POULTRY BREEDING

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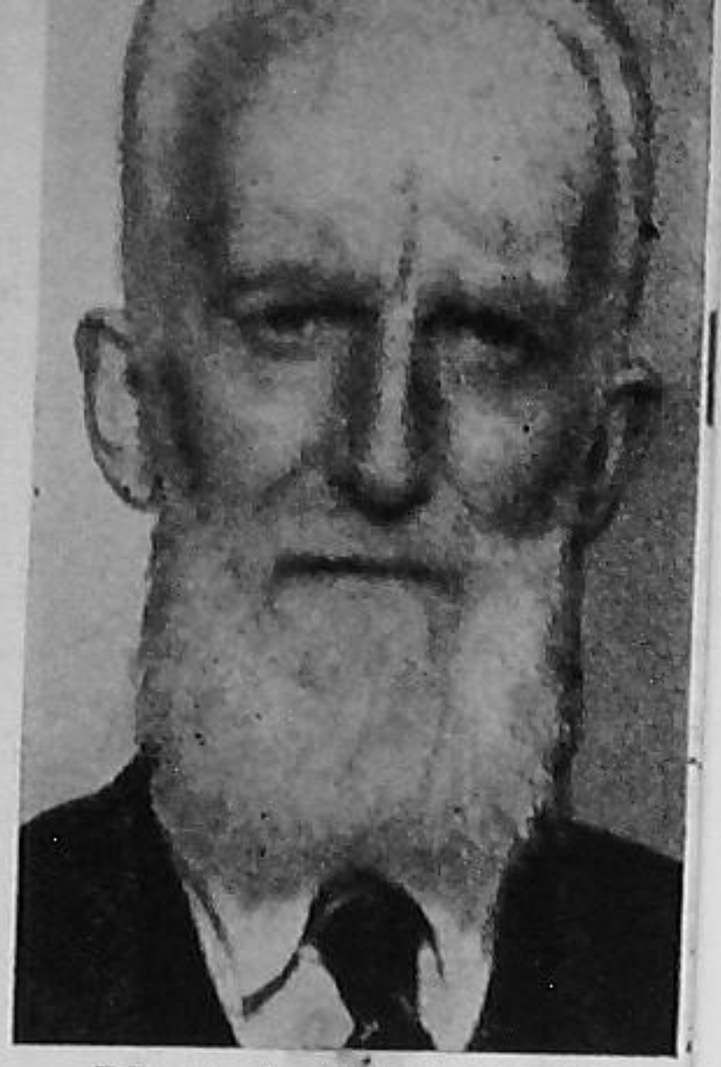
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Far-reaching developments are forecast for the poultry industry in the early future, with important results for the food production of the world. The combination in one volume of the geneticists' ideas about the application of genetical principles and their working out in large-scale general practice will indicate the lines upon which such important developments are expected.

GEOFFREY SYKES



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POULTRY BREEDING

Theory and Practice

BY

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AND

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Publishers' Note

THE fourth edition of "Animal Breeding" contained as an appendix an account by Mr. Geoffrey Sykes of the application of Dr. Hagedoorn's Nucleus Breeding System in commercial practice in Wiltshire.

An outcome of this publication was the suggestion that Dr. Hagedoorn and Mr. Sykes should collaborate in the production of a work on Poultry Breeding, combining the theory and practice of the consulting geneticist with the application to commercial practice in a large way.

The present volume has resulted. It is written in two sections. Hagedoorn and Sykes have only occasionally been in the same continent at the same time since the volume was planned, so that the constant collaboration of joint authorship was found to be impossible. Dr. Hagedoorn has made extensive lecture tours in Australia among cattle, sheep and poultry breeders since then and has been engaged in work in South Africa and Rhodesia.

Mr. Sykes has spent a considerable period in the United States, for part of the time on a Nuffield Farm Scholarship to make an intensive study of poultry keeping. This work has brought him in contact with poultry specialists and research workers over a wide area and some of his findings are recounted in his section of this work.

Far-reaching developments are forecast for this industry in the early future, with important results for the food production of the world. The combination in one volume of the geneticists' ideas about the application of genetical principles and their working out in large-scale general practice will indicate the lines upon which such important developments are expected.

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PART I

Introduction

WHEN, in the very beginning of this century, *Correns*, *Tschermak* and *de Vries* drew the attention of biologists to the extreme importance of an almost forgotten publication by *Gregor Mendel*, we obtained a clue to the understanding of seemingly disjointed facts. *de Vries*, one of the first men to conduct large-scale and very careful experiments on the inheritance of small differences in plants, was one of the foremost among what we now call geneticists, and his results could be interpreted in the light of this clue, the realisation that the material basis of heredity is particulate.

Almost all the early geneticists were botanists, but very soon a few biologists showed that what *Mendel* and his followers had found to be true in plants also held good with animals. *Cuénot*'s paper on the inheritance of colour differences in mice was followed by *Bateson*'s and *Punnett*'s publications about their poultry-breeding work.

To me, in my teens, *Mendel's* papers available in Teyler's Institute, Haarlem, came as a real revelation, as they furnished a key to my own breeding work with mice and bantams; it started me off as a geneticist, a student under *de Vries*, and in all my wanderings I have never stopped breeding my experimental plants and animals, chiefly the smaller rodents and poultry.

As experimental animals, poultry have their excellent points. They are fertile, easily housed and quick maturing. Breeds of domestic poultry are enormously diverse, in size, in colour, in shape. We can easily breed three generations in two years in

experimental series, and the methods of breeding fowls and ducks are very well understood. Before insects came into fashion for experimental breeding work, mice and rats furnished the most promising material, but poultry have the enormous advantage over the smaller mammals that they have some economic value. Breeding experiments with poultry will always be cheap, their eggs and carcases will always pay for the cost of keeping them, even, in our experience, in times of famine caused by war and systematic looting by occupying armies.[1]

From the standpoint of an experimental geneticist, interested in the first place in questions of evolution and purely scientific problems about the nature of the inherited factors, poultry offer some advantages not found in other material. And when we are interested in matters of agricultural economy, we geneticists interested in ducks and fowls find hundreds of amateur and professional breeders, eager to discuss their problems with us. I have considerable experience of co-operating with fanciers and commercial breeders, and more than half of my correspondence about results obtained or about methods of selection has always been about poultry, with sheep as a close runner-up.

Whereas in our purely scientific work, and equally in the work of the tens of thousands of fanciers, the numbers of birds in every generation must necessarily be restricted, the professional poultry-breeders tend to count their chicks in tens of thousands. The result is that an experimental geneticist who is deeply interested in agricultural economics, and in working out really efficient methods of breeding, will, if he is lucky to meet the right type of poultry-breeder or sheep-breeder with an efficient system of book-keeping, be able to have his theories tested out on a sufficiently large scale.

Those of us who have had the pleasure of co-operating with commercial poultry-breeders and fanciers in a great many different countries have had good opportunities of seeing that exactly the same phenomena of heredity are found in this material as in agricultural plants. And the same is true of

[1] In the Second World War Dr. Hagedoorn lived in Holland.

methods of selection. Our readers will see that the methods of breeding and ameliorating productive poultry advocated in this book are by no means new, in the sense that they are based on scientific theories and considerations. We are discussing dozens of different methods, but we are only recommending those which have been tested and proved efficient over and over again, with plants, small animals, and especially with poultry on a really commercial scale.

I am firmly convinced that in the breeding of poultry we must consider very many more things than simply the best and most economical way of producing first-class profitable ducks and hens. If things were as simple as all this, inefficient methods would have been abandoned long ago.

I am not only speaking of conservatism, of the reluctance of breeders and authorities in *loco parentis* to abandon some of the beliefs and tenets that were in vogue at the time when they were young, although I will try to show a few examples of this. But we must also realise that occasionally the professional interest of the breeders does not run entirely parallel with the interest of the poultry-producing or egg-producing farmers and specialists, or even with a national interest in the efficient production of poultry products. And as, after all, the breeders and hatcheries will have to produce the great bulk of the poultry kept for profit, we must always keep in mind, in improving our breeding methods, that in order to fulfil their function of distributing profitable poultry, they must make a profit to keep going.

On the other hand, it is incumbent on the vigilant theoretical geneticists to see to it that this consideration does not lead the commercial breeders to misuse genetical experimental results or unwarrantable generalisations as " the flag which covers the doubtful cargo ", to adapt a Dutch proverb.

This book is not written for geneticists or even for students of Genetics. It is written primarily for the army of people interested in keeping ducks and chickens, for the fanciers, interested in breeding show winners, who are always in the majority of the many amateur-geneticists who write to us professionals for advice, and secondarily for the many professional and semi-professional men, striving to breed their

stock up to a higher degree of usefulness, either for meat or for eggs.

Of course we must hope that the very many official and semi-official advisors in matters of poultry-keeping and poultry-breeding in the countries to which this book will go, will find it useful as a guide to what their colleagues in other parts of the world are doing, and as a help in understanding the very many diverse aspects of their dealings with the egg-consuming public on one hand and the poultrymen on the other.

I have considerable experience of breeding methods as a consultant geneticist. I have recently made an extensive lecturing tour in which the main object has been to discuss breeding policy in matters of animal-breeding (mainly poultry, sheep and cattle) with the authorities, breeders and breeders' associations after short introductory lectures. Such discussions and visits to the establishments of successful breeders of show-stock and of commercially useful stock are of great interest to a geneticist, and help to give him a proper appreciation of practical difficulties. The author of the second part is a commercial farmer with a rapidly expanding poultry-breeding establishment. We two have been happily co-operating for many years and a great many poultry generations.

Chapter One

Evolution : the Origin of Domestic Poultry

OUR domestic chickens, ducks, turkeys are descended from wild ancestors. There are several species of wild chickens and wild ducks, and many authors have speculated upon the way in which this domestication of wild material has taken place.

It is not possible to know with certainty just how the first ancestors of our domestic ducks and chickens were tamed—poultry have been kept by mankind for untold generations—but we can make a good guess. In constructing a theory about the origin of our poultry, we can, with *Darwin*, compare the present species of wild-living poultry with our domestic breeds, and base our theory on the resemblance between domestic poultry and those wild species. Or we can base our theory upon what we know about the relation between primitive man and wild-living birds. And finally, we can make use of what we know about very recent cases in which domestic animals have been seen to originate from wild ancestors under conditions of experimental control.

It is certainly true that the general coloration of the red Malayan jungle-fowl and its single comb and double wattle are found in most breeds of domestic fowls, and this induced *Darwin* to assume that *Gallus ferrugineus* must have been *the* ancestor of all our present breeds of domestic poultry. Two questions, however, must be asked. First, is this *Gallus ferrugineus* (*bankiva*) a species so easily tamed that it is probable

that it was taken into cultivation by man? and, secondly, could we explain the enormous variability and multiformity of our domestic chickens by assuming that one single wild species was taken into cultivation?

Primitive people all over Asia and South America take an enormous interest in raising young animals and birds as pets. Wherever one meets natives travelling, one sees them taking along their pet parrots or hens, monkeys or otters. In Malaya and Java every house has its chickens, and the owners take an enormous pride in pet roosters with special voices or peculiar colours. Males are often kept in bamboo cages slung from high poles, where they can see and greet the rising sun. Hens are running around the houses, and conduct their chicks all over the place.

Under such conditions the only birds that can be called domesticated, whether born in captivity or raised from eggs or chicks found in the forest, must have the instincts which bind them to their home. Now, if we compare the three wild-living species of fowl, *G. Sonneratii*, *G. varius* (the black jungle-fowl), and *G. ferrugineus*, we find that this last-named fowl certainly has not the disposition which will make it stay around the house where it was raised as a chick. Several of my friends and correspondents have raised chicks from wild-found eggs under domestic hens, and two men I know have bred the birds in aviaries. They are enormously flighty and hard to tame, and they seem to lack the strong homing instinct of our domestic chickens. Chicks running with a tame hen will act like pheasant chicks: they roost very early and tend to wander off, sometimes abandoning their foster-mother, or even taking her with them, so that she will become as wild as they. *G. varius* chicks will act in the same way, although adults confined to an aviary will be tame enough. *G. Sonneratii* chicks, on the other hand, according to *Ghigi*, who has had considerable experience with such wild species, happen to have a strong homing instinct—chicks and adults can be given their freedom and will come home to roost.

These facts, I think, make it quite impossible to assume that *G. ferrugineus*—the red jungle-fowl—is *the* ancestor of our domestic poultry, in the sense of this being the first species to be taken into domestication.

In every group of really domestic animals or birds we find that at least one related wild species has a genotype that admits of a thorough domestication. Among the wild fowls, this points to *G. Sonneratii* as the species that has originally been tamed.

To *Darwin*, the circumstance that both *G. varius* and *G. Sonneratii* exhibit qualities that are not seen in our domestic breeds—such as the median wattle and the coloration of the comb in *varius* and the voice and scaly points on the hackle-feathers of *Sonneratii*—was a strong argument against the possibility that either of these species contributed to the evolution of our chickens. On the other hand, *G. ferrugineus* in its wild state also differs in a few striking points from what we see in tame poultry. Wild males of *G. ferrugineus* have peculiarly shaped hackle-feathers, with the tips curving from front to back, and, what is still more striking, their plumage changes with every moult. In the breeding season only, the hackles are pointed and yellow; after the moult the hackle-feathers are short and rounded and much less conspicuously coloured. So far I have never met a breed of domestic chickens in which the males regularly moult from a nuptial plumage into an inconspicuous plumage in the off-season.

If we ask the question whether it is probable that one single species, be this *G. Sonneratii* or *G. ferrugineus*, can have produced the variability that has given us the enormous diversity of breeds of today, this must surely be answered negatively. It is true that even in the wild state all species vary somewhat, according to locality. I have seen wild-caught *G. ferrugineus* males with yellow, with bluish and with greenish legs, and *G. varius* males also vary in size and shape of comb and in leg colour.

It seems to me extremely doubtful that in such groups as our domestic ducks, our domestic chickens, our rabbits, the host of varieties should have descended from one single wild species. There are several reasons for assuming that in all those groups more than one wild species has contributed to the diversity of our present breeds.

In *Darwin*'s time, and even in the first twenty years of Mendelism, it seemed absurd to assume that the cross-breeding of

a few closely similar species could be the direct cause of the origin of wholly novel "inherited" qualities. Even to *Davenport* the existence of striking dominant qualities, such as white skin, rose-comb, barring, in domestic poultry, pointed to

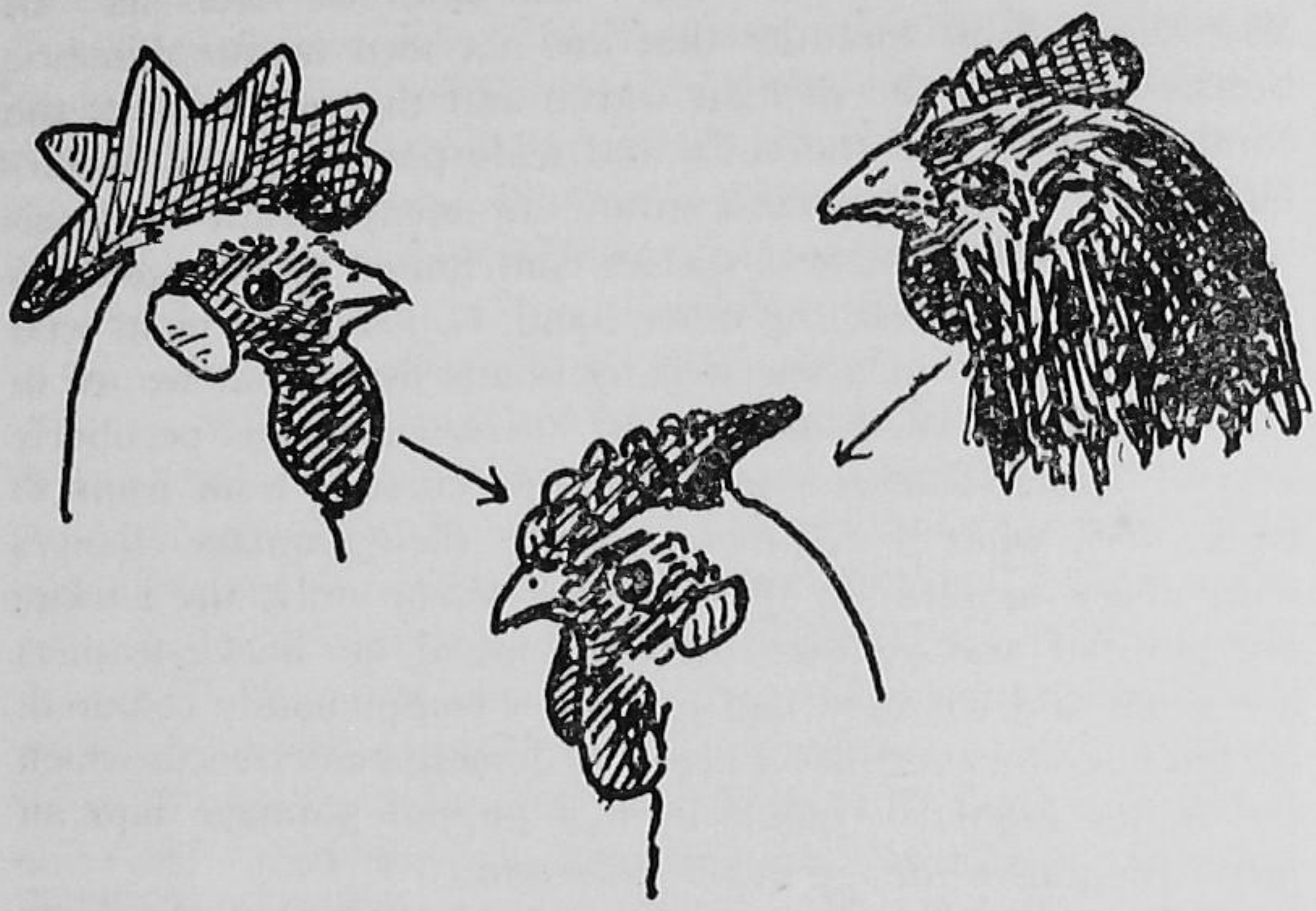


FIG. 1.—Occasionally, the mating of two single-comb birds will produce a rose-comb individual. Mr. *Weekers*, a well-known poultry-breeder, once gave me a white, rose-comb cockerel, produced from a White Leghorn father and a Rhode Island Red mother, both single-comb. Several other cases have been brought to my notice, especially in breeding single-comb strains together, e.g. single-comb strains of Rhode Island Red or single-comb strains of Ancona. Ordinarily rose-comb is dominant over single-comb. Such cases throw light on the question of the origin of dominant qualities in poultry. See chapter on *Evolution*. (Fisher.)

some extinct wild poultry species that would have introduced such widely spread genes.

We know today that cross-breeding between two or more wild-living species, with its resulting recombination of the differentiating genes, is a very potent cause of variability. Although in variety-crosses rose-comb is dominant over single-comb, so that in such cases we may speak of a rose-comb gene, it is nevertheless true that crosses between single-comb

breeds not infrequently produce double-comb chicks. If we want to speak in terms of " determinants ", we must say that the gene we know as a determinant of rose-comb in one breed may be present in some other breed of single-combed poultry, in which some other link in the long chain of factors necessary for rose-comb is lacking. Novel dominant qualities may arise as a result of what are often called " complementary genes ". The horticulturists know that species-crossing is a fertile source of the sort of variability that may lead to the production of strikingly novel characters—qualities never seen before. In our own experiments species crossing in ferrets (ferret × polecat) gave rise to waltzing ferrets. And in the crossing of sub-species of wild-living rats a long list of novel qualities originated: albinism, waltzing, spotting and even tameability!

The cross-breeding experiments of *Kuiper* and *Lotsy* and of *Ghigi* with the wild species of fowls have shown that although the female hybrids are sterile, this does not preclude an introduction of the genes from one species into the other.

In Java, charcoal-burners often take domestic hens with them into the forest in the hope of raising a few hybrids from *G. varius* males. It is even possible to trick a caged *G. varius* male into treading a pegged-down domestic hen. The male hybrids, called " bekisar ", were much sought after. They are naturally monogamous, like the pure *G. varius* males. Their sisters are worthless; they lay an occasional egg, but are entirely sterile. " Bekisar " males, however, if given a choice of mates and fed a suitable diet, are fertile, and from back crosses of such hybrids with domestic hens strikingly variable, gorgeously coloured specimens often used to be bred by Javanese and Chinese fanciers. Among the caged roosters one sees in the native bazaars and markets in Java, the median wattle of *G. varius*, and several others of its striking qualities, such as its peculiar voice, green and yellow in the comb, and a bright-pink gloss on black plumage are occasionally met with.

From all this it appears to me that we have to picture the evolution of our domestic breeds of poultry as follows: Originally, chicks of some readily tameable wild species, presumably *G. Sonneratii*, were tamed and bred in and around

the houses in native villages. Such birds have been transported into localities where *G. varius* or *G. ferrugineus* or both occurred, and from matings between wild-living cocks and tame hens hybrids have occasionally been produced, hybrids that were highly prized as novelties. Such hybrids, mating with native, tame hens, have given rise to highly variable poultry groups, and the variability of such groups has been occasionally enhanced by later species crosses.

Selection of striking-looking individuals, especially males, is common even among primitive people, such as African natives, who seem to have very little pride in their domestic stock and to give them only a minimum of attention. This may have helped to make such qualities as rose-comb, bare-neck, white colour, etc., dominant if they were not dominant from the moment of their origin.

It seems evident that *Fisher* is right in assuming that even originally recessive striking qualities, which originated by a process of mutation, can become dominant as a result of selection. Mutations evidently occur in our domestic poultry, although I am convinced that, in the process of evolution of our present poultry, cross-breeding has played an infinitely more important role than mutation.

Although wild-living species of poultry or ducks are relatively pure, and often not widely different one from the other, we must remember that they may nevertheless differ in many dozens of genes. All those genes which are not common property are re-combined in the hybrid's germ-cells in a kaleidoscopic way, so that the resulting potential variability, and also the obvious multiformity of hybrid populations, is prodigious.

Among the surface-feeding ducks, hybrids between species—mallard, shoveller, pintail—are highly fertile. The mallard is easily tameable, and the idea that the wild mallard is the original species tamed, and the main ancestor of our domestic ducks, seems well founded. But here again the enormous variability in domestic ducks, with their giants and dwarfs, and breeds of all shapes and sizes, is evidently caused by species crosses.

Chapter Two

Genetics, the Poultry Fancy and Breeding Utility Poultry

WHEN we are visiting poultry-farmers and discussing breeding problems with poultry fanciers breeding for the shows, the old question comes up time and again: What good will a knowledge of genetics be to the breeders? Is not breeding rather an art than a science? We frequently meet successful exhibitors or well-known show judges who are rather proud of the fact that they do not care for science; they rely upon what they call "stock-sense", and they are decidedly of the opinion that all this science and certainty rather takes the fun out of their work. They often point to successful breeders who never heard of genetics or of vitamins or any such new-fangled ideas.

To a certain extent such breeders are right, of course. A poultry-breeder really does not have to take the trouble to learn any science; he can buy his mash, leaving the suppliers to worry about the ingredients; if he is a fancier he can buy some excellent birds at a show and raise a great many chicks with a good chance of producing a few show winners. If he is a commercial breeder he can just buy some good males from well-known breeding establishments to bring up the quality of his chicks and his pullets. And even a good breeder, competing in the laying tests, may have very good success if his methods are good, no matter whether he *understands* why

those methods should be better than those employed by his less successful competitors, or not.

In discussions with groups of ambitious breeders, an experienced geneticist will sometimes take the attitude that it is his own particular job to study genetic principles in so far as they touch on practical breeding, and that he just wants his audience to take it for granted that he will tell them the most efficient methods to apply, so that all they have to do is to try out those methods and report upon the results.

This attitude is entirely defensible. Nothing succeeds like success. If a geneticist helps a few breeders to produce better birds, they should all be content. The geneticist can get a lot of practical experience in this way, and the result is that he can teach those successful methods to other struggling breeders. For all this it is not necessary that the breeders themselves know just how their methods differed from older and less successful methods of selection.

It is certainly true that the sort of breeder who talks most glibly in terms of a scientific jargon—the man who boasts that he " applies genetics " to his matings, or that he makes his chickens " Mendelise "—is seldom found at the top of the honours list of a laying test or among the winners at the shows. A little knowledge is a dangerous thing.

On the other hand, serious men hate to work blindfolded: they want to know what they are doing, and it is up to the scientists to tell them. The principles of heredity are essentially simple, and it is easy enough to explain them by using some carefully chosen, very simple examples. Here, however, a difficulty arises. There is a discrepancy between this apparent simplicity in such an example, and the extreme complexity in the case of the inheritance of those qualities in which the breeders are interested. The cases in which we can directly apply what such classical school examples teach us are rare.

It is true that even here there may be cases in which we can save a breeder a lot of trouble and expense, but such cases are exceptional. I am thinking of such things as the hopeless struggle of fanciers breeding Andalusians or Blue Leghorns for the shows, in which case it is simplicity itself to show them how

to get 100 per cent blues to choose their show winners from, but even in this particular case breeding 100 per cent blue does not imply that such groups will be made up of show winners.

The importance of the science of genetics for poultry-breeders certainly does not lie in the possibility of making a complete analysis of all the inherited factors that will give us the desirable qualities we want to combine in our ideal ducks or chickens. Some geneticists may have thought so twenty years ago, and even today we meet the repercussion of those ideas in attempts to explain differences in quality in genetic terms. I have a very considerable experience as a consultant, helping poultry-men to solve their breeding problems, and I know that the cases in which genetical analysis was of real practical use are so rare that they could be counted on the fingers of one hand.

Breeding work with poultry, especially in so far as exhibition poultry is concerned, is fascinating. The poultry fancy brings an enormous amount of interest to the lives of very many fanciers, and I would be the last to take away any of this pleasure. On the contrary I have often helped fanciers to set out ambitious plans, blueprints for novel breeds, new colour varieties in existing breeds, and in their attempts to beat their competitors at the shows. In this work an experienced geneticist can very often help an ambitious fancier, and not least by helping the amateur to choose between attainable and almost unattainable breeding projects. A show-breeder whose space limits the number of birds he can keep will be helped in his hobby if we can point out a method of attaining his goal that will materially reduce the number of birds he needs to keep in any generation.

The methods employed by fanciers are sometimes quite different from those recommended to breeders of productive poultry, for the reason that the aims of these men are wholly diverse.

There are quite a number of entirely ill-founded ideas, firmly held by many breeders, which merely hamper them in their work. It is not enough to tell the breeders or the authorities who regulate the breeding industry that such ideas are

wrong. We must show them just why such erroneous beliefs should be dropped, what is wrong with them, and how they originated as unwarranted generalisations. Here a geneticist may be of very great help.

Whereas the breeding of fancy poultry for the shows is of vital interest not only to the fanciers but equally to the geneticist, this same poultry fancy in some countries is something of a menace to the aims of the breeders of utility fowls, aiming to produce profitable poultry fitting into a really economic scheme of national agriculture.

I am glad to say that in comparison with the breeding of sheep and of cattle, economic poultry-breeding is rapidly shaking off the shackles that bound it to the shows. When travelling in Australia, I have recently seriously proposed prohibiting the showing of the few breeds of utility poultry in that country, or at least of barring the White Leghorn and the Australorp from the shows. This would leave the poultry-fanciers the fifty-seven other poultry breeds to play with, and it would enable the serious breeders of profitable poultry to concentrate upon those qualities that will give the country excellent poultry fitting into the national agricultural economy. The Australians are hard-headed business people, and it would not surprise me if they took this hint.

The foolishness of so-called "utility classes" at poultry shows, where serious-looking judges solemnly try to classify second-rate Leghorns according to fancied "utility points" by looking at them, and the folly of debarring excellent groups of pullets or ducklings from laying tests because of some fault in eye-colour or cock of the tail, are a survival of the time when breeders believed in correlations between profitable production and visible qualities. In some countries some of the old judges of "utility classes" are still alive, and we suppose the custom will survive with them. If we can convince the authorities that there should be a clean-cut divorce between fancy and utility, this book will have achieved some good.

The poultry fancy should be completely unhampered by any consideration of utility. Its object should be to cater to the sporting instinct of the fanciers. There is quite as much pleasure in the breeding and showing of fancy fowls and

bantams, guinea-pigs or mice, for that matter, as in the breeding of prize-winning fat Shorthorns or race-horses, and the handy size and fertility of the smaller stock make it possible for tens of thousands of serious amateurs to breed a few very good fowls whereas only a few dozen bull-fanciers can afford to live where they can indulge in their more costly pastime.

The breeding of utility poultry is a major agricultural enterprise. Its object should be to supply our farms and our specialist poultry-keepers with material that will transform the foodstuffs that can be spared for them in the short periods between world wars into high-grade produce for home consumption and export. Nothing should hinder our breeders in attaining these aims; profitable production—that is, the relation between costs (all costs) and incoming (all incoming)—must be the sole aim of our utility poultry-keepers, and certainly of the authorities regulating the poultry industry.

Chapter Three

Inheritance and the Inherited Factors

IN the early days of genetics many of us thought that the separate characters of the living beings were represented in the germ-cells by small units—the " determinants " for what were called " unit characters ". This idea implied that some of these determinants could sometimes be dormant or latent. And the determinants were generally thought to be somehow alive, protoplasmic particles that could divide and reproduce like bacteria.

In 1911 I proposed another hypothesis—the so-called biomechanical theory of inheritance, which is now generally accepted by the theoretical geneticists. We now assume that the genes, whose transmittance constitutes inheritance, are chemical substances of a peculiar nature, proteins with large molecules that are able to help build up (from building-stones in the cells) a quantity of material of their own kind. We call such substances autocatalysts. The presence of a quantity of such a substance in the nucleus of every cell of an organism helps to make this organism grow and develop in a certain way. But this action of the gene does not determine any complete character; the qualities of an organism result from the way in which growth proceeds under the simultaneous influence of tens of thousands of genes plus all the many forces and substances that influence this growth and development from outside the nucleus. Just how the genes present in the nucleus exert their influence has been a matter of speculation. It is

not at all probable that they diffuse out of the nucleus, or that they send out substances of any kind. I incline to the hypothesis that the genes in the nucleus are not active in any such direct way, but that it is the simultaneous *synthesis* of all those genes from the material in the cell outside the nucleus that will make the contents of the cell different from what they would be when the genes were not present and doubling in quantity.

The genes are present in thread-like bodies—the chromosomes—and on or in that chromosome they follow each other in a regular sequence like beads on a string.

In every germ-cell there are a certain number of chromosomes, each composed of hundreds, perhaps thousands of different genes. When an egg is fertilised, the egg, and the whole embryo, and the fowl growing out of that egg, contain a double set of chromosomes in every cell nucleus. In every tissue that grows every cell divides into two daughter cells, after the whole nucleus, every gene on every chromosome, has first doubled in quantity.

In every pair of homologous chromosomes the genes are usually present in the same sequence, and at a certain stage of development of the cell those chromosomes range themselves alongside each other with all their genes in close contact, each gene with the corresponding one.

In a general way we can say that the two homologous chromosomes are composed of the same string of genes. But this is not true in the finest detail, for the quantity of some gene on each chromosome may be different. In fact, we know that sometimes a gene, or even a small part of the chromosome with a number of genes, may lack altogether. In special cells of certain flies—Drosophila—that have been used extensively for fundamental genetical studies, the chromosomes are large enough to admit of correlating such visible peculiarities of the chromosomes with action of the genes on the shape or colour of the animals.

Whereas in all the cells of the body we find the presence of pairs of chromosomes, the germ-cells have only half that number (namely, just one chromosome of each kind) of each pair. When germ-cells are formed, there occur *two* cell

divisions in rapid succession, with only one doubling of the chromosomes, and at each division the chromosomes wander to opposite poles of the mother-cell that divides. If, as in the case of the sex chromosome in poultry, the females have only one, instead of a pair, there will be two kinds of germ-cells, here two kinds of egg-cells, with and without that chromosome.

If in one pair of chromosomes at a corresponding spot (locus) there are different quantities of one gene, this means that there will be two kinds of germ-cells, one kind with one quantity, the other kind with the other.

Sometimes this means presence and absence of one gene, sometimes just more or less (more or fewer molecules). Often we discover such differences when they produce alternate qualities, such as rose-comb and single-comb or black and white in rose-comb bantams.

The key to all this was discovered by *Mendel* in his experiments with peas, which showed clearly that inheritance was particulate, having to do with separate, separable things, which we now call genes (after *Johannsen*).

The smallest difference between two cell nuclei and between two birds is a difference in one gene—a monogenetic difference. Many geneticists still believe that in such a case there exist *two* genes, two different *substances*—for instance, one gene "for" single-comb and one "for" rose-comb. There is no proof for this idea, which really followed out of the notion that the genes were "determinants" that each gave one "unit character".

In science such an idea is very rare; we speak of hot and cold, wet and dry, acid and alkaline, but we always think of the cause of such differences in terms of more or less (or presence and absence), of just *one* cause, and a similar view is simpler, and therefore preferable in science.

The phenomenon of *Dominance*, discovered by *Mendel*, is best understood when we think of the smallest (monogenetic) difference as being due to more or less of one substance. We can then understand why the presence in the nucleus (or, in other terms, the synthesis of more of this substance) has a positive or stronger influence upon development and changes things more than the presence of less of the same thing (or even its complete absence). If we compare the embryo of a

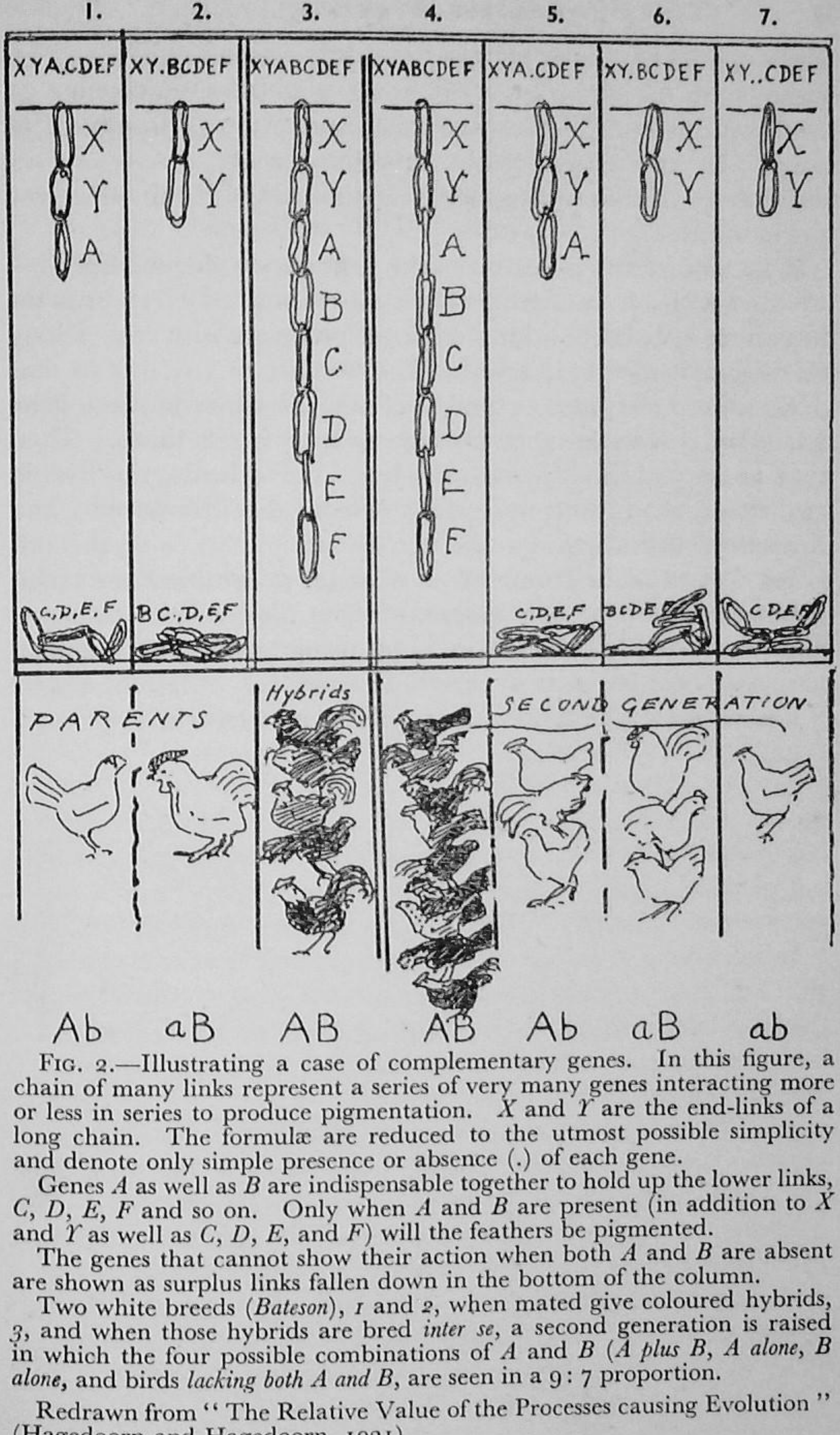


FIG. 2.—Illustrating a case of complementary genes. In this figure, a chain of many links represent a series of very many genes interacting more or less in series to produce pigmentation. *X* and *Y* are the end-links of a long chain. The formulæ are reduced to the utmost possible simplicity and denote only simple presence or absence (.) of each gene.

Genes *A* as well as *B* are indispensable together to hold up the lower links, *C*, *D*, *E*, *F* and so on. Only when *A* and *B* are present (in addition to *X* and *Y* as well as *C*, *D*, *E*, and *F*) will the feathers be pigmented.

The genes that cannot show their action when both *A* and *B* are absent are shown as surplus links fallen down in the bottom of the column.

Two white breeds (*Bateson*), *1* and *2*, when mated give coloured hybrids, *3*, and when those hybrids are bred *inter se*, a second generation is raised in which the four possible combinations of *A* and *B* (*A plus B*, *A alone*, *B alone*, and birds *lacking both A and B*, are seen in a 9 : 7 proportion.

Redrawn from "The Relative Value of the Processes causing Evolution" (Hagedoorn and Hagedoorn, 1921).

single-comb chick with that of a double-combed one, it will be found that the single-combed chick will have that shape of comb because of the presence and interaction of hundreds of genes. In the other chick something more is present in addition to all this, and under its influence the comb will grow out in width.

If we picture the influence of the genes upon the end result—the fowl with all its qualities—we must think of every growth-process as caused by a long chain of processes in which a long list of genes have their action. The absence of any link in that chain may interrupt it. One fowl may be white because gene *A* is missing, and another because gene *B* is not there. Then if we mate two of such "incomplete" white birds, the hybrid will inherit everything including *B* from the first parent, and everything including *A* from the second parent, and the offspring will have the complete set of genes to complete the chain of processes leading to pigmentation, so they will be coloured (*Bateson*). *G. Shull* showed in 1909, using an elegant chemical class-room model, that in threshold cases the (relative) *absence* of a gene may give a dominant quality in a hybrid.

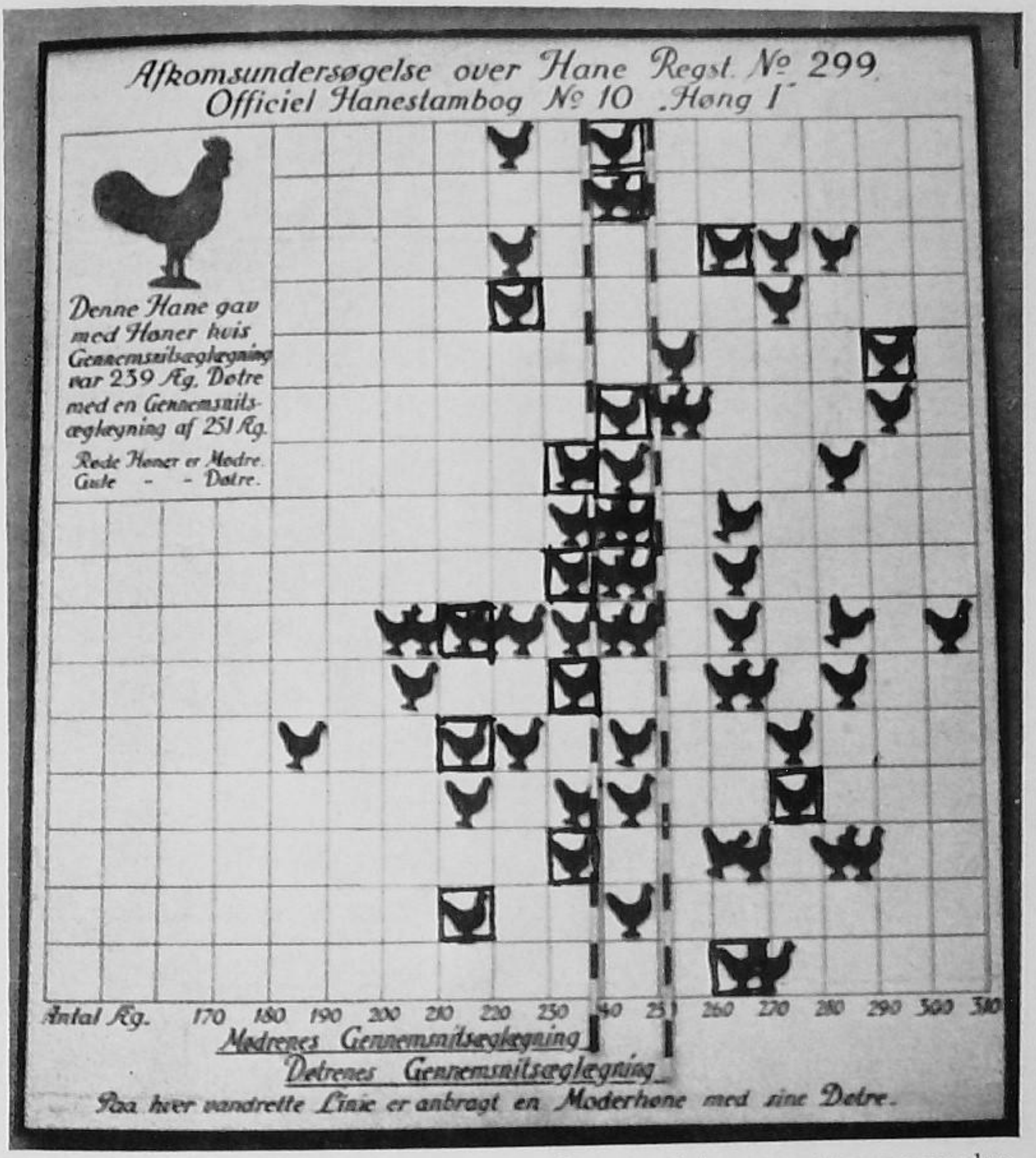


FIG. 3.—Graph showing the progeny of one cock in respect to egg production. On every horizontal line a hen and her daughters are arranged, the mother in a heavily ruled square. As can be seen from this table, some hens have given better daughters than others, but there is very little relation between the number of eggs laid by a mother and the average quality of her group of daughters.

Konsulent Davidsen kindly made this photo for the author from a wall-chart shown at the International Agricultural Show in Copenhagen 1938. It is reproduced by courtesy of Statens Aegudvalg, Denmark.

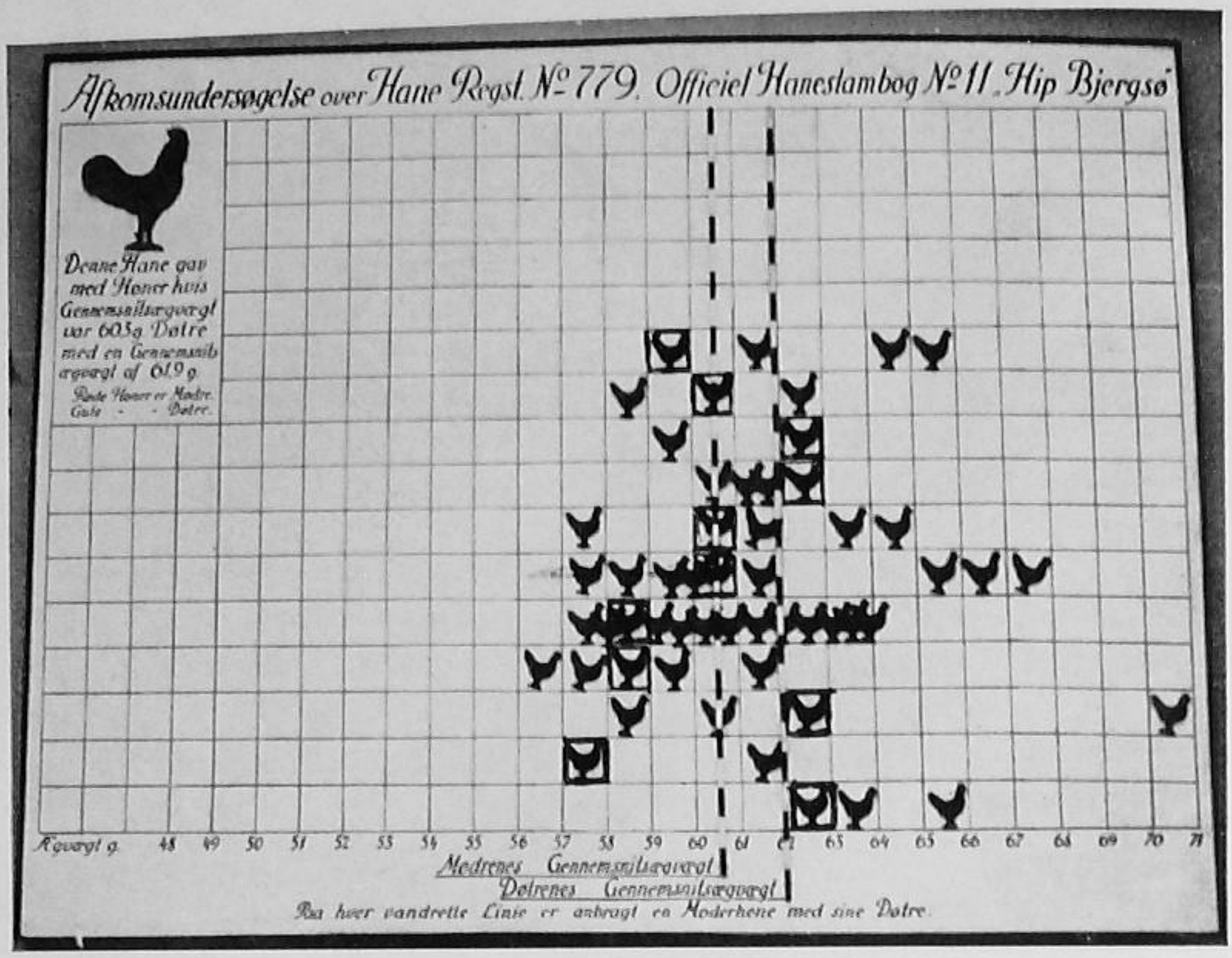


FIG. 4.—The progeny of one cock and eleven hens in respect to egg-weight. The mothers are enclosed by heavy squares, and the daughters of each mother are grouped on the same horizontal line as the mother. Some mothers have better daughters than others, but it is impossible to prophesy the egg-weight of the daughters from the weight of a hen's eggs. The daughters of this male average higher than the mothers.

