongolian idiots have shown, even the tiniest chromosome, when present thrice instead of twice, can make the trisomic individual hopelessly subnormal.

To the best of my knowledge, the only aneuploid syndrome identified thus far in a domestic animal (excluding hybrids) is that of the tortoise-shell male cat, which is XXY and thus the feline counterpart of the Klinefelter syndrome of man.

Since Hippocrates, the embryologists have considered the chick embryo ideal material for their researches, and in the future, as now, they will undoubtedly look to the poultry geneticist for stocks in which to find how mutant genes cause deviations from normal development. Creeper, talpid and other mutants have proven useful for this purpose.

We are frequently asked by embryologists, physiologists and pathologists to provide albinotic chicks, dwarfs, or other mutants for their researches. Asmundson's fowls afflicted with hereditary muscle dystrophy are being studied to learn more about hereditary muscle dystrophies in other species, including our own.

In the future, as in the past, there will undoubtedly be more of those assorted statistical studies which, with more convenience than accuracy, some people lump together under the banner of population genetics. If I were to cast myself in the unaccustomed role of spokesman for that group, I would be repudiated immediately. Nevertheless, I think that the statisticians deserve honourable mention for their attempts over the years to elucidate our knowledge of quantitative inheritance. The true disciples are convinced that they have done so, but I have heard that there are dissenting unbelievers.

Now that the statisticians have determined all those estimates of heritability, and have told us how to predict gains from selection, it is to be hoped that they will not relax into pleasant speculation from an arm-chair about the limits to which productivity might some day be raised by selection to be practised by other people. Some of them are already extracting from the bowels of their computers unsuspected interactions between genetic and environmental forces. It is to be hoped that in the future we may learn not only more about which interacts with what, but also, how it does so, and when, and why.

Other fields for research in poultry genetics could be listed, but these few examples should suffice. Who knows what problems now unforseen will arise in the future? It is enough to say, with Hamlet:

There are more things in heaven and earth, Horatio,
Than are dreamt of in your philosophy.

Lest I be accused of having cast the big breeders as the villains in this play, it is desirable that they now be given credit for their remarkable contributions to the poultry industry. One could write a chapter on this, but perhaps it will be enough to say simply that they are now giving the egg-producer a better layer, and the broiler-grower a more profitable broiler, than ever before.

Average (corrected) egg production to 500 days in two consecutive years 1961-63 at 20 random-sample tests in the U.S. and Canada was 216 eggs per pullet housed, and for the best of those tests the figure was 245·6. As I write, there is a report of one batch of broilers reaching three pounds by six weeks of age.

Big breeders have given us a turkey even better than that memorable specimen whose fame has persisted for over a century—the one so big that "he never could have stood upon his legs, that bird. He would have snapped 'em short off in a minute like sticks of sealing-wax." The modern bird is no bigger than Scrooge's turkey, and it can stand on its legs, but it is so broad, so roly-poly, and so delightfully abnormal in conformation that it cannot reproduce efficiently, and hence is largely dependent on artificial insemination for its multiplication.

Some of the larger breeders have published helpful reports of research on blood antigens, quantitative inheritance, the influence of different systems of lighting, or on other subjects. This has led to suggestions that they should accept even more reponsibility for the research that must be done in the future. Perhaps so, but let us recognize their limitations. What breeder, having discovered something that gives him an advantage over his competitors, will be altruistic enough to tell them about it? Furthermore, there are many kinds of research in which breeders have no interest whatever, and one, at least, that might almost put them out of business.

As an example, let us consider the long-distance layer. Fifteen years ago I listed the records of four remarkable hens, each of which had laid more than 1,000 eggs during her first five years. If one hen can do that, why can't others? Is it feasible to breed hens capable of economical egg production for three, four, or more years? If so, one of the egg producer's greatest costs, that of the annual renewal of the flock, would be drastically reduced. So would sales of chicks.

Here is a nice field of study for some young poultry geneticist, but let us not ask any of the big breeders to tackle it. When, some years ago and in an unguarded moment, I mentioned the need for such research to one of them, the response was one equalled in my experience only by the Bronx cheer with which the Rhode Island Red breeders of Massachusetts rejected long ago at Amherst my suggestion that the gene for rapid feathering might reduce their problems with bare-backed chickens, and that they could easily get it from New Hampshires.

The big breeders have enough problems already. Apart from perennial competition among themselves, where are they to get new strains for crosses still better than those now available? The small breeders, on whom they relied for such stock for two decades, are mostly gone, and with them has gone much valuable genetic diversity in the world's stock of the fowl's genes.

Perhaps the genes retained from the sifting of many crosses are enough. Perhaps they can be recombined in the future in even more effective combinations than we have now. One problem for poultry geneticists of the future may be to find ways of restoring again some of the genetic diversity that has been lost by the demise of the small breeder.

These few glimpses into the future for poultry genetics suggest not only that there will be plenty to do, but also that it may prove as interesting, as desirable, and as rewarding as it has in the past.