Photo made by Konsulent Davidsen from a wall-chart shown by the Danish State Poultry Selection Institute, at the 1938 Agricultural Show in Copenhagen.



Photo. 'Poultry Farmer'

FIG. 5.—Creeper Fowl: Black Scot Dumpie cock. (See page 90.)

Chapter Four

Individual Selection

POULTRY vary. No two birds are ever exactly alike, a fancier needs no leg-bands to know hundreds of hens apart, and as chickens vary, selection becomes important. We must choose which birds to keep for breeding stock, and it stands to reason we choose the best ones to continue the breed with. But here is the difficulty: which are the best birds?

To this question different breeders would probably give different answers. One would speak of beauty, the other of health, a third of utility. Perhaps all would probably agree that the birds which show the qualities we admire in the breed will be the birds to choose as breeding-stock. And yet, this criterion of personal merit is not altogether sound. As will be seen in another chapter, the idea that the qualities of an individual are somehow passed on to the offspring is unsound. The final results of the development, the final qualities of an individual, give only an incomplete picture of its qualities as a parent. So many non-inherited influences help to make up the final result! Not only this: dominance obscures the picture. A bird may be excellent as an individual, but even in so far as her good quality is due to a happy combination of genes, she may be heterozygous for some of the most important ones and unable to pass them on to more than part of her daughters. An excellent layer may be hopelessly impure; she may be heterozygous for many important genes—the example of a hybrid hen from a well-tried combination of breeds comes readily to mind.

Breeders of utility poultry have always laid great stress upon the desirability of retaining male birds from outstanding mothers. They all know that such sons from a fine mother often disappoint us in the quality of their daughters, but they think such disappointments are unavoidable, and a son of an excellent mother is still their best bet!

It seems quite logical to assume that the higher production a hen gave, the better her offspring must be. We assume that differences in yield between individual hens are, in the main, due to differences in their hereditary quality; that is to say, in the genetic composition of the egg-cells they produce. Whenever we try to find out whether the highly producing hens really have the best offspring, by finding out what the egg-laying capacity of their daughters is, we are surprised how very little we can count upon this quality of a hen as a means of prophesying her value in a breeding-pen.

Whole selection systems, often semi-official ones, like the old Canadian R.O.P. scheme, have been built up on the assumption that individual quality of a hen is a good sign of merit in poultry. It may come as a shock to many when I state that selection according to personal merit has only a very limited value and should be scrapped now that we know better and possess more efficient methods.

As soon as we study the influence of easily manipulated environmental factors, we begin to understand that individual quality is not a reliable sign of inherited quality, and when we know the first principles of genetics we see at once that even in so far as quality depends on the best obtainable set of genes, this quality is no good criterion to judge a hen by as a suitable member of a breeding-pen.

It is very difficult to know exactly what is the most suitable birth-date for a pullet that we want to develop into an excellent layer. So much depends on the weather, that in some years in a temperate climate March-born pullets will be found more productive during their first laying season than April-born ones, but in other years the April-born pullets will average ten to fifteen eggs more than their slightly older sisters.

The exact date at which a pullet comes into lay, her age at first egg and the way she has been raised have such a great

influence upon her year-production, that we can only with difficulty compare pullets from different hatches. I am assuming that all chicks are raised under identical conditions. But unless those conditions are highly artificial, and unless the pullets are drafted off to individual laying-cages early in life, there is no great probability that climatic influences, and even that the diet actually consumed, were alike from one pullet to the next.

I should like to state with emphasis that chance has such an influence upon production that any prophecy based upon the record of any one individual hen is very insecurely founded.

We now come to hereditary composition as a cause of production. Surely many qualities in hens are "highly hereditary"? A great deal of effort by geneticists working with poultry is directed towards a study of what qualities are "highly hereditary" and which ones are much more influenced by differences in the environment. To name a few, feather colour, shape of the comb, presence or absence of top-knot are highly inherited, leg colour, egg colour, presence of supernumerary toes, broodiness, are examples of qualities that are much less "hereditary". But even if we make this distinction —which, to my way of thinking, is highly unscientific—and turn our attention to such qualities as feather colour and comb-shape, where we can actually know by inspection whether a given gene is or is not present, the appearance of an individual male or female is often a very poor guide to the sort of offspring we can expect from it. This is the result of dominance; when there is no visible difference between birds homozygous or heterozygous in respect to some gene (*AA* or *Aa*), the personal quality of a bird gives us no idea about its value as a parent so far as this point goes. Breeders of fancy poultry are continually meeting these difficulties, good birds surprising them by giving them faulty or aberrant chicks (see chapter on Trial Matings).

Cases in which we are dealing with similar simple instances of monofactorial differences must be very frequent; indeed, I think we can safely say that individual selection lets us down wherever we try to obtain purity for the desirable dominant qualities.

On the other hand, individual selection—the usual method of the "trap-nesters"—will be quite efficient when we are wanting to eliminate undesirable dominant faults from our strains. This should happen in a very few generations. The old conundrum, why individual selection should seem to be so efficient, while complete success, stability and purity are never reached by means of it, finds its simple solution in Mendelian dominance.

The poultry-breeders, and even some good geneticists, are firmly convinced that only constant selection will bring up the quality of a strain of poultry, and that as soon as this selection is relaxed the quality will go down. I am firmly convinced that this experience is simply based upon inadequate methods of selection. There is no reason to doubt that we could in theory bring a breed of poultry to the same degree of purity and high quality as a pure line of wheat or beans, a state of purity which will make it possible to relax our efforts with no loss of quality.

Chapter Five

Correlation

ONE and the same inherited factor may show its presence in different ways, as in the case of bare-necked chicks, which always have bare patches of skin on the back, or in the case of polydactylous breeds, where we always find supernumerary fingers as well as toes in the same chicks. These are cases of true correlation.

Then there is a correlation caused by the circumstance that genes present in one chromosome tend to be inherited together, and to stay in that combination when the chromosomes are shuffled at the time of the reduction division when germ-cells are formed. The most striking examples of this are found in poultry in the case of the genes in the sex chromosome. In the purest breeds of poultry the males differ from the females in a host of different qualities, some directly dependent on the combination of genes present, or on the fact that the males are homozygous and the hens heterozygous for those genes, some indirectly dependent on the hereditary constitution by the intermediary of organs secreting hormones. This very strict correlation makes it possible to distinguish the sexes at birth—in all breeds by the shape of the external genitalia, in most breeds, but especially in the autosexing breeds, by means of the colour of the down.

Then there is an entirely different type of correlation which might be termed accidental or spurious correlation. When we compare two breeds, or even two groups of breeds, in which

the majority of the individuals are pure (homozygous) in regard to genes causing a striking effect, the qualities typical for each breed or group of breeds will always be found together. It is not easy to distinguish this accidental correlation from true, causative correlation.

When we see that White Leghorns lay white eggs, and Brown Barnevelders lay dark coffee-brown eggs, the fact that Brown Leghorns also lay white and White Barnevelder brown eggs, at once shows us that there is no causative true correlation between feather-colour and egg-colour. But if somebody points out that both colours of Leghorns have white ear lobes, while Barnevelders of both colours have red ear lobes, we may easily be led to believe that ear lobe colour and egg colour are firmly correlated.

We would be strengthened in this belief when we found that all the so-called Mediterranean breeds have white ear lobes and lay white eggs, whereas all the Asiatic, heavy breeds have red ear lobes and lay tinted to brown eggs.

It may appear as if this distinction between true and false correlations were of academic interest only, but this is very far from true. True correlations are of some value as an aid to selection, while accidental correlations are not. When in our autosexing Leghorns we kill 90 per cent of the pale chicks at birth, we kill superfluous males and save money. When we select cockerels and pullets with pure-white ear lobes, we give undue attention to a completely irrelevant point, and this may lead us astray in our work; it will in any case make selection of the best groups unduly difficult.

Why should so many breeders pin all their faith to selection for accidentally correlated characters? There is only one answer. They know that in pure-bred strains of a valuable breed there is very little, if any, deviation from the usual type that presents all those qualities. Any aberration from this type, this combination of fixed qualities, is in most cases caused by cross-breeding, and cross-bred birds are notably unsafe as breeding-stock; they cannot be relied upon.

In a show breed the upper limit of quality may have to be raised by raising the variability by means of cross-breeding. When this has been done, and back-crosses have been made to

reduce some of the excessive variation, all attention should be given to real quality, and when our attention is unnecessarily

Egg weight in grammes	Body-weight in grammes:				
	1600	1800	2000	2200	2400
70			128	332	
65		41	32 95		
60	27	119 111 30 403 64 50 39 60	29 96 298 31 99	49 89 56 329	33 109
55	47 26 115 65 503	131 35 249 100 311 116	320 466 55 600 604 59	376 433	61
50	381 528 450 474 479 455 117	107 489 451 475 53 482 479	297 38 103 449		
45	98 435	405			
40	308				
Average egg weights .	50·94	55·21	57·22	60·00	58·33

Fig. 6.—Table showing the relation between body-weight in grammes and egg-weight in grammes in a group of sixty-seven F2 hens bred from hybrids between White Leghorn and Barnevelder. The hens are represented by their foot-ring numbers.

(From a report to the Council of the Genetical Society on genetical experiments with poultry over 1926, 1927 and 1928–29 by Hagedoorn.)

divided by attention to non-essential points, we handicap ourselves.

If we see that all Mediterranean breeds have white ear lobes,

this does not prove anything but that they have been selected deliberately for this point. When I mated White Leghorn to Barnevelder, and mated the hybrids together, it became clear at once that all sorts of correlations were broken. Egg colour, ranging from white to deep brown, ear-lobe colour, body-

	Colour of ear lobes:				
	White	Almost white	Half red	Almost red	Red
Egg colour: 1. White	474	131	35	60	107
2. Cream	497 528	249 311 381	29 128 95 475 403	435 604 50 41 53 332	376 479 450 466
3. Tinted	31 47	298 308 329 405 433 455	27 297 449 30 98 451 33 600 503 61 117	65 55 99 96 59 103 100 64 115 26 56	32 482 38 109 49 111
4. Brown	320		89 116	119	39
Average egg colour:	2·50	2·50	2·74	2·63	2·58

FIG. 7.—Table showing the relation between colour of ear lobes (white, almost white, half red, almost red and red) and egg-colour (white, cream, tinted, and brown) in a group of sixty-six F2 hens from hybrids between White Leghorn and Barnevelder. The hens are represented by their foot-ring numbers.

(From a report [to the Council of the Genetical Society] on genetical experiments with poultry over 1926, 1927 and 1928–29 by Hagedoorn.)

weight, egg size, age at first egg—all those qualities which were always seen together in the two different breeds—were now seen to be independent of each other to a very high degree.

There is one type of correlation I have not yet treated—namely, causative correlation. Some adaptation of the animal

to its environment or some function of its organs may cause a change, which can be observed or measured. The most obvious one is age. Old hens look different from pullets, and this ageing may bring along a change in quality, both in table-birds and in egg-laying breeds. Some breeds and strains may last better than others; many hybrids are notable for their long, useful life.

High production will also change the looks of a bird, and, again, some birds will change less than others; they wear better under the same production and in the same environment (see chapter on Handling).

Except as an aid to culling, all this is not of great importance, except to poultry-men without any system of book-keeping, and the same is true of changes due to disease. When we know that certain changes can be the result of a functional or infectious disease (eye colour), this does not mean that we should select our young birds according to such signs! Eye colour is a good example of this. Anæmic birds and birds suffering from at least two different diseases may have pale, greyish eyes. But there are breeds in which all birds have grey eyes, and in Wyandottes and Rhode Island Reds certain strains and individuals are grey-eyed. Here eye colour has no more importance than side-sprigs on the comb, or stubs on the shank, or any other small points that detract from the beauty of a show-bird.

It is easy to believe in plausible-sounding correlations, and to assume that certain qualities, such as light body-weight and heavy eggs or white ear lobes and broodiness, can never be combined because we do not see them go together in our present breeds. In poultry, just as in dogs, the breeders firmly believe that anatomical characteristics are correlated with and denote such physiological qualities as speed or ferociousness. We have very good reasons to believe that if such qualities are bred into a breed, they are just fixed into the breed for looks.

The bulldog and the Indian Game are certainly not as aggressive as the Bedlington or the Leghorn, and the show-whippet bred to look speedy cannot win against the terrier-like business-whippet! In fact, there is much less correlation

between looks and performance than fanciers seem to think —the chemical make-up of an individual and the functional activity of its glands cannot be seen by simple inspection.

There is no evidence for, but quite a lot against, the common belief that important economic qualities can be fixed in a strain by watching for visible signs. But it is not difficult to understand why so many breeders want to convince themselves and others that all this is sound. It simply shows that breeders are disappointed in the results of the old system of breeding the best to the best and hoping for the best. They see that individual quality is not a measure for success in the breeding-pen, and they hope they can do a little better by adding additional indications of merit.

Chapter Six

Progeny Testing

THE old system of selecting poultry based upon mating the best individuals was especially difficult where we were dealing with qualities that can only be judged in one sex. The best most breeders could think of in breeding egg-laying strains was to trap-nest a lot of hens, take the best layers in breeding-pens, and mate them to cocks that were the sons of the very best individual hens.

This system has always been very wasteful, and the reason for this was not very well understood until genetics became a science and we gradually began to understand the relation between inheritance and quality and discovered how to overcome the handicap of Mendelian dominance.

We found that the personal quality of an animal is only a vague indication of its breeding power, for two reasons: because environmental influences, hatching date, diet, accidents, have an enormous influence on the production of a hen, and because a hen of very good quality, that carries the right combination of genes, may easily be heterozygous, impure, for many of those, so that her contribution to the quality of her offspring will be very "spotty".

If a good hen has poor-quality daughters, it is more than probable that she will have poor-quality sons. This reduces the certainty with which we can rely on the quality of males with " eggs behind them ".

But of course there is one certain way of knowing whether

a male is or is not an excellent father-bird, and this is the rule-of-thumb method of judging him by his actual performance as a breeder. We test him by the quality of his offspring.

The idea of progeny testing is as old as the breeding of domestic animals. In the beginning of the century the geneticists emphasised the importance of sampling a male's breeding quality to find out whether he was pure for the right genes. In my first book on applied genetics in Dutch this point was explained and its importance emphasised (1911).

There is an enormous difference between such progeny tests and the popular stunt of having a "sire and get" class at a stock show. For it is evident that if a progeny test is to be a test of breeding value and of the desired prepotency, the test must show the weak points as well as the good ones.

As the object of progeny testing is to distinguish the good breeders from the poor ones—and this means the animals homozygous for many important genes, from the ones not so pure—a very important point in such a test is the quality of the group to which the animal to be tested is mated. A deliberate test-mating (see this chapter) with recessives will be feasible only in cases where we have such recessives available. When our object is to test the prepotency (purity) of our breeding stock in regard to an *unknown* number of unanalysed genes, the best we can do is to mate the animal to be tested to a number of mates among which we suspect a few to be heterozygous in respect to genes for which we desire purity. In the chapter on the Nucleus System we shall see that this can best be accomplished by inbreeding tests.

One thing we must be perfectly clear on: we cannot say that we have progeny tested an individual unless we have seen its progeny from *several* mates. In the breeding of poultry this means that it is relatively easy to test males as breeders, but practically impossible to test hens. A hen that has given a group of excellent daughters in one season is not necessarily homozygous for the genes her daughters carry. Her mate may be! I have carefully studied many groups of daughters from excellent hens in poultry-breeders' books and the same thing is found time and again: the same hen may have given six to ten excellent daughters one season (with one male), but

a very variable group of daughters the next year (with another male).

All one can say is that in regard to breeding productive poultry our main progress must always come from *progeny testing the males*. This seems to be rather a revolutionary statement, for it seems logical to regard the hens rather than the males, as we are out to breed excellent hens. But, after all, progeny testing the males means comparing groups of hens, the daughters of those males.

There is a great difference between poultry and ducks on the one hand and the larger farm animals on the other in respect to progeny testing as a tool in improvement. In cattle and horses progeny testing some sires is an excellent method of finding ideal sires to be used very extensively in preference to inferior and untested sires. In our artificial-insemination schemes we need only very few ideally good and prepotent sires to make an enormous improvement in the quality of our livestock, and this is especially true if we can use such males co-operatively.

The purification, the reduction of the variation within our breeds, is not easily organised where very few cattle-owners have large enough herds to take this matter into their own hands, and the organisation of co-operative cattle-breeding schemes is still in its infancy.

In poultry, as in sheep, the larger breeders own sufficient numbers of stock to start ambitious breeding schemes on their own, and in a later chapter we shall see how those can be organised to obtain the full benefit of progeny-testing methods.

Both in Denmark and in England there is some trade in progeny-tested male birds of proven good quality. On the whole, however, we tend to think that progeny testing as a means of discovering good males, in order to sell such males to others, can hardly be regarded as the best system of utilising the results of all this work to improve the country's poultry.

Chapter Seven

Purity and Uniformity

A GROUP of poultry is uniform when all the birds start off in life with the same set of genes and are subsequently treated alike. On an efficiently managed poultry-farm, where chicks are raised under good conditions in large lots of one hatching date, the variability we find in such lots is largely due to the circumstance that there is some genetic diversity in the group: they do not really have identical sets of genes.

When we are dealing with commercial breeds of utility poultry, selected according to the quality of their ancestors (trap-nesting), we notice that hybrid lots, bred from two suitable breeds, are strikingly uniform, and we find fewer variations, culls or aberrant chicks in such hybrid groups than in the " pure-bred " lots that were used for the cross. Yet we know that such hybrids must be impure (heterozygous) in respect to all the numerous genes in which the parent breeds differed (see the chapter on Hybrid Vigour). From this we see that uniformity, although it is due to the presence of similar sets of genes in all individuals, is no indication of genetic purity. This is caused by dominance, by the circumstance that in respect to most of the genes the heterozygotes with one dose of a gene show its effect in the same degree as homozygotes that have a double dose in every cell nucleus.

Within a pure-bred strain great uniformity is a sign of genetic purity. Although we can certainly produce very uniform lots of poultry by means of crossing between breeds or

strains, even if these are variable, it has been shown during the last twenty years or so that by the use of efficient methods it is quite possible to obtain a high degree of genetic purity within one excellent family. So long as this seemed hopeless, a commercial cross seemed the only solution of the problem of obtaining excellent, very uniform lots.

A great deal of variability is simply due to the circumstance that birds that both happen to be heterozygous for a gene (*Aa*) will give a minority of *aa* chicks, different from their parents. Impurity in respect to genes for this reason is the *potential cause* of variability, and *Shull* and *Hagedoorn & Hagedoorn* (both 1921) have found that in discussions about selection and evolution the term " potential variability " is extremely useful. The potential variability in a group (or, for that matter, in a single individual) stands for the number of genes in respect to which the germ-cells produced are not identical. We must remember that in birds the females only carry one sex-chromosome. And we must realise the fact that we can only *know apart* a limited number of the genes concerned.

The potential variability of a group may be heightened or lowered. Cross breeding—the mating of birds with different sets of genes—is the chief cause of a rise in the total potential variability (T.P.V.). What we are dealing with in this chapter are the causes which reduce it.

The random distribution of chromosomes and genes over the germ-cells as a result of the reduction division scatters genetic variability all over a group. And it is obvious that *isolation* of any kind reduces the T.P.V. If one buys a trio of chickens from a breeder, it is certain that this sample of the breeder's flock is less variable than the entire flock. It has occurred time and again that a breeder who started with two or three birds happened to find the flock he raised from those few was very excellent (*Tancred*), but of course there is more chance of hitting upon something indifferently good. If we import a new breed, and specially if we import just a few good ones, our imported group is certainly purer than it was in the country of origin. In fact, the potential variability of any species or breed must automatically reduce itself, unless the sample of germ-cells produced by the birds in one generation was

entirely representative of what the preceding generation produced, and this is extremely unlikely. When the population of any plant or animal varies occasionally, the T.P.V. goes

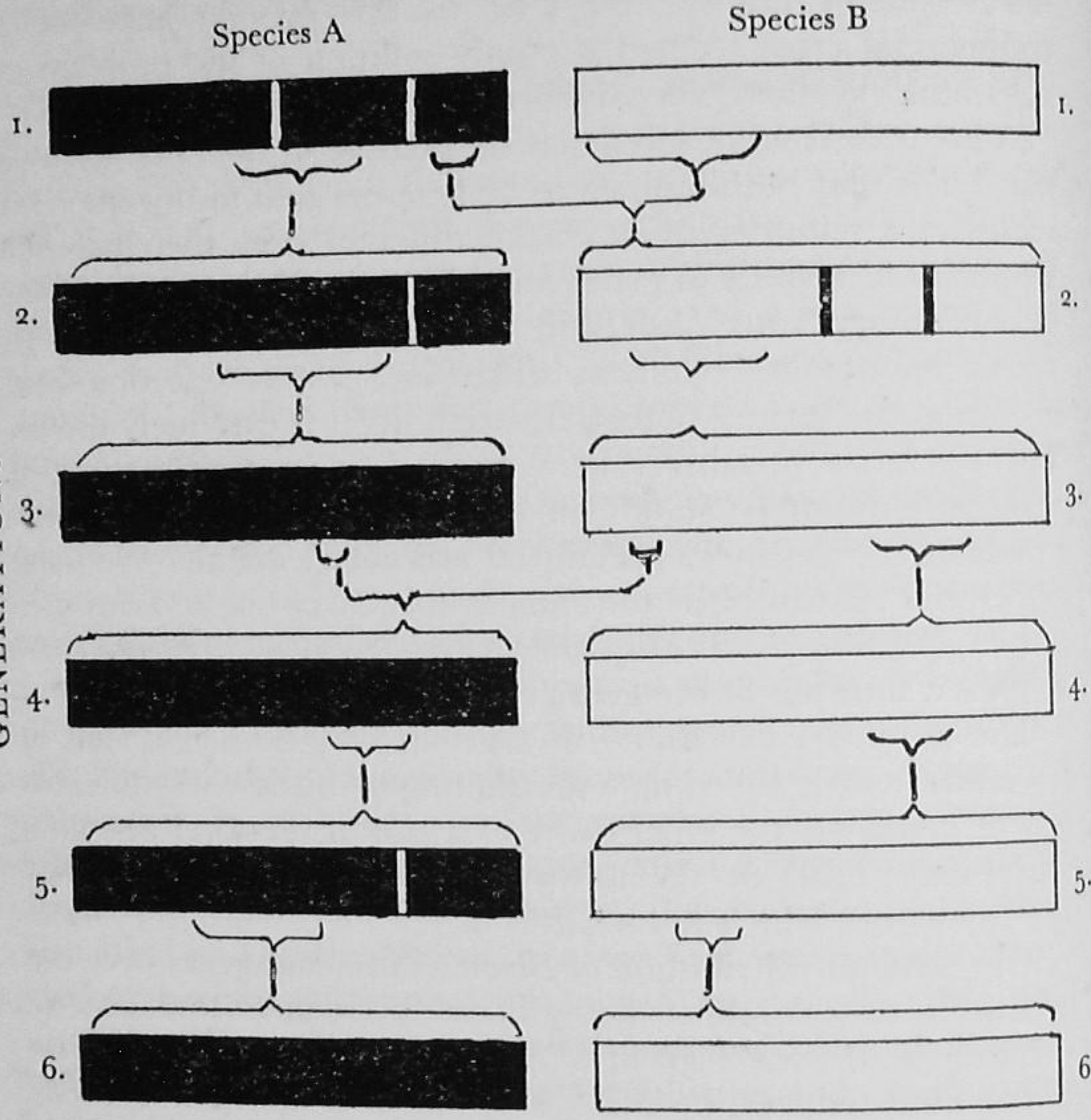


FIG. 8.—Two breeds (or species) that very occasionally are crossed, will nevertheless retain their identity, simply because in every generation the proportion of individuals procreating is relatively *very* small.

The illustration, taken from "The Relative Value of the Processes causing Evolution" (Hagedoorn and Hagedoorn, 1921, Nyhoff) symbolises this in a very simplified way.

down. If we think of the way in which any breed or species continues from generation to generation, we shall see how the parents of the next generation are often a relatively small group. This is obvious in such animals as rats or field mice, or in the case of weeds, but any poultry-breeder must realise that only

relatively few of his chicks (especially in the case of males) really have any offspring.

While natural selection acts greatly by chance, the poultry-breeder tries to govern this process of purification in his selection work.

Inbreeding is a most potent cause of isolation, and in the absence of cross-breeding (which brings in new genes and impurities) the automatic reduction of the T.P.V. will proceed rapidly. We must clearly remember, however, that it is not the family relationship in inbred groups that makes them purer, but this reduction of the number of ancestors per generation. Two illustrations will make this clear. When we buy a pair of chickens from a show, those two birds, even if unrelated, will certainly have the majority of their genes in common, and in a good many cases they will both be homozygous for one and the same gene, in respect to which some other birds in the breed may be impure.

The progeny of our two birds is less variable; it has a lower potential variability than the entire population of which they are representatives. On the other hand, we can calculate that in a regularly expanding group, in which every individual has an equal chance of producing offspring, the proportion between homozygotes and heterozygotes (*AA*, *Aa* and *aa*) remains the same, when selection plays no role, so that the *AA*, *Aa* or *aa* birds have the same chance of breeding and procreating.[1] From this fact some geneticists have concluded that only selection (natural or intentional) can bring down the potential vari-ability, and that it will persist when selection plays no role. This is certainly true mathematically, but it ignores the fact, emphasised by *Malthus* and *Darwin*, that populations may expand for a while, but that they cannot go on expanding. Statistically we can say that on the average one individual has one descendant. But periodic reductions of the number of individuals (especially males) that have any offspring auto-matically brings down the T.P.V. It should be the object of the breeder to guide this purification, and to see to it that the final genotype (set of genes) is the very best obtainable with the material in hand.

[1] *Hardy*'s law.

This can be done by selecting the males according to purity (homozygosity) for desirable genes and mating them to females of their own group (inbreeding), comparing the progenies of several of such breeding-groups (Nucleus System).

Inbred lines, continued for a large number of generations, even if selected for trivial qualities only (show stock), must eventually become pure in respect to their set of genes. In the end this will make every chick like every other chick of the same sex, so that differences between them are wholly due to chance and circumstances. In as far, e.g., as the hatchability of the eggs depends on the correct hereditary make-up of the chick, they should all hatch if one hatches. I am continuing a group of Polish bantams bred by Mr. *Van der Linde*, a fancier who used to breed brother to sister or father to daughter, with only one male in his breeding-pen for over fifty years. Of forty-seven of their eggs, incubated in 1948, every single egg gave a promptly hatching chick. On the other hand, I know of a strain of highly inbred White Leghorns in which the hatchability was zero! In this strain every chick was so located in the shell that it could not break it. The breeder peeled them all out, and had enough surviving chicks to continue the strain with, and to use some males for cross-breeding purposes.

Mutation next to cross-breeding is another, minor, cause of new potential variability. As I have shown elsewhere, mutation in poultry is only of very slight importance in the evolution of breeds and superior strains. The effects of indifferent mutations tend to disappear, for in polygamous groups the automatic reduction of the T.P.V. does not give the loss of, or change in quantity of a gene any good chance to affect the final constitution, if we compare its effects with cross-breeding which produces individuals and groups with an enormously enhanced T.P.V.

To resume, there is in our domestic poultry a constant automatic reduction of variability—or, in other words, a purification—mostly as a result of breeding poultry in breeding-pens with few males. This results in a slow formation of separate local breeds, and, in so far as highly selected poultry are concerned, in strains that differ in quality.

Unless we take care, the final constitution of such strains will

rarely be the best possible one, important genes being lost in the process. Crossing strains will then often bring the quality up. But this cross-breeding will also produce a great amount of new variability. When all this is understood the moral is obvious: we must so arrange our breeding programme that the best strains become pure, homozygous for the useful genes we want to retain, for this will give us uniformly good quality and an absence of culls, and it will free us from the necessity of crossing to bring back the quality and vigour we are losing through bad methods.

Chapter Eight

Inbreeding

As I explained in the chapter on Uniformity, inbreeding is having an influence on the composition of future generations mainly through the fact that inbreeding spells isolation.

When a population is variable, when it has some potential variability, this means that in respect to many genes individuals occur in it that are homozygous and others that are heterozygous for them. And since, as a result of the reduction division, chromosomes and even smaller groups of genes are constantly being shuffled and recombined at every generation, the smaller an isolated group of birds is, the smaller its potential variability will be. This is especially true when we are mating small groups of closely related individuals. Birds that are closely related have more chance to be alike in regard to any gene that is not common property of a larger group.

The purification which goes on in a population that is constantly being renewed from only a few birds goes on slowly but surely.

In ordinary practice—let us say in the case of farmers of a village keeping chickens—the reduction of variability in one farm will be going on for a few years until some neighbours swap settings of eggs or somebody buys a fancy rooster.

If we look at the effect of inbreeding, we must realise that it is almost impossible to keep track of what happens in a large

population and during several generations. It is simplest to follow the fortunes of just one inbred "line", the descendants of a few birds and the offspring of just a few of their descendents, and so on, disregarding the rest of the group. In chickens the smallest group is one pair. Let us follow what would happen if we started from one pair of birds, if we took just one male and one hen from among their chicks, to continue the line with, and so on. This would be continued brother–sister inbreeding. Many small poultry-fanciers are breeding in this way, substituting a pair or a small group of chicks for their parents every season.

There is an unknown quantity of genes in respect to which the two original birds were both pure and identical. It is probable that (with the exception of the genes on the sex chromosome in respect to which no hen can ever be homozygous) an overwhelming majority of genes are the same in both.

Next there may be some genes which only one of the two possesses, while the other lacks them. This difference may be of different kinds; to put it in formulæ, one may be *AA*, the other *aa*; or one *Aa*, and the other *aa*. And there are certain to be several genes in respect to which both are heterozygous, *Aa*, *Bb*, *Cc*, *Dd*, *Ee*, *Ff*, and so on.

We shall see that the result of continuing such an inbred series must be a purification, and we can follow this best by looking at just one single gene, gene *B*.

Here are the possibilities:

BB × *Bb*, *BB* × *bb*, *Bb* × *Bb*, and *Bb* × *bb*.

What kind of chicks can we expect from each possible sort of mating?

BB × *Bb* will give equal chances of *BB* and *Bb* offspring.
BB × *bb* will give only *Bb*.
Bb × *Bb* gives 25 per cent chance *BB*, 50 per cent chance *Bb*, and 25 per cent chance *bb*.
Bb × *bb* will give equal chances of *Bb* and *bb* offspring.

If we are simply continuing from one pair of birds in every following generation, and calculate the chance for variation in respect to *B* to persist, we realise that in this loss of potential

variability we are dealing with a "ratchet" mechanism. Every time we happen to mate two *BB* birds together, or two *bb* birds, the strain we are following is pure, homozygous, in respect to gene *B*. This will happen at least once in eight times, one chance in sixteen that both will be *BB*, and one in sixteen that they will both be *bb*.

This means that if we start from material that is variable in respect to a large number of genes brother–sister matings will reduce the potential variability.

In larger groups this automatic reduction of the potential variability (number of genes for which every member is not alike and pure) will be more rapid the smaller the absolute number of individuals. A simplified formula is $1/8M$ for the part of the potential variability that is lost per generation, M standing for the number of males in the group (*Lush*).

This means that on a poultry-farm with ten breeding pens only about one eightieth part of the potential variability would disappear per generation if no selection were practised. Selection according to individual quality of the hens (trap-nest selection) might help a little, but even if this were 50 per cent effective—which it certainly is not—progress towards purer poultry and a better expectation of good-quality chicks will still be extremely slow. Even this very slow purification would only be expected provided the breeding-farm stopped importing breeding-stock, and just rotated the males, the sons of one pen heading pens of hens from another group.

If, however, this breeding-farm with ten breeding-pens should start to keep ten parallel lines and stopped crossing its birds, filling house number *three* with a young breeding-pen derived from old pen number three, and so all along the line, the picture would change entirely. For now in each line a succession of just one male per generation would be kept, and a good proportion of the remaining variability will get worked away per generation. Those ten lines will then become more and more pure, and will certainly become different.

If we just blindly bred ten separate lines, those lines would all become pure slowly for different sets of genes, and this is what a few of the American firms, following the example of the maize-breeders, have been doing. Their method is to

produce a multitude of pure families first, without bothering about their quality, in order to try whether by good luck they can later find strains which, when crossed, will give them good, profitable poultry.

The quality of such (blindly) inbred lines is generally low. If we inbreed without selection, starting from the usual very variable stock available, there is a good chance that valuable genes in respect to which the original material was impure get lost by the way.

In the chapter on the Nucleus Method we shall see that it is quite possible to take advantage of the purifying influence of inbreeding, while we guarantee ourselves against the loss of valuable genes by directing our attention to homozygosity in the males (in hens this is practically impossible, as we shall discuss).

Chapter Nine

Inbreeding Degeneration

Most breeders of livestock are very much afraid of inbreeding, because they fear inbreeding as a cause of degeneration. Rightly so! In most domestic animals the system of eternal cross-breeding, buying and using "new blood", is both the remedy against the dangers of inbreeding and the cause of those same dangers.

A geneticist co-operating with plant- and animal-breeders is able to see general principles in applied genetics that would not occur to the specialist working with one sort of material only. In this particular subject it is very illuminating to look at the experience of the plant-breeders.

In plants, some groups are habitual self-fertilisers. In garden beans, or in wheat or barley, every plant is both the father and the mother of its seeds—a group of barley plants is a mixture of strictly isolated and long-inbred "pure lines". Such pure lines are really so pure that every seed is completely equivalent to every other seed; differences within the line are entirely non-hereditary. And such pure lines are also completely "inbreeding resistant". Inbreeding will not change or harm them.

In cross-fertilised plants, like rye, maize or beets, however—and the same is true in artificially cross-bred families of beans or barley—there is considerable genetic variability. Inbreeding will be the cause of the production of many genetically inferior plants and families. If we go on inbreeding, differentiation

will set in, and after several generations our fields of barley, for instance, will contain a heterogeneous mixture of lines that are pure again, a few good ones, but very many lines of indifferent value and many very inferior ones.

The only thing which makes pure lines of barley or beans inbreeding resistant is their purity, the fact that they do not carry hidden impurities—heterozygotes in regard to important genes. And this purity, this resistance against inbreeding, in its turn was the *result* of inbreeding!

Here we have a paradox, which always tends to confuse and surprise the breeders who are not conversant with genetics: Inbreeding is frequently the cause of the production of inferior individuals and strains, and yet the only way to avoid all this trouble is inbreeding!

Inbreeding—the mating of closely related birds—may be the cause of the birth of unwanted recessives, not because those birds were closely related, but because they both were heterozygous for the same important hereditary factor, whose absence from a chick makes it inferior. And when such heterozygotes are relatively rare, the chance that full brother and sister or first cousins whose common ancestor carried the impurity will have such recessives in their offspring is correspondingly heightened.

Now, there is one very significant fact in regard to inbreeding degeneration, and that is that we never get into trouble by inbreeding in regard to the qualities we prize in our material—the qualities for which we select our birds. It is quite common to find that in some highly prized and very successful strain of show-birds—let us say modern Game bantams—the egg production is very poor. Poor layers of very good shape have naturally been chosen by the breeders in preference to others that were less "typey" but laid more eggs!

Conversely, breeders often deplore the fact that in our most successful strains of utility Rhode Island Reds or Light Sussex, the "type" or the feathers have deteriorated. Again, the explanation is the same, the breeders, when having the choice between beautiful and good individuals in their selections, have given preference to good ones.

It is certainly true that all sorts of faults in quality and in

appearance in show-birds, as well as in utility strains, are recessive (due to the absence of important genes), and that for this reason, such faults tend to be found when we start inbreeding. This is certainly true of causes of death of embryos —poor hatchability is partly due to hereditary weaknesses.

The obvious immediate remedy against all such troubles is crossing in " new blood ", and why this helps is fully explained elsewhere (crossing). The " hybrid vigour " so obtained may be very striking, and it is small wonder that in the light of this, " inbreeding " has a very bad reputation.

On the other hand, it must be emphasised again that the only way to avoid inbreeding trouble is inbreeding, combined with very efficient selection (see chapter on the Nucleus System).

Inbreeding troubles will almost always appear where inbreeding must be carried out. Wherever we carry out an inbreeding programme, however, we see that such troubles, when we understand their nature, can easily be by-passed, and in practice, where we have to carry out an inbreeding purification programme, such troubles become less and less serious.

The idea that inbreeding should always bring along lack of vigour and lack of fertility is probably simply due to faulty observation and to unwarranted generalisation. In the first inbred generations from highly variable (outbred) stock a high proportion of weaklings, badly viable embryos and sterile individuals may be expected as a matter of course; but it will be seen that if we breed enough and discard the bad lines, this trouble will soon pass. On the other hand, close inbreeding, especially in the larger, less fertile animals, should always be avoided when it is suspected the breed is variable, as most breeders must avoid the birth of a deformed, sterile or otherwise valueless young animal. In fact, the only reason for taking inbreeding risks must be an attempt to " fix " the quality of really first-class breeding-stock.

In fowls or ducks there are two reasons for inbreeding. In the first place, to obtain high quality and to produce strains of great purity, high hatchability and free from the necessity of culling; and in the second place to retain this purity and high quality, once we have obtained it.

In the matter of fertility and hatchability we meet with the

usual paradox when inbreeding. When a strain is highly variable, inbreeding may cause the conception of many embryos of poor constitution, and corresponding low hatchability—e.g. a high percentage of dead in shell. But, on the other hand, it is very striking that poultry families that are inbred for very many generations are noted for the surprisingly high hatchability of their eggs. I have heard of 100 per cent hatches in Modern Game. I obtained 100 per cent hatches in a family of Polish bantams, inbred brother to sister and father to daughter for over half a century by a fancier. This is really what we should expect, if the non-viable embryos are genetically inferior, in a strain where the potential variability has been bred out: if one embryo hatches, they should all hatch, if given the opportunity.

As will be seen from this chapter, we geneticists do not deny the danger of inbreeding in ordinary cross-bred stock. But at the same time we affirm that inbreeding, when carefully worked in combination with progeny testing in respect to purity, will be essential to produce the kind of stock in which " inbreeding degeneration " will cease to occur.

In the chapter on Transgressive Variability is explained how cross-breeding may be the cause of novel (mostly unfortunate) variability. If we want to understand why the offspring of excellent first hybrids in poultry, such as Rhode Island Red × Sussex or Leghorn × Barnevelder, are so very disappointing in quality, a simple calculation will show us why. Let us assume that such hybrids are heterozygous for a number of genes that have such an influence on the quality that the pullets that are lacking in them are definitely inferior in some quantitative or qualitative respect.

This would mean that three pullets out of four would be better than the inferior recessives, *aa*. And out of the 75 per cent with *A*, again there would be three with, and one lacking, *B*—the *bb* ones. Now, this means that for a given number, *n*, of genes a proportion of 3^n out of a total number of 4^n would be as good as the original hybrids, and the rest inferior, for a variety of reasons.

This means that if the number of such genes in which the parents of the hybrids differed was ten, only $3^{10} \times 4^{10}$ would be

good. And if we were dealing with fifteen genes, the proportion of good ones would only be $3^{15} \times 4^{15}$. And this is only a very small proportion of all the second-generation birds, for $3^{10} \times 4^{10} = \frac{59{,}049}{1{,}048{,}576}$, which is only about one good one in eighteen, and $3^{15} \times 4^{15} = \frac{14{,}348{,}907}{1{,}073{,}641{,}824}$, which is only one good one in seventy-five!

Chapter Ten

The " Nucleus System " of Selecting Utility Poultry

To devise a very good system of selection, the method must be adapted to the material. It must be easy to understand and to work, and of course the final test is that it leads to complete success.

When I proposed the method about to be described, I based my method on the following considerations:

A. Poultry are highly polygamous—we need only one male to several hens.

B. The fertility is high, so that we can build up excellent flocks from small nuclei of first quality.

C. To obtain high quality combined with great stability, our male birds must be pure (homozygous) in respect to all the desirable genes. Hens are heterozygous (haplozygous) for all genes on the sex chromosome.

D. It is not possible to study the desirable genes one by one; they are too numerous, and their action and interaction cannot well be studied separately from the effect of environmental influences.

E. It is possible to recognise homozygous individuals by their prepotency in suitable test matings and progeny tests.

F. Such progeny tests must be so designed as to show which animals are homozygous for valuable genes, but as

deliberate test matings with recessives are impracticable, they can only be worked by testing those individuals in matings with groups of others, in which groups we suspect the presence of heterozygotes.

G. This makes it quite practicable to test males for purity (prepotency) by testing them in matings with closely related groups of females, sisters or daughters. In poultry, progeny testing the females by mating each to several closely related males is impracticable.

H. In breeds which have been subjected to several generations of selection according to individual quality, the undesirable dominant qualities have been eliminated, the breeder's difficulty is to obtain purity and stability in respect to dominant good qualities.

I. Inbreeding will tend to produce homozygosity—purity—but in material heterozygous in respect to desirable genes it tends towards the production of undesirable recessives as well as to that of the desirable prepotent homozygotes.

J. Considerations of Mendelian dominance and of the influence of " chance " on final quality make the results obtained from one individual hen of very doubtful value (trap-nesting). In groups kept under uniform conditions such individual modifications cancel out.

The " Nucleus " system has been designed to furnish a small central group (nucleus) of highly pure breeding-stock from which, according to the fertility of the species of animals in which it is worked, highly prepotent males (in sheep, pigs, or cattle) can be used to head the country's flocks, or which, in the case of hens or ducks, can be multiplied, just as in the case of the selection of small cereals.

And this is how the nucleus method is worked in poultry and ducks: as we want to work towards purity, we must at all costs avoid the introduction of outside " blood ", no matter how promising. For this reason our start must be made with the *very best foundation material* we can obtain. It helps enormously if we can start with pure-bred stock which has been subjected to the ordinary system of individual selection (trap-

nesting). From such material undesirable genes have already been eliminated, and all we want to do now is to make the strain pure and stable and obtain a nucleus in which all the well-managed individuals will be as good as the exceptional good ones we start with. In other words, what we want to obtain is a strain in which " culling " from other causes than accidents will be quite unnecessary.

We make up a considerable number of breeding-pens, dividing the available hens at random over the males. We now reap the eggs from each breeding-pen separately, hatch them in separate lots, and immediately start noting down the results. Good fertility and hatchability certainly depend partly on the hereditary composition of parents and of embryos. The chicks are toe-marked or wing-marked at birth, and raised in mixed lots, and of course chick mortality or the presence of deformed chicks will be chalked up against the breeding-pen (or against the father if one prefers to call it thus). By the time the pullets mature, one or two lots may have to be eliminated (with the parents) as unsatisfactory.

The pullets are now housed for the laying season in suitable houses. The conditions under which they are kept should be identical, and as the different lots of pullets may be of unequal size, it is ideal to keep the groups divided over several small pens. Folds are ideal, but a laying battery will do at a pinch. It is inadvisable to combine two or more groups in trap-nesting, semi-intensive houses, unless we want to ignore food consumption per group (a point of great economic importance).

All we have to record now is the hen-housed production of the separate family groups. If for any reason pullets die or must be culled, this will appear in the final record of the hen-housed average of the group, and so will the winter production and average egg-size, which should be recorded on certain days when time permits.

All this will, with a minimum of book-keeping, allow us to judge the real genetic value of the breeding-pens we started with. And our choice must now be made, not according to the quality of individual layers, but according to the quality of the daughter groups, which means according to the actually proven value of our breeding-pens *as such*.

When the next breeding season comes round, our best daughter group will be divided up into new breeding-pens. Those breeding-pens will now be headed each by a son of the best father, half-brother of the hens. It is clear that when we proceed in this way the inbreeding will often result in the production of culls, or inferior or aberrant chicks, or weak or abnormal pullets. This is inevitable. In practice, where the nucleus system has been worked for many generations in poultry, ducks and sheep, it is always remarked that during the first few generations the percentage of culls is of the usual order. Only—*and this is important*—those culls are now found concentrated in the progeny of one, or a few sires.

The pens that gave us culls will be eliminated with all the progeny, good, bad and indifferent. In other words, the comparison between parallel progeny groups makes it possible to base our judgment not only upon high, profitable egg-production, but equally upon high vigour, health and the absence of any culls.

While we are taking advantage of the close inbreeding to bring the genetic variability down (and the purity up), we guarantee ourselves against the dangers of inbreeding from heterozygotes, by selecting some parallel lines free from this inbreeding trouble.

In the breeding of poultry, but especially also of laying-ducks and of wool-sheep, this nucleus system of bringing up both the purity and the quality of a relatively small stud within a stud, which will then serve to improve very large flocks, has abundantly proved itself. All along the line the nucleus-breeders have the same experience: in a few generations they find that the average quality *goes up*, to a surprisingly high level, while at the same time their chief bother—the necessity for constant culling—*disappears*.

It is not surprising that a system of selection which at first sight appears to run counter to all the warnings and prejudices of the old school was looked at with great suspicion, and in the beginning all sorts of improvements and compromises between individual and group-testing were proposed and tried.

At first sight it appears as if the use of trap-nests in the system would be an improvement. It can be reasoned that the possi-

bility exists that one unrecognised poor layer in a breeding-pen might happen to be the mother of a son, used to head a pen of half-sisters next season. Theoretically this possibility is not excluded. But of course we must remember that if this unlikely chance should happen, and if, in addition, the inferiority of such a hen should have a genetic cause, this son, as the head of a pen of half-sisters, would certainly be scrapped as a breeder with all his progeny in the next season.

From a considerable experience as a consultant, co-operating with all sorts of animal-breeders, I am opposed to the use of trap-nests or laying batteries in poultry-breeding, as a method of *comparing* quality in individual females (but see the Second Part). When we are once determined to base our selection upon genotype (actual breeding performance) rather than on phenotype (personal quality), we should stick to our principle. If we compare the resultant offspring from two parallel breeding-pens, we should choose the best group, as a group, because it is the offspring from the best lot. In an inferior group one or two daughters may still be phenomenally good layers. If we know them, it calls for enormous determination not to take them into some breeding-pen. And yet, being the daughters of a second-class father, they ought to be thrown out. It is bad enough if in some countries the paternal authorities, in their mistaken conservatism and mistrust of science, insist upon forcing obsolete breeding methods upon progressive breeders.

The most spectacular success of the nucleus system of selection has been that in which it has been worked during the longest series of generations: the improvement of Khaki Campbell ducks by our friend *Jansen* in Tonsel (Holland). Jansen started as a trap-nester, and had excellent foundation stock, of which many ducks laid 345 eggs and over in laying tests. When he started, his duck-housed average on his big farms was 270 eggs. By means of a comparison between daughter groups, and by strictly selecting only the sons of his best, purest drakes, he brought his average up to 304 eggs and his culling percentage down to five! This was just before the war, and during the war he was unable to feed his ducks on the usual fish and yellow maize, so that his farm production went

down during those years. But he continued selecting his ducks according to the system (notwithstanding the fact the Government had forced him to start individual as opposed to family recording). When I visited him after he had rebuilt his flocks almost to his usual 30,000 to 50,000 head and when his feeding was again adequate, his farm average egg production had gone up to over 340 eggs (number laid in one year after the first egg) and he had *stopped culling entirely*! A great many of his ducks lay series of well over 400 eggs before they miss a day.

Several breeders of different breeds of poultry, mostly Leghorn in Holland, Leghorn and Rhode Island Red in England, Leghorn and Australorp in Australia and Africa, have had exactly the same experience. Working along this method they have brought up the farm average, while at the same time they have reduced the percentage of culls and faulty, susceptible pullets to negligible proportions.

It has been my experience to see how in almost every instance a breeder starting to improve his flocks by this method needs some encouragement during the first two or three generations, chiefly for two reasons: his colleagues make him scared of the "inbreeding", and he begins to see many culls grouped together in some of his experimental flocks, where they look much more impressive than scattered all over his pens as before, even if he actually has fewer of them.

Most "nucleus" poultry-breeders neglect food consumption. On the Seven Hills Experiment Station in New South Wales, however, very promising results have already been obtained in breeding poultry for the production of *cheap* eggs rather than *many* eggs only.

Chapter Eleven

Culls and Culling

In keeping poultry successfully a very important thing is the elimination of any individual that is not worth its keep. In laying breeds it is often an economic loss to bother with male chicks, and the sooner we can separate the worthless males the better. We can then use the available brooder space and the expensive chick-food for the females. The sexing of new-born ducklings in the duck-egg-producing districts north of Amsterdam must have been used for at least two centuries. Hundreds of thousands of Khaki Campbell drakelets are killed in Holland on the day they are born, and the same was true with cockerels when the Assendelvers were popular. The breeders mated silver hens to golden cocks and killed off all the cockerels that could be easily recognised by their white colour. This " sexing " of chicks is far from new, and the sexing of chicks by looking at the vent has been done in China and Japan for centuries. The auto-sexing breeds have been established to avoid this process, which delays delivery and sometimes harms the chicks (*Punnett*, *Pease* and *Hagedoorn*).

In the usual lot of baby chicks a percentage is born with defects which make it unprofitable to raise them. The hatcheries cull the baby chicks before sending them out to their customers. The causes of such deformities and weaknesses—crossed beaks, blindness, inability to stand, extruded yolks, general weakness, lack of the instinct to eat, etc., etc.—

are very diverse. Faults in incubation are very serious, and the diet of the hens that produce the eggs has a great influence on the hatchability of the eggs and the quality of the chicks. Even the size of the hatching eggs has its influence; very large eggs have a bad reputation in this respect, and this is one of the chief reasons why hatchery-men prefer eggs from pullets to eggs from hens.

It is evident that, in addition to such non-inherited causes, genetic factors play a role. The percentage of dead in shell greatly depends on inherited faults. One striking type of fault —malposition of the chick—is clearly due to an inherited aberration, but as the practice of helping such chicks to be born is frowned upon, the parents of such chicks are always normal. Such malpositions, as far as they are due to the genotype, can only be recessive.

We know of one instance in which a breeder of Leghorns had an inbred strain in which hatchability was zero per cent! Every chick in this family had to be helped out of the shell on the twenty-second day.

When the chicks grow up, some are often of poor vitality, and it is generally wise to cull those as soon as they are recognised. Again, non-inherited factors, such as infection or chilling or overheating, may be the cause, but where the chicks are raised under perfect conditions, unthriftiness is probably due to some inherited weakness. In any case when early culling is indicated it may help to prevent the spread of illness, and it seldom pays to bother with unthrifty chicks. Again, in very highly pure strains the proportion of such culls is extremely low when conditions are perfect.

If we compare the chick mortality of two batches of chicks raised from eggs of similar or even the same hens, but in which some are pure-bred and some are hybrids, it is often found that the hybrid chicks have a much lower mortality rate; we remember the case in which chick mortality in a batch of White Leghorn chicks, as well as that in White Wyandottes, was over 40 per cent, whereas it was below 1 per cent in hybrids between these breeds, mixed with the other chicks under the same hover. In this case mortality was due to B.W.D., and it illustrates that an inborn disease-resistance may be due to inherited quality.

Culling should be continuous, both in commercial flocks and in the breeding-pens of the fancier. In young and adult birds, just as in chicks, aberrant individuals may be inferior for a variety of reasons; but it is unwise to take any chances. In fancy poultry the percentage of birds good enough to retain in the breeding-pen is generally rather low, for here genetic variability is usually high. A fancier of such breeds as Silver Wyandotte or Barnevelder who tries to avoid double matings may have to shift out nearly all his pullets and cockerels as they moult into their final plumage. In some cases, as in dominant blue breeds, half the birds are off colour (25 per cent black, 25 per cent dirty white), but it is very easy to sell off the blues and retain the white and the black culls in breeding-pens, as they will give the breeder 100 per cent blues when interbred.

While commercial flocks of hens are in production, it is often found that a considerable percentage will not be worth their keep. If we keep such flocks in batteries or trap-nest them, the laying records will soon show us which hens are passengers and should be got rid of. When we keep our pullets in flocks, this is not so easy. It is, of course, possible to recognise pullets in full production from non-laying drones, especially in yellow-legged breeds. The duck-keepers have one great advantage over the poultry-keepers, in that one can tell the "wet" layers from the "dry" non-layers at a glance. On the mammoth duck-farms in Holland a continuous shifting of ducks is taking place at the beginning of the laying season. The wet ducks are housed separately from those that are still dry, as the layers have to be fed more protein. Up to ten years ago handbooks of poultry-breeding were devoted to methods of culling laying hens to such an extent that it often appeared as if even in breeding-flocks culling according to appearance was the alpha and omega of successful poultry-breeding.

Again, just as when we are dealing with the culling of chicks, we must state that the ability of a hen to lay a large series of eggs profitably depends partly on her inherited make-up and partly on non-inherited factors. A very frequent cause of poor productivity is starvation, or partial starvation. Many pullets are timid and let themselves be cheated out of choice morsels. One of my correspondents bought two hundred under-weight

pullets from a large-scale poultry-keeper and housed them in batteries. While fed on the same all-mash diet, his underweight hens produced more eggs than the hens at his neighbour's farm.

Culling of all non-thrifty, late-maturing or poorly laying hens should go on at every commercial egg-farm, and every poultry-keeper should find out for himself just where profit disappears.

On the other hand, this does not mean that culling of chicks and hens is a method of selection that is worth while on a *breeding-farm*. In the first place, too many breeders used to be firmly convinced that there is a very high correlation between individual quality and breeding quality. We used to think that somehow the qualities of a bird were transmitted to its offspring. Now we know that the final qualities of a bird are due to a combination of excellent care plus excellent inherited constitution, we understand that individual quality is a poor guide to excellence in the breeding-pen. In fact, the excellent quality of a hen may be due to the very best set of inherited factors, as in a hybrid hen, while she is a very poor producer of good daughters, simply because the germ-cells she produces are highly different one from the other. In other words, dominance (see the chapter on Dominance) may lead us very far astray when we are relying upon the excellence and splendid performance of individual ducks or hens.

In the chapters on Selection and Selection Methods I have tried to show how important it is for a breeder to find the breeding value of his breeding-pens. If a breeder wants to make sure that he is on the right course in his selection, it is absolutely necessary that he should be able to collect data, not only on his good, but also about the quality of his aberrant birds. This means that the good poultry-breeder should *never cull* his experimental flocks. As I explained in the chapter on the Nucleus System, the breeder should never base his judgment on individual quality, he should never expect his excellent birds to be exceptionally good breeders; he should cull, of course, but he should cull out poor breeders, he should cull disappointing families, and never just poor individuals. In other words, a breeder who eliminates his culls is on the

way to cheat himself. If one culls out poor chicks, the number and nature of the culls must always be recorded. If one culls poor pullets, or records some pullet mortality, this discouraging fact should never be forgotten; the breeder should base his selection upon the quality of his groups—good, bad and indifferent.

Really efficient methods of selection should always be aimed at reducing the percentage of culls of all description. As I explained in the chapter on Inbreeding, inbreeding has a tendency to bring out hidden weaknesses, recessive faults due to impurity in the parents. Throwing out the bad ones while keeping their good brothers and sisters is not a good system, as those good birds are very likely to be impure, like one or both parents. This is the main reason why we must know all the weak points as well as the good qualities of every group. For this reason, the breeder, whose aim must be to produce the kind of stock that will give nothing but good ones, would cheat himself and defeat his purpose if he glossed over what he knew about those weaknesses. He must know the hatchability of the eggs from each breeding-pen, the number of dead in shell, the chick mortality, pullet mortality and any other faults, such as small eggs, tendency to neck-moult, etc.

In order finally to obtain stock that will not need culling, he must give very much more attention to all the disappointments than to the quality of his top-notchers. Of course there are two ways of doing this. One is to run a very complete and efficient system of book-keeping, and as a geneticist I like this sort of thing, which gives us valuable data. On the other hand, by using the system of just noting the number of healthy chicks per hundred eggs, the number of pullets housed and the hen-housed average production (value of the eggs divided by number of pullets originally put in the house), the breeder will get all the data he really wants. If he leaves obviously poor pullets in the pen, this will bring down the hen-housed average, so that such a pen will not be retained as breeding stock.

It is very clear that the ultimate qualities of breeding-stock are due partly to heredity and partly to circumstances—chance. We could speculate upon the "heritability" of each separate quality, and state that broodiness or small eggs is highly

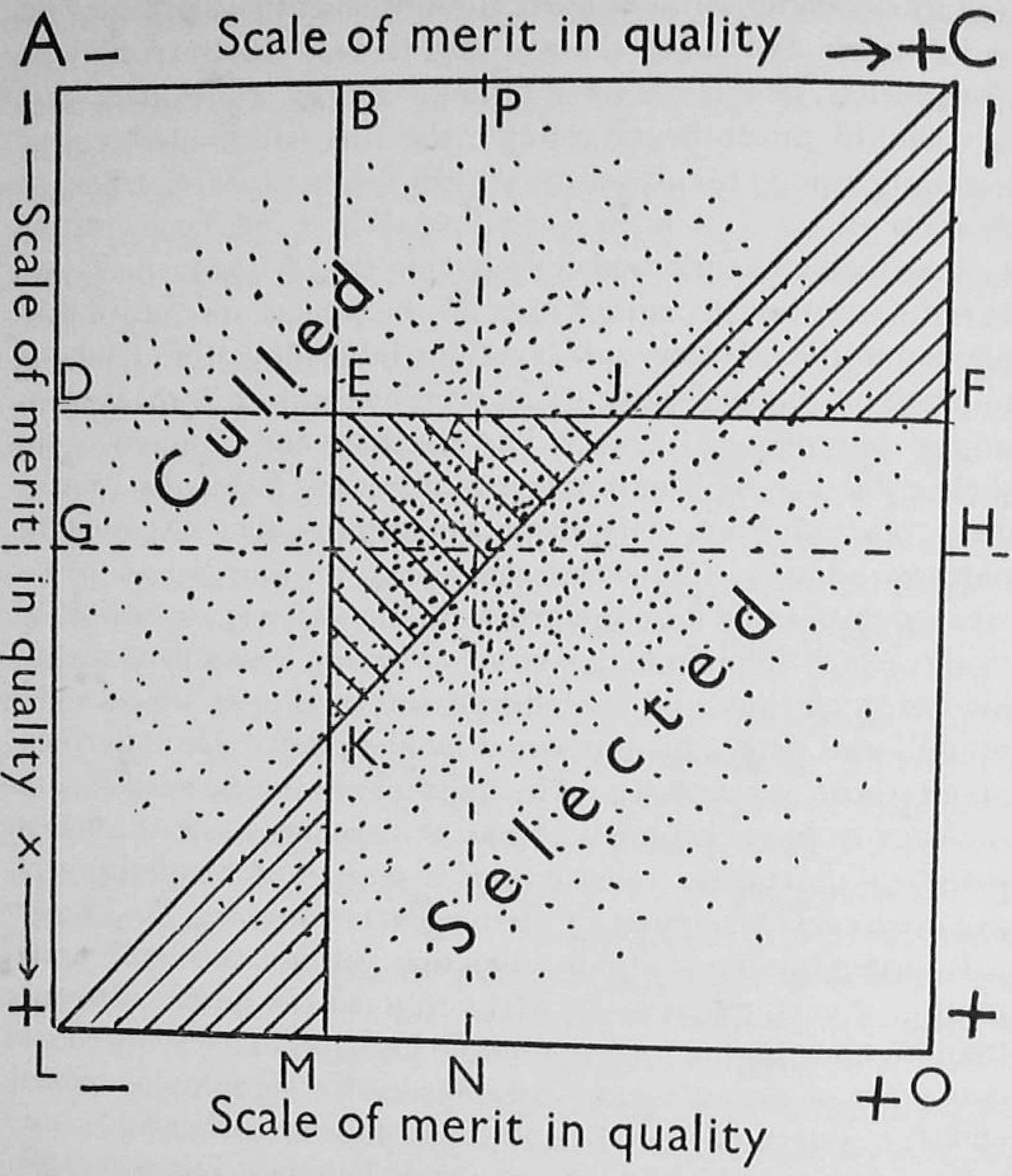


FIG. 9.—Superiority of selection on total score as compared with culling first for one quality and then for another. Diagram after one in J. L. Lush's book, *Animal Breeding Plans*. Each dot represents an individual, and merit in quality x is independent of merit in quality y. One half of the individuals must be culled. If we cull first for quality x and reject all the animals above line D–F, and then for quality y, rejecting all the animals to the left of B–M, we keep all the animals within E–F–M–O. If, however, we score each animal for both qualities x and y, we reject all the animals above the diagonal L–C and select all those below it.

Animals of outstanding merit in one respect, included in triangles J–C–F and L–K–M, would be kept if selecting for total score, but rejected when culling first for one, then for the other quality. On the other hand, the individuals within triangle E–J–K, animals below the average, would be kept when culling first for one, then for the other quality, but in selecting for total score they would be culled.

heritable, while cannibalism is only slightly heritable. A lot of work has been done along those lines by American colleagues. This is very interesting. But as it is evident that the effect of environment changes with the skill of the breeder, those percentages cannot very well be used as a guide to breeding work. In a well-conducted breeding-farm, where the conditions under which eggs are hatched and chicks are reared are optimum, and where all the pullets are housed and fed under almost identical conditions, the effect of chance is reduced to a minimum, so that differences in mortality in groups of embryos, chicks and pullets, and differences in production, are highly significant. On such farms the "heritability" is relatively very high, and accidental causes of death and unproductivity are relatively rare.

From the above it should be seen that there is, in respect to "culling", a far-reaching difference between commercial egg-producing farms and breeding-farms. The poultry-keeper should *everlastingly* cull his unproductive birds. He may then forget about those culls. The breeder, however, should aim to give the poultry-keeper chicks or breeding-stock of such a quality that culling on the egg-farm should be practically unnecessary. The breeder, in order to produce his highly pure and highly profitable, vigorous families that will need hardly any culling, should make this culling percentage one of his main criteria of quality. If he just culls and forgets about his culls, breeding from the good birds, like his fellow-breeders ten years ago, he cheats himself as well as his customers.

Fig. 9 shows that in selecting it is better to select for all factors at once, rather than for one at a time.

Chapter Twelve

Handling and Selection According to Appearance

To the poultry-men of the period before the Second World War, "selection" and "handling" were practically synonymous. We all know the type of poultry expert who professes to be able to judge so-called "utility classes" at poultry-shows. In a few countries he may even today survive in a few rare specimens; a very important personage if he happens to be a Government inspector, but a figure of fun to the experienced breeders.

Now, I must not be misunderstood in this. To a great extent, the non-layers, the starved, henpecked culls, the birds that are broody or that are moulting when their sisters are in full lay, can be picked out of a pen. In ducks the layers and non-layers can be picked out at a glance. On a commercial egg-farm it certainly pays to pick out the unthrifty birds—the passengers—and to market them before they lose too much weight. All this reduces losses, but it has nothing to do with selection as a breeder understands this term.

The professional "handler", however—the judge of utility classes—goes a long way farther than this. He is firmly convinced that he can pick out the excellent producers, the mediocre ones and the culls, even if they are all apparently healthy and in production; more, he will handle your pullets "on point of lay" for you, or even your cockerels, and put

them in three lots, by looking at some points of quality, like the shape of their pupils, the colour of their eyes, the " expression " of their faces, the thickness and pliability of the " laying bones ", etc.

I clearly remember the late *Walter Hogan*, one of these wizards, solemnly filling in laying scores on the cards of the utility classes in big Californian poultry shows, marking one cockerel 228 or 310 eggs. This meant that this cock, if he had been lucky enough to have been born a female, would surely have laid 228 or 310 eggs. I have seen pedigrees of White Leghorns in Petaluma, with the Hogan score all nicely marked in all the ancestors, male and female, for three generations (without any mention of the actual score of any of them!).

In this branch of magic the fashion changes, and the wizards change the relative value of the signs. One day it is the " expression of the head ", sometimes it is the colour of the gloss in Australorps; again it is the softness of the plumage; often it is the pelvic bone, or the relative length of the breast bone. Almost always it is the rate of moulting of the wing-feathers in relation to age.

What happens if we put those systems to the test, as some of us have had the malicious pleasure of doing occasionally? At the Ottawa Poultry Congress in 1927 two of us, with the consent of the owners, put the world champion laying hen and a show hen with a record of eighty-five eggs in a basket with their heads sticking out, and, with serious faces, confronted them with a famous " handler " who had just regaled us with a lecture on the enormous importance of the head as a sign of quality. He promptly lectured us on the points of those hens, telling us the show hen had all the marks of quality, while the champion was a real " dud ". But I must confess we had spent some time in picking out those two particular birds!

One day a famous British judge of utility classes came over to Holland to " grade " a large batch of White Wyandotte pullets on point of lay. I happened to arrive on that farm when the lady owner had crated all the rejects for the market, and with some difficulty I induced her to keep all those pullets and trap-nest them. The result was that of the three lots—the very superior hens, the culls and the mediocre, the second lot laid a few

more eggs than the mediocre, and the superior hens came last; but I must say that there was on the average only three or four eggs difference between the groups kept all in one semi-intensive house.

I was recently forced into a very embarrassing position at a famous old agricultural college. I heard a well-known "handler" demonstrate to a large field-day audience how the gloss of the feathers and the feel of the skin, the length of the legs and the colour of the eye ought to be in a prospective high producer, and while I was taking it all in I was tapped on the shoulder and told that I was next on the programme! So I had to stand on the platform with two loudspeakers and tell the multitude how in my opinion it was the task of this original home of the laying test—the first college in the world where hens had ever been tested for production—to study the possibility of finding correlations between actual production and handling points. Without directly saying that this was all nonsense, I tried to make it clear that counting the eggs was safer than prophesying their number, but that it would be enormously useful if it was ever shown that any visible point was a sure indication of merit.

When, in countries with an official inspection of laying hens, one visits the houses of pullets just before the inspectors arrive, one is often struck by the presence of some obvious duds, deformed, spindly, pale pullets. If we ask the breeder why he does not cull those duds, he will tell you they are for the inspector to cull out. The breeder knows that the inspector will conscientiously throw out about 10 per cent anyhow, and if the breeder does not leave in (or put in) those cripples, he risks the elimination of 10 per cent of his valuable breeding stock. A trusted consultant geneticist will pick up many tricks of the trade! To conclude this short chapter, selection according to so-called correlative qualities (as distinct from culling out crippled or diseased birds) is unsafe and outmoded. Actual value, not prophesied value, should be the basis of selection.

Chapter Thirteen

Adaptation, Environment and Management

IT is quite impossible to say that one group of poultry or ducks is better than another one without taking into consideration the circumstances in which they are kept.

A few instances will illustrate our meaning. Let us start with ducks. When we can keep ducks without feeding them, duck-eggs are produced very cheaply. When Java was still prosperous, enormous numbers of "Indian runner ducks" were hatched in the South and slowly walked to market while growing, and a few weeks later laying. The owner walked his ducks in enormous flocks along the roads, gave them a chance to forage on harvested paddy-fields and to swim in irrigated fields; he went to sleep in the middle of his flocks when *they* had a snooze, and sold the eggs they laid in the villages. Not a penny was spent on duck-food, and such eggs were very cheaply produced. Another case is that of the flying "town ducks" in Akkrum in Friesland, spotted ducks that live in competition with wild mallards. The villagers have the right, on payment of a small tax, to place straw nests high in the trees around the farms, and to collect the eggs those town ducks lay in them. Cheap duck eggs!

Again, duck-farmers around Edam keep a special breed of black ducks, with a crooked bill, that have the peculiarity of foraging in the dark of the night and coming home to lay eggs

and sleep during the daytime. The land-owners hate to see ducks damaging their grain-fields and the banks of their water-courses, and for this reason Khaki Campbell ducks or Aylesburys would not be tolerated loose. The discreet crook-bill Edam ducks fit the local conditions and give their owners a profit!

Turning to poultry, here again the cheapest poultry and the cheapest eggs are certainly produced under very extensive conditions of housing and management. In my travels I have always been intensely interested in poultry kept by aborigines and by people under great economic pressure. The poultry of the American and Canadian Indians, Javanese kampoong chickens, the poultry in African native reserves and the buff semi-bantams in Hongkong are surely all examples of poultry that are kept with a margin of profit of which our intensive poultry-farms have no idea! It would not be surprising if some of the native Chinese breeds would furnish some of the most profitable foundation stock for making good economic breeds. Even in our small West European countries climatic conditions in the South may favour other breeds of poultry than in the chilly and rainy North-West. American highly intensive methods of keeping poultry in crowds suit the smallest Leghorns, while heavier breeds do better under the conditions in exposed folds or in hen-yards. Where food is very cheap economic egg production (food units consumed per egg) is certainly not as important as in countries where most of the food must be imported.

If we turn our attention to " civilised " poultry, we see again that the problem of economic housing and feeding does not arise until chickens or ducks—great scavengers, and collectors of wasted food and insects on our farms—are kept in larger numbers, so that we must buy in all their food.

Chickens following steers on the American cornbelt farms, or kept in hen-yards in England, are in an intermediate position between scavenging fowls and poultry kept in batteries where we must supply them with everything.

The method of keeping poultry and ducks intensively, in large, dense crowds, or even in batteries, is relatively new, and attempts to fit the poultry to the system have been mostly

confined to haphazard observations as to the most suitable breeds and hybrid combinations for those systems of poultry-keeping. There are always two methods of producing a better fit: we can adapt the food to the hens, or we can adapt the hens to the food. The feeding of battery hens is a subject that falls outside the scope of this book, and here I would only like to suggest feeding experiments with cultures of unicellular algæ (*Chlorella*) and other suitable micro-organisms. The problem of hen-batteries is not solved before it is possible to keep hens in good breeding condition, and laying first-class eggs from which strong chicks can be hatched. I have proved to my own satisfaction that this problem is purely one of feeding.

The fact that some breeds of poultry are much more suited to intensive poultry-keeping methods than others shows that hereditary differences exist here. The enormous difficulties the zoological gardens experience in breeding some of the wild species of fowls and raising the chicks prove the same point. It would be quite feasible for an enterprising breeder to produce a breed of poultry specially for batteries and intensive housing, and it would even be possible to suggest suitable foundation material for such experiments.

Even within one breed some strains require much more food for the production of a dozen eggs than others. At the laying tests the Dutch Genetical Society ran at Nymegen before the Second World War, this difference sometimes amounted to five or six shillings per hen in the laying year, for an identical value of eggs produced. Some of this might be wastage, most of it seems to be just poor ability to utilise the food consumed. Battery laying tests at Stoke Mandeville by Dr. Blount confirmed these results. Economic food consumption should be regarded as an important point in selection.

Chapter Fourteen

Cross-breeding and Hybrid Vigour

A GREAT difference between the breeding of *fancy* poultry for the shows and *economic* poultry-breeding has always been that the crossing of distinct breeds is so often done by commercial breeders. Cross-bred poultry have the reputation of being vigorous and more productive than pure-bred ones. Much has been written about hybrid vigour, and many different theories have been proposed to give an explanation of the phenomenon. Let us examine the facts first.

It is certainly not true that the luxuriance and vigour of hybrids is a universal rule in living nature. Both in plants and in animals some hybrids are very feeble and weak. Some hybrids, like most goat–sheep hybrids and turkey × chicken hybrids, are not even born alive. Many species hybrids are highly sterile, both in plants and in animals, and there may be some connection between the complete sterility of some hybrids and their abundant luxuriance (*Karpechenko's* red-cabbage × radish hybrid).

In hybrids between poultry breeds we have never yet met with sterile first-generation hybrids, although sterility and very low fertility among descendants of breed crosses are quite common (Leghorn × Barnevelder).

If we examine the commercial quality of poultry first crosses, and compare this quality with that of the pure breeds crossed, we generally find the following facts: the hybrids are seldom

stronger, more vigorous and productive than the *best individuals* in the best of the two breeds crossed. The advantage—if there is an advantage—lies in the circumstance that the variability in quality in the hybrid group is very much lower than in the two original breeds. In other words, when within the two breeds crossed there is a certain proportion of second-raters, weak chicks, culls, in the hybrid group this proportion of inferior individuals is much lower.

Many of my correspondents regularly cross Australorps and Leghorns, and at the Weert experiment station, Holland, hybrids between Barnevelder and White Leghorn used to be produced in great numbers. In such cases, where eggs of the two kinds—two pure breeds and the eggs giving hybrids—are hatched side by side in the same incubator, it was always remarked that the hybrid chicks hatch early and all together, while the pure-bred chicks are hatching over a longer number of hours, while many more die in the shell.

Chick mortality is generally lower in hybrid lots than in ordinary pure-bred strains, and during both growth and production many more pures than hybrids must be culled out of the flock.

And this is how we must explain hybrid vigour: it is mostly relative. When we compare two variable groups in which many inferior chicks are born, with the hybrids, we find that the proportion of bad ones is lower in the cross-bred generation. By combining the germ-cells of breed *A* with those of breed *B*, we hide the fact that many of those germ-cells in both breeds are genetically inferior. If we state this in terms of genetic formulæ, breed *A* may be pure for gene *X* (*XX*), while in respect to gene *Y* it may be variable, so that in this breed we find many heterozygotes, *XXYy*, and even some that are lacking *Y* (*XXyy*). Conversely, all birds in breed *B* are pure for *Y* (*YY*), but some are lacking gene *X* (*XxYY* or *xxYY*).

X and *Y* we suppose to be genes which are necessary (with hundreds of other genes) for a good hereditary make-up. Now, if we cross the two breeds, *A* and *B*, all the hybrids will have both *X* and *Y* at least once, and there will be no chicks lacking either *X* or *Y* amongst them.

To say it in other words, the purity of one breed for some

genes covers up the fact that within the same breed there exist inherited weak points, impurities in respect to valuable genes. And vice versa, of course.

If this explanation of hybrid vigour and of the great apparent uniformity and lack of culls in hybrid lots is the correct one, it would follow from this that it will be possible, by careful work, to bring up the quality of one pure breed to that of the best hybrids. We should be able to do this by starting with first-class foundation stock and by methods that will allow us to get the group homozygous in respect of all the necessary genes (see chapter on Nucleus Method).

It is very remarkable that practically all our well-known commercial breeds of poultry, even the very best ones, started life as show breeds. And if we trace back the history of those show breeds, we find that the great majority of them were originally "just chickens" that somebody remarked in a peasant village, liked the looks of and imported (Leghorns, Rhode Island Reds), or the result of more or less haphazard backyard breeding "to see what would happen" (Wyandottes), or deliberately bred in different colours for the shows (Orpingtons by *Cook*). Even our best laying duck, the Khaki Campbell, was just a breeder's fancy, selected entirely for colour by *Mrs. Campbell* during the Boer War.

Attempts to construct new, more useful breeds, such as we see in plant-breeding, are very rare; but we have no doubt that now we know better methods of selecting for purity this would be quite feasible.

There is one aspect of cross-breeding that should be treated here—namely, the advantage accruing to the breeder of selling hybrid chicks to his customers. Up till recently a trap-nester breeder, selecting his birds by the old method of choosing the best individuals, could sell his choice birds to others without much fear of creating competitors, his strains were so very impure anyhow. The usual system of buying in somebody else's males to make up breeding-pens (cross-breeding between families) makes most breeders sell material from which their customers could breed up first-class *pure* strains only with great trouble. The nucleus-breeder who specialises in purity, nevertheless had better sell cross-bred chicks; it would be like

selling the goose that lays the golden eggs to give his customer-breeders highly homozygous stock.

As the superiority of first-generation hybrids over so-called pure breeds results from the circumstance that the variability and deficiencies of one breed are hidden by the fact that the second breed happens to be pure for those points, it follows that the closer two breeds are related, the bigger the chance that hybrids between them will not be particularly good. Many new hybrid combinations are continually tried by breeders and hatcheries. For battery pullets, Leghorn × heavy breeds seem to be much in favour just now.

Recently much has been written on a comparison between poultry-breeding and the breeding of maize. In maize, where the natural increase is enormously great, and cross-breeding much easier than enforced self-fertilisation, the commercial methods of seed production mostly consisted of keeping two pure strains separate and of crossing them to get seed for a commercial crop. The seed merchants, for reasons of personal profit, are propagating a double cross—the crossing of a hybrid with a hybrid. Harvests from double crosses are generally not as good as from single crosses, but as seed production is much cheaper, profits for the seed-merchants are greater. Where good uniformity is important, as in sweet corn for canning, the firms are still selling first cross seed.

Some American firms have started something similar in poultry. The method of issuing hybrids between inbred strains to different egg suppliers, and buying back their hatching eggs, is eminently suited to enterprising individuals who hate risking the possibility that somebody else may profit from their efforts. Blind inbreeding is the first step, and the next is to try out combinations of those inbred strains to find suitable hybrid combinations to lay the eggs that will have to be fertilised by males of still another hybrid. Just as in maize, both theoretically and practically, a single or a triple cross should always be superior to such a double cross, the advantage lies entirely in the possibility for the originator of such methods to build up a big business monopoly.

In the production of first-class first-generation hybrids for direct use, be they table-birds (Game × Sussex) or laying

hens (Leghorn × Rhode Island Red), the quality of the hybrids depends on the "nicking" of the two breeds. It is important that the males shall be homozygous for all the important genes in regard to which some of the hens are impure (and vice versa). But as we need only comparatively few males, it is of greater importance, and certainly more promising, to select a strain of males especially for this particular purpose (*Jaap*).

This should be done as follows: in a family of Rhode Island Reds selected for quality, a number of males should not only be mated to hens of their own family, but equally well to Light Sussex hens. This will give us data about the greater or lesser suitability of those males for this particular purpose. The most successful males should then be bred to their own pure-bred Rhode Island Red close relatives, and such test matings should again be made with their sons, and so on. This is the same system of selection I taught to the Australian breeders of Southdown rams, destined for the production of fat lambs from cross-bred ewes.

Two instances of successful cross-breeding schemes may be used as illustrations of what can be done in this field.

One of my correspondents in Holland, *de Vries*, mated Leghorn males to North Holland Blue hens. The cockerels were sent out as petits poussins, the pullets were housed in dozen lots in large battery cages on wire. They were kept for high-priced winter eggs, and during February they were all killed off in full production when the Jewish festivals produced an urgent demand for young, tender, fat hens. This was in the 'twenties.

Another man in the South built up a trade in petits poussins that he used to bring into the Brussels market every week. He bred those chicks in summer and autumn from his Barnevelder and Rhode Island Red breeding-pens, headed for the season by North Holland Blue males, specially selected for the purpose. The chicks were all barred and enormously growthy. When January came around, the males in the breeding-pens had all been changed to Barnevelder and Rhode Island Red males again for the sale of chicks from his hatchery. This firm was the first to make a success of "nucleus" selection in poultry (Rhode Island Red and White Leghorn) (*Weekers*).

Chapter Fifteen

Genetic Analysis as an Aid to Breeding

THERE is no question about the fact that the most diverse qualities in poultry at every stage in development are influenced by the composition of the nucleus, by the set of genes present. Differences in disease resistance, in hatchability, in chick and pullet mortality, differences in the amount of food required for producing a dozen eggs, differences in broodiness, in egg-size, in the rhythm in which eggs are produced are to a great extent modified by the inherited constitution. In some of these cases, geneticists, working with poultry, have shown the existence of genes that differentiated some birds from others. Especially from a purely scientific standpoint, this work is of very great interest. However, I feel somewhat doubtful about the direct *practical* value of these sort of studies.

At first sight it seems obvious that an exact knowledge of the genes that differentiate between broody and non-broody birds, or between those laying brown and those laying white eggs, should be of enormous practical value. But if we look very carefully into this matter, we shall see that it is extremely doubtful just how much either broodiness or small eggs reduce the value of the group for economic egg production. In another chapter I have argued against selecting poultry for so-called correlative qualities, showing that it is safer to judge quality by the direct economic advantage of *good* birds, rather than birds that appear or that *promise* to be good. And approximately the same argument may be used here.

The practical use of this factorial analysis should be in helping us to obtain more profitable groups—groups that repay our trouble and expenditure with very good egg production. Causes of loss, like poor hatchability and high mortality, are of as much importance as good egg-size and the right number of eggs.

It is evident that such apparently simple qualities as broodiness, or low hatchability, or small eggs, are subject to the influence of so many genes, as well as to environmental influences, that an exact analysis of all those genes is very difficult. Would it greatly help if we knew all those genes separately? On the face of it, we might believe that when we knew all those genes separately we could recombine them at will and construct ideally good new groups or novel breeds. But when we really try to calculate what this would amount to, the numbers of birds to be analysed, the hundreds of trial matings required to test our birds for purity, this becomes staggering.

Again, it may well be asked whether we are sure that the qualities studied are really *all* the important ones that go to make up our final result.

In plant-breeding, where breeders and geneticists have a colossal amount of practical experience, attempts to build up novel, useful strains by a deliberate recombination of a few dozen analysed genes have largely been abandoned, and we are quite sure that in animal-breeding we should follow the plant-breeders' example.

If we want profit, we must select for profit. If we want winter eggs, we must select strains that produce them, and the final test of value is the real economic value of our strains under the conditions we can give them. In so far as broodiness or high pullet mortality will reduce our hen-housed profits these must be looked after during selection. But the only safe way to do so is to stop analysing, to work by rule of thumb, and so to arrange our system of selection that we can recognise the family groups that will give us a profit that exceeds that which we obtain from similar and parallel groups to which we offer the same chances. As will appear in other chapters, this necessitates the progeny testing of males combined with some inbreeding and the selection of family groups.

After all, the exact way in which the genotype influences the final qualities is so enormously complex that our analysis can hardly be expected to be complete, even when we are confining ourselves to one breed.

It is pleasant to find broodiness absent in some strains of Leghorns and Barnevelders. And it is obvious that in choosing between reciprocal crosses we must avoid the one which gives us hybrids with a great tendency to get broody. A genetical analysis of broodiness shows at least four genes, of which one is sex linked, that affect this quality. They certainly do not affect broodiness in a simple direct way, as in the case of feather colour. They just help, in combination with genes affecting egg production, to make hens of a certain age and birth-date, managed in a certain way, to have a greater or lesser tendency to get broody.

This shows how enormously difficult it is to attribute a certain value to separate faults and virtues in selecting our birds. It is obviously not of great importance just to eliminate any individual hen who ever went broody.

The same is true of winter pause in egg-laying. It is obvious that in a group of hens born on the same date, raised together and fed and housed alike, some will continue laying during the winter, and a few will stop. But we also know that the conditions in the widest sense, especially the exact age at the beginning of production, the number of hours of light, the diet, are of the highest importance. The Javanese runner duck, adapted to short days, will lay continuously when it once starts, if it is kept in the tropics. In higher latitudes it will do so only if it is born in the right month to get it sexually mature in early autumn; later-hatched ducklings will simply wait till spring. The Khaki Campbell happened to differ; ducklings will start production at five months, no matter when hatched, and this difference resulted in the disappearance of the Indian runners and the hybrids with Campbells that once were popular commercial egg producers in our latitude.

All such cases are much too complex to make a complete gene analysis possible. I do not doubt that an analysis of those differences in terms of genes would be highly interesting

from the point of view of theoretical genetics. But the point I want to make is that it is very much more important that the methods of selection employed shall be so efficient that a very good end result is reached, than that the geneticist who teaches such methods to the practical breeder shall know just what genes are involved and how many.

Chapter Sixteen

Lethal and Semi-lethal Qualities

THE first case of what *Cuénot* called a lethal gene was discovered by him in mice. Immediately after this a very similar instance was seen in the Japanese wheat, Shirno, by de Vilmorin, and later a great many similar cases were found in poultry, in foxes, in mankind—in short, in the most diverse living creatures.

The facts are always the same; when plants or animals heterozygous in respect to a certain gene are mated together, we would expect them to give 50 per cent of heterozygotes *Aa* and 25 per cent *AA* homozygotes, as well as 25 per cent *aa* ones. But occasionally only one kind of homozygotes is viable; the other kind die off, either as embryos or sooner or later after birth.

There are two alternative hypotheses to account for this. *Cuénot* assumed that in his mice the gene that in heterozygous *Aa* mice made them yellow, killed off the embryos when it was present in double dose *AA*. This explanation fits the facts, but it is hard to understand how a gene in itself could have a lethal effect, and we think that the alternative hypothesis is preferable. I suppose that in all such cases we are really witnessing the presence of some gene that is an important link in the chain of substances necessary for normal growth and development. As the heterozygotes, who carry only one dose of the gene, produce 50 per cent of germ-cells that lack it, they must, when mated together, give 25 per cent of germs that are deficient in respect to this substance.

In the classical case of the yellow mice new evidence shows that we are actually dealing with the absence, not of just one gene, but of a small section of a chromosome (a so-called *deletion*) and in Drosophila, where we can actually see the chromosomes, several cases of such lethal deletions have been noticed. In such cases the heterozygotes *Aa* are viable because they carry the gene (although in single dose), but the homozygotes, born from two germ-cells lacking in the gene (*aa*), are abnormal.

We might distinguish between two kinds of lethals, *dominant* and *recessive lethals*, of which the latter group is more frequent. Here the heterozygotes are normal and indistinguishable from the pure birds. If, however, the heterozygotes can be distinguished from the normal homozygotes, we can know them as such, and here the abnormals mated together produce a minority of normals.

" Dominant " lethals are rare in poultry. The case of the creeper fowl is a good example. (Fig. 5, p. 33.) In ducks, mating two crested birds will give us half as many crested chicks as fertile eggs, one fourth of the eggs will hatch plainheads, and the remaining embryos will generally die in the shell, with open skulls and quite abnormal bills. It is interesting to compare ducks with chickens in top-knotted breeds. In such breeds as Polish the chicks will all hatch with large cerebral hernia, and a feather crest soon grows on this protuberance. If we breed Polish to ordinary poultry, the hybrids will have plain skulls, but feathered top-knots. If now we breed such hybrids together, they will give 25 per cent plainheads, 50 per cent with feathered knots, but of the remaining 25 per cent only some will hatch with top-knots like the Polish. Many will die in the shell with open skulls, as in ducks. In other words, in long-established top-knot breeds selection of birds with large top-knot, that survived notwithstanding their aberration, has in the end been effective. We cannot say that this one gene or the absence of this one gene is lethal *per se*; it is the combination of the deficiency and the rest of the genetic constitution which kills the chicks.

The American geneticists have analysed at least six different genes that are sometimes absent in poultry germ-cells; cases of lethals.

In practical poultry-breeding every breeder is meeting all sorts of abnormalities that are partly due to a faulty set of genes. Sometimes the development of the embryo stops at an early stage, often the chick is unable to break the shell (frequently as a result of malposition). Some chicks cannot stand, or some anatomical abnormality may keep them from eating, some chicks are just silly, and patiently wait for starvation. It is very hard to distinguish between lethal and sub-lethal aberrations; they come to the same thing as far as the owner is concerned—loss of the chick.

Faults in incubation may account for poor hatchability, and the diet of the hen makes a great difference; but when the diet is sufficient, and incubation is not at fault, hatchability depends to a great extent on inherited faults. This is clearly shown by the circumstance that while inbreeding in impure stocks generally gives rise to many deaths of embryos and chicks, long-inbred strains show a very low embryo mortality. And in strains subjected to a combination of inbreeding and progeny testing, embryo deaths, chick mortality and pullet mortality are very soon going down.

Chapter Seventeen

Building Up a New Breed

As I have said elsewhere, the simplest way to make a new pure breed of poultry is to start from an existing one and to bring in one or two genes by a cross followed by back-crosses to the breed into which we want to introduce the dominant quality. In this case we can follow this quality and keep hold of it during succeeding generations.

Very often we can so choose our breeds that this is the method we can use. Let us suppose that somebody would want to breed a Leghorn that lays dark coffee-brown eggs. When he found a breed with such eggs—let us say a Barnevelder—he would find that the hybrids from Leghorn fathers lay tinted eggs, but are earlier maturing and less broody than the Barnevelder. For this reason it would be really preferable to give up the idea of making that brown-egged Leghorn, and to make an improved Barnevelder by mating back to this breed while choosing non-broody hens.

Now, of course there is nothing fundamentally impossible in this project of really making a brown-egged Leghorn. If we breed the hybrids together, some rare hens will actually lay dark brown eggs (*Punnett, Pease*). But they are not likely to be like Leghorns in other qualities. We can now use such hens and mate them again to Leghorn. We can go on with this process, alternating a back-cross to Leghorn with a generation in which we breed the hybrids together, producing enough chicks to find at least one hen that will give us dark-brown

eggs. In the end we will actually produce some hen that will look like a Leghorn, but that will lay dark-brown eggs, after which we will then have to build a new breed from that one hen. This will probably be possible if she lives long enough to be mated to a son, a grandson and so on. Several poultry-breeders have tackled this problem, but I do not know of anyone who has made a success of it. It certainly is a hopelessly difficult task.

In the chapter on Transgressive Variability I touch upon the possibility of making either a super-giant or a very minute dwarf in poultry. In general, we must warn against wanting to aim at too many things at once. If we just want a miniature, we had better leave colour and shape entirely to chance and go all out for size. And the same is true if we want production. When we are satisfied with the vigour and productiveness of first-generation hybrids, it will certainly be possible to introduce some of this extra quality into one of the original breeds. However, we might also produce a wholly novel breed from those hybrids, by breeding them together.

This, however, is enormously difficult, as I have explained elsewhere, and almost always there will be relatively very few good birds among the offspring of hybrids. It is certainly much easier to improve an existing breed, even if we have to use a cross, than to make a new one starting from hybrids. The great difficulty in poultry-breeding is to reduce variability while improving quality. Back-crosses to a relatively pure family help a lot in this.

A breeder or an institute who want to make a new useful breed of poultry starting from hybrids must remember:

Firstly: To breed as many birds as possible during the first few generations, thousands rather than hundreds.

Secondly: To use trap-nests during the first two or three generations, as this will help to rid the stock of harmful dominants.

Thirdly: To select only for really economically useful qualities, leaving all unessential points, such as colour and shape, to chance.

Fourthly: To bring down the potential variability while

retaining very good quality by a combination of inbreeding with the progeny testing of males, after two or three generations.

Fifthly: To make up a high standard of utility for the breed and rigidly adhere to this while selecting.

Making a new *fancy* breed is much less difficult than making a good utility breed, for several reasons. For one thing, no utility breed, be it destined for egg-production or for dual purpose, is of any value unless it can compete with a number of existing and very good other breeds. In show-birds every new breed is in a class apart, except when we are dealing with a new colour variety in a popular breed.

When we look over the list of breeds that are bred for any useful purpose, we find that most of them belong to two groups: first, breeds that were discovered as village fowls in some more or less isolated locality, and which had " just happened " there, like the Barnevelder, the Rhode Island Red and the Campine; and secondly, show-breeds that just happened to be good egg-producers or table-birds, like the Wyandotte, the Leghorn and the Cornish Game.

Mostly the sequence of events in the making of an excellent utility breed runs as follows: somewhere it is found that farmers happen to have poultry that take the fancy of some amateur, who starts to breed the variety for the shows. A standard of beauty points is made, and selection (and inbreeding) reduces the variability. Other show-breeds, like the Wyandottes and the Orpingtons (*Cook*), are produced by fanciers, entirely as show-breeds. Most of those novel breeds remain in the " fancy " class, but once in a while it just occurs that in popular show-breeds somebody hits upon a small group that happens to be of great value as an egg-producer. In other cases a cross has improved some strain that was entirely ornamental, such as the Langshan cross that gave the Australians their Australorps, or the Maran cross that regenerated the Barnevelder, and possibly the Minorca cross in the White Leghorn.

Many poultry-farmers and Institutes have set themselves the task of producing an ideally good new utility fowl, but the fact

that few of those novel breeds seem to " catch on " shows how difficult this really is.

Of course we must remember that the dice are loaded against the would-be originators of novel utility breeds who try to stabilise the qualities of a few dozen excellent hybrids by means of individual selection.

Our show-breeders, who do not need to bother about poor fertility, or even to worry about very high culling percentages, are in a much better position.

Chapter Eighteen

Introducing One Gene into a Breed

ONE of the striking experiences of a consultant geneticist, co-operating with plant- and animal-breeders, is to find the same problems recurring in the most diverse material, and frequently a similar solution of such a problem proves to be very successful.

One such instance is that in which an important change can be made in an existing plant or animal by the addition of just one single gene. This method is used in the amelioration of inbred maizes, in improving tomatoes, in dehorning beef-cattle and wool-sheep. In poultry the method has already proved its usefulness in many instances, both in fancy and in utility breeds.

Genes are present on chromosomes, and if we speak of introducing one gene into a breed, it might be more correct to speak of substituting a chromosome carrying a certain gene for the corresponding one from which it was absent. The point is not very important, because of the frequency of crossing over in poultry, so we can let it stand as it is.

When we are crossing an existing strain with another in which some gene exists that has a very marked influence, we can follow this gene through the course of a series of generations.

One good example of this gene substitution is that of making an auto-sexing breed out of any breed with brown down colour (see the pedigree of the autosexing Barnevelders).

Another good example is that in which a dominant white

variety is made on the basis of an excellent all-black breed. The White Australorp was made in this way.

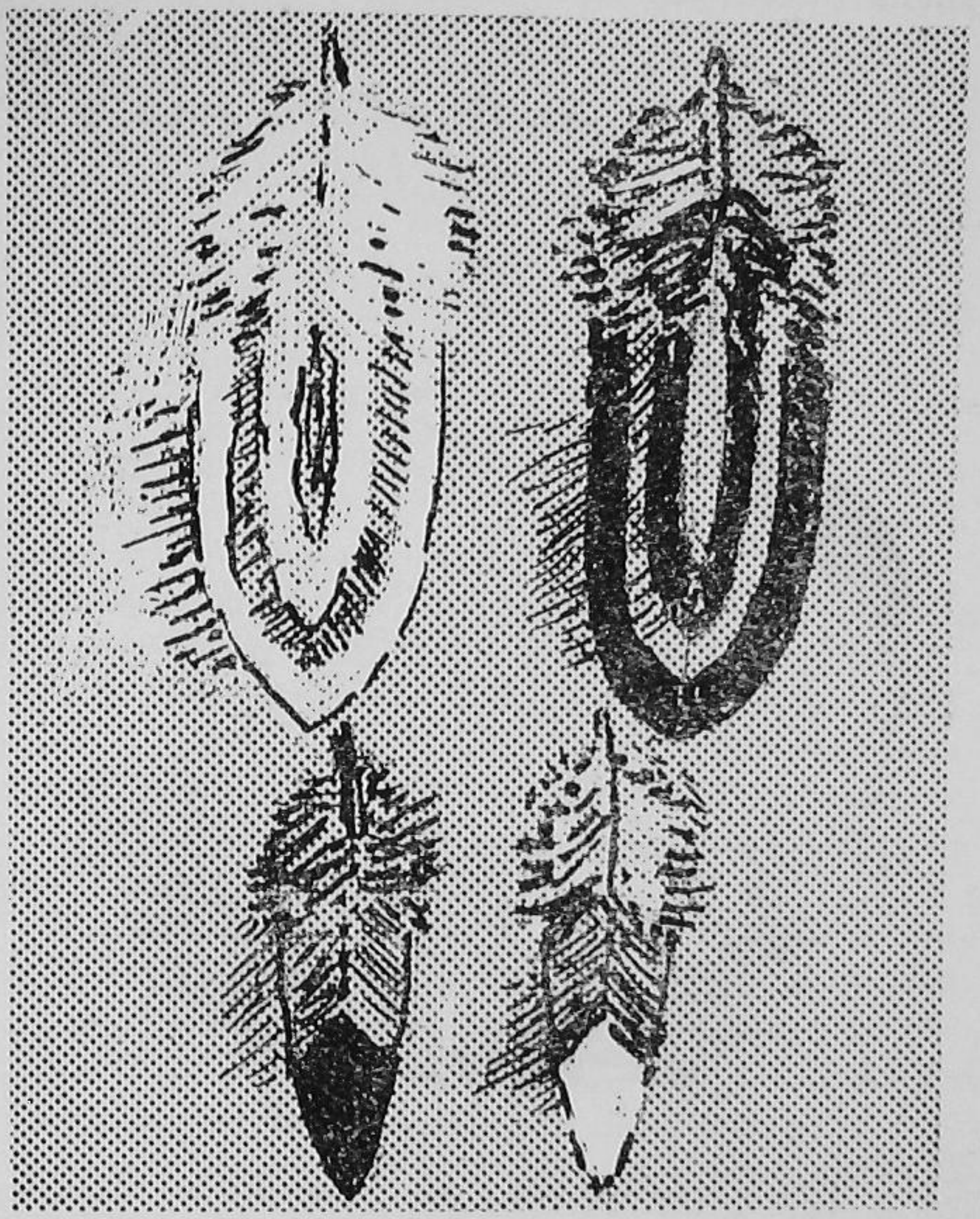


FIG. 10.—The gene which distinguishes White Leghorn from Black or Barred Leghorn does not affect red or brown but suppresses black pigment in some way. By repeated back-crossing to show birds, it is possible to make a red-and-white marked breed out of any black-and-red marked one. The drawing shows the difference between a feather of White-spangled Hamburg next to the original Black-spangled, and also the difference between ordinary Barnevelder (or Cornish Game) and "Jubilee". In the same way Black-red can be made into Pile, etc.

I once made the Jubilee Barnevelder in this way, adding a gene from the White Leghorn, holding on to this gene while numerous back-crosses were made to well-marked Brown

Barnevelders, and purifying the colour by test matings. Very beautiful Blue-laced Barnevelders were made in the same way, and similar breeds can easily be made from every breed that



FIG. 11.—From a cross between a bare-necked Rhode Island Red hen with a Silky, dark Black-red bare-necked hens were born with some pigment in the skin and a band of feathers around the neck. Those hens, mated back to our (non-booted) Silkies gave us 50% white and 50% coloured chicks. In both groups some were feathered, and some silky, and in all four groups birds with bare necks and feathered necks were seen. Two birds were born in this group that were fair show Silkies, with five to seven toes, dark blue skin and a bare neck. Another back-cross to show Silky would have produced booted show birds without any doubt.

shows black markings on dark-red background (Golden-laced Wyandotte, e.g.).

I have taught several fanciers to make blue varieties of the same quality as their black counterparts in many breeds—in

Orpington, Rose-comb bantams, Cochin bantams, Wyandotte bantams, Blue Minorcas. Here the process is very simple indeed; for, as *this* blue will not breed true, there is no reason for trying to produce homozygotes.

In the chapter on Table-birds we have spoken of the possibility of producing white-skinned strains of breeds that are now yellow-skinned. Some colour-modifying genes have a striking effect in coloured and marked breeds. The Chamois and Jubilee and Pile variants are all strains in which one and the same gene is added to otherwise black-marked breeds. In many cases birds of such colours are regularly bred together with the parent variety: Pile Leghorns with Brown ones, Jubilee Indian Game with Brown-laced, Chamois Hamburgs with Gold-pencilled, etc., etc.

In this field poultry-fanciers can still obtain very gratifying results in producing wholly novel breeds and colour-varieties. To name a few, Blue-laced Silver or Golden Sebrights, White-spangled Red Hamburgs, Rose-combed variants of single-combed breeds, Blue Anconas, etc., etc.

In commercial poultry the utility of the method is not quite so apparent, but it exists nevertheless. I once happened to transmit a dominant non-broodiness from the White Leghorn to Barnevelder, while I was producing my autosexing Barnevelder. The gene in question happened to be linked to the " barring " gene, and this was a pure stroke of luck.

After a breed, by means of inbreeding combined with progeny testing, has been brought to high quality and purity, it may happen that a cross with another breed gives us hybrids that are still better. In that case it would probably be possible by means of repeated back-crosses to improve the pure breed by adding something from those hybrids.

Chapter Nineteen

Recombination of Genes

MENDEL, in his experiments with peas, first discovered that the characters he studied in his material that depended on differences in one gene were independently transmitted over the germ-cells. Later it was discovered that this mutual independence of the genes was due to the fact that when the chromosomes are singly distributed over the germ-cells at the time of the reduction division, each germ-cell obtains a complete set, but chance determines which chromosome of a pair will go to a certain pole. When the two chromosomes of one pair are wholly identical this cannot be noticed, but when they differ in some gene that gives a visible difference it is evident. If we mate a Black Rose-comb bantam with a White Single-comb bantam, the resulting chicks will be black and rose-combed.

In one pair of chromosomes at one spot there will be a difference, and if we call the gene *A*, one chromosome of that pair will carry *A* and the other will not (we denote this by *a*). In some other pair of chromosomes there will be in one a gene *B* and on the corresponding locus in its partner there will be no *B* (we call this *b*).

The hybrids for this reason carry only one dose of genes *A* and *B*. We use the term "Heterozygous" (or impure) for *A* and *B*, and we can write this into a formula, *Aa*, *Bb*. Such hybrids will give 50 per cent germ-cells *A* and as many *a*, and in both kinds again there will be half *B* and half *b*.

If, therefore, we breed such a hybrid back to white single-comb, the hybrid will give 25 per cent *AB*, 25 per cent *Ab*, 25 per cent *aB* and 25 per cent *ab* germ cells, and as the white single-comb partner has only *ab* germ-cells, there will be four kinds of chicks in equal proportions: black double-comb, black single, white single and white double. Thus we get not only the old combinations, but also both novel combinations of qualities in which the breeds crossed differed. If we bred the hybrids together, we would get a proportion of three blacks to one white, and at the same time a proportion of three double-combs to one single. This means nine *AB*, three *Ab*, three *aB* and one *ab*.

Germ-cells

	AB	***Ab***	***aB***	***ab***
AB	*AABB*	*AABb*	*AaBB*	*AaBb*
Ab	*AABb*	*AAbb*	*AaBb*	*Aabb*
aB	*AaBB*	*AaBb*	*aaBB*	*aaBb*
ab	*AaBb*	*Aabb*	*aaBb*	*aabb*

It will be seen that when the parents of a hybrid differ not in two, but in many genes, the variability—the different recombinations of all those genes—is enormous. It is 2^n, where n is the number of genes. And if we remember that the influence of the presence of a gene must depend on the set of other genes present, it will be seen that the most unexpected novelties (many of them very inferior!) can often be found in the offspring of hybrids.

Chapter Twenty

Genetic Coupling

IN the chapter on Recombination of genes I spoke about the chance combination of chromosomes as the cause of the independence of a great many genes, each carried

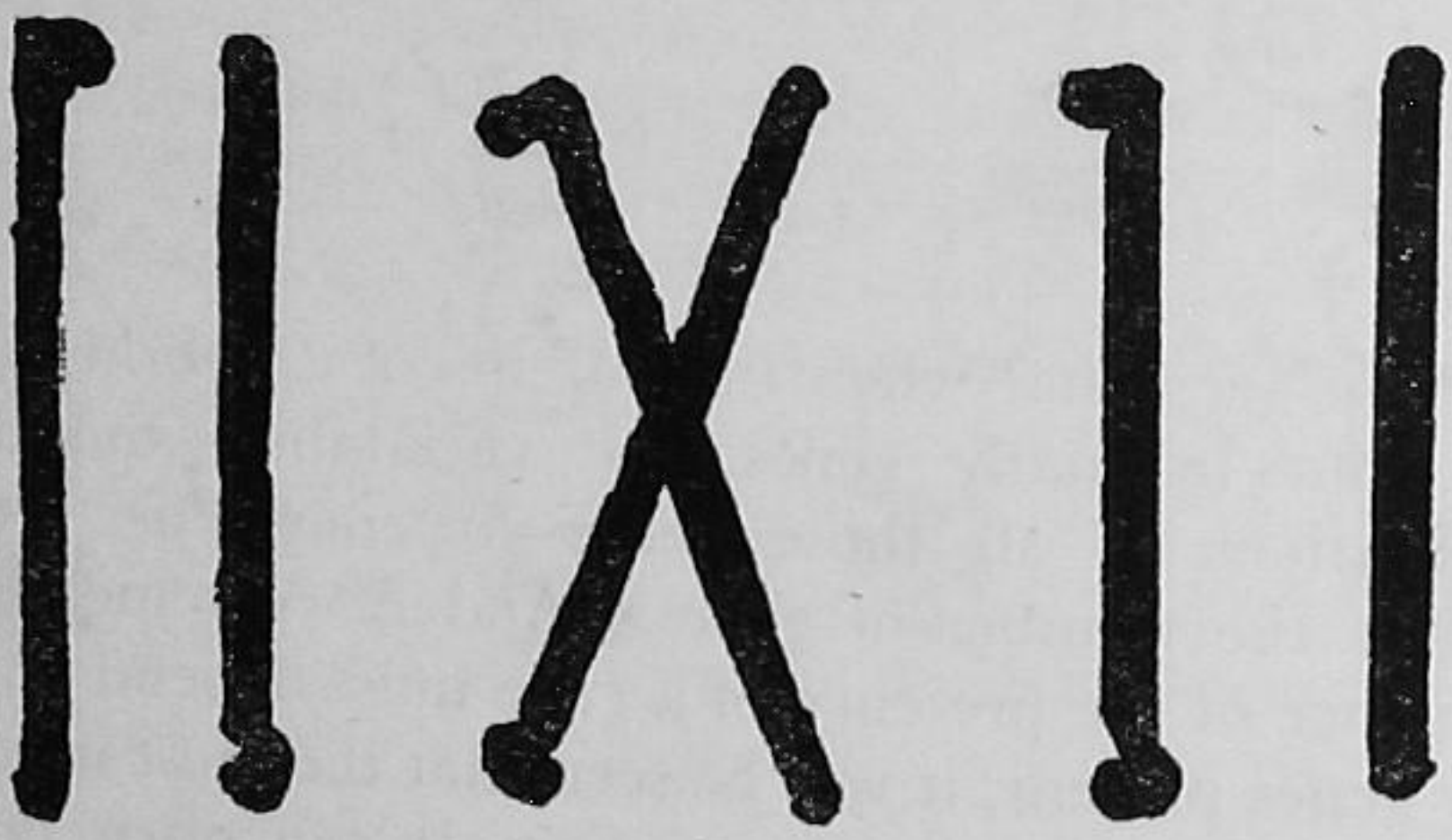


FIG. 12.—*Curt Stern* in his paper on Zytologisch-genetische Untersuchungen als Beweise fuer die Morgansche Theorie des Faktorenaustausches (1931 in "Biologisches Zentralblatt") brought the first proof for the reality of crossing-over by an ingenious experiment in which he combined two strains of Drosophila flies, in each of which the same chromosome was characterised by a slight aberration. By crossing those strains he obtained novel combinations of those characteristics in those chromosomes in subsequent generations. (Very simplified.)

on a separate chromosome. But there are many cases in which we know two or more genes that are present on one and the same chromosome. Such genes tend to be inherited together. It is quite possible that what appears to be one

single gene, in reality consists of two very different genes that just happen to be very close together.

Early in the history of Genetics, *Bateson* discovered this coupling, while *Morgan* gave a plausible explanation of it. It appears that sometimes genetic peculiarities that are due to two different genes and their different alternatives on the same

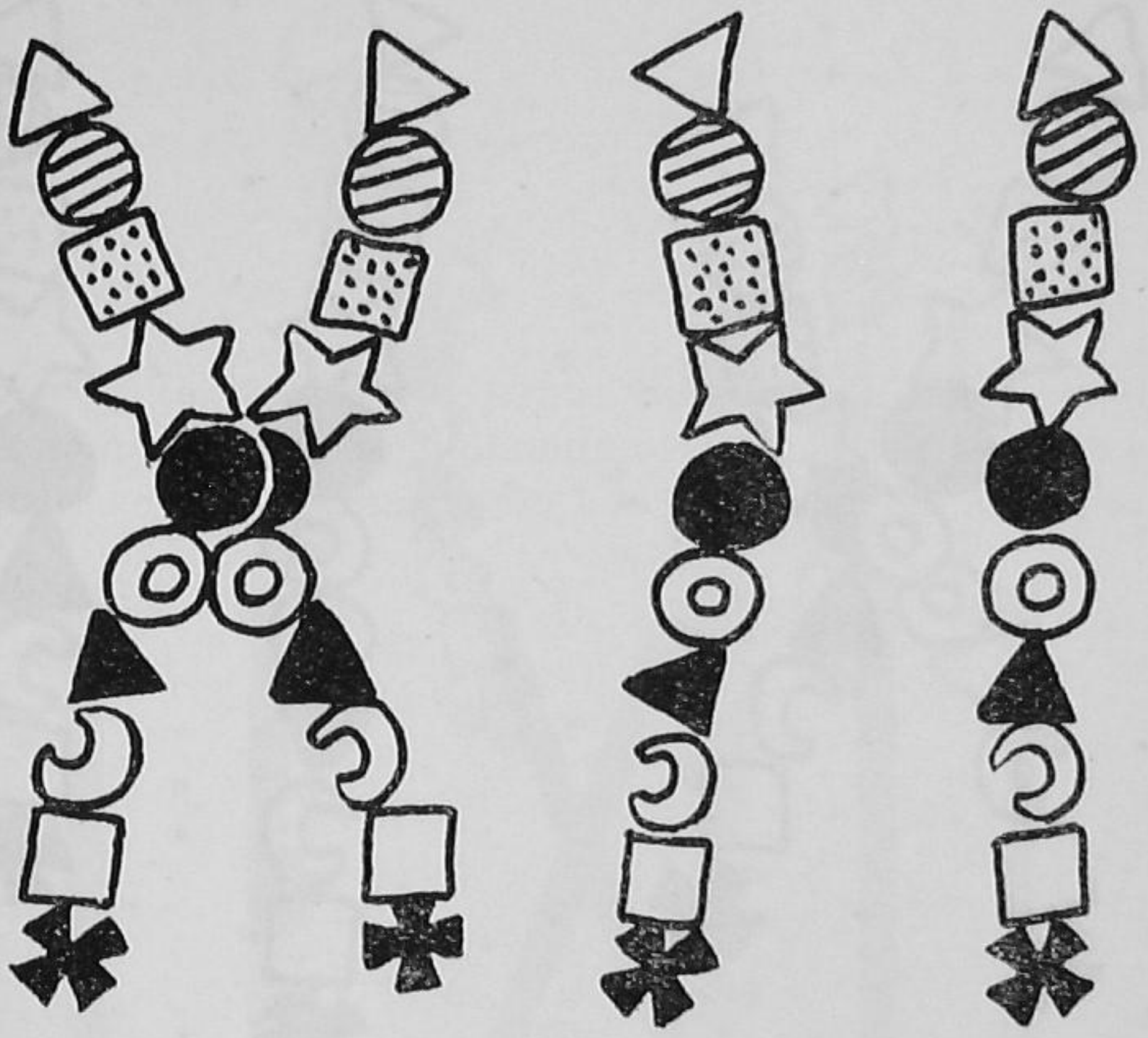


FIG. 13.—Regular crossing-over between two homologous chromosomes. The two new chromosomes each consisting of part of the two original ones are identical, the break occurring on each at exactly the same spot.

chromosome break apart. In that case the number of chromosomes, and even their identity, is preserved, with the exception that there has been an interchange of material. This phenomenon has mostly been studied in Drosophila, a small fly in which certain cells have giant chromosomes. The most common thing that happens is what we now call *crossing-over*. In this case the "top" half of one chromosome of a pair combines with the "bottom" half of its mate, and vice versa. This phenomenon can best be pictured in such a way that we

are witnessing a partial twisting between the two chromosomes before they are drawn apart, the break generally occurring at the same spot, in a pair of identical chromosomes.

In poultry several cases have been found in which different genes are in one "linkage group", which here means in the same chromosome. The geneticists can even discover the mutual

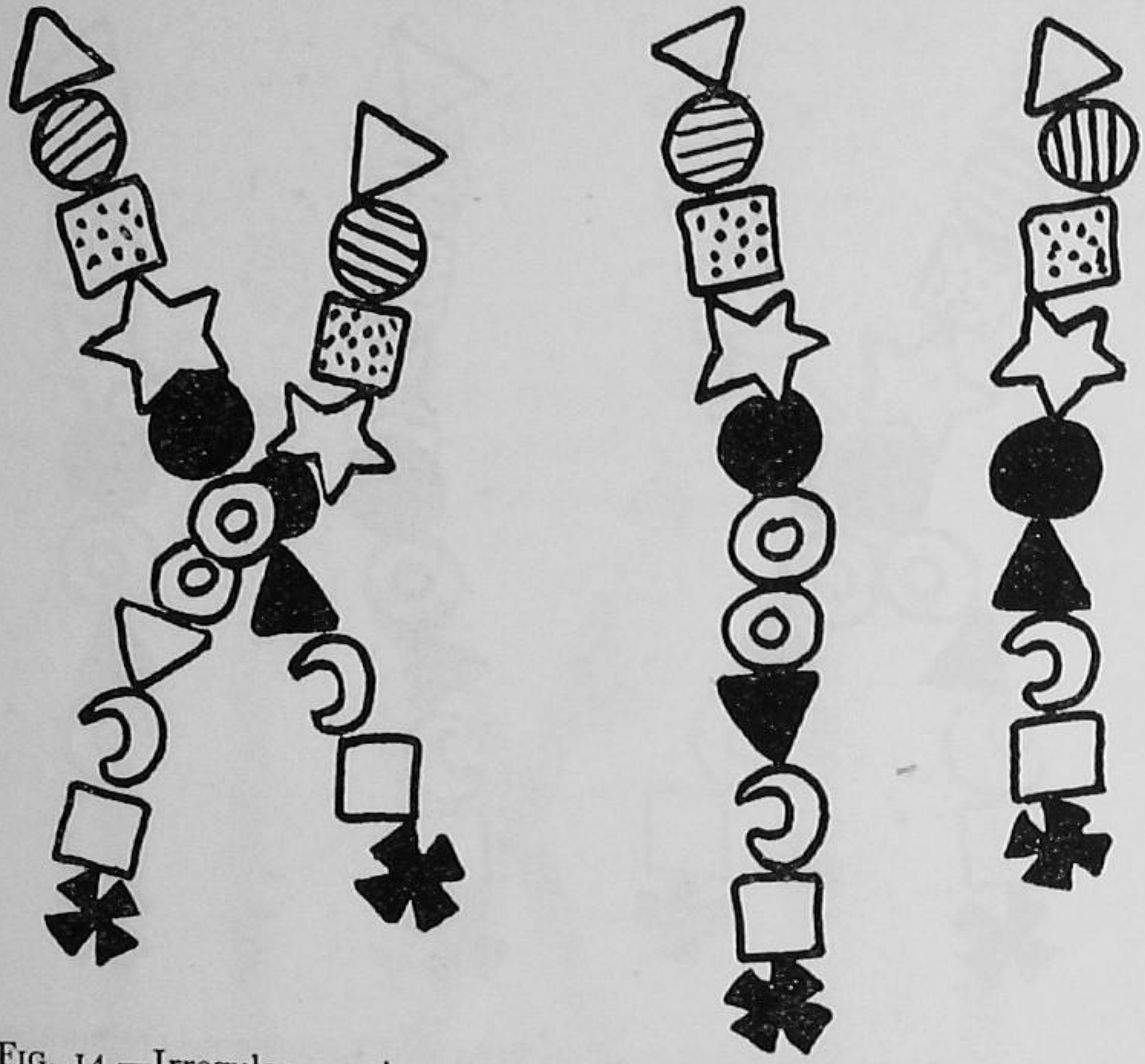


FIG. 14.—Irregular crossing-over. When the break does not happen to occur at exactly the same "locus" in the two original chromosomes, one of the new chromosomes may have one gene in duplicate and the other one may be lacking it. Mutations may arise in this way from small irregularities during crossing-over.

position of different genes on one chromosome. All this would lead us too far here. It is enough to remember that the possible recombinations of the different genes in poultry are not exhausted with the recombinations of the chromosomes.

It will be seen that this crossing-over between parts of the chromosomes in one pair will not produce anything new when those two chromosomes are wholly identical. But this is true

only when on both chromosomes the break really occurs exactly at the same spot. In the chapter on *Mutation* we discuss the possibility that occasionally there is a very slight irregularity, the effect of which must be that the new chromosomes are not quite identical. *Serebrowsky* is the author of the ingenious hypothesis that such very small irregularities must

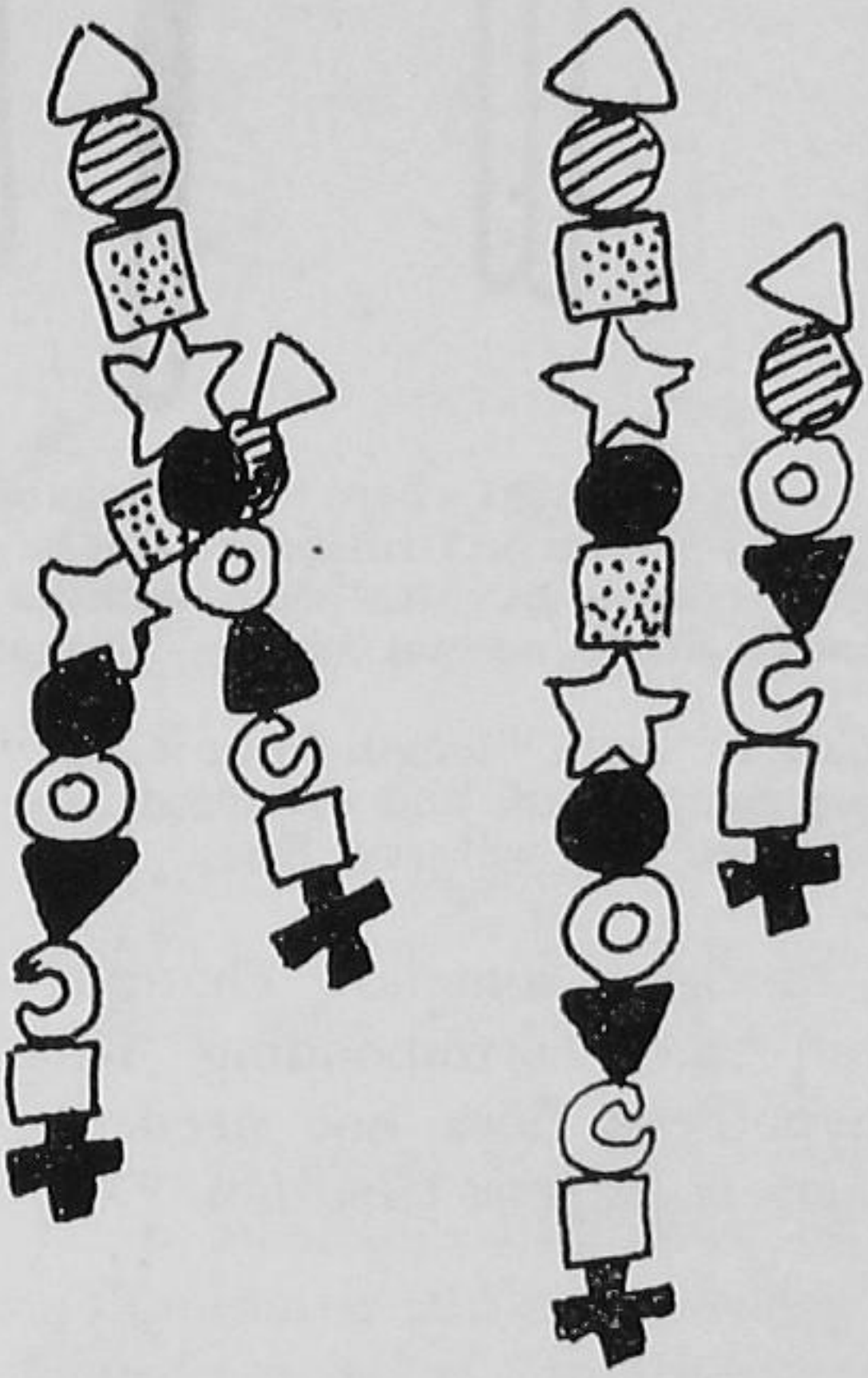


FIG. 15.—Larger irregularities in crossing-over may result in duplications. These can actually be witnessed in the giant chromosomes in the salivary glands of some flies (Morgan, Bridges and Sturtevant).

Even if the added section is long, the ordinary and the longer chromosome can still conjugate, as in that case a *loop* is formed (Darlington *et al.*). (See also Fig. 16.)

necessarily give rise to very great changes—namely, to cells that differ from their mother-cells in that they have either something too much or something too little. It appears to us that this hypothesis to account for factor-mutations is infinitely to be preferred to the older one that occasionally one gene changes into a (chemically) different one. So long as we thought of genes as of " living " corpuscles, we could believe them to

be variable. When we thought in terms of " pairs of genes "—a gene for normal feathers and one for silky ones—it could be

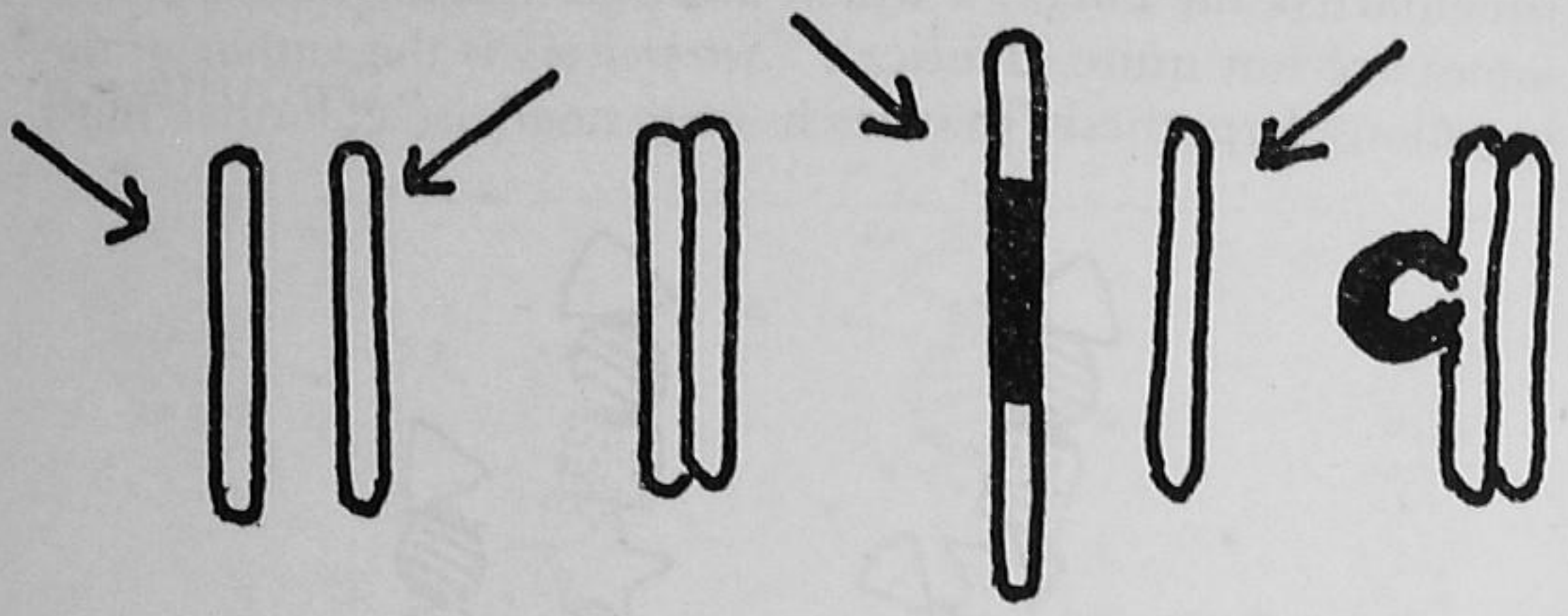


FIG. 16.—It has been shown that where the conjugation of chromosomes, combined from different parents on fertilisation, can be *seen*, an abnormally long chromosome (containing an extra piece, such as a duplication) can combine perfectly well with its normal " mate " so that the corresponding genes coincide.

In a case like this the " extra " length forms a *loop*. In reality the story is enormously more complicated, and cytologists are fighting about the details, but this simplified story will serve here.

supposed that the gene somehow changed from a *dominant* determiner into the corresponding *recessive* determiner. *Serebrowsky*'s hypothesis does not need the assumption of molecular changes *in the genes themselves*.

Chapter Twenty-one

Dominance

When we mate a black rose-comb bantam to a white one, or a Brown Barnevelder to a white one, the chicks are coloured, not white. We say that in this case colour is dominant to whiteness.

When we mate black hens to " barred " males, the resultant chicks are barred. Barring is dominant.

When we thought in terms of " determinants ", we spoke of dominant and recessive *genes*, the *barring factor* being stronger than the *black factor*.

But now we think of genes as of chemical substances—substances with large molecules that must be synthesised at every cell division, dominance can be explained in exact terms, and not as the effect of a mystical " relative strength ".

Fisher and *Goldschmidt* have done most to elaborate the 1911 *Hagedoorn* hypothesis. The presence of a certain quantity of a gene (or perhaps we had better say the synthesis of a certain number of molecules under the influence of a certain quantity of any gene) will only make itself felt according to the constitution of the residual gene-complex with which it " collaborates ". We speak of complete dominance if the gene and the nucleus in which it acts are of such a nature that one quantity of the gene in a heterozygote, who inherited it only through one germ-cell, has as much influence as the double quantity in a homozygote. In another case the heterozygote *for the same gene* may be intermediate, e.g. blue in poultry when the

parents are respectively black or white, as in Andalusians. And sometimes the whole situation may be such that half the dose makes no impression at all, while only in homozygotes can we see any action of some gene (*G. H. Shull*, 1909).

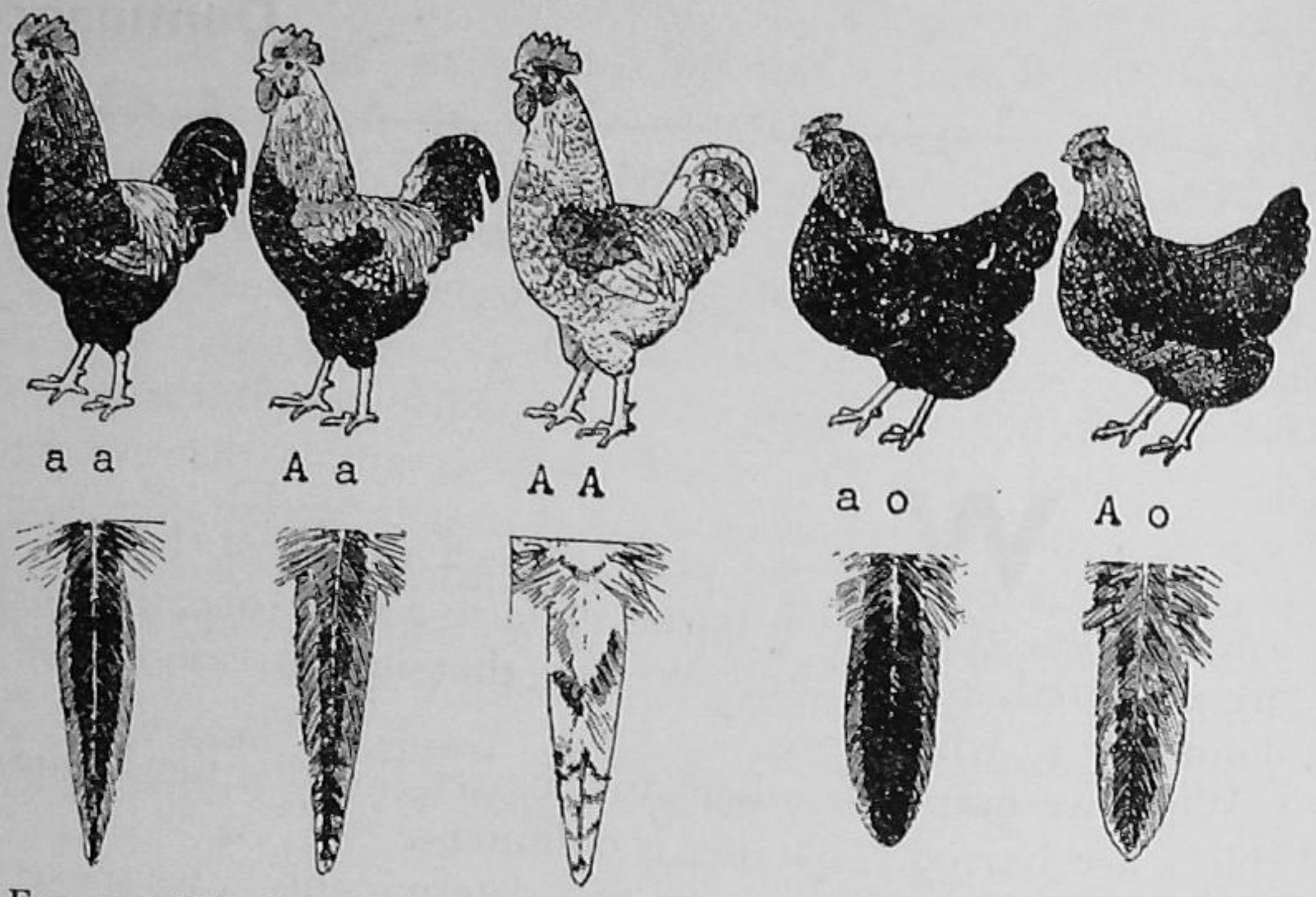


FIG. 17.—The five possible genotypes of the Autosexing Barnevelder in respect to the "barring" gene.

Above: the general aspect of the birds, below each one a typical neck hackle feather. In colour of the feathers, as well as in down colour, the *aa* *males* resemble the *ao* females, and so do the *Aa* males and the *Ao* females. One single dose of the "barring" gene has a similar effect in cocks as in hens. This shows that the absence of the gene from one sex chromosome in hens (there is no second one in the female sex) is the same thing we call *a* in males. In other words, the "lower-case" *a* in this case is shown to be the *absence* of *A*.

From "The nature of recessive genes and the biomechanical theory of Inheritance," by Hagedoorn, Gentika, 1937.

A good illustration is that of the Dutch autosexing breeds. Barring—the effect of the presence of the "barring" gene in the sex chromosome—is dominant in poultry with black chicks, e.g. North Holland Blues or Plymouth Rocks. Here the heterozygous birds are almost as light as the homozygotes. *Punnett* and *Pease* found quite a large difference in brown-downed breeds.

In the autosexing Barnevelder or Leghorn, with brown chicks, barring is only partly dominant. We can easily distinguish the

heterozygotes from the homozygotes—in fact this is how we distinguish the chicks of different sexes at birth.

In the autosexing Rhode Island Reds, barring is recessive. That is to say, there is no appreciable difference in colour between the newly hatched chicks heterozygous for the barring factor (the females) and normal Rhode Island Red chicks. Only the homozygotes (the cockerels) are distinguishable.

Fisher assumes that a quality which is recessive when it is first seen can, by selection acting upon the rest of the hereditary composition of a variable group, become dominant. This is quite a plausible explanation. Of course in some cases the first occurrence of a dominant new quality (new in the sense of novel) could easily be explained by assuming that we were dealing with the *combination* of genes already present in different families of chickens. In fact I know that often enough in poultry, rose-comb chicks are born from the cross of two single-comb parents, when strains or breeds are crossed.

Such novel characters are then dominant from the very beginning. Many qualities that seem new (if we compare them with what we see in wild species) are dominant in poultry—white legs, barring, bare neck, top-knot, black colour, white colour, frizzling, etc. We certainly need not evoke mutations to explain *their* origin.

Chapter Twenty-two

Transgressive Variability

WHAT can be done by breeding and selection in a group of poultry is limited by the potential variability. There may (theoretically) exist groups of poultry—inbred lines—that are so pure that all the birds of one sex are entirely identical as far as hereditary make-up goes. On paper, mutation—the spontaneous change or loss of a gene—can always occur at any cell division, although it is very improbable that mutation really plays a role of any great importance in bringing up the potential variability in poultry. But of course *cross-breeding does*!

Even if we should cross two birds, each of which belonged to a very pure breed, the hybrids would be heterozygous in respect to all the genes that were not common property of the two. In many cases this means that we can, by cross-breeding and going on from the hybrids, produce novel combinations of the parental characters and new striking poultry breeds. But entirely new qualities, never before seen, may result from crossing, or it may be possible to bring some desirable quality of our birds to a point we had formerly not been able to reach.

To explain this, we must go into some more genetical theory. In the early chapters of this book I explained that the presence of a gene in the cell nucleus of a fertilised egg and in the bird that develops from this makes itself felt in a rather indirect way. We may say that the end result of growth and development (or that any separate quality) is partly helped

along by the presence in every cell nucleus of certain genes. But it is certainly not true that it is scientifically defensible to speak of " the gene for black " or " the gene for broodiness ".

The fact is that two very similar breeds, which show the same quality to the same extent, may be quite different in their genetic make-up, even as far as genes go which help to influence this quality in the same way. In all such cases, cross-breeding is a source of surprising variability.

When we compare two popular and perfectly normal and

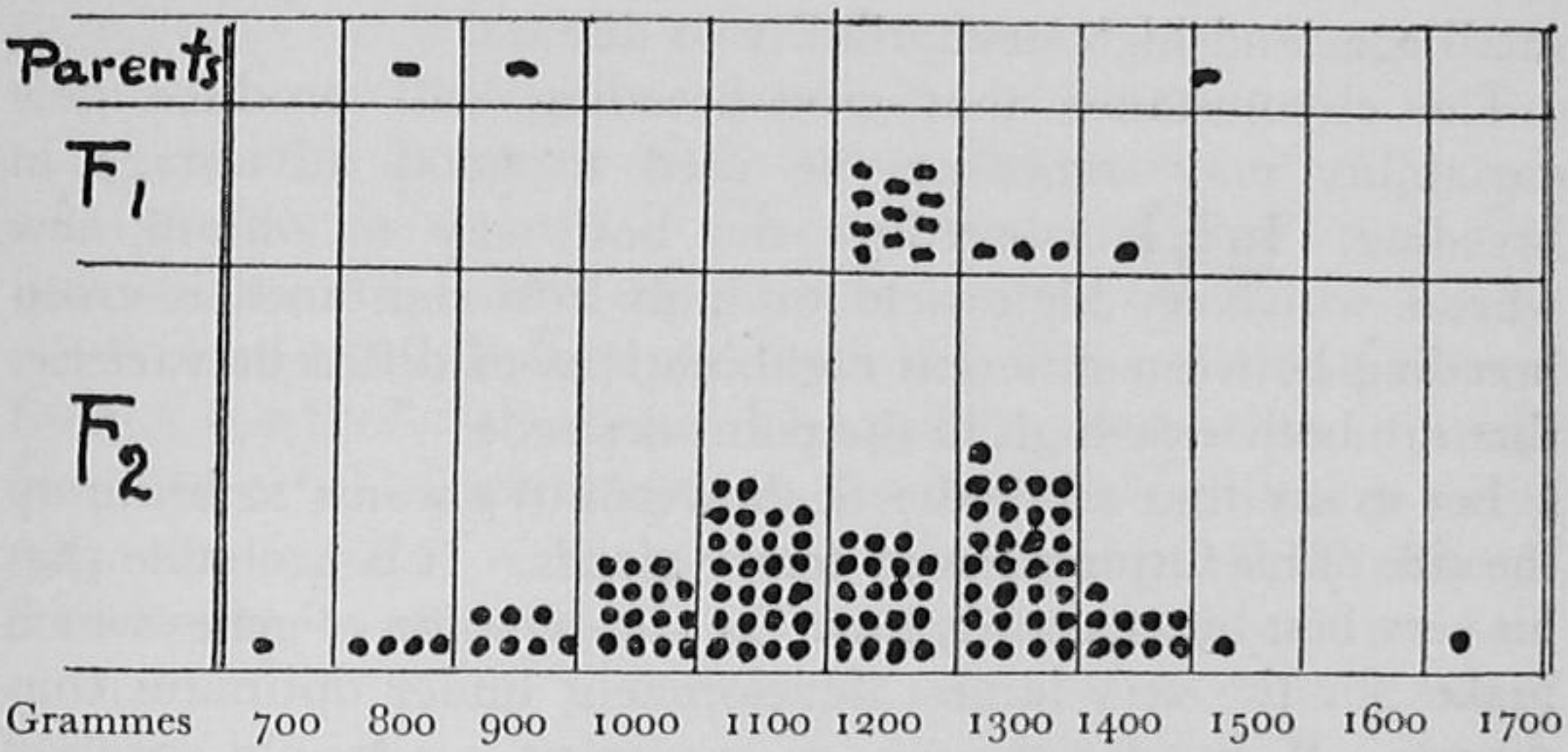


FIG. 18.—Size inheritance in a cross between Hamburg cock and Sebright bantam hen. Redrawn from Christian Wriedt's " Heredity in Live Stock " after Punnett and Bailey's experiments.

productive breeds of fowls, we know that in each case the set of perhaps thousands of genes present makes normal harmonic development possible. But of course those two sets of genes may be *different*! Cross-breeding and subsequent recombination of differentiating genes may give us a number of quite novel, and often disharmonic and inferior combinations (*Mjoen*).

I have sometimes explained this unexpected disharmony by a mechanical parallel. When we have two perfectly good machines of some kind—typewriters of different make, or bicycles—the two machines of different make are both perfect, although their parts are not interchangeable. If we do try to interchange some of the minor parts, we seldom get another harmonic whole, a usable typewriter or bicycle.

When we try breeding hybrid chickens together the result is

very often terribly bad. I interbred the strikingly good hybrids between a strain of excellent Barnevelders and one of very good Leghorns. The percentage of embryos dead in shell, of malformed chicks, cross-beaks, chicks unable to stand up and, at a later stage, pullets that were infertile or nearly so, was surprisingly large. And anyone who has tried inter-breeding hybrids has had a similar experience. Unexpected qualities that we never see in either breed may crop up as novelties either in the hybrids or among the second generation. Broodiness is quite common, and so is the tendency to lay small eggs and high susceptibility to disease.

The circumstance that cross-breeding will produce new variability may sometimes be used to good advantage in breeding. In plant-breeding the best way to obtain new wheats with very high yield or high frost-resistance is cross-breeding between different combinations of different varieties that are both very high in the point desired.

Let us say that a breeder of show-poultry wants to bring up the size of his Orpingtons or Jersey giants. It is probable that his very best birds already have the combination of genes which makes for the very largest development under optimum conditions. If, just for the sake of argument, we should speak of large-making and small-making genes in the make-up of our breeds (but see the beginning of this chapter!) it is not necessarily true that the largest birds in the breed already have the most favourable gene combination. There might be entirely different "large-making" genes in the Malay or in some other largish breed. I would not be at all surprised if it were found possible to produce still larger birds than we have now by means of cross-breeding followed by interbreeding of hybrids or back-crosses, depending on the first results obtained.

One of my correspondents, whose death put an end to his experiments, started them to find out to what extreme of minute size it would be possible to breed chickens. He had been trying all sorts of combinations: first crosses between the smallest breeds—Antwerp Caille, Sebright and Rose-comb bantams. In this particular experiment the curious fact emerged that we have a very good indication whether a given cross is a promising one with which to attain the end in

view. This will be the hybrid combination that will give us the *largest* hybrids! To state the problem in the simplest terms, what we must hope for is to find a combination of two small breeds that are small for a different genetic reason (small size being recessive). By interbreeding such larger hybrids we would have a very good chance of obtaining bantams that were even smaller than the smallest breed we now possess.

The breeding of fancy poultry presents many problems that could be brought to a happy solution by fanciers. I am thinking of the breeds in which the dictates of the fancy make it desirable to bring some particular point to a still further extreme, such as length of feather in Brahmas or Orpingtons, extreme length of shank in Game or the reverse in some other breeds, etc., etc. Here a cross between two breeds which both show the desired quality to a high degree would be indicated, even if the mongrels should be terribly nondescript. Careful breeding work, back-crosses to the breed of his fancy, would give the breeder a chance to make further strides toward winning at the shows in his favoured variety.

Chapter Twenty-three

Sex-linked Crosses

When I was a schoolboy, a neighbour bought a hen with day-old chicks in the market, and it turned out that all those chicks were cockerels. In the first years of this century large flat boxes of baby chicks were imported from Belgium into the Paris Halles, and here again every chick turned out to be a silver-pencilled male.

In the Campine district, as well as in the Waterland poultry district north of Amsterdam, the poultry-breeders used to breed light non-broody chickens in two colours: silver-pencilled and golden. Their commercial flocks consisted entirely of golden pullets, and those pullets were produced from matings between golden males and silver females. This mating gave chicks in two colours, white and yellow, and those whites were drowned at birth, for as far as a few dealers did not palm them off to unsuspecting chick-buyers. The golden chicks were pullets. The eggs were sold under the name of "schei-eieren"—literally "separating-eggs"—and they were sold with the guarantee that all the dark yellow chicks were pullets.

I went round to about twenty poultry-farms in Waterland in the breeding season, collecting data. At a few farms I got data on mating between golden hens and silver males, or between golden *inter se* or silver to silver. Most matings were between silver females and golden males. The data collected were as follows:

Silver males, gold females:	Gold males, silver females:	Silver males, silver hens:	Gold males, gold hens:
162 silver males	249 silver males	11 silver males	0 silver males
163 silver hens	0 silver hens	4 silver hens	0 silver hens
165 gold males	0 gold males	0 gold males	53 gold males
160 gold hens	243 gold hens	5 gold hens	51 gold hens

FIG. 19.—Data gathered in "Waterland", the poultry district around Landsmeer and Assendelft, North of Amsterdam, around 1905 and 1906 on the colours of chicks in the "Assendelver schei-eieren fowls" from different matings.

Both the Waterland poultry-men and those of the Belgian Kempen knew the trick of separating the sexes by colour from birth. *Doncaster*, working with the gooseberry moth, found the explanation. In such cases we are dealing with genes carried on the sex chromosome. In poultry the males carry two chromosomes of which the females possess only one specimen. We happen to know quite a number of the genes present on this chromosome, and although males may be pure or impure in respect to such genes, *AA* or *Aa*, females can never be pure in regard to them. They must always be heterozygous (some colleagues say haplozygous) in respect to every gene on the chromosome. Every silver hen must be *Ss*, if we use *S* as the symbol for a gene which here distinguishes silver from golden. She will make two sorts of egg-cells, some with, some without the sex chromosome. And when her mate is a golden cock (*ss*), only the eggs that give cockerels will also carry the *S* gene.

For this reason the mating of silver hens to golden cockerels will always give two colours of chicks: silver males and golden females.

In the Assendelver and Campine fowls the breeders used two colours in one breed. *Bateson* and *Punnett* found the explanation.

Of course such distinctions can be seen just as well when we cross two different varieties. *Punnett* and *Pease* in England popularised the Rhode Island Red cock × Light Sussex hen cross which is still perhaps the most popular commercial pullet. In Holland Brown Leghorn × White Wyandotte was

very popular for a time; in Australia the most popular commercial pullet for egg production is the White Leghorn × Australorp hen, in which cross the pullets can be recognised by the presence of wing-feathers at birth.

The so-called " barring factor " is a gene which is present in barred but absent from black poultry. Here matings of barred hens, and non-barred males give us barred sons and non-barred daughters. The chicks can be recognised by the large white head-spot on the males.

In all these cases there is dominance of silver over gold, of slow feathering over quick feathering. So much so, that there is almost no difference to be seen between the " haplozygous " females and the homozygous males in pure breeds with the dominant quality, such as Barred Rocks.

It seems very curious that in any breed of pigeons and doves, even in wild-living species, all the females should be heterozygous for a factor that distinguishes them from albinos, but that it is true can be seen when we mate such females with recessive white males—even males of another species or genus.

This dominance is not always present or complete. In fact, in any species of bird, and certainly in any variety of poultry in which the males have a plumage that differs greatly from that of the females, this difference is entirely due to the fact that the males have two sex chromosomes with many genes, while the females carry only one, and for this reason possess only *half as much* of the quantity of all of those genes.

When, immediately after the egg that will give a male embryo is fertilised, some accident happens, owing to which one of the two sex chromosomes is absent from one of the two first cells, the bird may develop into a typical " half-sider ", which will show the male colour on one side of the body and the female colours and design on the other, with a clear median line of demarcation. Wild chaffinches and bullfinches with these characteristics are very striking. Here dominance is incomplete. Although both sexes possess a complete set of all the genes present on the sex chromosomes, the homozygous males are strikingly different from the haplozygous females.

In some of our breeds of chickens this makes it possible to distinguish the sex of the new-born chicks with a great deal of

accuracy. From a tray of newly hatched Silver Wyandottes anybody can pick out about 40 per cent as males and about 40 per cent as distinct females, the rest being more or less intermediate in the amount of white on the head. In the same way it is possible, but not easy, to sex Brown Leghorn, and especially black red Game bantam chicks by looking at the back-stripes, which are much more distinct in females than in males. And in this respect barred Plymouth Rocks are like Silver Wyandottes.

Punnett and *Pease* made the discovery that the "barring" factor, the presence of which helps to lighten the down colour, has a very much more distinct effect in breeds with brown than with black down colour. They introduced the "barring" factor into Golden Campines (the breed used for commercial "schei-eieren" in Belgium). Their "Cambar" was the first deliberately made "autosexing" breed of poultry. When this result was published I immediately started to produce some autosexing breeds of more commercial importance than the semi-bantam Campines; and *Pease* and some British poultry-breeders under his guidance have produced a whole range of autosexing varieties.

There are two distinct methods of doing this. We can cross a commercial brown-downed breed with a fowl carrying the "barring" factor, and cross the hybrids together. This will give us a very variable lot, from which we can then pick out some distinct homozygous males and some dark female chicks, selecting them for qualities we admire in the breed we wanted to transform into an autosexing variety. This method is generally used in England.

I followed a different path. I started from the fact that in some of the commercial brown-downed chicks excellent highly productive strains have been developed by commercial breeders. My method has been to make use of the relatively high purity of such strains, to introduce the barring factor (substitute a sex chromosome carrying it would be a more correct way of stating things), and by a series of back-crosses to the commercial strain, to obtain this strain back in all its purity and quality. The pedigree showing the making of the "Autosexing Barnevelder" shows plainly how this is done. The autosexing

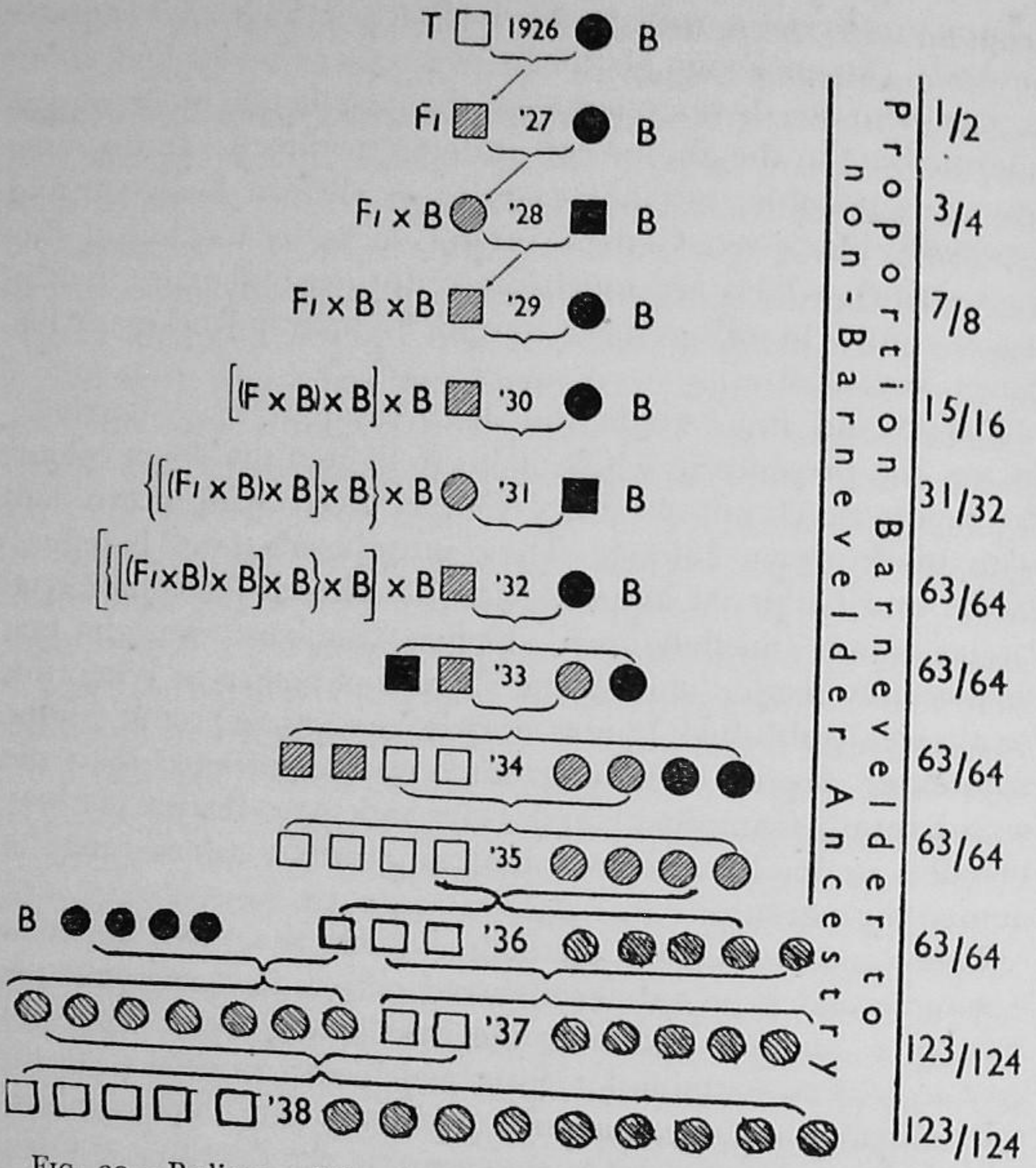


FIG. 20.—Pedigree of the Autosexing Barnevelders. Squares stand for males, circles for females. The birds of the present generation have one non-Barnevelder ancestor, eleven generations ago, from which the "barring" gene has been derived. White figures denote birds homozygous for the barring factor (*AA*), cross-hatched figures stand for heterozygotes (*Aa* or *Ao*), and black figures denote non-barred birds. After six back-crosses a few homozygous (*AA*) males were produced by mating hetero-zygotes *inter se*, after which the breed was practically pure. A further introduction of pure Barnevelder females was made in 1936.

Brown Leghorn was made by crossing a show so-called "wild-coloured" Leghorn homozygous for barring male I obtained from the president of the Show Leghorn Club, Mr. *Hulshoff*, on very good hens bred by Mr. *Wolfswinkel*. The cross was made by a friend, Dr. *Hirschfeld*. Both of us have

gone on with the material; there is no non-Leghorn " blood " in the autosexing Leghorn.

The Autosexing Rhode Island Red was made in the same way as the Barnevelder. All this takes a little more time, but the method has two distinct advantages: firstly, it can be done with only a very few individual birds in every generation, and secondly, the end result will be as good as Mr. So-and-so's well-known pure strain of birds, it will just be a colour variety of a very good commercial breed, and not a new departure of debatable quality. Our autosexing Leghorns were still Leghorns when ready, non-broody and laying many large pure-white eggs; they are in this respect quite distinct from the English Legbars. What was said about the possibility of sexing Silver Wyandotte chicks and Brown Leghorn chicks according to colour, shows that in a variable breed it is probable that many different genes in respect to which the breed is variable have some influence on down colour, and so on the ease with which we can distinguish the sexes. This was quite noticeable in the autosexing breeds made in Holland. The closer they came to the constitution of the pure, relatively inbred strains, the easier they were to sex. Some geneticists would speak of " modifying genes ".

It is certainly possible to start from a commercial strain of Brown Leghorn, Silver Wyandotte or Australorp, and, by selecting chicks that show distinct signs of belonging to either sex, to develop the breed as an autosexing one. Whether this is practicable simply depends on the question whether we can take up this further difficulty in addition to the work of improving the strain for quality.

Chapter Twenty-four

Mutation

A BIRD, heterozygous for any gene, will produce germ-cells of two kinds, and if the individual is simultaneously impure for many genes, the germ-cells it produces will be of 2^n (two power n) kinds, n being the number of genes concerned. This means that a hybrid between two breeds or two species will hardly ever give two identical germ-cells, and if we breed hybrids together, the offspring will vary enormously. When, in the first years of genetics, we tended to think of genes as of " determinants " for " unit characters ", each gene giving one definite quality, we thought of cross-breeding and of the variation caused by crossing as of a re-combination of the qualities shown by the parents of the hybrids. Today we realise, as the result of many experiments, that re-combinations of existing genes will often give us entirely novel qualities, characters which did not exist in the group before (see chapter on Transgressive Variability). I know of a great many instances of the origin of wholly new qualities in experimental plants and animals: doubleness in flowers of horned poppies, albinism in rats, waltzing in rats and mice and ferrets, crossed beak and double-comb and slipped tendon in chickens and dominant white colour in pheasants, dominant spotting in the rabbit–hare cross.

The fact is that the effect of the presence of a gene in the cell-nucleus is entirely different when this nucleus contains one set of genes or the other one.

We must bear this in mind when we discuss mutation in poultry! We use the term "mutation" for any hereditary change which is not simply due to the re-combination of genes and chromosomes in the normal process of cell division and the normal reduction division in individuals who are heterozygous, and which for this reason give germ-cells of unexpected constitution.

When a cell divides and the nucleus divides, normally every chromosome with every gene upon it is first doubled in quantity, and each daughter-cell receives a set of chromosomes and of genes that is exactly like that of the mother-cell. It is really remarkable that this exact doubling, and especially this exact distribution of all those chromosomes, is happening without any hitch for thousands of cell generations.

But actually accidents—hitches—*do* occur in this process, and these are what we call *mutations*.

In poultry the largest mutations so far found are cases in which one chromosome has got lost somewhere. In other experimental animals and plants this lack of a whole chromosome has been actually seen under the microscope; we are not really dealing with the disappearance of a chromosome, but with the lagging of one chromosome at the moment of cell-division, so that the two daughter-cells differ, one receiving that particular chromosome *in duplo*, the other lacking it.

A mutation of lesser magnitude is the loss of part of a chromosome or the loss (or doubling) of just one gene, or even a quantity of just one gene. Such small mutations can be caused by very small irregularities in the crossing-over of chromosomes (see Crossing-over).

It is evident that if mutations are caused by irregularities—small abnormalities in the normal distribution of the gene-material—the smallest mutations should be the most frequent, and this is in accord with the facts. Such small irregularities always occur, and it has been shown that their frequency can be greatly enhanced by such disturbances as heat-shocks, Röntgen rays, radium radiation and certain drugs.

If we remember that (with the exception of the sex chromosome in hens) the chromosomes occur in pairs, it will be seen that the dropping out of a gene by mutation in one chromosome

will be noticeable only if there is either a visible difference between a homozygous bird (*AA*) and a heterozygote (*Aa*), or when, in a case of dominance where *AA* and *Aa* look alike, the animal in which the mutation occurred happened to be heterozygous (*Aa*) in the first place.

Mutations can occur at any cell division, and at any time or place. They occur in body-cells, they also occur at the formation of germ-cells. Germ-cells with a genotype that is not expected from the genetic constitution of the bird which produced them may have occurred in tissue of the sexual organs, in which case numerous " mutated " germ-cells are given off by that particular bird.

Such " somatic " mutations—cases in which a gene is lost somewhere in the body—can best be seen when the gene concerned has an influence on feather colour, or when the mutation happens to occur in the skin. Such mutations are not rare. If we mate the White Leghorn with any coloured bird, the hybrids are white. But such white birds, in some combinations only in one sex, show many black or barred spots, from little specks of colour to half and whole feathers, islands of dark feathers up to cases in which one-half of the chick is coloured. Here white is wholly dominant, so that in homozygous white chicks a mutation from *AA* into *Aa* cannot be seen. In fact, the occurrence of coloured specks in White Leghorns shows them to be heterozygous for this gene.

While making one of our autosexing breeds, I could compare many brown-downed birds, homozygous and heterozygous, in respect to the " barring " gene. Here it could be seen that homozygous (*AA*) birds, very pale cuckoo, almost always showed a number of " mutated " patches, with whole or parts of feathers of the colour of that of the heterozygotes (*Aa*). And again, such heterozygous (*Aa*) birds frequently showed feathers or parts of feathers coloured like those of ordinary (*aa*) Brown Leghorn (Barnevelder) birds.

Homozygous autosexing males, pure for the " barring " gene, should, when mated to autosexing females of their own kind, always give pale (*AA*) males and dark (*Aa*) female chicks. This is because all their germ-cells " ought " to contain the barring factor. Very rarely, however, such a homozygous

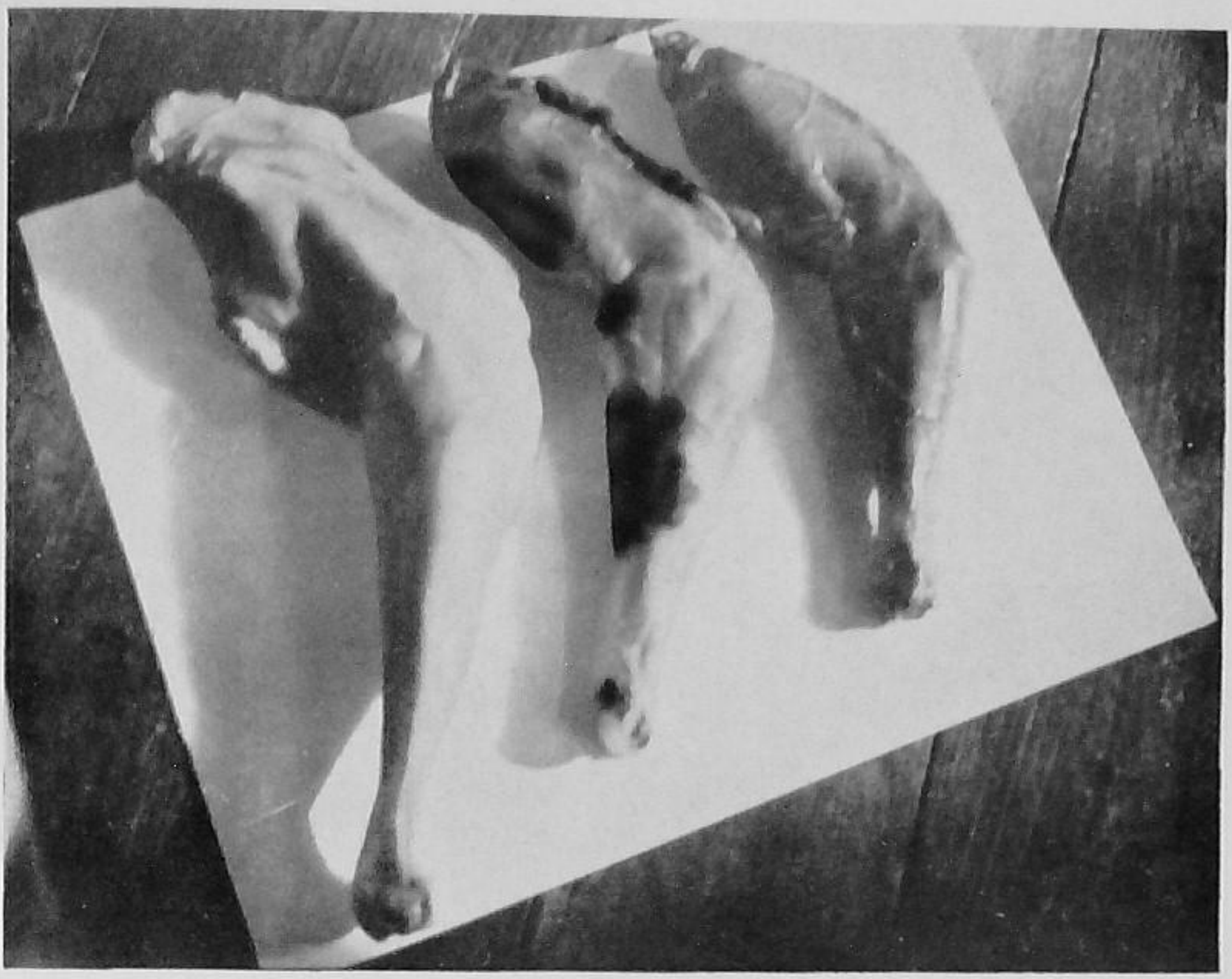


FIG. 21.—Skinned legs of Leghorn, Silky, and F_1 Silky × Leghorn (in the middle). In the hybrid evidence of somatic mutation is seen. Darkly pigmented spots show up in the muscles.

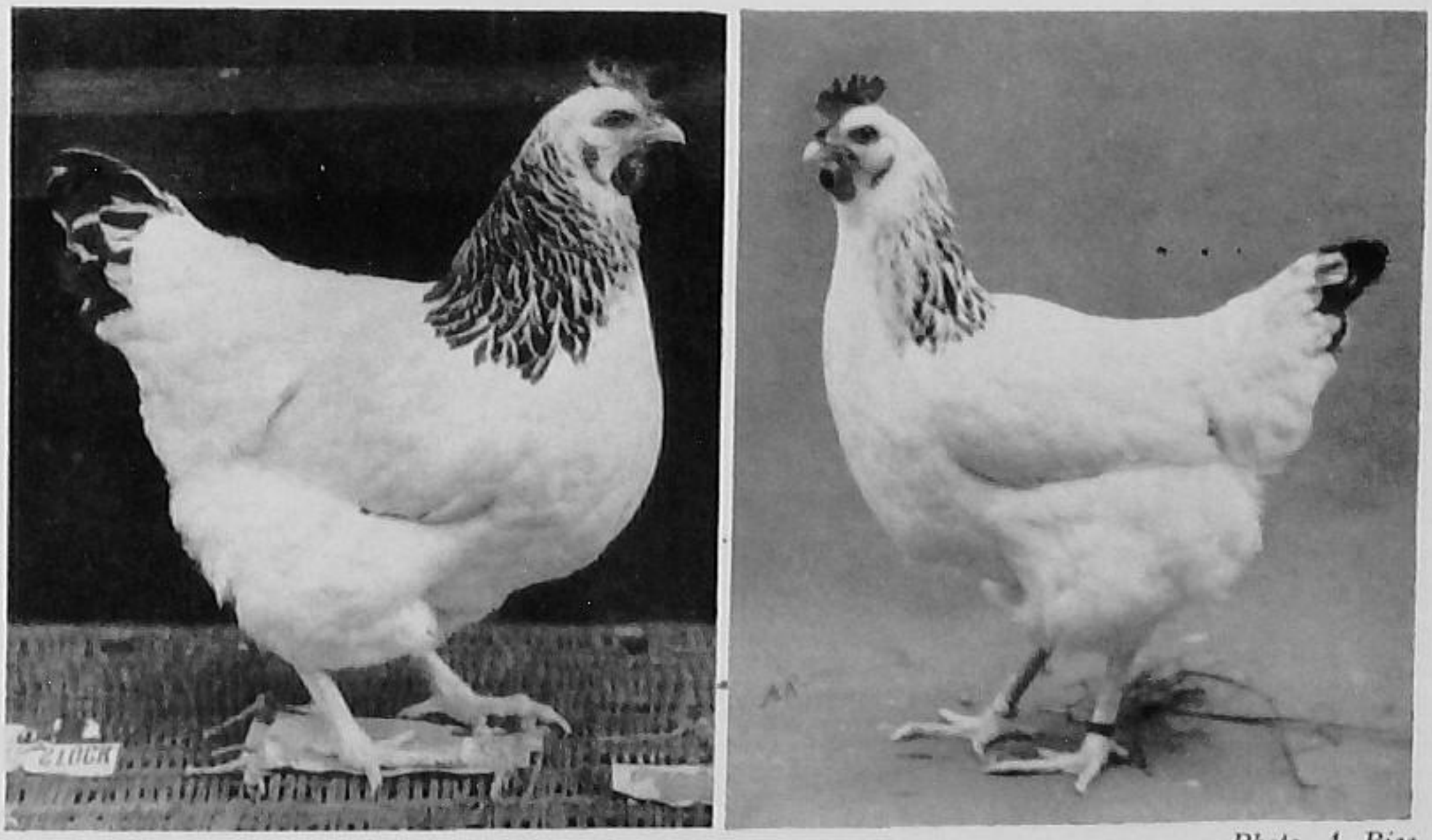
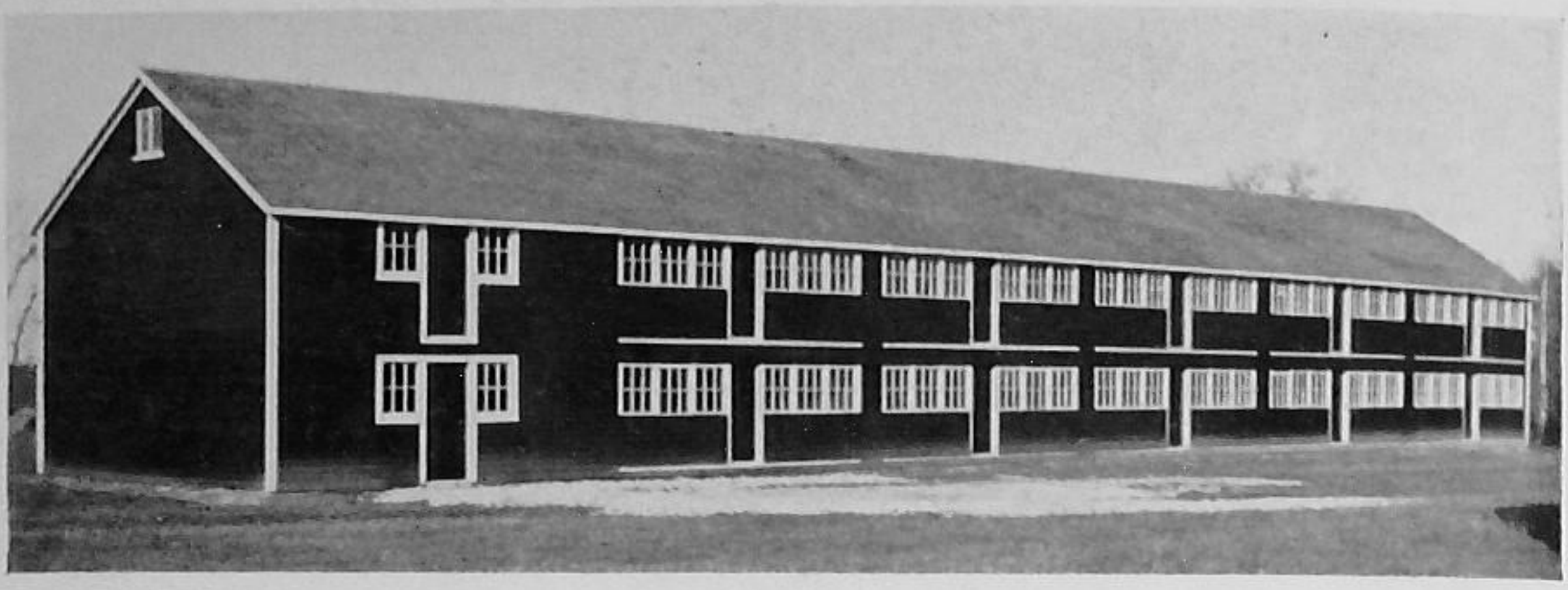


Photo. C. Hosegood *Photo. A. Rice*

FIG. 21a.—Light Sussex (*left*) Exhibition (*right*) Utility.



Two-storey deep-litter intensive poultry-breeding house. Fisher Farms, Ontario. (See page 209.)



Photo. 'Farmers' Weekly'

Folds are excellent for nucleus breeding. Each of these folds houses twenty sisters and half-sisters. The record of the performance of one family of two such folds forms the major part of the progeny test of a cock without recourse to a trap-nest. (See page 186.)

male which shows a few feathers of heterozygous tissue also produces an occasional sperm lacking this " barring factor ". A few cases have been observed in which this occurred, of which two are cases in my own experiments, where a typical brown Leghorn hen was born from two pure-bred autosexing parents.

The only explanation of this must be that, whereas we only *see* the effects of mutations of this kind if they occur in the skin, they really occur in all the body-tissues, including the sex-glands.

If we mate a bird with intensely blue skin (and bones) of Silky extraction with a white-skinned bird, the hybrids show no pigment in the skin. That is to say, as a rule they do not, but if we prepare them for the table we often find spots and streaks of blue colour in the skin. We may also find spots on the shanks, and if we examine the bones, we find patches of blue on them. We have seen such spots on the long bones, on the breastbone and even on the testicles.

It should be added here that in the mutations which affect the " Barring factor " or the " Silver factor ", both genes carried on the sex chromosome, such mutations are frequent in males, but so rare in females that we have never yet noticed one. This, I venture to think, is rather good proof of the hypothesis that in those " loss " mutations the cause is a small irregularity in crossing-over. In the male, where two sex chromosomes are present, crossing-over between them can occur; in the hen, with only one unpaired sex chromosome, this is impossible.

We now come to the difficult question whether mutation must be regarded as a major cause of variation in poultry. Or, in other words, whether it is probable that mutation is responsible for the enormous diversity we notice among all the breeds of domestic chickens.

It seems to be the opinion of many geneticists that *new genes* arise by mutation. The hypothesis that the chemical constitution of the gene itself may be altered by what caused the mutation is becoming popular.

It must be stated, I think, that although certainly such a hypothesis furnishes a plausible explanation of mutations, the burden of proof lies on the authors who propose it. Spon-

taneous generation—the origin of fleas from dust—is an equally plausible hypothesis, but the facts did not support it.

My main objection to the hypothesis that we *must* suppose that genes change in quality as well as in quantity because there is no alternative hypothesis to account for mutations that affect only one gene, is that there is only a gradual difference between large chromosome mutations, losses or reversions of parts of chromosomes and mutations affecting just one gene. The old objection to the idea of a real loss—namely, that it would make the chromosome "fall apart"—has been proved invalid by microscopic observations of cases, in which whole sections of chromosomes are lacking. So long as we can explain the facts of mutation in terms of what we really know, the hypothesis that new genes are created or changed out of chemically different genes is superfluous and gratuitous.

Now we know that hybrids between wild species of fowls and domestic chickens are fertile in the male sex, it is possible to explain almost all the prodigious variation in poultry by the assumption that more than one wild species (probably three) must be considered as the original ancestors (see chapter on Evolution).

We know that novel recessive, as well as novel dominant characters originate by cross-breeding, in poultry as well as in many other animal groups. Cross-breeding causes a swarm of novel re-combinations of genes, and the sort of material from which natural (or human) selection can select the most fantastic new things.

To sum up this chapter: Mutations *do* occur in poultry, mostly small ones; they result in quantitative changes in genes or chromosome parts. The rapid evolution and the prodigious variation in poultry are due to recombinations of genes, etc., rather than to mutations.

Chapter Twenty-five

Table-poultry and Dual-purpose Breeds

ALL poultry and ducks end their life as table-poultry sooner or later, and the carcase value should always be taken into consideration. By this I mean that in making up a balance of outgoing and incoming, the carcase value of the cockerels and of the females after a useful laying life should be taken into account. In typical egg-producing districts, as in Petaluma (California) with White Leghorns or in Tonsel (Holland) with Khaki Campbell ducks, the value of the new-born males is rated very low indeed; in Tonsel the central hatchery supplying the egg-farms will not even consider selling a drakelet—they are drowned in their tens of thousands at birth and sold for pig-food. Old hens and two-year-old Khaki Campbell laying ducks in Holland are a drug on the market; before the war they were not worth their weight in grain.

It is certainly remarkable that both in poultry and in cattle the breeds that are highly specialised and bred for high production, like the Channel Island cattle, the Leghorn and the Khaki Campbell duck, are all small, light and scrawny; that in all three groups we have dual-purpose breeds, such as the Redpoll or the Milking Shorthorn, the Sussex and the Aylesbury, and also specialist breeds for slaughter, such as the Hereford, the Pekin and the Dorking fowl. Those breeds bred for meat are low in egg- or milk-production, and as to the dual-purpose breeds they tend to vary enormously, between

strains and individuals good for one of the two purposes, rare individuals good for both and many that are good for neither purpose.

Why should there be this apparent antagonism between production of eggs (milk) and fleshiness? Is it physiological, so that the energy taken in can be used in only one of two ways?

I venture to think that the problem is more complicated than this. It appears that in fact there exist dual-purpose females, and dual-purpose breeds, that will give as much production as the specialised production birds, and will, at the same time, give us a better carcase, and also sons with a good flesh-producing tendency. There certainly are circumstances in which Sussex or Rhode Island Red hens will produce as many eggs as White or Black Leghorns.

It is very probable that a firm belief in the correlation between appearance and production has influenced the selection of our domestic animals, and that the hope of obtaining better production by selecting for production type—"scrawniness"—has helped to give the high-production strains their present appearance.

Or let us say it in other words, since we have very much more efficient methods of stabilising and purifying our breeds of animals and poultry today than twenty years ago, we are able successfully to solve difficult breeding problems that our parents could not possibly cope with.

What we need, in the first place, are good, efficient costings. We require to know just how profitable our present breeds of poultry are and the separate families within those profitable breeds. Different groups of poultry differ enormously in economic food consumption, as the result of some of the German and Dutch laying trials of twenty-five years ago have abundantly shown—results that were corroborated in England after the Second World War.

It is certainly not true that the problem is so simple that we can state that the smaller the bird the smaller is the amount of food consumed for the same number and weight of eggs produced. Unless our birds must forage for themselves, when small birds are probably more profitable, profit from egg-

money with cost of food and labour subtracted seems to be more highly dependent on an *internal chemical efficiency* of the organism than on mere size or similar things you can judge by handling the hen or looking at her.

If the variation in efficient egg-production and the variation in shape and tendency to meat production are *entirely independent*, it is very unlikely that selection for good production would ever give us birds that were first-class table-birds.

Now, if our methods of selection are not very efficient (and selection on individual quality is a very poor tool), we must certainly give all our attention to this one point, and we cannot afford to do two things at the same time: selection for production and for table quality. While we are getting the breed tolerably pure for production, it must automatically become pure in respect to factors influencing shape and meatiness. And if we neglect table quality, table quality must automatically become mediocre. Or the other way round: if we go all out for table quality, and breed from the best-looking birds, we are bound to get the breed pure for a set of factors which will make it a mediocre layer.

Now, all this changes when we start using very much more efficient methods of selection. When we combine inbreeding with group selection into what I called a "nucleus" system, we have a much more efficient method of quickly reducing the variability of a variable group and getting it pure for the most desirable inherited constitution. This method is so much more efficient that it will now be possible to tackle two things at once: egg production and table quality (or milk and beef in cattle, for that matter).

I must not be misunderstood in all this. I am not saying that dual-purpose poultry breeds would pay better than pure egg-laying breeds. This is a matter that depends on the market for eggs and meat and on the price and available quantity of foodstuffs.

How should we set about the work of producing the ideal dual-purpose chicken? Should we improve an existing breed, or construct a new one? Could we improve some of the existing egg-laying breeds for the table or some of the table-breeds for laying?

One thing is very clear: the tendency to judge utility classes at poultry shows will not lead to any improvement; such classes are a pure farce. Poultry-breeders should understand something about genetics before they set themselves a goal or a standard of perfection. The idea that a breed of any domestic animal is infinitely variable and plastic has done a lot of harm. Any circumscribed group has a limited po-

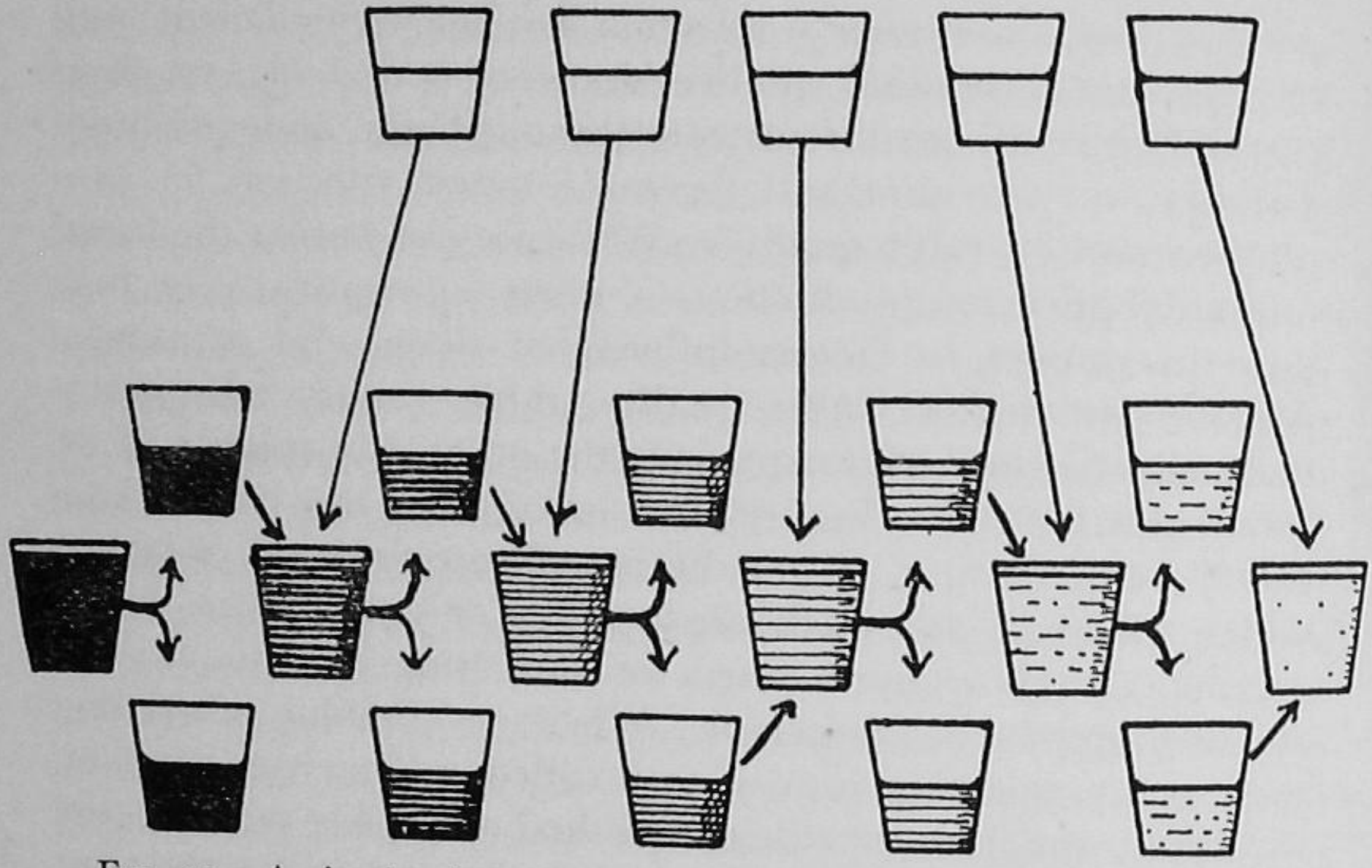


FIG. 22.—A simple classroom experiment to illustrate "grading". A tumbler of coloured liquid (or preferably coloured seeds, such as beans) representing a specimen of one breed, is emptied into two similar glasses (representing germ cells). One of these is rejected, the contents of the other one are combined with one of several tumblers half-full with colourless liquid or white beans, representing germ cells of the second breed, to form the hybrid generation. The process is repeated until the liquid is colourless or until all the beans happen to be white.

tential variability (number of genes in respect to which not all individuals are alike and pure), and in a group improved by selection this variability has been greatly reduced. Nobody could hope to bring up the average weight of a very good egg-laying strain of Leghorns to anything above the weight of the heaviest hens in that strain without first cross-breeding. At a certain time, thirty years ago, when large size and heavy eggs became popular in Leghorns in the U.S.A. and Western

Europe, all the White Minorcas suddenly disappeared. They were bought up by Leghorn breeders for cross-breeding purposes.

The so-called dual-purpose breeds, like Plymouth Rock and Sussex, are more likely to be good material for working with, as cross-breedings with show-birds and with table-strains have been frequent. In countries like England, where white skin is preferred in table-birds, it would be the simplest matter to breed white skin colour into a good strain of Rhode Island Reds or White Wyandottes by using some excellent Sussex hybrids and repeated back-crossing (see the corresponding chapter).

The white-skinned heavy hybrids between Cornish Game and Sussex have the very best reputation as table-birds. The exaggerated shape of this breed of game makes a lot of sterility trouble for the breeders. The hybrids named would, I think, be excellent material for an ambitious breeder out of which to construct a brand-new dual-purpose fowl, first class both as a table-bird and as an egg-producer. This breeder should, after the first two or three generations of mongrels *inter se*, go all out for males that give the best groups of offspring, in respect to both egg-production and table quality, and he should leave such things as colour, feather-length and comb-shape entirely to chance. In the end the breed would have a shape and colour all its own as a trade-mark of quality. In the chapter on Cross-breeding I have tried to explain how it is possible to improve a poultry-breed for top-crossing on another one. This scheme could easily be worked with Indian Game or with North Holland Blue or any similar breed used for top-crossing to produce table-chicks.

Chapter Twenty-six

Grading Up

POULTRY have a high rate of reproduction, and from a small group we can, in a few generations, build up flocks of good size. In the larger farm animals, where reproduction is low, especially in the horse, cattle, sheep, this is not practicable, and breeders are wont to bring up the quality of their herds by the use of highly-bred males.

In poultry the practice of buying male breeding-stock to bring up the quality of the flocks is quite common, and we shall see that, provided we can establish strains of very high quality and purity, the trade in and distribution of males can be utilised to bring up the quality of a country's poultry in a very rapid and efficient manner.

The Mendelian explanation of what is taking place when we use pure-bred male breeding-stock in flocks of different (inferior) quality is very simple indeed. We start from the assumption that the males used are alike and that they are pure, homozygous, in respect to the factors we need in good birds of their breed, and, on the other hand, that they do not have, and for this reason cannot pass on, any genes that are undesirable in birds of this particular breed.

If we use a male pure for *A* (*AA*) on females that are lacking in this gene (*aa*), the offspring will all have *A*, but they will be heterozygous (*Aa*). If *A* is a desirable factor, this will mean an improvement. If we use the same or another pure-bred male again, the mating of the pure male to impure females (*AA* × *Aa*)

will give us 50 per cent pures (*AA*) and 50 per cent impures (*Aa*). Let us see what happens in the next generation. Here there will be two kinds of matings, *AA* × *Aa*, which will again give 50 per cent pures, and matings of *AA* with *AA*, in which all offspring will be pure in respect to *A*, like the father.

This means that in a series of repeated matings with males, homozygous for some *desirable* gene, the proportion of birds

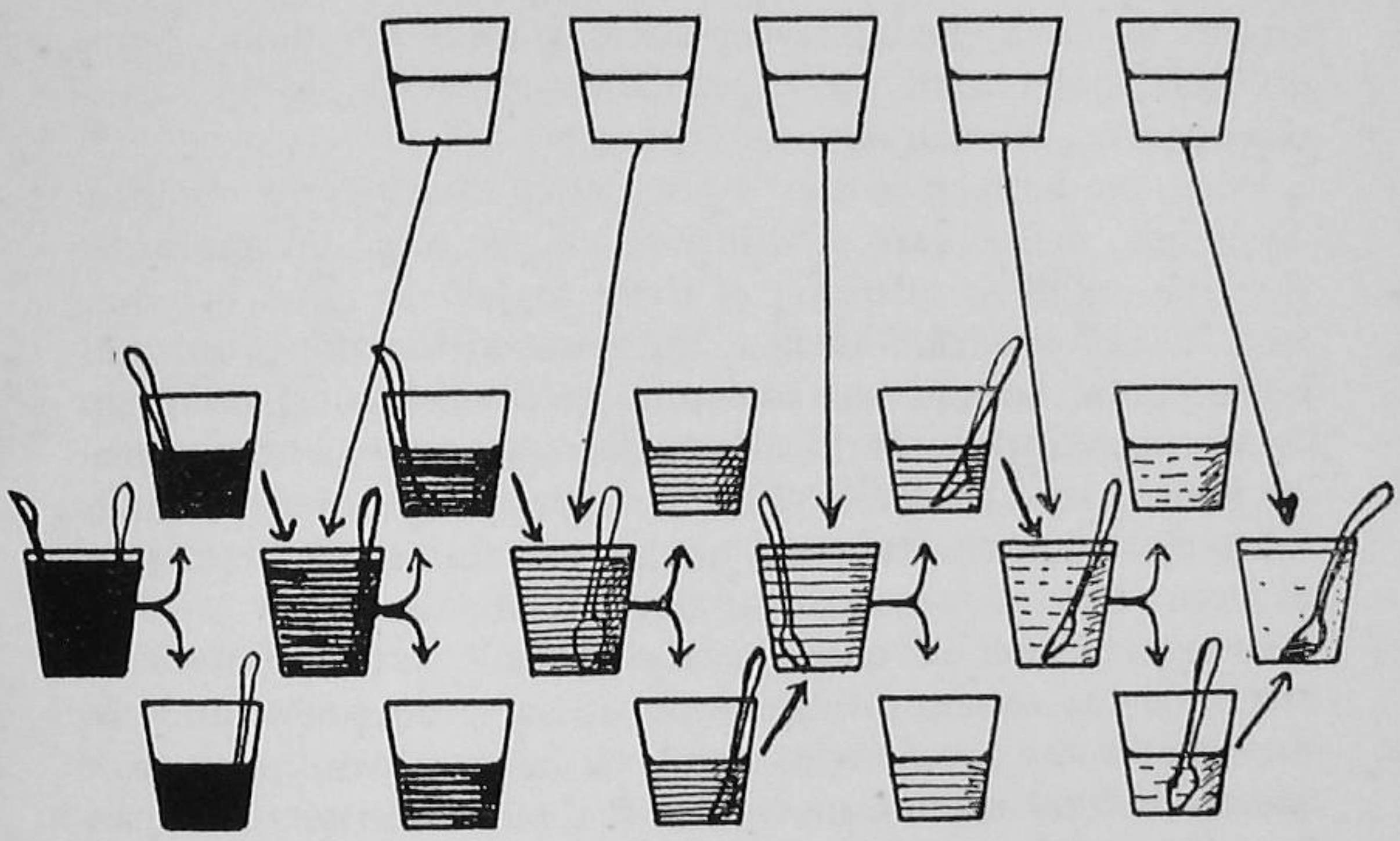


FIG. 23.—An experiment illustrating the adding of one gene to a breed. Everything is arranged as in Fig. 22, with the exception that a spoon is placed in the first tumbler. When the contents of the glass are divided over two glasses, the spoon is present in only one of them. At every division the tumbler containing the spoon is chosen and the other one rejected. The experiment is continued until the spoon is standing in a glassful of exclusively white beans.

that are still not pure in respect to that particular factor *will be halved.*

Now we must calculate the same thing in respect to the absence of an undesirable gene. If the mates of our good male carry it, their chicks will be heterozygous (*bb* × *BB* gives *Bb*). In the next mating (*bb* × *Bb*) 50 per cent of the young stock will already be pure (*bb*) like the pure father, and exactly as in the case of a desirable dominant, the proportion

of individuals who differ from the constitution of the pure-bred males will be halved in every subsequent generation.

In other words, repeated matings of males of high purity, even when starting with quite different poultry stock, will rapidly transform the whole group into a pure-breeding group of the same constitution as that to which those males belonged.

We must now discuss the practical possibilities of all this. The practice of buying males from poultry-breeders of good repute, let us say laying test winners, is quite common. Some of such males give quite satisfactory service, some others disappoint. We can now see why!

When we happen to buy a few males that give us excellent daughters, in the case of utility stock, we have no guarantee that the excellent offspring of those males are good breeding stock to go on with. In fact, the cross within the breed may be successful because the sum total of the genes—those of our own birds plus those of the new males—is excellent (see chapter on First Crosses). Even when we repeat our order for males from the same breeder, the males we obtain may be quite different from the males that did so well, for many breeders believe in eternally " changing the blood " on their farms.

The whole system of improving utility strains of poultry by means of males brought in, stands or falls with the purity and quality of the strain from which the males derive. When a breeder, or when a Government breeding-station succeeds in producing a highly pure, highly productive strain of utility poultry, in which, by good methods of inbreeding combined with group selection, practically all undesirable impurity (genetic variability) has been bred out, improving the flocks of the other breeders or multipliers in that country can be based upon this trade in cockerels. This is one of the reasons why we are using the name " nucleus system of selection " for the well-proved system of group selection we geneticists endeavour to teach the breeders of utility livestock.

Chapter Twenty-seven

Disease Resistance

It is certainly not true that we can classify diseases into infectious diseases, nutritional diseases and hereditary aberrations. There is no quality in living beings, and surely no disease, that is not caused by the combination of a great number of the most diverse factors in development. But, of course, if some of those factors are constant, or if we disregard them, one single cause may stand out as "the" cause of some quality, or of some disease.

The first case in which it was clearly shown how the presence of just one gene can protect animals against a micro-organism that rapidly killed the individuals who lacked that gene was published in 1920 by my wife and myself. This case was found in laboratory mice. Very soon after this *Frateur* (1925) in Leuven found a very similar case in poultry where one gene protected chicks against fowl-pox, and since then very many similar cases have been published by many geneticists.

In none of those cases can it be said that either the infection alone or the genotype alone is responsible for the disease. We must state that in the presence of the infection the birds with one set of genes are more likely to be harmed, whereas in many cases the right food or the right drug administered in time may save even the susceptible chicks.

So much is clear, that there is no reason to think that we have disproved an influence of heredity when it is shown that only infected birds are affected. Even if we know that certain

birds have a hereditary disposition towards any disease, this does not mean that this disposition is equivalent to an unavoidable fate.

On the other hand, it is certainly true that an inherited

Litters of F_2 mice weighed Jan. 4th, 1919	Same litters Feb. 14th	Litters of F_2 mice weighed Jan. 4th, 1919	Same litters Feb. 14th
7	4	1	1
3	2	3	3
6	6	3	3
2	2	6	2
6	6	2	2
5	2	5	4
5	4	4	4
4	3	3	2
2	2	1	1
3	3	3	1
4	3	6	5
5	4	7	6
6	3	3	3
6	4	2	2
3	1	4	0
5	3		
		Total 125	Total 91

Fig. 24 (*a*).—In crossing Japanese mice with European (Mus Wagneri × Mus musculus) in California we obtained fertile hybrids. An epidemic that was diagnosed as caused by a Staphylococcus broke out in the mousery early in 1919 and rapidly killed off all the Japanese. In the above table the numbers of mice in weaned, unmated litters of F_2 animals were compared between two weighing dates (the mice were bred for experiments in weight) approximately six weeks apart. At the last date every susceptible mouse was dead in the mousery. About one fourth of the mice had died. In back-crossing F_1 animals to Japanese a 57 : 25 ratio was observed (same dates).

As far as is known, this is the first case in animals in which immunity resp. susceptibility was clearly shown to be "Mendelian". In plants similar cases were well known in 1919.

(From "Inherited Predisposition for a Bacterial Disease", Hagedoorn and Hagedoorn, *Amer. Nat.* 1920.)

natural immunity to a prevalent disease is of enormous importance, if measures to protect or cure susceptible birds are costly, risky or inefficient. It is very well worth while to breed for disease resistance whenever we can, and epidemics will often show us just what individuals happen to have the genotype which makes them resist.

It seems as if generally, disease resistance is a dominant quality, and this opens up new fields of investigations on the borderland of pathology and theoretical genetics. When we select for high egg production while protecting our birds against infections, it may easily happen that we lose one or more genes that made for disease resistance. One of my correspondents once raised a great number of chicks under one large hover

RR = Homozygous resistant
Rr = Heterozygous resistant
rr = Susceptible

\+ = susceptible
− = resistant

Nature of the mating	Results	
I. *rr* × *rr*	+ + + + + + + + +	−
II. *r* × *RR*		− − − − − − − − − − − − − − − − −
III. *R* × *R*	+ +	− − − − − − − −
IV. *rr* × *R*	+ + + + + + + + + + + + + + + +	− − − − − − − − − − − −
V. *R* × *rr* (?)	+ + +	−
VI. *rr* × *rr*	+ + + + + + + + + +	

FIG. 24 (*b*).—In this table, *Frateur* notes down the result of matings between susceptible and resistant poultry that were inoculated with a hypodermic needle with bacillary diphtheria. The experiments lasted through several generations. We think these are the first results obtained with poultry that proved an inheritability of resistance to bacterial infection.

(From: "Note sur la résistance héréditaire de la volaille à la diphtérie bacillaire", *Annales de médecine vétérinaire*, Bruxelles, 1924, by Léop. J. Frateur.)

—namely, pure-bred Wyandottes, pure-bred Leghorn and a great many first-generation hybrids between those two breeds. From this mixed lot he lost over 40 per cent of his Leghorns and almost exactly as many from amongst his Wyandottes. But less than 2 per cent of his hybrid chicks died. Here the losses were due to B.W.D., and it is probable that healthy chicks hatched out of infected eggs.

In this particular case it would certainly have been possible

to transfer this natural resistance to either of the breeds by repeated back-crosses (see chapter on Adding a Gene).

In fowl paralysis it has been shown that selection is the best method to fight the trouble. The same is true in the case of prolapsus in laying-hens (*Sykes*) and tumours (*Coles*). And of course the best way to fight such troubles is to incorporate selection against them in the normal group-selection scheme. When we take hen-housed production as our basis for the selection of daughter groups, while taking account of chick mortality, etc., we cannot go far wrong, as we are automatically selecting against every genotypical inferiority that allows the birth of weak or susceptible birds.

This, I think, is the place to repeat my warning against too much analysis. No matter how important any factor in profit, we should never go all out for this, while neglecting others. We should not lose sight of the forest while avoiding any particular tree.

Disease resistance as such is not really worth much! We do not want disease-resistant fowls: we want *profitable* fowls, and disease resistance is worth while only as a factor in profit. It would be very easy to produce a family of chickens naturally immune to B.W.D. or paralysis or fowl-pox, in which the birds would not be worth their food. On the other hand, it would be quite possible and effective to breed resistance to some prevalent disease into a highly inbred and excellent strain by means of a cross and repeated back-crosses, if this were necessary.

Very special cases are those in which, in a series of generations, something is passed from the mother to the offspring, not through the cell nucleus, but in some other way. In plants and animals several instances of this are known; in mice the case of cancer is the best known example; in poultry it seems as if some tumours fall into the same class.

In such instances very peculiar data are found, and although males may show the abnormality, they do not transmit it to their offspring, or only in a very indirect way, when the disease is due to a combination of a genetically determined susceptibility plus some substance transmitted through the egg only. (A virus or another cytoplasmic constituent or even a micro-organism!)

Chapter Twenty-eight

Double Matings

As every cock has two sex chromosomes and every hen only one (see chapter on Sex-linked Crosses, etc.), males have twice as much of every gene present on this chromosome as hens. The result is that where the dominance is not complete, males must differ from females—for instance, in feather shape, in leg colour, but especially in markings and colours of the plumage.

Now, show standards are made by fanciers and judges, and they are generally constructed and put down on paper as descriptions of ideally beautiful birds. But, even so, those standards and descriptions are quite arbitrary, and it is certainly not true that the ideal cock and the ideal hen " belong " together or, in other words, that it would always be possible to breed a strain of birds in which the males would be like standard males, while the hens would have the colour of the ideal standard females.

Sometimes there are two different colour standards for one and the same breed in different countries. The Barnevelder hen is required to have every red feather doubly laced with black, both in the German and the Dutch show standard. In Holland the shows ask for very dark Partridge males, whereas at the German shows the males must be almost black with a red triangle in the wing. It so happens that this is the colour of males that " goes " with the show Barnevelder hen, so that the German breeders can breed their Barnevelders in normal

single breeding-pens (the same colours are seen in Indian Game). The show-breeders in Holland who want double-laced hens must use almost black cocks with red in the wing to get these; if they want to exhibit males, the show-hens are no earthly use to them—such hens are more like Gold Wyandottes in colour.

If anyone asks how it was possible for the judges in Holland to make such a standard, the answer is that this was an enormously variable local breed evolving from complicated hybrids when the standard was made, and both cocks and hens still varied from yellowish through partridge to black, and anyone could choose whatever colour or type he liked best. In fact, the most successful exhibitors and exporters found it much more expedient to buy their winning birds from among the farmer's flocks than to try breeding them. At present the show standard forces the breeders to double matings, and those not in the know find the breed hopelessly difficult as a show-bird.

Another example is that of the yellow-legged black breeds, such as the Black Leghorn, Black Wyandotte and Black Barnevelder. It is quite impossible to stabilise a pure strain in which the hens have clear yellow legs and glossy black plumage, at the same time as the cocks.

In breeds with feathers marked with black on a silver or golden background, such as Paduas and Silver or Gold Wyandottes, the males tend to be several degrees less heavily marked than the hens. To breed well-marked males one needs the sort of hens that belong to a cock-breeding strain, hens that are much too black for exhibition, and the cocks of hen-breeding pens are far and away too white (resp. red) for show purposes. In fact, if anyone should buy a prize-winning trio of silver Wyandottes at a show and would then breed from those, he would, in fact, hybridise two breeds, and if he went on trying to breed show-birds, he would be very lucky indeed if he produced an occasional well-marked male or female.

This case of double-pen matings for show-birds looks much more difficult than it is. If we once accept the necessity, which is forced upon the fanciers by arbitrarily made standards, it is not really difficult to use the system. It only *looks* difficult and complicated if we try to fix an ideal picture of just how

a cock-breeding hen or a correct male for a hen-breeding strain ought to look!

Several times I have solved such a problem for poultry-fanciers. The solution of the difficulty is to stop entirely bothering about the looks of the cock-breeding hens, or hen-breeding males! The only feasible way to breed a cock-breeding strain is to select the males for beauty and conformation to the point fashion dictates, and breed them to a number of closely related hens, sisters and daughters. If the breeder can trap-nest or recognise the eggs his hens lay, he will find which hen gives him the best males, and he will then give preference to this hen for breeding, mating her to a very good, closely related male. The criterion of quality in a hen must be that she has the same constitution as the best exhibition male and the way to obtain this is *inbreeding to correct males and disregarding colour and markings.*

Exactly the same is true for hen-breeding pens. The best cock is the father or the brother or son of a series of prize-winning females, and the more we disregard any pre-conceived notions of how such a male should *look*, the quicker this matter will arrange itself to everybody's satisfaction. If a fancier has room for a number of breeding-pens, each headed by a prize-winning male, and composed of the daughters and sisters of such males he will soon find out which pen gives him the best cockerels, so that he can concentrate on the progeny of that pen (see chapter on Progeny Testing).

When a set of standards of perfection in any breed is so constructed that the inherited set-up of the show-males does not correspond with that of the exhibition hens, this almost automatically destroys the breed as a utility breed. No matter how profitable Barnevelders or Black Leghorns or Silver Wyandottes or Welsummers in some strains happen to be, so long as the breeders seek to conform to the dictates of the shows, so that they will use males that must be genetically different from the hens, such breeds will always look like a lot of mongrels, unless the owners consent to cull out more than half of their birds on appearance alone.

This produces a prejudice against such breeds as commercial breeds, and makes solid-coloured white breeds (Leghorns, Wyandottes, recessive White Barnevelders, White Rocks) or

solid coloured Red (Rhode Island Reds) or slate-legged black breeds (Australorp) so popular as commercial fowls.

In the commercial hybrids, such as Black Leghorn × Rhode Island Red, it does not matter that the groups look like variable mongrels, but even here the enormous variation in appearance between such groups and the uniform appearance of hybrids in which both parent breeds have a " natural " standard is very striking.

We are glad to say that the hobby of breeding good-looking fancy chickens for the shows is becoming more and more divorced from the business of breeding profitable poultry. The influence of show standards on the breeding of *utility breeds* is nothing short of deplorable, and of course the fanciers realise that breeding their fancy breeds for utilitarian purposes often detracts from the beauty and purity of their show-breeds.

The breeding of fancy poultry or fancy pigeons is, or should be, *a pure and very interesting hobby*. Any considerations of utility, making some bantams bigger so that they can lay a few more eggs, should only be regarded as feeble attempts to justify the keeping of fancy chickens in the eyes of the fancier's wife or his neighbours!

In countries where only one or two breeds of poultry are kept commercially, as for instance in Australia, the agricultural authorities should seriously consider helping the good breeders of first-class birds by barring those two breeds from show competitions, leaving the fanciers only the other fifty-seven fancy breeds to compete with.

As we have said elsewhere, " utility " classes at poultry shows are not only a complete farce, but they hinder the work of the serious breeders of profitable poultry. If, in some countries, such classes cannot be abolished at one stroke, a step in the right direction would be to confine such classes to females, and stop the ridiculous practice of guessing at the quality of a cockerel as a breeder of profitable hens by his appearance! If we could abolish the attempt to make the males of our best commercial strains of egg-producing poultry look like show-birds, we could at least breed our coloured utility breeds into some semblance of visible uniformity, and remove the handicap under which they now compete with uniformly coloured breeds.

Chapter Twenty-nine

Management : Food and Feeding

POULTRY *eat* to grow and to produce eggs. In the chapter on Adaptation I discuss how the cheapest eggs are laid by ducks and chickens that find their own food. Even when great numbers of birds are kept together, so that they compete for lost grain or insects, such birds may still pick up sufficient of some material of which only minute quantities are needed for efficient growth or production. When we have to supply everything, as in battery-birds, it becomes necessary to give much thought to the composition of the mash.

The composition of mashes is a subject which appears to fall outside the scope of the present part. But chickens vary almost as much as mashes, and one ideal standard complete food for poultry could never be devised. The ideal mash from the point of view of the poultry-man is the one that allows him the best profit *when counting everything*—hatchability, chick growth, chick and pullet mortality and the income from eggs or carcases. The ideal mash from the point of view of the food trade is the one that can be compounded from the cheapest possible materials and sold at the highest price the poultry-men can pay without losing money and going out of business.

In times of chronic food shortage, pigs and poultry have to compete for cereal wastes from which everything saleable to humans has been extracted, and slaughter-house and fish-packing wastes from which the pharmaceutical laboratories

have extracted all they can sell. After the wheat-germs have been removed, before the grain is ground up for flour, the poultry get most of the bran, while some of the high-priced wheat-germ oil is bought to add to chick-rearing mashes and breeding-pen mashes to ensure good growth and fertility. We pay more for maize-meal, ground maize (corn) that is ground up after the oil-bearing germ has been removed, than for the entire grain. Minerals and vitamin-rich extracts are manufactured and sold to poultry-breeders.

It is practically impossible for poultry-keepers to mix their own food-rations from such ingredients as highly extracted bran, soybean-cake meal and extracted liver-meal, without adding so many things that the food becomes as expensive as the highly advertised proprietary mixtures. On the other hand, we sometimes find highly specialised egg-producing centres where the rations of the ducks or hens are made up entirely from non-processed raw material, such as raw, entire or ground cheap fish and whole yellow maize in the case of ducks before the war, in Tonsel, whole barley and ground whole horses in Petaluma. The war years have shown the possibility of utilising steamed potatoes to a surprising extent. And where wheat or sorghum is available for animal food, as in Australia, soaked whole-grain fed with tankage and chopped green constitutes an economical high-grade diet. With a little ingenuity enterprising poultry-farmers can often make efficient use of locally obtainable raw materials.

Before the era of proprietary mashes, poultry on the farms fed on grain and what they could pick up as scavengers—insects, maggots—what they could steal of the pig-food or could find on the manure-heap. When it becomes necessary or desirable to keep poultry intensively we must bring them everything they require, and this diet must differ according to whether they can still graze, as in folds, whether they can still fill some of their food requirements from deep litter, or are kept on wire.

Evidently, at least in theory, we could make the feeding of poultry more efficient in two ways: by adapting the diet to the birds, or by adapting the birds to the diet. And if both ways are feasible, the best results will, just as with other domestic

animals, be obtained when we can work from both sides simultaneously.

In many countries the same controversy goes on in the poultry journals, whether we should or should not limit the amount of food given to our ducks or hens. When we are dealing with foraging ducks or turkeys or hens, judicious underfeeding becomes economical where this induces the birds to supplement their diet with food they can hunt up. In intensively kept birds this is a different matter, and the question then becomes whether or not the birds use up more food than they require for maintenance and production. When we note that nowadays battery hens eat much greater quantities of mash on an all-mash ration than they did ten years ago, it simply shows that with a rise in price of such mashes their quality as chicken-food has gone down. This need not mean that the reliable firms make use of such good-looking fillers as maize-cob meal, ground peanut hulls, rice hulls, but simply that the food-refining processes are more efficient and leave less and less of value in the residues available for poultry.

Most poultry-men, when they see the price of food go up, think only in terms of better egg-prices that will leave them a sufficient margin of profit. Very few of them consider the possibility that there may be an inherited difference between breeds or between strains within breeds that make them more or less efficient in the *use* of the food furnished.

In the case of pigs, most countries are now following the Danish example and have established pig-testing stations in which the efficiency of young pigs in utilising food to build up the desired type of carcase is measured and compared. Large differences in the amount of a standard ration fed, necessary for the same increase in weight, have been found. And the Danish cow-testing stations, where groups of daughters of one bull are compared as to their economical transformation of food into milk, are proving to be of very great value in the improvement of dairy-cattle.

In poultry, differences in food requirements between breeds are striking. In the first place qualitatively: if we compare Malines (or North Holland blues) to Leghorns, in their vitamin requirements, we find that Leghorn chicks become

rickety on a diet that gives no trouble in the heavier breed adapted to being raised for poussins in winter in crofters' cottages. Anyone who knows how the wild species of chickens resemble the more delicate pheasants and quails in the diet required to raise their chicks, understands that in respect of their food requirements our present domestic chickens have already been adapted to our modern simpler diets.

My attention was first drawn to the fact that some kinds of poultry are better than others in the way they utilise the food put at their disposal when Mr. *Janssen*, of the Weert poultry experiment station, showed me that in some of his poultry cabins the same number of laying hens produced almost twice the quantity of droppings as those in others. Such differences might be caused by excessive eating of indigestible material, such as sand or litter, or by an excessive food consumption due to sheer greediness or to the circumstance that some hens required more of a certain ingredient in short supply in the food than other hens and made this up by a higher gross consumption of bulk.

When we feed hens with a high-protein mash *ad lib* plus one feed of grain, we find that their consumption of mash is correlated to their production. The hens instinctively regulate their diet according to their needs if we give them this opportunity. This makes it very probable that the greedy hens that consume large quantities of a standard pellet do so because their particular genotype forces them to take up more mash to make up their requirement of an ingredient in minimum supply in that particular standard mash.

Once I induced the authorities organising a laying test in Germany to measure food consumption as well as egg production on a standard mash, and just before the second war the Dutch Genetical Society again organised a laying test at Nymegen with pure breeds and hybrids, with the same object. In both cases it was found that even within one breed some pens would consume up to six shillings worth of food per hen per year more than other pens, for the same number and weight of eggs produced in the same months.

Recently the B.O.C.M. laying trials at Stoke Mandeville with hens in batteries gave similar results.

It will be highly desirable to test experimentally whether such strains or hybrid combinations that tend to eat excessively on a standard diet will eat great quantities of any diet, or whether they are simply birds that need more of some ingredient in short supply in the standard diet.

In other words, it will be necessary to adapt the diet to the breed, and this is especially necessary when we are working in a country where the supply of poultry-food is very limited, not where we can grow our own wheat or sorghum and buy old donkeys for a song, as in Rhodesia. A cafetaria system of supplying the food ingredients in separate portions will soon show us what composition of mash the hens themselves will choose, and we can then test out such mixtures, for we need not assume those hens to be more efficient than our food experts!

On the other hand, it will in any case be very much worth while to take food consumption into consideration while selecting our poultry. This could be done in batteries (provided we are selecting and improving our hens for use in batteries). One of the reasons why we have not been able to convince breeders that economical food consumption should be given as much attention as egg production, evidently arose fom the practical impossibility of registering individual food consumption with hens in groups, such as is possible for egg production.

As I discussed in the chapters on Individual Selection and on the Nucleus Scheme of Selection, a very efficient system of breed improvement and purification is worked with *groups* of hens (daughter groups), and just as we can base our selection of good production and low mortality, etc., on a comparison of groups, without data on individuals, we can do the same in regard to efficient food consumption.

So long as the chick-buying public are not interested in what their hens consume, provided they lay many eggs, we cannot very well blame the breeders for neglecting this extremely interesting point, as this would only add to their troubles.

It is evidently up to the scientists interested in poultry production to take food consumption into the sphere of their

interest, and the Seven Hills poultry experiment station in New South Wales has set the example as far as the breeders are concerned. I venture to think it would be wise to give this matter their early attention, to avoid fixing inefficient food utilisation into their high-producing very pure strains.

Chapter Thirty

Who Should Breed Poultry ?

MANY tens of thousands of people breed chickens—in fact, even when it is so easy to buy a box of chicks from a hatchery almost everybody who owns poultry occasionally breeds some. Often some hen takes the initiative. It is fascinating to watch the transformation of a few eggs saved from the breakfast table into promising little chicks.

The poultry fancy is an excellent hobby, and almost anybody with a back yard or a balcony can indulge in it. Even serious breeding work for the shows can be done with very little space, as I have explained elsewhere.

But in the breeding of utility poultry, things are quite different. The high variability in quality in most breeds, which results from the usual cross-breeding—the use of " fresh blood "—makes breeding poultry synonymous with selection for better quality. A result of this state of things is that almost everybody who keeps a lot of utility poultry wants to breed his own, thinking he can easily do as well as the breeders and hatcheries.

A division of labour in the poultry-breeding industry, in which relatively few people are breeders, others are multipliers who obtain their breeding-stock from the breeders and supply it to the hatcheries, is basically sound, although it can easily be made into a nightmare if the thing is over-organised and smothered in red tape.

In all polygamous animals, in cattle with A.I. and in poultry

in normal breeding, all we need to do to produce excellent stock is to buy a male of very high quality and purity, and a succession of such males will make our stock as good as that which furnished those males. It has been proved in practice that just one breeder can improve the quality of all the birds in a large district with great ease. The duck-egg district of Tonsel and Harderwyk in Holland is an excellent example of this.

I suppose that in no branch of agriculture nowadays can we escape Government control, and, as we have explained elsewhere, the laying-tests apparatus would be ample in almost every country to use as a testing ground for samples that would prove or disprove the excellent quality and purity of the stock in the hands of the foremost breeders.

When inadequate methods of selection and purification were universal, it was quite common to see that a well-known breeder was " unlucky " one season. Unless in the case of an epidemic, this need no longer happen, and if we need certification, such Government certificates could best be based on rule-of-thumb proofs obtained from sampling tests.

There seems no reason to restrict the number of first-class breeders, and some competition will keep the best men on their toes. On the other hand, it is true of poultry as much as of potatoes or wheat that when once very high quality is reached, purity and good quality can be kept up without any real selection at all. When once the potential variability of a strain of poultry or ducks is reduced to almost nothing, we only need to stop any chances of our neighbour's males to intrude upon our premises to keep the quality at the high level reached. Mutation—spontaneous change of genotype—would then be the only cause of loss of quality, and mutation is definitely a rare phenomenon. To guard against the results of either mutation or accidental crossing, any system in which one breeder continues the strain and keeps up group selection and inbreeding will be ideal, for such a breeder will then continue to furnish high-grade pure males to the multipliers. Several private breeders and experiment stations now own very pure, very high-quality inbred strains (*Greenwood*).

Chapter Thirty-one

Poultry Registration Schemes

THE advantage of registration schemes, poultry herdbooks, and co-operative breeding schemes under official guidance is, I venture to think, problematical, to say the least.

In the first place, we must remember that the preoccupation of animal-breeders with pedigree is firmly rooted in the erroneous idea that the ancestors of an animal somehow transmit their very good qualities to their offspring. Our ideas about inheritance and about the relation between the genes and the final qualities have changed as a result of experimental genetics. In so far as the good qualities of an individual are due to its genotype, to the set of genes it inherited, this genotype is a result of chance combinations of the germ-cells produced by its father and mother, one germ-cell from each, and ancestors farther removed have only a very indirect influence, in that they and their germ-cells were responsible for the genotype of an animal's parents.

The quality of an individual as a breeder, as a parent of children, does not depend on its quality as an individual; it only depends on the sort of germ-cells its hereditary constitution makes it produce. If we look up a very complete pedigree of a Friesian bull or of a Wyandotte hen, we shall never find other than black-and-white cattle or rose-combed poultry among the ancestors, even many generations back, and yet the animal we are interested in may prove impure, and will give us dun and white calves or single-combed chicks. A pedigree in

which only good individuals are registered is very incomplete. If we ignore the culls, we also ignore the impurity of the ancestors whose impurity made them produce those culls. Dominance hides genetic impurity. And high individual merit may be due to "nicking", to fortunate combinations of genes, introduced from parents that were heterozygous for many genes. If pedigree were of great importance, full brothers would be alike. We shall never forget our friend *Boutflour* telling us at one of his lectures that his brother is a tall and silent man!

If a breeder succeeds, by a combination of good breeding methods and good luck, in producing a group of excellent sheep or hens, so pure that they give him no more disappointing young ones, it will be instructive to follow back the data obtained in the preceding generations, especially the record of production, the percentage of culls, etc., and the disappointing sidelines. The good individuals at the end of the pedigree are good because they have the right genotype, and because they are homozygous for a set of genes that fit together.

Another owner who has also been inbreeding and purifying his breeding stock while he has been registering his stock may also have very excellent and highly homozygous beasts. But we know there is no good reason to assume that both breeders have stock of *the same* genotype. If Mr. *A* should buy a few cockerels from Mr. *B* "for a change of blood", he may breed excellent hybrids, but if he wants to breed from those, he finds that he has thrown away the purity he has obtained with so much trouble. In other words, even within pure pedigree stock, cross-breeding, with its attendant mongrelisation, can and does go on.

If we are out to buy excellent foundation stock, we must go to the man who owns the very best highly inbred strains, and if we can induce him to sell some of his high-producing inbreds, we can very well pay him ten times as much for them as for his cross-mated commercial stock, that under any of the existing registration schemes would be sold with the same guarantee of high-grade pedigree.

The point, of course, is that nothing can really take the place of personal reputation of integrity in the trade in breeding-stock.

Most R.O.P. schemes are founded upon the (erroneous)

idea that high individual quality in a pedigree hen is a fair indication of her quality as a breeder, and for this reason trap-nesting and trap-nest records are so often insisted upon. In so far as progeny-testing results are insisted upon, such data have only a very restricted value. A progeny-tested male whose daughters were all first class is worth buying as such, provided the progeny test was not a "nicking test". *Progeny testing hens is mostly a farce.*

Even if progeny testing (combined with inbreeding) is quite necessary to purify good strains in the hands of a capable man, it is not true, of course, that it helps if we force breeders into trap-nesting, or into progeny testing. If an excellent breeder uses square drinking-bowls, it will not, for this reason, be a step in the right direction if we force all breeders to use drinking-vessels of that shape. In the Dutch scheme the breeders must keep trap-nest records, and all birds are wing-marked. Chicks are sold to multipliers—after being marked with fixed wing-tabs—and cockerels from individual mothers are added. The multipliers supply the hatcheries, and every step, every bird, every wing-tab is numbered and registered and tabulated, the wing-tabs going back to the Government bureau. In all such schemes *the Government bureau and the inspectors* really do the breeding. The result is that the quality of the work is reduced to the quality of the work of the least efficient poultrymen admitted and licensed, while the managers and inspectors of such schemes are generally very conservative, and great believers in what they were taught in their youth.

When a maximum price as well as a minimum one are fixed for eggs and chicks and adult breeding-stock, all incentive to first-class work disappears.

If we *must* have control of the poultry industry by a paternal Government and I believe, with *Burnham*, that things have gone too far in this *managerial revolution* to hope for any return to individual freedom and enterprise—let us have control of the quality of the final product of the poultry industry, the chicks delivered to the trade, by a system of *sampling tests* comparable to that in the control of agricultural seeds, and let us try to leave our breeders the choice between old-fashioned and modern breeding methods.

Chapter Thirty-two

Technical Aids, Artificial Insemination, etc.

In almost every case the normal breeding-pen of one male and up to a dozen females will suffice in breeding poultry. There are certain cases, however, in which it is preferable to use a different system of mating.

If, for any reason—let us say for experimental purposes—a very great number of different matings should be necessary, a multitude of small pens is not always the most economical or practical system. Miss *Heringa* and I once worked out a system of hand-mating poultry, and we found that by means of this system it was possible to have the double advantage of handy management and of breeding enormous numbers of chicks from certain cocks. The system works as follows:

We cage up our males in separate cages in a row, and these males will remain in excellent breeding condition even in roomy battery cages, provided the diet is adequate (green food and yeast) and the birds can see and hear each other. We can now house the hens in large groups in semi-intensive houses, and trap-nest them. We use the ordinary system of calendar laying lists to record the eggs, with this addition: that we use a coloured pencil to record matings. The trapped hen is not released before we have seen on the list when she was last mated. Only when the last mating happened more than eight or ten days ago, is the hen again mated to her special mate. She is brought to the cage of her male and hand-mated, being held for the male. In Soesterberg we

found that it took only a very few days to train the males to tread a hen that was being held. We found that one mating in ten days was ample—in fact, we obtained much better fertility from a largish number of hens by this system of hand-mating than from mating the hens in a pen, as some hens avoid the male.

This system of hand-mating makes it possible to get excellent fertility from a very large number of hens mated to one male—up to 150 hens—and it seems possible this number can be greatly exceeded.

Artificial insemination in poultry was successfully used by me in 1906 to cross-breed Leghorns and Game bantams reciprocally, the male in one experiment being killed to obtain the sperm. Sperm can easily be recovered from the cloaca of a hen after natural service, and our American colleagues developed a technique of collecting the sperm in a small paraffinated glass funnel by stroking the sperm-ducts of the male. No metal must be used.

The sperm can, if necessary, be diluted with a mixture of Ringer's solution and egg-yolk. To inject the sperm into a hen, she is held head downwards, and the cloaca is gently everted slightly when the mouth of the oviduct becomes visible at the left side. A small drop of sperm can then be inserted with an ordinary medicine dropper.

When diluted sperm is used, two collections daily will give us enough sperm to fertilise all the hens of a large pen that happen to lay on that particular day. This method can be used when it becomes desirable to mate two or three hundred hens to one male.

At the Swedish Wiad experiment station under *Bonnier* a system of artificially inseminating groups of hens with a mixture of sperm of several males was worked out. The object of this procedure was to ensure that the quality of the progeny of a large group of poultry would not change when the selection was stopped after a certain average quality was reached. This is the reverse of purifying a strain of poultry by means of a combination of group selection and inbreeding, and the object is reached by counteracting the reduction of the potential variability (and thus risking a different quality) as a result of

isolation. The system could be worked where it is desired to retain the quality of selected groups during multiplication, long before purity is obtained.

This is a suitable point to discuss the old questions whether breeding from hens will be better than breeding from pullets, and whether the breeding males should be well grown and mature before they are used for breeding.

These questions treat of very complicated matters. When a strain of poultry is very variable, it is quite possible that high pullet mortality is due to the circumstance that many birds die young because their hereditary constitution is insufficiently good to enable them to stand the strain of normal good production. In such impure lots it is quite possible that the sixty second-year hens, taken as a group, are genetically better than the hundred pullets in the original flock from which the sixty are the survivors. This does not mean that those sixty hens will give better chicks than the same sixty birds when they were a year younger. This last idea is, indeed, highly improbable; the hatcheries always prefer pullet eggs, and certainly not only because they can stuff more of those smaller eggs into their incubators, but also because they obtain better hatches.

There is some relation between the size of the egg and the size of the embryo; in reciprocal crosses between large poultry and small bantams, the hybrids hatched from the bantam eggs will hatch much more easily than the reciprocal hybrids born from the large eggs. Also the excessively large eggs of some breeds (Welsummer) have a bad reputation with the hatcheries.

It appears that the better hatching of eggs from hens that had a rest is *entirely a matter of diet*. Eggs at the end of a long laying season from hens that have been adequately fed (liver, yeast, green) will hatch as well as the first eggs from the same mother.

In highly inbred purified strains, in which the vigour and hatchability have been raised by adequate methods, there is no reason to prefer breeding from hens rather than from pullets. And of course breeding from pullets will considerably speed up the amelioration and purification of the strain, as it will allow us to have one generation per year instead of one

in two years. Unless we "put all our eggs in one basket" and gamble on just one pen in our nucleus-breeding work, the risk we take in choosing our best lot after just one winter's production is entirely justified.

The fear that an immature male may have less viable offspring than the same animal when fully mature is surely a survival of the old idea that somehow the personal qualities of an individual are passed on to the offspring. There is no reason whatever to think that an animal's genetic constitution changes with age, or that in the case of a male anything is transmitted to the offspring except only the genes in the sperm nuclei. In the case of the hen, of course, the mother furnishes not only the germ, but also the yolk, with all the nutrients needed for the embryo during pre-natal life; but nothing like this occurs in the males.

The story that young males, or adult or old males should have more male or more female offspring is pure nonsense. The sex of the embryo is determined by the genotypic constitution of the egg, not by the sperm.

The sperm remains viable and able to fertilise eggs for a considerable time. Hens will lay fertile eggs for two weeks, and often longer, after the last mating, although it is well to have a mating or insemination every week or ten days to ensure good fertility. Curiously enough, this does not mean that for a long time after re-mating the hen will lay eggs fertilised by her first mate. Our own results confirm American and Swedish observations that a new male in a breeding-pen will be the father of all the chicks from the second day. Although the older sperm can still fertilise the eggs, the older spermatozoa cannot compete with fresher ones. When after a new mating the hen is again isolated from the males, she will, after a few days, lay eggs of which some are fertilised by one and some by another male (*Wiad*).

Chapter Thirty-three

The Laying Tests

LAYING tests for poultry were originally intended to give an objective answer to the question, which poultry breeds were the most profitable. Very soon, especially at Hawksbury, New South Wales—birthplace of the laying test—the tests became competitions between rival breeding establishments.

There have been bitter controversies about laying tests and laying-test methods, and breeders, poultry-men, agricultural authorities and scientists have all contributed to those discussions.

The fact is that the laying tests serve, and can serve, wholly different purposes.

In the first place, the laying tests are competitions between poultry-men and breeders. The object of the laying tests, viewed from the standpoint of the competing breeders, is to provide a shop window for the poultry-breeding industry, Tests of this kind tend to be run by the breeders and for the breeders. The competitors are out to win the tests, and the regulations are drawn up in a way to suit the chick-selling farms and hatcheries. England and the U.S.A. are typical homes of this sort of tests. Very often the rules and regulations are such that the scores made are somewhat flattered, as when the rules allow a competitor to withdraw his pens, or when a reserve hen is carried whose score will take the place of that of a hen dying during the test.

A typical feature of this sort of laying test is the use of trap-nests or (in the hot countries) separate pens for individual hens. Often some provision is made to register the record of individual hens, such as special leg-bands to be awarded to individual high-scoring hens. This regulation is generally based on the idea that hens that score very high in the tests are of great value to the breed as superior breeding-stock, an idea founded upon the supposition that the best individuals must necessarily be the best breeding-stock.

A typical symptom of the thoughts behind this sort of laying test is that the rules seldom stipulate anything concerning the origin of the groups with which the breeders compete. A few years before the war some of the well-known British laying-test competitors openly offered laying-test pens for sale to other breeders, in the same spirit in which promising yearling race-horses are offered for sale.

Most of the controversies about laying-test reform were started by agronomists and scientists, who pointed out that laying tests should have quite another use than just showing which poultry-owner knew how to win the tests.

The fact is that there are *two* parties interested in the results of the tests. There are the breeders and hatcheries, who want to show what they can do in the way of producing small groups of very profitable hens, but there is also the chick-buying public. The farmers and poultry-keepers who are interested in buying profitable poultry, mostly as chicks, are interested in finding out which quality they are likely to obtain if they patronise one hatchery rather than the other.

And here lies one enormous difficulty. The old-fashioned laying tests as they were organised by and for the breeding industry, give no answer to this important question, simply because such laying tests are *by no means sampling tests.*

Sampling tests run under the auspices of the agricultural and horticultural authorities to sample the quality of new varieties of plants, or of selections of sugar-beet seed from different firms, are quite commonly accepted as a safeguard of the farming community in many different countries. Of course, wherever such tests are conducted at official agricultural experiment stations, the officials running the tests are

responsible for drawing the samples from the product as it is sent out to the customers. There is no possible chance that a seed firm is allowed to send some specially selected white clover seed or seed of some super-elite sugar-beet selection to compete in the tests. Of course not. Such tests are conducted in the interest of the farmer seed-users, the results of the tests are published, and the published facts give an objective picture of the quality.

After some unpleasant controversies in the agricultural Press in Holland, a committee under the presidency of the Director of Agriculture, composed of poultry-breeders, authorities and a geneticist, after ample discussions, devised a poultry sampling test, to be run as a laying test. The test was conducted as follows. An official inspector visited the breeder's farm, and after a round with the owner, in which all nests and trap-nests were emptied, stayed alone in the establishment, gathering eggs as they were laid from all over the place, until he had collected a hundred. This sample of a hundred hatching eggs was then hatched at a central experiment station, the chicks wing-banded and raised in bulk. In the autumn a pen of healthy pullets, chosen in the presence of the owner of the farm whose product was sampled, was caged up. From that moment the pens were treated as ordinary laying-test pens at the Government poultry experiment station, and it was the intention of the authorities to publish all the data—hatchability, chick mortality, pullet mortality and the average egg production—of each sample of hens.

The results of this test were so damaging to the reputation of a few well-known laying-test competitors, that publication was suppressed, to the chagrin of all those breeders whose results corroborated their normal laying-test figures. This whole affair, however, had one very curious and unforeseen result. It effectively killed all interest of the chick-buying public in Holland in ordinary laying tests, and except in very small local affairs, laying tests in that country are now a thing of the past.

Official laying tests should, of course, always be run as sampling tests. Trap-nests are quite superfluous, as the object is simply to find what is the average quality of the sample.

And of course there is no real reason to return those samples of a breeders' hens to him at the end of the test. Either such groups of hens are really samples of what the breeder has, such as is implied in the test—in which case he can easily spare those ten pullets—or they are valuable breeding-stock—in which case the sample is a fraudulent one.

There is a very good reason for destroying the samples of hens at the end of a laying test, just as the samples of beet or maize at the experiment station; there is ample evidence that laying tests, where dozens or hundreds of groups from all over the country are managed in one establishment, are veritable exchanges of every devitalising non-fatal parasite virus and micro-organism present in the breeding farms.

Now, all this does not of course mean that there should not be a great many poultry-breeders in every country who honestly send just any six or any ten healthy pullets of the right age to the tests.

Many of them undoubtedly do. But the trick to win laying tests is to try out a great number of small breeding-pens, and trap-nest the resulting pullets. Then, when any of those combinations happens to give you exceptionally persistent layers, to repeat the same mating next year, moving the pullets to new surroundings frequently. The few of those who are not put off laying when they have just started are the ones to send to the tests. Buying such specially bred flocks from a specialist is frowned upon nowadays.

Does Disease Follow the Pen at the Laying Trials ?

The rising mortality among the pullets at the classical laying tests in many different countries, laying tests in which groups of pullets of half a dozen or so are kept in cabins and trap-nested, is alarming. It could, and often is, explained by assuming that a one-sided selection of poultry for high production would bring up production, but would weaken the strains. Some other authors, on the contrary, contend that the ordinary system of breeding from the best layers is so inefficient that this is not very likely. It seems very probable that an alternative explanation is more likely to be true—namely that the high mortality is directly due to an infection of the cabins

(respectively compartments) and the runs by germs, coccidia, worm-eggs or similar things.

Does disease follow the pen? This question was asked of an officially installed special committee in England around the middle 'thirties. Perhaps an article in *Feathered World* 1935 (Hagedoorn: " How I Would Reform Your Laying Tests ") had something to do with this.

In *Chanticleer*, Vol. X, January 30th, 1936, Mr. *Frank Hood* gave some data that seem very significant. They show the mortality figures at a newly established English laying test with a very low mortality: the Southern Laying Test in Surrey. Let me give the facts first, and later comment on them.

The Surrey laying test was started in the autumn of 1930 with forty-eight groups of six pullets each, and every group was given a new cabin and 144 square yards of new pasture. At the end of every test season the cabins were thoroughly cleaned and made ready for the next lot and the sward was given a good overhaul. In the autumn of 1931 the test was enlarged, and thirty-four additional cabins were built on new grass.

Now we must keep several things in mind. The incoming pullet groups were distributed at random over the pens, not pens of one owner following each other in the same pen. And the fact that two sets of pens were started in two succeeding years makes the results to which I want to draw attention more striking.

For now we can compare the mortality during the second year of this test in the two groups of pens—namely in pens that had no deaths during the first year, and in pens in which during the first year of occupation one or more pullets died.

If we do this we find the following mortality figures:

Every year the test took eighty-two pens of six pullets each, 492 in all. During the second year of occupation we find in the pens in which no deaths occurred during the previous year a mortality of eighteen out of 276 pullets (18: 276 is 6·52 per cent).

In the pens, however, in which at least one pullet died during the previous year, twenty-seven died out of 216 (27 : 216 is 12·50 per cent).

Or if we split those results into what happened in the pens

started in 1930 and what happened in the pens that were new in 1931 we find:

Where there were no deaths, 8 from 120 (6·66 per cent) and 10 : 145 (6·41 per cent). Where there were deaths, 16 : 132 (12·12 per cent) and 11 : 84 (13·09 per cent). In other words, during the second year of occupation of the fresh runs and new houses at this test, occupied by very many different groups from over sixty owners, distributed at random, the mortality was about twice as high in those pens where there had been at least one dead pullet the previous season than in the pens with a clean mortality record during the previous year.

What is the moral of this story?

It is very simple—namely that *disease really follows the pen.* But this makes this kind of laying test—and I repeat, this was a very well-managed test—a real menace! Laying tests are supposed to be shop-windows, where the competing breeders show what their birds can do. All right. Now, either the groups of pullets really show what kind of birds the breeder sells as chicks—*they are samples—or they are not,* when his prospective customers are fooled.

At the end of such laying tests the pullets should be destroyed, and not sent back to spread infections all over the poultry-keeping and poultry-breeding world. It is only a simple matter of good sense and hygiene!

Chapter Thirty-four

Breeding Fancy Poultry for the Shows

THE poultry fancy is a hobby that tens of thousands of amateurs indulge in. There is just as much satisfaction to the really devoted fancier in defeating his competitors at a good show with a really first-class home-bred bantam hen under a judge he respects, as there is in winning a race with a home-bred horse, and as a thousand times as many sportsmen can afford to breed some chickens compared to race-horses, the poultry fancy is of much greater national importance than horse-racing.

For the same reason, a consultant geneticist meets a great many more keen and intelligent poultry-fanciers than he meets horse-breeders with a similar claim to sportsmanship and intelligence.

Success in the breeding of fancy poultry for the shows depends on three wholly different things that seem of approximately equal importance:

A. *Producing the birds* with the right combination of genes, breeding.

B. *Preparing the birds* for the shows, raising them, training, washing, conditioning and packing.

C. Knowledge of the standards, and the trend of the fashion; ability to pick your shows and the judges officiating; knowledge of the way the different judges interpret the standards and their pet likes and aversions.

This book does not pretend to do more than to give the breeders some useful hints about breeding methods. At the same time we must not ignore the fact that in breeding fancy poultry for the shows, the standards and goals towards which fanciers work are entirely *arbitrary* and artificial. The goal is never reached; when we approach it, it recedes. In this respect the breeding of fancy stock—mice, rabbits, dogs, poultry—is entirely different from the breeding of, let us say, sheep-dogs or egg-producing hens.

The breeder of laying hens or ducks has (or should have) a fixed goal; his aim is to produce groups that will fit into a system of agriculture, and that will, if suitably raised and handled, produce a good profit.

Utility in *fancy poultry* is of very *secondary importance.* If the hens produce enough chicks to give the owner a good enough choice, this is sufficient. Size, shape, type, colour, markings, etc., are important. In any breed of fancy poultry there are so very many points that it is quite impossible to balance them all in their order of importance. As soon as a breed gets reasonably uniform in any respect, some other point may assume much more importance.

In a utility breed, in a group of a hundred hens sixty may give us a good profit, twenty may just barely pay their way, whereas twenty are culls. The test of quality at a poultry show is quite different. At the show nobody judges a hen as a very good one unless the judge considers her just a little better than her competitors in the class. A cock that is placed nowhere at a big show in a strong class may win next week at a less important local show. This may be the effect of less competition, or of another taste in the second judge. Anyhow, it illustrates the fact that in fancy poultry there can be no real objective scale of quality.

When a breed is still variable in a great many points, the fact that the genes that help to bring about such qualities are independently transmitted over the germ-cells will result in many birds being good in a few points, a few will excel in more points, and only a very rare one will be a real top-notcher. If one can afford to have so many birds that he can discard the great majority, and breed only from the very rare perfect

ones, this will always be the best plan. It is still true that we can give most show-breeders a simple recipe to double their chances of breeding a winner, i.e., " double the size of your stock ! "

It is very important that a poultry-fancier shall choose the sort of breed or the sort of breeding problem that will suit his particular circumstances. On the whole, the advice that a fancier should take up a breed he happens to like is sound. And it is also good advice to specialise, and not to take up several different breeds at the same time. In the best-known and popular breeds there is so much competition that one needs very good stock, and plenty of it, to have a good chance of getting into the prizes.

On the whole, the fancier of moderate means, or the man whose space is limited to a small garden, should carefully deliberate what he had better do to save on space and number of birds. About the best breeding problem we can think of to suit a keen fancier who can keep only a few birds is the making of a novel breed, or rather a novel sub-breed in one of the popular varieties. In the chapters on " Adding a Gene " and on " Transgressive Variability " I have treated of some of the possibilities, and from experience I know that about the very best thing a small breeder can do is to *add a gene*. Just about the most satisfactory thing a fancier can do is to create something entirely new ! Let us take an example: the making of a blue-spangled Hamburg—a sub-variety in which the bottom colour shall be rich dark red, while the spangles shall be blue, instead of black. The breeder begins his work by buying one or two golden, black-spangled hens and any sort of a blue male, Blue Leghorn, Andalusian, or Blue Cochin. He might even get the loan of such a male for a few days, or get his hens mated in the breeding-pen of a brother fancier. Half his hybrid chicks will be blue, or carry blue markings; the remainder will carry black. Next season he will mate one of the blue mongrels to his gold-spangled hen or hens, and some of the chicks will then begin to look like something ! He should continue this during four or five generations at least, using an excellent show-bird after the first or second back-cross. It is quite certain that after a few generations the breeder will have

birds that are perfect replicas of good show spangled Hamburgs, but now in a new colour variety. He should certainly not show any before this goal is reached.

Now, the advantage of this sort of work is that such a fancier needs to keep only a very few birds in every generation, and needs to raise only a very small group of chicks, discarding the unwanted ones when they are very small. It is typically a problem for the ambitious fancier with very restricted space. It would be easy to suggest a few dozen novel sub-breeds, striking novelties—piles, blues, frizzles, dominant whites or blacks, rose-combed or bare-necked sub-breeds.

To combine the qualities found in two breeds is often more difficult—in fact, I have often helped fanciers who asked advice how to set about producing this or that novelty in poultry by counselling them to do something much more within the scope of their establishment.

To produce perfect miniatures of a well-known large breed is the ambition of many poultry-fanciers. Old, well-established breeds are never variable enough to make it possible to breed miniatures by means of selection. In theory it should be possible to mate a very small bantam to a large breed [1] (see chapter on Artificial Insemination), and to select between the immensely variable second-generation birds obtained by breeding such hybrids together. Nobody who has never bred such a second generation can know how disappointing this work is, how many culls are born, and what enormous numbers are necessary to produce satisfactory results. Most of the newer miniatures are not bred in this way; they are produced from crosses between existing varieties of bantams. Perhaps the best way to breed a miniature would be to make a cross with the large breed, select a few second-generation birds that have an approximately correct colour pattern and use these in a bantam back-cross.

[1] A large male can mate with a bantam hen, but not vice versa.

PART II

Introduction

FARMERS are beginning to realise that the modern science of genetics, which has already created a revolution in crop husbandry, can be just as applicable to farm animals. The methods of selection that have been in vogue for many hundreds of years—nay, the last three thousand years—are so inaccurate and ineffective that little further stock improvement is likely to accrue from them.

There have been Three Musketeers who have succeeded in capturing the imagination of farmers on this subject, Professor Robert Boutflour in England, Dr. A. L. Hagedoorn of Holland and E. Parmalee Prentice in Massachusetts. During the last thirty years these three men have mocked, derided and tilted at the agricultural fraternity to such good effect that many of us have been jolted out of the rut of orthodox methods of animal selection.

The modern dairy-cow is still judged to a considerable degree at our numerous and popular cattle-shows on external characteristics which have no correlation with economic values. Such methods of selection have been passed down from father to son for hundreds of years and according to Parmalee Prentice they have changed little since they were included in a book of agriculture in the Punic language by a Carthaginian, Mago, and later translated into Latin by order of the Roman Senate. Mago's book has been lost, but Virgil, Varro, Palladius and Columella, all agricultural publicists of their day, made full reference to and use of it and the conservatism of world agriculture can be gauged to some extent

by the fact that when farmers came to select their cattle for beef rather than for draught purposes, the same yardstick of external characteristics was largely used. Today most farmers selecting their cattle for milk still demand a similar conformation in their cattle.[1]

The selection for that better dairy-cow has admittedly gone through the pedigree stage during the last thirty years, but milk in the pedigree is a pretty elastic measure in practice. Robert Boutflour and Ken. Russell have illustrated this fact recently at the Royal Agricultural College. When restarting the college Steadings herd after the war, they purchased commercial cattle of promise in local markets at an average price of £68. This herd of commercial cattle was managed for maximum milk production, and was costed by Bristol University with eighty-seven other herds in South-west England, of which several were old-established pedigree herds. The Steadings herd came out top of the whole survey with an average of 1,394 gallons, with a lead of 200 gallons on the next-best herd. Such an example of phenotype so completely masking genotype should serve as a warning to pedigree dairy-cattle-breeders who cannot hope to apply modern methods of selection until they adopt a more rational basis to work upon. As a mere poultry-breeder I have gained the impression that most pedigree dairy-cattle-breeders claim to have bred a proven sire—probably no difficult achievement when using this conveniently elastic measure, the cow's milk-yield.

The practical difficulties of constructive dairy-cattle-breeders are such that one must probably look to the scientific set-up of Joseph Edwards in the Milk Marketing Board, which is taking steps to breed consistently productive cattle, making sure they are not fooling themselves as they set about it. Dairy-cattle improvement will be accelerated when the breeders learn to work in unity with the Board, acting as satellites. The Board can provide that essential continuity, adequate control of the matings of sufficient numbers of cattle, for this long-term work.

The breeding of more productive poultry comes into a different category, as the breeder controls large numbers of

[1] Parmalee Prentice, *U.S. Political Science Quarterly*, Dec. 1951. Columbia University.

stock—several thousand of a breed and a new generation of improved stock is bred annually. The flocks of breeding poultry can be managed in a relatively uniform environment, with the result that the factors egg-yield and carcass quality have a considerable degree of heritability, enabling the breeder to select annually with a reasonable standard of accuracy the best of his material from the moderate, the mediocre and the bad which every breeder carries in his flock, instead of flounder-ing like the cattle-breeder in a mass of records which are little more than an expression of herd management. Even so, after discounting the rapid rate of reproduction and the small value of the individual bird, poultry-breeding is nowadays a highly competitive business into which the larger hatcheries have launched themselves on well-planned stock-improvement schemes. Taking a long-term view, the poultry-breeding pursued by these large hatcheries is likely to be far more successful than the work undertaken by the small breeder. Poultry-breeding demands the services of the specialist more than ever. These are developments that have a lot to recom-mend them, as it is obviously most irrational and wasteful for a man to spend a lifetime as an individual animal-breeder making no provision for the continuity of his herds and flocks, and any genetic improvement in his animals may be thrown away at the inevitable dispersal sale.

As a practical farmer of little scientific training I know nothing of genes, and so shall not take the reader gene-hunting. Dr. Lush of Iowa is credited with having said that if there were 200 gene pairs causing heritable differences between the best and the poorest chicken in the breed, the numbers of kinds of chickens possible would be greater than the number of electrons in the universe. As a consequence, I believe the most rational approach to stock improvement is via Hagedoorn's nucleus breeding, where in poultry-breeding large numbers of cockerels are submitted to a progeny test, the whole of the next generation being sired by sons of the cocks thrown up in the best light by the test. We select our numerous family groups for the factor " total profitability ", and in all our work we aim to reduce what can be a most complex business down to the simplest, most practical way of achieving results.

In recent years breeders have been shy of publishing the results of their efforts at stock improvement. The exceptions have been Raymond Cochrane *The Milch Cow of England* and George Odlum *The Manningford Herd Analysis.* I shall feel this effort has been worth while if it stimulates others to record their experiences and results in this fascinating modern exploration of the application of scientific precepts to animal-breeding.

Chapter Thirty-five

Pedigree Poultry-breeding in England

POULTRY-BREEDING in Britain is in the main worked on the old rule-of-thumb methods which have been in vogue for some thirty years. The impact of the scientific outlook on the problems of breeding more productive poultry has by no means taken the place of the old orthodoxy, but it has compelled every breeder to take stock of his position. The fresh outlook has also created a ferment which points to a rapid development of poultry-breeding technique in the future.

In brief, this orthodox poultry-breeding has incorporated the following techniques.

All breeding stock, male and female, must pass a frequent handling test. On each such occasion a proportion of the flock is rejected for its failure to come up to the breeder's own personal conception of the ideal appearance he hopes one day will be carried by his entire flock. The breeder endeavours to select stock which conforms to his own interpretation of the standards laid down for breed type in each breed. The breeder also keeps a sharp eye open for signs of ill health, continually culling individuals on visible points which the breeder believes are associated with some form of ill health. One of the many guesses is that poultry with red eyes are free from the leucosis complex, whereas those with grey eyes have a tendency towards leucosis. This is just one instance of many where the breeder should be sure there is some proven correlation before he uses it as a tool to aid him in his work of selection.

Culling is continuous from birth to death. The eggs set in the incubator are carefully selected and only good specimens set. The incubator and chick-brooder does some automatic culling. The chicks are culled at all stages of growth. The poultry-breeder is always afraid of an outbreak of disease, and he culls all the harder in the hope that by removing unthrifty individuals at the earliest possible stage, such birds will not act as spreaders of disease. Frequently such birds can be marketed with advantage.

The pedigree poultry-breeder will trap-nest a proportion of his pullet flock. Generally the breeder can only afford the labour to trap-nest a small proportion of his pullet flock, trap-nesting being particularly laborious work.

During their first laying year the pullets are mated to cockerels of another breed for the production of first-cross pullet chicks for sale to commercial egg-producers. This business provides the bulk of the bread-and-butter of the pedigree poultry-breeder.

The pullets which put up the best performance in the trap-nests with good-quality eggs and have successfully survived a lifetime of culling, and have shown their ability to lay eggs of good hatchability, are retained for two, three or four laying seasons. The breeder produces from this older stock of poultry, male and female, stock cockerels and pullets for sale at a fancy price, and it is from this stock that he breeds his own replacement stock. The breeder hopes he is maintaining vitality in his stock by breeding from old cocks and old hens which have at least shown their ability as individuals to survive some twenty-two months.

Environment is maintained at a high standard for the poultry, chick-rearing is carried out from an early age on pasture, and all poultry are housed on pasture throughout their life. The poultry-breeder, being a specialist, generally feeds his poultry several specific feeds daily, using to a high degree his highly developed stock sense, in the belief that poultry so fed are that much healthier and in better tone than by the usual methods of poultry-feeding used in commercial egg production, where the flock has food in front of it all the time. Usually the poultry-breeder is trying to pursue his

business on a strictly limited acreage of pasture carrying a high stocking of poultry per acre—in fact, a far higher rate of stocking than a cattle, pig or sheep man would consider wise.

In Britain the poultry-breeder generally has the idea that he must not push his stock for maximum production, as he may thereby undermine their constitution. The American poultry-breeder believes that only by pushing his stock for high production can they express their varying genetic capabilities. This latter view coincides with that of the dairy-cattle breeder who pushes his cows by every possible means for maximum production. If stock is not managed for a high production, the different families will tend to produce around a common mean, and thereby defeat the breeder making his selections.

However, Dr. Hutt [1] makes the very interesting point that during a progeny test pullets should not receive artificial light in winter. With a pullet flock that does not have winter lighting, it is only the families of persistent winter layers that will come through with high egg scores. If the flock is winter-lit, less persistent families will also lay well; thereby making an accurate assessment of the different families more difficult.

I do not suppose that Dr. Hutt's point is popular with poultry-breeders in the United States, who generally use artificial lights on their breeding-and-progeny-testing flocks, striving by every possible means to get as high a proportion of their pullet flock into the official United States Record of Performance grade (see Chapter XLIII).

The orthodox breeder's methods of selection are manifold. To a greater or lesser extent, he selects his own foundation stock by type and conformation, by his hatchability and chick-rearing records, according to the egg-yields, persistency of egg production, broodiness, quality of shell and egg-weight produced by each individual pullet as revealed by the trap-nest records. He selects on a pedigree basis in the hope that like will beget like. He also acknowledges that the methods of selection recommended by the geneticist are sound, and so endeavours to introduce these recommendations on top of all the other methods he has been accustomed to apply. He endeavours to assess the breeding-value of his stock by some

[1] *Genetics of the Fowl.*

loose form of progeny-testing, and he pays lip service to family breeding.

The orthodox breeder acknowledges the necessity for these modern breeding methods, and of course in some small degree has been using the modern tools of stock improvement for a long time. He has known that the best way of doing well at a laying trial is to send pullets which are the result of a repeat mating which has thrown up superlative stock on his own farm.

Unfortunately, it is impossible to compromise; there is no satisfactory method of blending the old rule-of-thumb methods of breeding poultry with the scientific conception that selection must be carried out only on a family basis, on the basis of a strict progeny test of the male. The new is incompatible with the old.

Any statistician can convince a breeder that he is unlikely to make much headway in a lifetime of poultry-breeding if he clutters himself up with innumerable unattainable, irrelevant factors for selection. The poultry-breeder must ration himself very strictly to breeding for a few essential proved factors in his selection work, such as egg production of the family and viability. The breeder cannot afford the luxury of including fancy and irrelevant points in his selection.

The breeder who culls his flocks is only working with the balance of his flock after culling, and this balance, being unrepresentative of the whole, is an unreliable guide to the productivity or otherwise of that whole. As far as possible, the breeder should have an unselected representative sample of his family to record. The breeder who culls his flock has no idea of his incidence of mortality, and does not know the reasons for such mortality. The scientific approach necessitates no culling. The autopsy of dead birds, or at least the autopsy of a representative sample of dead birds, produces valuable information. The breeder's aim must always be to combine high production with high vitality in his poultry.

To breed better poultry, only one cock in five or one in ten can be expected to effect an improvement, depending on the quality of the flock one is working with. The poultry-breeder records his pullets individually with the help of that laborious tool, the trap-nest. Under British conditions he probably

carries pullet flocks of 1,000 to 3,000 pullets on his farm—a sufficient number with which to carry out excellent progeny-testing work in one breed. Unfortunately he can only raise or afford enough labour to trap-nest a proportion of his pullet flock, say 10 to 25 per cent; the balance are just flock-mated on the farm for the production of commercial pullets, and do not enter into the stock-improvement picture of the farm at all. Therefore, although numerically the breeder is in a large enough way of business to carry out some effective stock improvement via progeny testing, in reality, the pedigree section of his farm being so small and divided amongst several breeds, it is doubtful whether progeny testing can be of much help. The breeder should be housing the great bulk of his pullets (mated up for cross-breeding) in some simple nucleus breeding-system—in folds, breeding-pens or even deep litter-houses or henyards, each family housed and recorded as a group. The breeder can then set about some constructive breeding with his entire flock of 1,000 to 3,000 pullets, instead of, as at present, a mere 100 to 200 pullets of a breed.

The breeder still tries to incorporate an element of progeny testing in his scheme of things, notwithstanding, that, as a result of his culling, he is not working with a representative sample and notwithstanding the small number of pullets he is recording individually. In his mild attempt to progeny test, the breeder has perhaps some four cockerels with some 150 to 200 daughters under trap-nest. At much expense and labour he assembles a great mass of egg-production, hatchability, fertility and viability data. He soon finds, on analysing this data, that he becomes less interested in progeny testing these four sires and more interested in the fact that many of his females are turning out to be superlative producers, that a large proportion are somewhat mediocre and that a small proportion can be classified as poor. He will analyse his data into groups of progeny, the result of mating a certain cock to a certain hen. The breeder believes he is carrying out a progeny test of his hens, when in fact he is progeny testing a mating.

There are several reasons why poultry-breeders should not attempt to progeny test hens.

To progeny test a hen satisfactorily she must be mated to at least three of four cocks in one breeding season—an impracticable procedure.

When all such expense and labour have been incurred, a hen proved to be a good breeder is of much less value to a flock than a proven cock.

One must not lose sight of the fact that the cock himself is unable to express the characteristic of egg production. His value can only be measured by the productivity of his daughters.

The breeding of foundation-stock poultry from second-year or older cocks and hens is an excellent practice for the breeder who is really doing nothing more than multiplying stock. He is breeding from individuals which have shown their ability to survive two or even three years.

When, however, the breeder is actively engaged in stock improvement, it is better practice to breed his flock replacements from the pullets which are daughters of the cock which proved himself to be best breeder. For one thing, by breeding from pullets, they lay more eggs of better hatchability and rearability. Consequently one requires fewer poultry from which to replace one's own pullet flock. The fewer pullets required for this stock replacement, the higher is their breeding quality likely to be, for the intensity of selection is higher.

The higher the intensity of selection the breeder achieves, the more rapid is likely to be the genetic improvement in his flock.

As a generalisation, it is much preferable to breed from the pullet daughters of a cock doing the best in a progeny test than from a collection of older hens probably selected purely as good individual producers. If the breeding scheme is producing the hoped-for genetic improvement year by year in the stock, it can easily be realised why I recommend the breeding of foundation stock from pullets, when these pullets are daughters of the best cock. In a first-rate progeny-testing scheme, where some ten, twenty or thirty cocks are being subjected to a progeny test, the best cock of such a test must have thrown progeny of a high order, combining high egg production with low mortality. In the nucleus system the breeder only has a record of the family group: he has no record of the individual pullets resulting from trap-nesting.

The orthodox breeder criticises the nucleus-breeding system on the score that one is breeding from the best and the worst pullets in the winning group of pullet-daughters of a cock. As long as there is sufficient competition in the progeny test, as long as there is a large enough number of cocks being subjected to a progeny test, then one can have every confidence in the breeding worth of the *whole* group of daughters of the cock who has proved himself to be the best breeder.

Green fingers are a great asset to a gardener. Stock sense is, of course, an essential attribute to everyone engaged in livestock husbandry. I would, however, make one reservation. By the application of stock sense to his herd or flock the breeder is in no measure improving the genetic value of his flock, he is pursuing no selection. By applying stock sense he is improving the productivity of his stock on his own farm. By first-rate management and the use of stock sense the breeder is raising the productivity of his stock in his own hands, which is helping his stock to express their genetic capabilities, whereas where stock is poorly managed, low productivity results, and the good and the bad animals are dragged down to a common mean of productivity, and the animals are that much the less capable of expressing their genetic capabilities. It is believed that the reason "Lysenkoism" [1] has received the official support of the U.S.S.R. is that in a Continent where relative low productivity is the rule throughout their agriculture no genetic improvement can be anticipated until the environment of both plant and animal receives a big lift.

There has been a tendency on breeding-farms with mediocre-quality stock to put a reasonable show on the breeder's own farm as a result of strict culling, but the progeny of course proved most disappointing in the hands of the breeder's customers.

[1] Lysenko is the Soviet geneticist who has prevailed on his Government to legislate that his own creed is the only type of genetics to be taught throughout the U.S.S.R. Those geneticists who refuse to toe this party line are liquidated. Lysenko's creed is that the hereditary constitution of plants and animals is profoundly altered by the environment—a principle which is unacceptable to Western geneticists.

Chapter Thirty-six

Objectives

FROM the beginning the breeder should have a clear conception of his objectives when starting a progeny-testing project. Probably the best rule is that the breeder should breed for "total profitability", drastically excluding any and every objective which has no clear definite link with it. Most animal-breeders add to the above objectives a long list, most of which is entirely irrational, being required only by the artificial necessities of "stock judging" and by the fashion of the agricultural shows.

The fewer objectives selected, the more likely is a breeder to achieve some success in stock improvement. In the egg-laying breeds of poultry and in the dairy-cow there are, practically speaking, no proved correlations between the type and conformation of the animal and the productive capacity of the progeny. It is consequently safe to rule out all the multitudinous points of type and conformation on which breeders have always put their main selection emphasis.

On our own poultry-breeding farms we are breeding for the following objectives:

(*a*) Maximum egg production of good-quality eggs weighing 2 to $2\frac{1}{4}$ oz.
(*b*) A chick that is easy to rear into a pullet with a low adult mortality.
(*c*) High fertility and hatchability.

I have here condensed the essential factors for selection to improve the egg-laying breeds of poultry. In our work it will be noted that all selection of all breeding-stock is carried out from the progeny-test records, and that no selection is carried out by handling or appearance of any one bird. Now that commercial egg-production methods are swinging over to the more labour-saving mass-production systems of intensive poultry-keeping, the breeder must pay greater attention to the toughness, the disease-resistance capabilities of his stock. It is of little value to anyone if a breeder succeeds in breeding stock of maximum productive capabilities which cannot exhibit these characteristics in the everyday practical tough conditions under which the commercial egg-flocks are maintained.

Progeny testing is the only reliable method of selection for factors of a low degree of heritability.

Individual selection is still the most efficient method of selection for characteristics of high heritability. Dr. George Jaap points out, " Strains of chicken which grow most rapidly, have largest egg weights, most uniform egg colour and shell texture and (believe it or not) the highest hatchability in the U.S.A. were produced from flock matings: no pedigree and no family records." [1]

The objectives of a table-poultry breeder should consist of (*a*) carcass quality. (*b*) Capacity for rapid growth, rapid feathering on a low feed conversion ratio under mass floor-rearing management. Feathers should be white and come off clean on the modern rubber-finger-pluckers. (*c*) Efficient reproduction (egg production, fertility, hatchability and chick rearability).

Many British breeders have aimed at too high an egg size. Generally 250 2 oz. eggs realise more than 200 $2\frac{1}{2}$ oz. eggs. The bird laying the smaller egg is less liable to fail from some reproductive breakdown. The hatchability of the 2 oz. egg is nearly always better than the $2\frac{1}{2}$ oz., which is a biological monstrosity in the modern breeds of poultry.

We have for several years been progeny testing thirty Rhode Island Red cocks annually. As a result of such progeny tests,

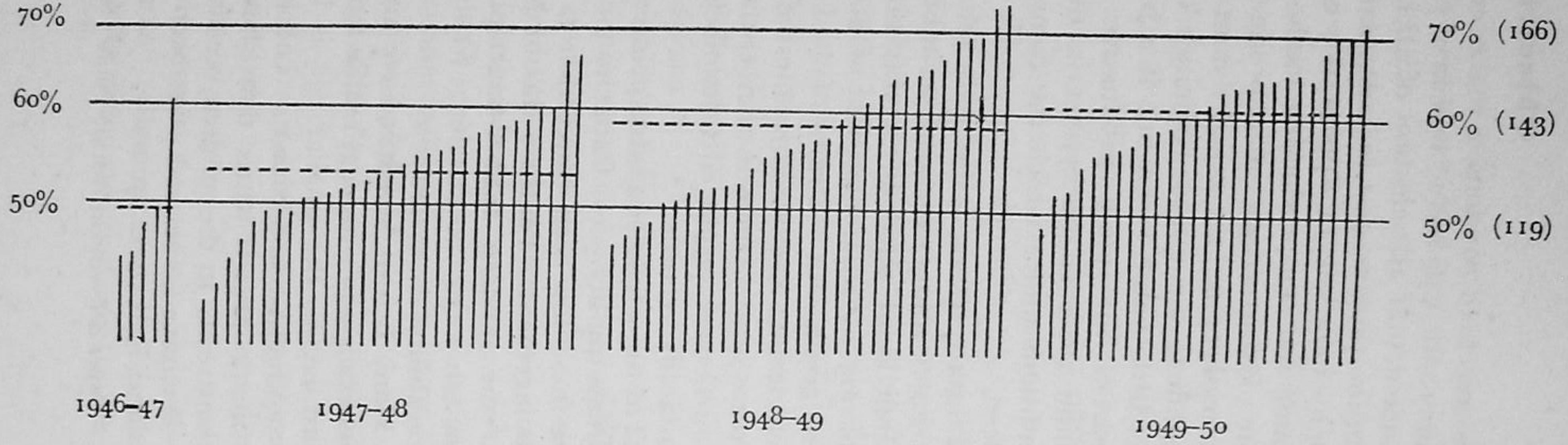
[1] Paper delivered at World's Poultry Science Ass., London. March 1952.

PRODUCTION AVERAGE THROUGH PERIOD OF TEST

FIG. 25.—Each column represents the hen-housed egg average of a family of Rhode Island Red pullets (20–40) each of which was sired by one cock. Each cock was under progeny test for a 238-day period, December 5th to July 30th. Each generation of families in this extensive testing programme was sired by sons of cocks which had proved themselves to be superlative breeders in the previous season's test.

Note the steady rise in their productive capacity, generation by generation. By using a whole series of sons of proven sires we no longer reproduce mediocre families, the general egg production has been raised and the overall mortality has been lowered.

PRODUCTION AVERAGE THROUGH PERIOD OF TEST



we select thirty sons for the ensuing progeny test. These thirty sons will have been bred from the four most promising cocks out of the thirty. All the progeny, male and female, of the other twenty-six cocks are scrapped every generation. One of the great beauties of poultry-breeding is that we can afford to scrap every year these twenty-six complete families out of thirty, and at very little cost achieve a really high intensity of selection on the male side. We would increase still further our intensity of selection if we only bred from sons of the winning cock, but should then have to make sure we reared thirty sons of the winning cock and thirty sons each of all the other twenty-nine cocks—some 900 cockerels. Also in practice we have two or three superlative families to choose from, all of which have characteristics we are interested in maintaining.

For instance, we have a family of Rhodes (*a*) which lay in folds, hen-housed egg averages between 220 and 230 eggs in eleven months. Excellent all-rounders except for a weakness in egg-size.

Another family (*b*) put up hen-housed egg averages of 190 to 215, egg-size satisfactory and again good all-rounders.

For our purpose it is desirable to maintain both families (*a*) and (*b*) in strength. A considerable part of our production is of the sex-linked Rhode Island Red × Light Sussex chick. Probably cockerels bred from family (*a*) are better sires for such a cross than cockerels (*b*), as the egg-size from the cross is increased from the Light Sussex and/or from hybrid vigour. For marketing pure Rhode Island Reds, family (*b*) is more suitable.

The mild continuous inbreeding involved in the nucleus system is a safe method of poultry-breeding without serious loss of vigour, as long as this high intensity of selection is maintained.

A comparison of this procedure of breeding every generation from cockerels whose sisters and half-sisters have put up the best show in the progeny test of their sires, the procedure of scrapping 90 per cent of the families under test each generation, the 10 per cent of whole families that are retained on their overall productive vitality as a family, is very different from

the Wallace Hybrid approach to the problem. The breeding of Hybrid maize in the U.S. has undoubtedly been the major conquest in the world by the geneticists, who can take the credit for increasing the yield per acre of United States maize by some 23 per cent, an annual increase in yield of some 600 million bushels (U.S.D.A. statistic).

Henry Wallace, the politician, in the years 1914–1924 was one of the pioneers of this great achievement. His son, Henry B. Wallace, is a specialist in poultry-breeding, and is now endeavouring to put the maize-breeding methods into practice in his poultry-breeding. Wallace jun. maintains large numbers of closely inbred lines of poultry, most of which have low stamina and low productivity as a result of the inbreeding. He is prepared to maintain inbred families of extremely low productivity in themselves so long as such a family carries one characteristic that might be of value to him.

He has an intensive system of testing out thoroughly these inbred families to discover which "nick" and give him the uniform high production he is after. Wallace markets his Hyline pullet chick, which is the result of a top-cross, bringing in four inbred lines to the make-up of each pullet chick. This chick is marketed at twice the price of the ordinary standard pullet chick of the Middle West, and Wallace produces tens of millions of these chicks annually at this high price—a strong indication that the chick he breeds has a very high productive capacity.

In the last year or so samples of his chicks, which are mass-produced, have been entered at laying trials through the United States and have put up hen-housed egg averages of 230–260 in fifty-one weeks. These creditable averages compare favourably with the entries of stock in laying trials from the large American breeder who puts up very similar egg averages, but from stock which has been specially selected for the purpose of doing well at a trial. In the United States the battle rages between such hybrid chicks and the chicks of the standard breeders, and the contest will continue for many years.

Hybrid chicks are marketed at a high price owing to the very high cost of maintaining large numbers of inbred families

of low vitality and productivity, and consequently the method is applicable only for a long-term breeding project with large capital resources. In the hands of the best commercial egg producers, the hybrid chicks do not appear to be more productive than the stock of the many first-rate poultry-breeders in the United States. Such chicks, however, are showing up to advantage under second-rate standards of management—it is proving tougher under adverse conditions: a most valuable economic property when it is appreciated that in North America and in Europe there is vast scope for improving poultry-keeping standards.

The nucleus system, by reason of its milder form of inbreeding and far higher intensity of selection of families, is a more economical system of breeding poultry of a capacity for sustained high production, as at all stages of the work the breeding flocks are in a highly productive state. There is no great difficulty in testing and breeding for hybrids of families of two breeds for their capacity to exhibit high sustained productivity under ordinary practical conditions (Chapter Forty-one).

Chapter Thirty-seven

Nucleus-breeding in Practice

I SHALL go in some considerable detail into our experiences, mistakes and successes during the last six years, when we have been breeding poultry on the nucleus system.

The main object of our poultry-breeding establishment has been to breed pullet chicks which would lay as many eggs as possible and live in the hands of the general farmer, our customer who almost invariably is engaged in commercial egg production as a sideline to mixed farming. For poultry-breeding we have some 300 poultry folding-houses, measuring 15 × 7 feet. Each fold consists of a breeding-pen of seventeen pullets and a cockerel. These folds are moved daily to a fresh patch of young ley on the Wiltshire downland of Salisbury Plain, which has excellent drainage in winter. The fold provides the poultry-breeder with an economical method of housing and managing the large numbers of poultry breeding-pens and pullet testing-pens necessary for nucleus breeding.

The constructive poultry-breeder is always carrying out two breeding operations at one and the same time with his pullet flock. The flock will be mated for the production of day-old pullets for sale, and at the same time the flock is being closely recorded to produce the progeny test data of the sires under test.

Each of our poultry folds houses an unselected sample of sister and half-sister pullets, all daughters of a common cock. For a progeny test of a cock we like to have three folds of

progeny of each cock randomised over two or three farms; each fold of pullets is hatched as closely together as possible. Up to now we have been working with two breeds—Rhode Island Reds and Light Sussex—the progeny of which have been housed in eighty to a hundred folds. Now that we have gained sufficient experience of the system, we are extending our progeny-testing programme so that we can take advantage of progeny-testing work involving some 4,000 to 5,000 pullets in these two breeds.

When starting a progeny-testing project, mate up as many cockerels as possible to a cross-section of the pullet flock, in individual matings in folds, deep-litter pens or hen-yards. There is little advantage in testing more than forty cockerels in one closed flock. In every case the daughters of a cock must be penned together for the great convenience of recording the performance and quality of the family as a whole. One therefore discards that pesky labour-consuming appliance, the trap-nest, where one collects innumerable individual records which anyhow have to be sorted into family groups for family analysis.

We have used the triple shift of cockerels as recommended by Hutt.[1] Hutt argues that had he started his cockerel shift-system at an earlier date he could have achieved with his flock at Cornel an improvement in five years which has actually taken ten years. In order to treble the numbers of cockerels under test without increasing the number of breeding-pens, Hutt writes, "Transfers of the males are arranged to accommodate weekly settings of eggs in the incubators on Tuesday. To illustrate shift one goes out of the breeding-pens on Friday afternoon and is replaced on Sunday in the late afternoon. Eggs laid on Monday night are credited to shift one, but eggs from Tuesday to Saturday, where paternity is doubtful, are marketed. Beginning on the following Sunday, eggs are collected for incubation and credited to shift two, this being seven days after the introduction of these cockerels and nine days after the removal of shift one."

In our major breed, Rhode Island Reds, we mated up thirty cocks in thirty folds of pullets—shift one. Their progeny

[1] *Genetics of the Fowl*, p. 521.

will be hatched on January 2nd, 9th, 16th and 23rd. We mated up to the same females the second shift of cockerels, and their progeny hatched on February 6th, 13th, 20th and 27th. The third shift of cockerels were in due course mated up to the same thirty folds of pullets, and their progeny will hatch on March 13th, 20th, 27th and April 3rd.

If we tried to carry out a full progeny test of these ninety cockerels in one breed, we should require some 270 folds. When the pullet progeny were due for housing for their test of egg production, we culled out about 30 per cent of the complete families on their hatchability, fertility and chick-rearing capabilities. Hitherto we had carried out no such culling, but it does appear to increase greatly the intensity of selection and overall efficiency if one mates up 20 or 30 per cent more cockerels than one can possibly put through a complete test. Then start the process of weeding-out whole families that have failed to make the grade in the incubator, brooder and on the rearing range.

Pinned to the nest of each of our folds is a record card for the day-to-day egg production and mortality. This card is replaced fortnightly.

Each egg at the time of collection is given the same number as the sire. We collect our eggs in the field in specially made square buckets which hold fifteen dozen eggs when full, on Keyes trays. The bucket has a pocket for carrying the empty trays. These containers help to prevent the eggs developing hair-cracks when being carted from field to incubator. The fact that the eggs are not mixed in a bucket facilitates the sorting of numbered eggs on to their respective setting-trays. We do not set eggs under 2 oz. each—an important point, as here an element of selection creeps in, and consequently we cannot claim that our progeny test consists of an unselected sample all along the line. We make this selection in order to comply with the requirements of the British Poultry Stock Improvement Plan.

We keep a record of the number of eggs laid and the number of eggs set of each family. The percentage ratio of these two figures gives us the egg quality of the family. This is preferable to the usual laborious method of recording the general

egg quality by maintaining records of egg-weights in grammes, and records shell texture and shape—another example of our efforts to simplify poultry-breeding technique.

When candling on the eighteenth day of incubation, a record of clear eggs is kept. After candling, the eggs are transferred from the setting-trays to the hatching-trays, and the eggs from the different families are isolated from each other by strips of cardboard retained in position by drawing-pins. When the hatch of chicks is removed, it is carefully boxed into numbered boxes. We rear all the cockerel progeny (wing-banded, of course, to the sire) of the first hatch of progeny of each series of cocks. The wing-tabs are attached to the day-old chicks before the chicks are placed in the brooder, each wing-tab carrying the number of the sire and the code of the date of hatch. The second, third and fourth hatches of progeny have to be sexed before the pullet chicks can be tabbed. A machine which stamps the number on the aluminium wing-tabs is a necessity.

The chicks of all families are reared mixed together, but of course the different hatches are reared separately. A record of all mortality in the families of chicks is maintained.

We start off our baby chicks indoors for three weeks in electric tier-brooders. From three to eight weeks of age the chicks are reared in chick-folds, with some form of heat for a week or two. From eight weeks to point of lay we rear on free range. In our chick-rearing we make a point of moving continually on to fresh land and of segregating all young stock from all adult poultry, as a rational disease precaution.

When near lay, the pullets are sorted into their family groups in their respective folds or henyards, where the egg-production and adult-mortality data of the progeny test are obtained, and this is the stage at which we cull a considerable number of whole families on their failure to make the grade through the incubator, brooders and range.

I must stress here that I am writing of culling whole families, and not culling of individual birds in the family. The orthodox breeders probably carry out their heaviest culling when their pullets are housed in their laying quarters. The constructive breeder working on a progeny-testing project must not cull at

this or at any stage individuals in a family; all the time he is trying to obtain a realistic picture of the genetic capabilities of the different cocks under progeny test. The more culling a breeder carries out of individuals in a family the less reliable is that breeder's knowledge of the productive capacity and vitality of the cock's progeny.

As long as the stock-improvement scheme is basically sound, each fresh generation of pullets should be an improvement on that which preceded it. Professor Lerner at Berkeley University, California, has made an excellent case for achieving a fresh generation of improved stock annually. Instead of going back to the proven sire annually (one generation every two years), the sons of the proven sire are mated up to the best families of pullets, the aim being to progeny test as many sons of the cock as showed up in the best light in the progeny test. Lerner, as a population geneticist, argues that progeny testing is really outmoded by the far more efficient method of stock improvement I have been describing, i.e. selection by sister family breeding (breeding from the brothers of the best families of sisters), as opposed to strict progeny testing (breeding from the sire proved best by his progeny).[1]

[1] *Population Genetics and Animal Improvement*, Cambridge University Press, 1950.

Chapter Thirty-eight

Starting Progeny Testing

WHEN starting a project, it is essential to work on a sufficient scale, otherwise the risks of the project being a failure from the start are considerable. I suggest that the minimum scale for starting should be ten cockerels with about forty daughters of each cock, involving a flock of a minimum of some 500 head of poultry in one breed. If one starts on a smaller scale than this, when the chances of none of the cockerels under test showing up well are greater, the scheme may be a failure from the outset. It is only rational to start off with the best stock, and one should be prepared to pay a fair price for the best stock one can find.

To start a project on the firmest possible foundations, I suggest buying a hundred pullet chicks from the breeding-pens of, say, the three best breeders one can—say breeders A, B and C. Buy, say, four stock cockerels from each such breeder, again from his foundation-stock pen, always mating up cockerels to the pullets from the same breeder. Have an autopsy taken of every dead bird. Having reared the pullet chicks, mate them in November, in order to hatch successive batches of chicks from the first week in January. Each day-old chick is wing-tabbed on hatching, the tab always carrying the number of the sire and the code of the date of hatch.

Apart from the progeny testing of these twelve cockerels, one should also be aiming to subject the stock from the three breeders to as severe and comprehensive a test as possible,

with the idea of scrapping all the stock from two out of three of the breeders in two or three years time. At the end of the first year's progeny test one can sum up how the twelve cockerels have turned out, and the general health and productivity of the pullets purchased. In our own case, when introducing a fresh breed, the day-old cockerels, all bred from the best pens of the best breeders we can find, are mated to different flocks of our own females, for the production of day-old pullets for sale. We make a rule that each such flock of our females should be mated to cockerels from only one such breeder. We then make a point of studying how the progeny of the cockerels from breeders A, B and C crossed with our own females " nick " in the hand of our customers, as in reality it is the customer who really carried out the ultimate and most important of all progeny tests. From an analysis of such data one achieves an excellent picture of how valuable the purchased stock from breeders A, B and C are under one's own environment. One retains only the stock from the breeder who is thereby thrown up in the best light, and by then one is in a position to get really started on a considerable scale of progeny testing the best stock for our purpose.



Chick-rearing in small folds. Illustrates the kind of difficulties British poultrymen run into in their extensive " grassy " systems of poultry management.



Photos. 'Poultry Farmer'

Nucleus Breeding pens. Sterling Poultry Products, one of Britain's biggest hatcheries, have their own progeny-testing farm in Hampshire.



Photo. 'Farmer and Stockbreeder'

Breeding in hen-yards results in high fertility and hatchability during severe winter weather as long as sufficient attention is paid to the nutrition of the breeding flock.

Chapter Thirty-nine

Planning and Management of Matings

In practice we have found it a relatively simple operation to carry out a progeny test of a cock. What has proved far more difficult has been the general overall management of the progeny-testing project to obtain a reasonable degree of efficiency.

Here is a typical example of the difficulty we have encountered. We have used April-hatched progeny for a test, coming into lay during October. From April we have been prepared to run a flock of stock cockerels, brothers of the pullets designed for the progeny test, round until December, when we hoped to be able to pick out the best 10 per cent on the basis of the performance of their sisters, putting the balance of 90 per cent on the Christmas table-poultry market. During our first year or two of work our flock was so lacking in uniformity that we were reasonably successful in selecting the best of these cockerels on the basis of the hatchability, chick-rearing, egg production and vitality of their sisters from October to December. We then ran into a very serious trouble. Our flock, as a result of these methods of selection, improved in uniformity. We reared to December this large flock of cockerels, but soon found we had very little to go on to enable us to decide which cockerels to mate up for the ensuing progeny test. We always want to use the maximum number of sons of a cock who has led in the progeny test, and at the same time we want the fresh generation of improved stock annually. In practice we have

selected many cockerels on the basis of this short October to December test whose sisters, although leading in the test by December, were well down in the test by the following August/September. In other words, our method was such that, having carried this large flock of cockerels round until December, we have as often as not failed to mate up the best breeding material in the flock.

Another way to manage this type of work is to depend on the proven sire. If working on an eleven-month progeny test of egg production and vitality, keep on all the cocks under test until the best one or two are proven. Assuming that the cocks are ten months old when mated originally, these cocks will be sixteen months old when their progeny come into lay; they will be twenty-seven months old by the time their progeny have completed their test, at a time when the flock is having its moult—an unsatisfactory time to breed from them. When the next breeding season comes along, the proven sire can be used, but he will be some thirty-one months old. If this breeding method is adopted, the best possible way of maintaining these old cocks awaiting the outcome of the progeny test must be adopted. If they are run as a flock, the experience is that, what with fighting and other accidents, the mortality is frequently high. Under this system it is a disaster if the breeder loses the particular cock which emerges the best from the progeny test. Having run these cocks on to such an age, their fertility and virility can be low, and the general result disappointing.

I believe that depending on the sons of the proven sire is the most rational method, as long as one can find an efficient method of short-term progeny test which enables the breeder to pick out with reasonable accuracy the sons of the best cock under test, in time for these sons to be mated to breed stock destined for the next progeny test.

The following method is the most promising in our experience. Depend mainly on pullets hatched in January. Rear in addition to the necessary forty daughters, ten to fifteen sons of each cock. This flock of early hatched and early maturing daughters are housed in their separate family groups by the end of April. The main egg-production and vitality records

Incubating and Brooding Record

Date set.	Eggs set.	Infertile.	Chicks hatched.	Deaths.
18–12–50	29	1	24	1
25–12–50	28	1	25	1
1– 1–51	40	3	33	—
8– 1–51	38	1	34	—

Record of Performance. Egg Production and Mortality

Week commencing	Fold number 19. Pullets started 19.		Fold number 42. Pullets started 20.	
	Eggs laid.	Deaths.	Eggs laid.	Deaths.
11th June 1951	31	—	—	—
18th ,,	50	—	—	—
25th ,,	61	—	—	—
2nd July	75	—	—	—
9th ,,	96	—	56	—
16th ,,	92	—	51	—
23rd ,,	82	—	74	—
30th ,,	100	—	88	—
6th August	91	—	101	—
13th ,,	94	—	101	—
20th ,,	85	—	93	—
27th ,,	99	—	97	—
3rd September	100	—	103	—
10th ,,	110	—	97	—
17th ,,	110	—	84	—
24th ,,	98	—	92	—
1st October	100	—	97	—
8th ,,	95	—	84	—
15th ,,	99	—	86	—
22nd ,,	96	—	83	—
29th ,,	99	—	89	—
5th November	104	—	87	—
12th ,,	97	—	84	—
19th ,,	84	—	81	—
26th ,,	76	—	79	—
3rd December	78	—	80	—

Hen-housed average for fold 19.
121 eggs in 182 days, no deaths.

Hen-housed average for fold 42.
94 eggs in 154 days, no deaths.

FIG. 26.—The simple progeny test record of cock number *A*25.

for the progeny test that decide the issue of the test are those from May to late November—six months of rather tricky egg production for the pullets. I believe that the families of pullets that come through this test the best—the early hatched families that will maintain production through October and November without neck-moulting and with the least mortality—are exhibiting persistency to a high degree and have been submitted to a severe test in a short period of six months. The problem, of course, with this kind of work on a large scale is that as soon as after two or three generations a degree of uniformity is achieved, when it becomes increasingly difficult accurately to pick out the best families. I consider the above method a great improvement on Lerner's method of testing. His test (by trap-nesting) is the egg production and viability of his pullets from September 1st to January 1st, using spring-hatched pullets. The egg-laying period that Lerner has chosen is in our experience a period when the moderate families cannot be accurately separated from the top-notch ones.

A weakness of this early hatching recommendation is that the chicks will be reared before coccidiosis gets into its stride, and consequently the chicks will have no opportunity to exhibit any genetic capacity to resist this disease.

However, a great advantage is that the test is over by late November, permitting the sons of 90 per cent of the cocks under test to be put on the Christmas table-poultry market. Under this system the parent cocks under test are killed immediately their first breeding season is completed—a great convenience.

Alternatively, the breeder can carry round the old cocks until November (instead of rearing ten sons of each cock), when their progeny will have completed their laying test May to November. If this alternative is adopted, the cocks could have been force-moulted in July, the proven cocks being in fine breeding fettle at an age of only twenty-two months, instead of at the more normal age of thirty-one months.

Here is another alternative method of mating management, which is especially applicable for March and April hatching. Run round the parent cocks under test until May 1st of the following season. When at an age of some twenty-six months, their daughters will have been in lay from October to April—

a progeny test of some seven months. During the first week of May mate up the proven sire on a repeat mating or on the best group of his daughters. Rear the resultant chicks as well and as rapidly as possible. If well reared, these June-hatched sons of proven sires will be fit to mate up for the ensuing breeding season late in January.

Little thought has been given to this most important aspect of progeny testing—the actual timing of the matings—and we are far from reaching any finality of ideas on the subject. However, we are finding that mating in November for January hatching is producing a severe progeny test, and we are completing our test at the time of year (late November) early enough to mate up the sons of the best cocks for the ensuing season's work, achieving that fresh generation of improved stock annually.

Chapter Forty

Some Results of Nucleus-breeding

THIS chart illustrates the results of the application of nucleus breeding to one of our families of Rhode Island Reds. During these our first four seasons we housed all families and pursued no culling of families at maturity. The first four cockerels submitted to a progeny test—Nos. 6, 7, 8 and 9—were purchased for £10 each, and mated to a cross-section of our pullet flock, which had been sired for several generations by cockerels from the same breeder. There was therefore little question of introducing fresh outside blood—any question of hybrid vigour or heterosis being ruled out. After four months of egg production of the progeny it was easy to see that the progeny of cock 9 were a far better family than the progeny of the other cocks. In January nine of cock 9's sons were mated up to the best folds of family pullets, the resultant chicks being wing-banded to the sire's number.

Cocks 6, 7, 8 and 9 were all of impeccable pedigree. If these breeding cocks had been selected by the usual methods used in the whole livestock breeding industry, the best cock would have been chosen on the basis of his appearance, his handling qualities and his pedigree. By such methods of selection it is three chances to one that we would have selected a mediocre to dud cockerel (6, 7 or 8) on which to have founded our future poultry flock. We judged cock No. 9 to be the best strictly on the basis of his progeny test—the paper records of performance of his progeny—and we took no notice of his

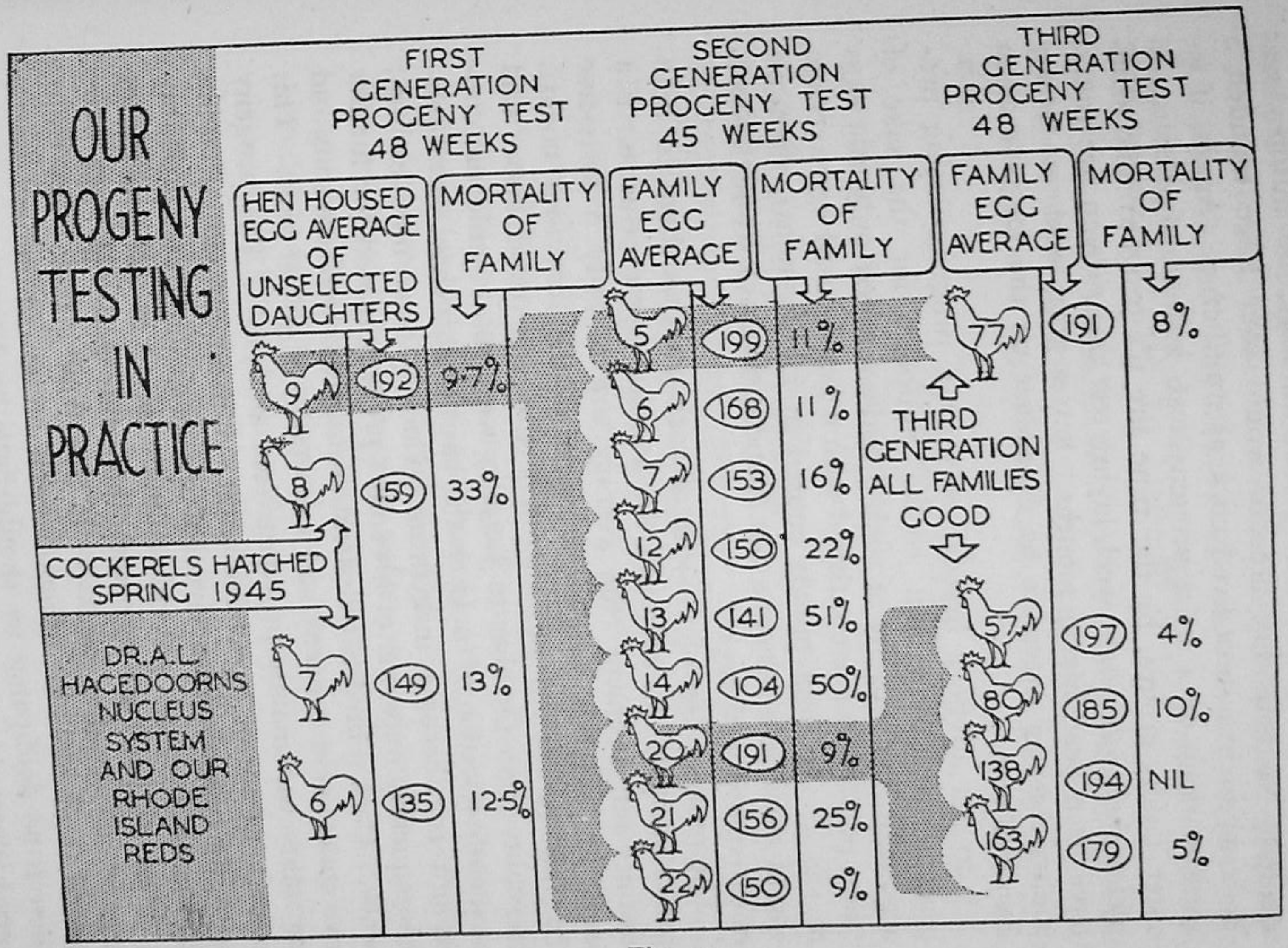

OUR PROGENY TESTING IN PRACTICE
FIRST GENERATION PROGENY TEST 48 WEEKS
SECOND GENERATION PROGENY TEST 45 WEEKS
THIRD GENERATION PROGENY TEST 48 WEEKS
HEN HOUSED EGG AVERAGE OF UNSELECTED DAUGHTERS
MORTALITY OF FAMILY
FAMILY EGG AVERAGE
MORTALITY OF FAMILY
FAMILY EGG AVERAGE
MORTALITY OF FAMILY
COCKERELS HATCHED SPRING 1945
DR. A. L. HAGEDOORNS NUCLEUS SYSTEM AND OUR RHODE ISLAND REDS
9
192
9·7%
8
159
33%
7
149
13%
6
135
12·5%
5
199
11%
6
168
11%
7
153
16%
12
150
22%
13
141
51%
14
104
50%
20
191
9%
21
156
25%
22
150
9%
77
191
8%
THIRD GENERATION ALL FAMILIES GOOD
57
197
4%
80
185
10%
138
194
NIL
163
179
5%

Fig. 27

body-size, his handling qualities, etc. No. 9 died at the end of his first breeding season. (Unfortunately, no autopsy was made.) No orthodox breeder would ever have founded a flock on such a short-lived cock as number 9. Again, if we were working on a strict progeny test, instead of selection of sister family groups, by the time sire 9's progeny had completed their forty-eight week laying test this proven sire would have been dead fifteen months. It is a great weakness for any poultry-breeding system to be dependent on the long life of an individual cock.

I do not advise a breeder to start a progeny-testing programme with only four cocks. Suppose, for the sake of argument, the progeny of cock 9 had averaged only 165 eggs (most poultry-men are satisfied with a hen-housed egg average of 150 to 170 from pullets housed in folding-pens), then we would have been selecting our foundation stock from the sons of three mediocre cocks.

The progeny test of the sons of cock 9 shows them to be a pretty variable lot, although the average egg production is a distinct improvement (the average are of only a forty-five week test, against forty-eight weeks of the first four cocks). In this generation of daughters the egg production and mortality from October to January were more uniform; consequently selection of cocks on the basis of this short-term four-month test became inaccurate. Cock 5 was not leading; consequently only one of his sons (77) was mated for further work. Cock 9 bred two first-rate sons, five mediocre sons and two cocks whose progeny had a mortality of 50 per cent. This mortality was mainly prolapsus (see analysis). The progeny of cock 13 are of especial interest. On an individual laying basis, the twenty-one survivors of this cock's daughters probably laid more eggs than any other family group in this generation (with a 51 per cent mortality they averaged 141 eggs hen-housed in forty-five weeks). If this family had been trap-nested, and had the selection been on an individual basis, there is no doubt that we should have bred from most of the very high-producing survivors of this most undesirable family.

Cocks 13 and 14 illustrate the necessity of putting little reliance on a cock until he has been subjected to a progeny test.

The pedigree of these two cocks was excellent, and they would probably have passed a handling test with flying colours.

We only bred from one son (77) of cock 5 and four sons (57, 80, 138 and 163) of cock 20, as we were putting hen-housed egg averages up to 227 eggs in forty-eight weeks in other families.

We are encouraged by the fact that in this third generation the cocks show up in a much more uniform fashion, and they are all as good as the winning cock (No. 9) of the first generation.

Analysis of Mortality

90 per cent due to prolapsus during nine weeks of May and June 1948

Cock No.	2	3	4	5	6	7	8
No. of daughters under progeny test.	52	65	16	36	42	48	31
Deaths during nine weeks	2	2	2	1	1	0	2
Cock No.	9	12	13	14	16	17	18
No. of daughters under progeny test.	27	45	43	24	74	56	42
Deaths during nine weeks	0	0	9	1	2	8	5

Three cocks had 120 daughters with no mortality during this May and June, yet the progeny of cock 13 had a mortality of 21 per cent during the same period with identical management. Prolapsus is generally ascribed to food and management. Breeders, by their individual selection and breed-type methods, are continually perpetuating many similar inherited causes of physical breakdown. As it is impracticable for a poultry-breeder to breed for a resistance to the main infectious poultry diseases on his own farm, the most practical approach is to breed for a combination of maximum production combined with minimum mortality—two fairly simple straightforward sets of records.

The following analysis, on a fold (housing seventeen sisters or half-sisters) percentage basis, illustrates how during the winter of 1946–47 we had only the odd fold of sisters in the high-egg-producing categories; the bulk of the flock were in the three lowest egg-producing categories of under sixty-nine eggs in 168 winter days. After two generations of breeding the flock from sons of proven sires, 84 per cent of the folds were in the

high winter-egg categories of eighty eggs and over per pullet in 154 days. In all tests when one is comparing the productive results from animals through different seasons account must be taken of the different weather conditions. The winter of 1946–47 was particularly severe, whereas the winters of 1947–48 and 1948–49 were particularly mild, and some of this improved winter egg production is due to the improved winter weather. However, a great deal of this difference is already discounted, as the 1947–48 test was twenty-one days shorter than the 1946–47 test.

Analysis of Winter Egg Production.

Hen-housed average egg production per pullet.	1946–7 (per cent).	1947–8 (per cent).	1948–9 (per cent).	
100–109 . . .	4	4	15	high egg averages
90–99	4	11	24	
80–89	4	21	45	
70–79	9	17	12	
60–69	40	24	4	low egg averages
50–59	35	21	0	
49 and under . .	4	2	0	
Duration of test . .	168 days	147 days	154 days ending March 31st	
No. of folds . . .	23	53	53	

Chapter Forty-one

Breed Cross Testing: Reciprocal Recurrent Selection

THE breed cross pullet chick has been most popular in Britain for many years, generally the sex-linked Rhode Island Red × Light Sussex or the various Leghorns crossed with Rhode Islands or Light Sussex. Breeders and farmers have believed that generally these first-cross chicks have been easier to rear and more productive than the pure breeds. Substantiation for this belief is difficult to find, but when two breeds carrying weaknesses are crossed it is probable that some element of hybrid vigour will mask some of these weaknesses in the cross-bred progeny.

Just as in most forms of plant- and animal-breeding, progeny testing is the most reliable method of uncovering the parents capable of breeding improved progeny, so it is necessary to test thoroughly the cross-bred progeny before a breeder can have confidence that his cross-bred chick is more productive than his pure-bred stock. During the last war the Black Leghorn × Rhode Island pullet made a great reputation (and hence a great demand) as a very high egg-layer combined with a low mortality. Since the war there has been a significant increase of Big-liver Disease in nearly all British stocks of pullets of this cross, yet there is not much evidence of this disease in British stocks of Black Leghorns or Rhode Island Reds. This is yet another instance that whenever you leave anything to chance in agriculture you will always be let down.

In Britain many breeders are pursuing progeny testing to a greater or lesser degree with their stocks of Rhodes and Black Leghorns, but they have neglected to test out how these breeds combine as a cross-bred. Just as there is great scope for breed cross testing, so there is also scope for work on strain cross testing.

In the United States many of the large poultry-breeders have been employing qualified poultry geneticists over a period of many years. During the spring of 1952 I attended a poultry-breeding conference in Chicago attended by twenty college geneticists, twenty-five qualified geneticists employed whole-time by poultry-breeders and a few large poultry-breeders, all students of applied genetics. Today the qualified whole-time geneticist is looked upon as essential for successful poultry-stock improvement, one of the organisations employing three leading scientists.

Many such large-scale breeders, however, after many years of intensive selection on a family basis with a closed flock, have noticed that in recent years they have reached a plateau of egg-laying performance (generally in the 230–270 egg range). Dr. Goodale at Mount Hope, in fact, is one of the very few poultry geneticists who does not admit to having reached such a plateau in a closed flock.

I quote Art Heisdorf, a leading U.S. poultry-breeder, who describes a new method of poultry selection—a method designed to break through this plateau, " Reciprocal Recurrent Selection ".

Dr. Hull said that there were many cases where it seemed that plant and animal breeders who had been selecting for a long period of years were coming to a point where it was almost impossible to make any further progress. This wasn't because the physiological limit of the individual had been reached, because in each generation there were many individuals which far exceeded the flock average, and the average of the best families. Quite often these star individuals came from otherwise average families.

Anyway, it seems that in some cases there is some barrier beyond which it is impossible to go as far as breeding progress is concerned. Dr. Hull said he could think of only one or two things which could cause this, and if his assumptions were correct, it would mean that a new breeding procedure would have to be used if a breeder expected to make any further progress.

Each individual has chromosomes in every one of its cells in the body. These chromosomes come in pairs, one member of each pair coming from the dam, the other coming from the sire. In poultry there are either thirty-nine or forty pairs of chromosomes. It is on these chromosomes that the genes are located which are the determiners of the characters an individual possesses. These genes are also inherited in pairs. Each individual has many thousands of genes in each of its body cells.

Let us assume that a certain trait is determined by the presence of ten pairs of genes. Let us suppose that there are ten desirable genes which we will designate by capital letters *A*, *B*, *C*, *D*, *E*, and so on through *J*, and that there are ten undesirable genes which we can designate by small letters *a*, *b*, *c*, *d*, and so on through *j*. The most elite individual would be one which inherited *A* from both its sire and dam, *B* from both its sire and dam, *CC*, *DD* and so on down the line. The genotype of the more desirable individual would be *AABBCCDDEEFFGGHHIIJJ*. That individual would have twenty desirable genes.

The next most desirable individual would have nineteen desirable genes, which in turn would be better than one inheriting fifteen desirable genes, which would be better than one inheriting only one desirable gene, but which would be better than the individual inheriting no desirable genes. The genotype of the poorest possible individual would be *aabbccddeeffgghhiijj*—it possesses twenty undesirable genes.

When we have a situation where a character is inherited like that, we say that the genes are inherited in an additive fashion. The breeder then would strive to increase the frequency of the desirable genes at the expense of the undesirable genes. He would do this by individual selection if heritability were high, a combination of individual and family selection where heritability was intermediate, and mostly family selection where heritability was very low. It is thought that genes are inherited in an additive manner in the majority of cases. It is this type of gene action which is assumed to exist in most of the studies made in the field of population genetics where, with the use of heritability values and selection differentials, the amount of progress can almost be predicted in advance. But there are other types of gene action which are also important.

Suppose an individual inherits gene *A* from its dam and *A* from its sire to produce a trait with a certain value. Suppose another individual with a genotype of *Aa* gives results equally as good. Then we have a situation which we call complete dominance. The "*A*" gene completely suppresses the expression of the "*a*" gene.

Sometimes the *Aa* individual gives results which are intermediate to what we would receive if the genes were inherited in an additive fashion, or if complete dominance existed. Then we have what

is known as incomplete dominance. But sometimes we find that the *Aa* individual gives results superior to what we get under complete dominance, something better than dominance, and so that situation is called over-dominance. That is the situation which Dr. Hull thinks is causing the trouble when a breeder does everything he can, using the usual systems of breeding, and yet fails to make progress.

The heterozygote gives results which are superior to those of either of the homozygotes. But when this superior individual, the heterozygote, is used for breeding, it doesn't breed true—in fact, all that happens is that a level of equilibrium is reached. Dr. Crow, of the University of Wisconsin, said that over-dominance could be at work only a small percentage of the time, and yet could be very important—that great progress could be made if the breeder could secure these heterozygous individuals in greater numbers. Dr. Hull replied that that was what a reciprocal recurrent selection programme would do.

The first thing to do to get a programme of reciprocal recurrent selection started is to identify two or three strains which nick well together to give results which are better than any of the strains in a pure condition. It will take some time to get this information, because if you are starting with a good strain, most strain crosses will not do as well as your own strain. Eventually, however, you can probably find something which will give you a lift in performance. It is more difficult to find still another strain which will cross well with the other two, but this also can be done.

Once found, the breeder will maintain these strains in a pure condition on his farm, crossing them for the production of commercial chicks. This sounds like a programme of simple strain crossing which has been practised by many breeders for a long period of time, but it is vastly different. The difference comes in the way the pure strains are multiplied. They are multiplied not on the basis of their own performance, but on how well they cross with the other line.

Probably the best way to demonstrate how this programme would work on a practical breeding farm would be to show how we are planning to use it in our own programme. We are completely sold on it. Each year we plan to test 100 new males in our breeding-pens. We don't have that many breeding-pens on our farm, but plan to use them several times during the year in the manner suggested by Dr. Hutt, of Cornell. Comparisons between males will only be within the various series of matings in order to get away from the effects of widely varying dates of hatch.

In fifty of the pens we will put males from strain *A* (or breed *A* if this were a breed crossing programme), and males from strain *B* will go in the other fifty pens. The males from strain *A* will be mated to females of strain *B*, and the *B*-strain males mated to *A*-strain females. The males from strain *A* which gave the best

results when their offsprings' performance was measured will be used to multiply the *A* strain. They will be mated to *A*-strain females which did well when mated to *B*-strain males. The same procedure would be used in the case of multiplying the *B* line. You can see that this is essentially a progeny-testing programme. As such, it has the disadvantage of any progeny-testing programme, in that the interval between generations is increased.

In our own case, if we tested fifty new *A* males each year we would probably select the best five surviving males to multiply the *A* line. The selection would be fairly close, and yet inbreeding would be held at a minimum. That was one point which was stressed at the Heterosis Conference. Inbreeding with the pure lines should be as small as possible in order that the wrong genes did not become fixed—which would make the programme ineffective.

What the breeder is trying to do in a programme of this kind is to select for the same genes in both strains where the characters were inherited in an additive manner, but to select for gene *A* in one line, and gene *a* in the other line, when over-dominance was important. The nice thing about this programme is that it is fairly efficient if genes are inherited additively, and very effective in cases where over-dominance is important.

This new system is designed for progeny testing, but at Salisbury we have adapted recurrent selection to sib-testing. We are testing Black Leghorns for their capacity to combine with our tester strain of Rhode Island Reds, and also reproducing pure Black Leghorn stock from the identical sires during the same breeding season.

Dr. Arthur Hanssen at Wiad, Sweden, has started a stock-improvement project for producing an improved White Leghorn × Rhode Island Red pullet. Each year he tests some fifteen cockerels White Leghorn × Rhode Island and fifteen on the reciprocal cross, but he is not recording his White Leghorns or his Rhodes as pure breeds, although he is of course reproducing them. Hanssen selects his parents to reproduce his pure lines of White Leghorns and Rhode Island Reds just by their capacity to combine together rather than their ability to live and lay as pure-breds. This fascinating new approach to breeding will have repercussions right through animal-breeding.

Chapter Forty-two

Should Breeding Poultry be Managed Extensively or Intensively ?

IN Britain poultry-breeding is universally carried out on the extensive grassy systems, it being the generally held belief that the breeding-stock is healthier and hardier as a consequence. Small houses and fixed breeding-pens for the pedigree breeder trap-nesting his pullets, flock mating of large flocks housed on free range—and in recent years the folding-pen has been used with success as a breeding-pen—are the usual systems of management used by poultry multipliers. It is interesting to compare this British breeding set-up with the methods of poultry-breeding used in North America. There, as a consequence of cold winters and hot summers, their breeding-flocks, as well as their commercial egg-laying flocks, are housed intensively on the deep-litter system (nowadays Americans prefer the name "built-up litter system" as being a more accurate description).

Historically it is interesting to remember that poultry-farming as an industry was built up rapidly after the 1914–18 war on both sides of the Atlantic, using an intensive type of housing, the flocks being confined to the floors of large houses. The poultry-men of both continents ran into plenty of disease troubles. In Britain a partial solution was evolved by housing the flocks in small units in the outdoor systems of slatted-floor houses folds, etc. The Americans, with their severer climate, had no such choice. The result is that they have been com-



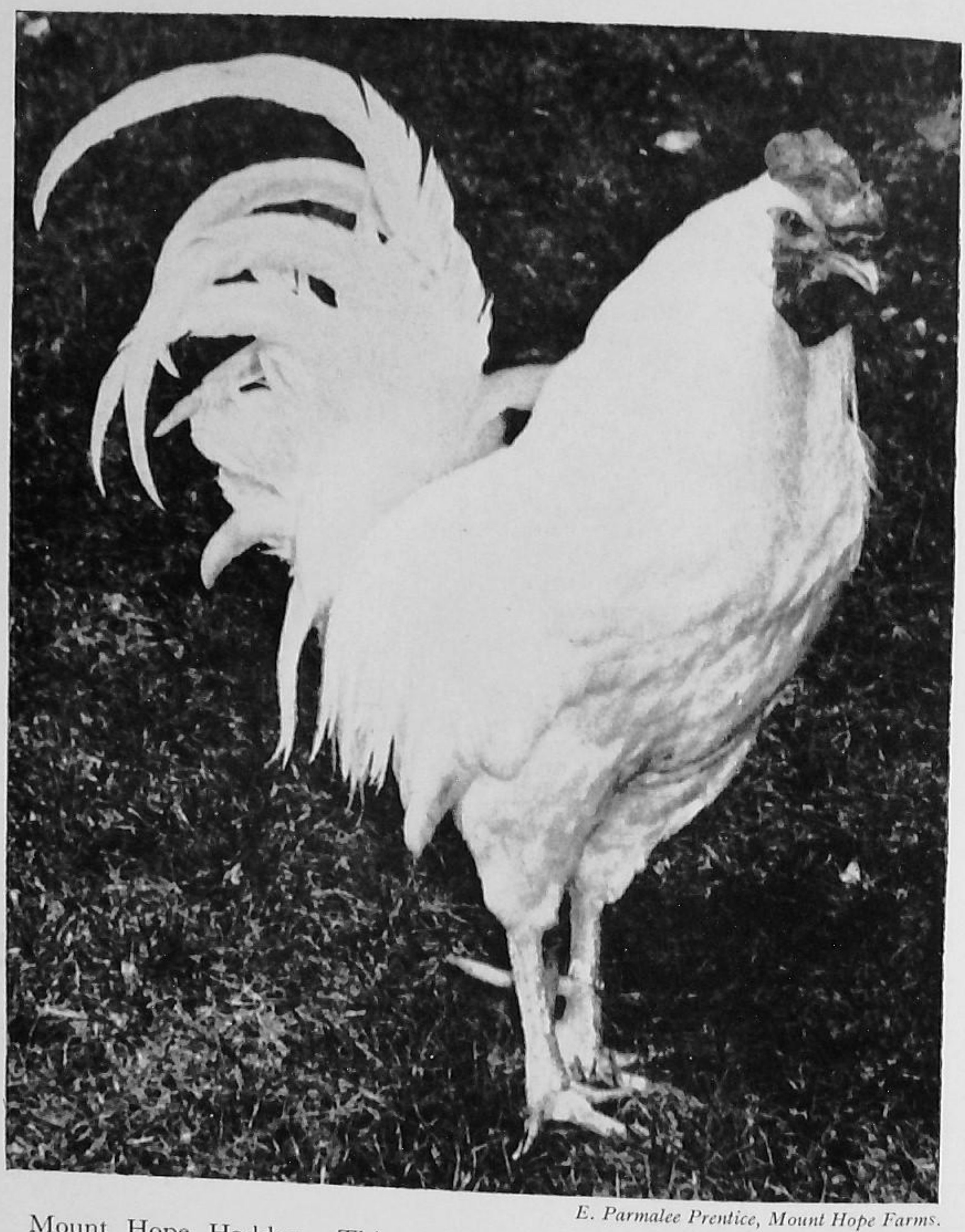


Photos, 'Farmer and Stockbreeder'

(*Above.*) A hand-trolley is used for the corn feed and egg collection in this hen-yard. Each little yard is 8 ft. wide.

(*Below.*) The hen-yard system adapted for progeny testing. Forty small hen-yards housing forty daughters of a cock in each.

(See page 213.)



E. Parmalee Prentice, Mount Hope Farms.

Mount Hope Haddon. This cock had the distinction of siring eighty daughters with an average production of 289 eggs weighing 25 oz. per dozen.
(See page 234.)

pelled to study the refinements and intricacies of intensive poultry-keeping, and have now come through with today's productive, labour-saving and efficient deep-litter system.

The deep-litter system consists of managing laying flocks of poultry in large, well-insulated, well-ventilated poultry-houses. The birds drink from automatic watering devices, designed to prevent them wetting the litter by flicking drips of water off their beaks. They always have access to dry mash supplied in troughs of waste-free design. The flocks roost on a droppings pit, a structure of perches and 2 × 1 in. welded wire usually fixed at 2 feet above floor level, which allows the droppings to accumulate to a depth of 18 inches on the floor. These droppings are removed only once or twice a year, another labour-saving feature of the system. Usually a floor area of 2 to 4 feet per bird is allowed, according to size of pullet preferred. For commercial egg production a 100 per cent pullet flock is housed in these deep-litter houses in July or August, the floor is littered down with a variety of waste products, according to district, wood-shavings and chopped corncobs being popular. During the season fresh litter is added, but the litter is removed only once a year. Since the discovery of the biological value of this litter, the tendency is to leave it in for several years between cleaning out. A gradual build-up in the depth of the litter is achieved to a depth of 8 to 10 inches by the addition of fresh litter and by the poultry droppings. These droppings are scratched into the litter daily, and rapidly broken down to a powder by bacteria, the resultant release of ammonia into the atmosphere being normal. Americans, indeed, aver that this ammonia has a beneficial effect in controlling coccidia.

American farmers evolved this deep-litter system from the ordinary intensive system during the last War, when they could not raise enough labour to clean out their large poultry-houses at regular intervals of two or three weeks. The farmers and the scientists were intrigued to find that the poultry were rather more productive as a consequence of this apparent neglect.

The main consequence of this deep-litter technique is that the efficient American poultry-man has such a labour-saving lay-out that is is considered that one poultry-man is fully

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employed with 5,000 to 10,000 pullets, producing up to some 6,000 clean eggs daily winter and summer. I must stress that this is a picture of commercial egg production by the efficient specialist in North America. Most eggs, however, are produced in small flocks by family labour in a far less efficient manner.

The United States poultry-breeding flocks are also managed on this deep-litter system. During the last twenty years American breeders have been taking up family-breeding and progeny testing their families of poultry in these intensive (and now deep-litter) houses. They have been progeny testing their families under the identical conditions in which the progeny in the hands of their customers are going to be managed. Undoubtedly one reason for the success of North American intensive poultry-keeping methods is that the poultry-breeders have achieved considerable genetic progress in their flocks—progress towards higher production in that particular environment.

United States nutritionists have discovered some of the reason why poultry thrive on deep litter. They found that poultry could be bred on deep litter whilst they were fed a diet containing no animal protein. This showed that one result of the bacterial action in deep litter was the production of nutrients which Americans grouped under the coined description "animal protein factor". One of these main factors was discovered to be vitamin B12, an essential vitamin for poultry reproduction. This was demonstrated by comparing hatchability of a poultry flock housed on deep litter compared with a comparable flock housed on litter which was cleaned out once a fortnight. No animal protein was added to the diet of either flock. Hatchability was high in eggs produced from the flock on deep litter, but the eggs from the clean-litter flock dropped to under forty chicks per 100 eggs set.

The animal protein factor is present in cattle-droppings, when voided, which possibly explains the predilection of the British farmyard fowl for the midden. These discoveries do not mean that farmers can at present curtail the ration of scarce and expensive animal protein feeds. It does mean that the future of animal husbandry is linked with the study of

getting the micro-organisms to work in harmony with the farmer's livestock.

As a result of applying scientific methods of stock improvement for fifteen to twenty years, and under this intensive method of management, American poultry-breeders achieved high hen-housed averages from their flocks of from 170 to 260 in spite of a poorer health record—a result of their intensive method of management. The wastage (the sum of mortality and culling) in the American commercial flock ranges from 20 to 60 per cent a year, even when there is no serious outbreak of disease. Notwithstanding these high flock-wastage rates—two to three times the comparative wastage rates in Britain—the American poultryman achieves from his flocks twenty or so more eggs per bird a year than does his British counterpart.

The American breeder achieves a considerably higher hatching percentage than we do in Britain, and also uses more mass-production methods in his breeding. Even with his high food and labour costs, he produces a high-quality day-old pullet chick for sale at 60 per cent of the price of the equivalent chick in Britain.

The American nutritionist claims much of the credit for the undoubted success of poultry-breeding on deep litter. Personally I believe we over-value the merits of our grassland in the nutrition of breeding poultry. It must be remembered that as most of our day-old chicks must be hatched during February, March and April, the important months for the nutrition of the breeding-flocks are November to February—the months when our grassland is at its lowest feed value.

Poultry Breeding in Hen-yards

After seeing this intensive American poultry-keeping, which clearly offered great scope for increased productivity and efficiency, I came to the conclusion that a simpler, easier-to-manage system of poultry-keeping could be evolved for the milder British conditions. I designed the hen-yard system—a hybrid between United States deep-litter and the yarding of cattle or pigs—as being suitable for the British general farmer who, under today's conditions, is the main poultry-keeper. Although he often has flocks of considerable size, I doubt

whether he is prepared to make a sufficient study of deep-litter poultry-keeping to make a success of it in our moist climate. I derive considerable encouragement from the fact that after only four years the hen-yard system has proved so successful that it is accepted as one of the main methods of commercial egg production in the South and Midlands of England. (*The Henyard*, Geoffrey Sykes, 1952. Crosby Lockwood.)

We have now carried out breeding experiments in hen-yards with flocks involving several thousand pullets over several years. Although we have a lot to learn, our results have been most promising. From these large flocks of 300 to 600 pullets in a hen-yard, our hatchability of chicks from all eggs set varies from 75 to 86 per cent—very high hatches by British standards. Chick quality has been excellent. For breeding as in commercial egg production the flock benefit physiologically by being an outdoor flock, yet are in an intensive method of management.

During bad weather, poor fertility and egg chilling materially depress British hatching results—troubles which are obviated in hen-yards. Wastage (the sum of culling and mortality) from a flock of pullets housed in hen-yards varies between 5 and 20 per cent—a fraction of the wastage incurred in the deep-litter system in the United States.

The labour requirement of flocks housed in hen-yards is little different from that of flocks on deep litter, the main day-to-day chores amounting to little more than feeding and collecting eggs.

Naturally a standard of nutrition up to an American breeder's mash specification is a necessity if good breeding results in hen-yards are to be ensured. The following allowances represent the best interpretation of studies on the nutritive requirements made by a committee of nutritionists of the United States National Research Council (1951). The specification should not be diluted by the addition of a corn feed.

Total protein (per cent)	15
Vitamins—	
Vitamin A activity (I.U.)	3,300
Vitamin D (A.O.A.C. units)	450
Riboflavin (mg.)	1·3
Panthothenic acid (mg.)	5·0
Pyridoxin (mg.)	1·6
Biotin (mg.)	0·07

Minerals—	
Calcium (per cent)	2·25
Phosphorus (per cent)	0·75
Manganese (mg.)	15·0
Salt (per cent)	0·5
Iodine (mg.)	0·5

The calcium figure includes that proportion fed as limestone grit or oyster-shell. The salt figure represents added salt.

Breeding poultry in hen-yards has led us to adapt the system specifically to suit Hagedoorn's nucleus system. At Tythering-ton Farm we now have a series of forty little hen-yards, each of which houses forty daughters of a cock.

Under today's conditions of poultry-keeping—conditions of high feed and labour costs and narrow profit margins—sheer economics are forcing British poultry-keepers to adopt some intensive method of poultry-keeping, such as laying cages, deep-litter or hen-yards, all intensive labour-saving systems conducive to high winter egg production. The British hen running out through the winter months on free range or in folds has never laid well through the winter months. In recent years only 30 per cent of our egg-packing station throughput has been produced during the scarce-egg months of August to February. Although British poultry numbers are up on pre-war figures, eggs are severely rationed during the autumn and winter, yet in some springs a glut of eggs is produced on our farms.

Now that the commercial egg-producer is taking up some intensive method of egg production, where does the poultry-breeder stand?

I believe he will have to change slowly over to intensive methods of management. I write "slowly" advisedly, because the breeder will have to learn the job as he changes. The poultry-breeder who is working on a stock-improvement scheme is doing two jobs at once with his pullet flock : his pullets are a progeny test of the parents, but they are also mated up and producing hatching eggs. It is desirable that the chick-rearing and management of the laying pullets (i.e. the progeny test) should be on similar systems to those used by the breeders' customers, to enable the breeder to achieve a genetic improvement for all those multitudinous factors required in today's commercial egg production.

Many of our breeders will take a poor view of this argument. They firmly believe that degenerate stock will result from such intensive management of breeding stock. I can assure them that where scientific principles have been applied for a large number of years in the United States, their breeders have produced poultry which in the hands of the efficient specialist commercial egg-farmers put up hen-housed egg averages in the range of 200 to 260 eggs per pullet—averages which are comparatively rare in Britain.

Disease Resistance

To some extent the American breeders are achieving some measure of disease-resistance in their poultry stocks by these methods. Many big U.S. breeders claim that they welcome an outbreak of disease on their own farms, as it shows up the resistant families. It is doubtful whether this is a practical approach to the problem, as, if the breeder is constantly introducing and exposing his flocks to various diseases, the debilitated flocks will fail to express their egg-producing capabilities. They will not be in proper breeding shape, and there is also the grave risk of the breeder introducing a disease on to his customers' farms.

When breeding for a genetic resistance to a specific strain of a disease in a plant or an animal, it is advisable to subject all families under test to the particular strain of the disease. When one appreciates the many strains of the many diseases to which poultry are subject, it is clear that it is impracticable for a poultry-breeder to try to introduce an actual genetic resistance to disease into his poultry flocks. A main object of the poultry-breeder must be to isolate his flocks as far as possible from diseases in the district, so that his flocks can be maintained in a first-rate state of health and productivity.

Generally speaking, poultry stocks are bred up to a level of potential egg production already far above the capacity of nine out of ten customers. The first job of the progressive poultry breeder is to sell his customers a *good husbandry programme*.

It is necessary to produce stock which will thrive well under a wide variety of management, climate, and varying strains

of various diseases. The logical approach to achieving some measure of genetic toughness is to test for egg production thirty to forty daughters of each cock under first-rate conditions on the breeder's own farm, and to get a liveability picture from 100 to 200 daughters of each of the same cocks in the hands of a number of customers. This wing-banded progeny of each cock should be evenly divided among the customers capable of only poor management, as there has to be considerable mortality before a breeder can select for a "genetic viability". This simple sire-testing programme which we are initiating is more logical and ahead of anything I have found in North America, which is engrossed in fully pedigreeing all its stock and the consequential International Business Machine cards to cope with the torrent of records.

In the U.S. there is already the situation where certain breeders can put up very high averages on their own well-managed farms, yet the stock they sell will only do well on good farms. There are also breeders who produce stock capable of putting up high averages under mediocre management, which illustrates that there are definite varying genetic resistances to disease and varying general toughness and ability to thrive under poor conditions.

Those poultry stocks which have some genetic resistance to common poultry disease are of great value, and steps should be taken to uncover such flocks. Here again the Americans in California and Cornell have taken the first steps by initiating random sample laying trials, the sample consisting of hatching eggs which are incubated, chicks reared, and resultant pullets put through a laying trial. (See Chapter Forty-four.)

Chapter Forty-three

U.S. and U.K. Official Poultry-breeding Schemes

IN Britain we have the Poultry Stock Improvement Plan (P.S.I.P.) the breeding section of which consists of a ladder of three grades.

A. *Foundation Stock Breeders.* This is intended as the grade in which breeders carry out progeny testing under a Government plan. This grade in 1952–3 is not in action, because, with the post-war shortages, the Government has not succeeded in raising sufficient staff to work it.

B. *Breeders' Grade.* This grade of poultry must have been bred from hens which have been trap-nested in their pullet year and in this pullet year have produced not less than 170 eggs weighing at least 2 oz.

C. *Commercial Stock Suppliers' Grade.* Here chicks can be bred from pullets: any purchased breeding stock must be derived from Breeder's Grade. No standard of egg production or viability is stipulated in this grade.

In the above grades B and C no particular standard of breed type need be observed, but the birds must be of the breed stated, and must be well grown, healthy and vigorous.

Breeders in P.S.I.P. receive a free service of blood agglutination tests and post-mortem examinations. A breeding-station must be completely clear of all reactors to B.W.D. In practice extremely few breeders avail themselves of the free post-mortem service, and consequently must be working largely in the dark.

The vast majority of poultry multipliers are in C grade, and the county poultry officers are striving to raise standards in this grade. Only a small proportion of poultry-men in this C grade maintain accurate records of egg production or mortaility, and consequently the poultry officer is only able to make a visual assessment of the quality or lack of quality of the poultry stock. These British flocks are always managed on some out-of-doors system, running out on pasture complying with the prejudices of the poultry-man and poultry-officer who believe that the stock is thereby gaining in health, who possibly even believe that the stock is improving in genotype, notwithstanding the fact that these poultry are usually housed under such conditions of winter slush, mud or snow that they generally fail to yield an economic winter egg production.

By and large, the health provisos of the British P.S.I.P. are excellent.

The breeding provisos leave much to be desired.

The foundation stock grade is at present not in operation, and is not likely to be put into operation, as the British Treasury is trimming rather than expanding expenditure on schemes involving increased Civil Service personnel.

Consequently Breeders' Grade is the top grade—a grade of little merit, a grade which stipulates all the inefficient breeding practices of trap-nesting, breeding from hens, individual selection. The only rational stipulation in Breeders' Grade is the negative one on breed type. At some future date it is proposed to introduce some elements of family breeding into Breeders' Grade, which would be a great improvement. British poultry-breeders should study the North American breeding schemes, and the consequent implication, before they rush into official poultry registration schemes. These schemes are summarised in H.M. Stationary Office Report No. 6, *Development of Poultry Industry in North America.*

The United States National Poultry Improvement Plan (N.P.I.P.)

This scheme was inaugurated in 1935, and is a co-operative project between the States and the United States Department of Agriculture.

The United States Record of Performance (U.S.R.O.P.) embraces records of egg production, egg-weight and body-weight made on the breeder's premises under official supervision. Each pullet candidate for U.S.R.O.P. is banded with a sealed and numbered official leg-band. Each such pullet candidate is trap-nested for 365 days from date of first egg. Three-day trapping is now allowed. Pullets or hens which are designated U.S.R.O.P. are those which have laid 200 eggs or more during the trap-nest year, such eggs to average a minimum egg weight of 24 oz. per dozen. All females must be of the minimum qualifying weights laid down, such as Leghorns 3·5 lb. and Rhode Island Reds 4·5 lb., the whole flock being individually weighed by the State Inspector between January 1st and June 1st.

This type of Government poultry-breeding scheme requires a tremendous amount of policing, as evidenced by the following duties of an R.O.P. Inspector.

It is the duty of the R.O.P. Inspector to visit and inspect the work of each U.S.R.O.P. breeder at least five times a year, his visits to be so timed that each season of the year shall be represented in his reports, and at least three of these visits shall be unannounced. On each visit he shall do the trap-nesting for the day, and shall record all eggs laid, and during the official egg-weighing period for the breeder shall weigh and record the weight of the egg laid by each individual bird entered in U.S.R.O.P. He shall examine pullets apparently out of production to see that they are not being credited with eggs. In most States, the hour of day the egg is laid is recorded on the trap-nest card, which method facilitates the inspector discovering faked entries in the egg record, as a hen when laying a sequence of eggs daily takes twenty-four hours plus to produce an egg. If a pullet is credited with an egg laid at midday on the day before the inspector's visit, yet is trapped at 9 a.m. by the inspector, then the inspector adduces that the previous day's entry is faked. He also compares the number of eggs being incubated from each hen with the number she is credited with having laid during the corresponding period, and has authority to test these eggs for fertility. He reports to the supervisor any suspicious circumstances or appearance

of fraud in the records or business dealings of a U.S.R.O.P. breeder.

Each male and female passed as U.S.R.O.P. must pass this inspector and possess strong constitutional vigour, and must be a good representative of the breed and variety as designated in the American Standard of Perfection.

The highest breeding stage in the United States scheme is the United States Register of Merit (U.S.R.O.M.). A U.S.R.O.M. cock is a cock at least half of whose daughters qualify for U.S.R.O.P. and which has a minimum of twenty daughters so qualified.

A U.S.R.O.M. dam is a female which has at least one half and a minimum of four of her daughters entered to qualify in U.S.R.O.P. In addition, there is the U.S.R.O.M. Honour Roll, with a stipulation for a sire of a family average egg-weight of 24 oz. per doz. minimum and a hen-housed family average dependent on the size of family, running from 200 for a family of forty daughters to 250 eggs for a family of twenty-five daughters.

The Pullorum (B.W.D.) testing is a service for which the breeder pays, and several degrees of freedom from Pullorum are recognised as Pollorum Controlled (less than 2 per cent reactors): Pullorum Passed and Pullorum Clean—a less strict Pullorum Control than in the British P.S.I.P.

All the breeding data for U.S.R.O.P. and U.S.R.O.M. are collated and analysed centrally at Beltsville, Washington, D.C. These data are handled mechanically on International Business Machines type cards. One such card, when appropriately punched, carries all the breeding data of one pullet.

It can readily be seen how complex the progeny testing of poultry becomes when the egg production of each individual pullet is recorded. It is a most complex business on the breeding-farm, but when Governments carry it that stage farther—carry this progeny testing of poultry into official registration schemes—the advantages of the nucleus system of progeny testing poultry, where the breeder records only the breeding characteristics of family groups of pullets, becomes obvious.

These poultry-improvement plans have resulted in the creation of a vast bureaucracy to administer them. The

genetic improvement resulting from these breeding plans is very difficult to measure. Americans are unanimous that whenever a poultry-breeder embarks on this improvement plan he gets interested in the records, improves his management, which results in a large increase in the hen-housed egg averages of his flock.

By enforcing trap-nesting on the breeders, only 10 to 30 per cent of the flock are entered as candidates for U.S.R.O.P.—usually such small numbers in the case of the smaller breeder that the labour of such expensive intricate work must be mainly nugatory.

In the United States poultry-breeding schemes the breeding-results from each flock are published in the Government register, which register becomes the poultry-breeder's " Bible ". It becomes the aim and object of every breeder to put up a good show in this register. Immediately it becomes necessary to have a large number of inspectors to police and ensure fair play in the breeding-scheme.

Some of the best American breeders, such as Parmalee Prentice, Dryden, Babcock, Kimber, De Kalbs, Wallace, do not play ball with the official schemes. Although there is no doubt that these breeding schemes are achieving a measure of genetic improvement in poultry stocks, it is far easier to pursue a more satisfactory, more accurate progeny-testing project outside an official scheme, where the results are not published, where the breeder takes as far as possible unselected samples of his stock for testing purposes, and where he can make due allowance for the day-to-day accidents and occurrences on his own farm. The published analysis of family averages of a poultry-breeder means one thing, but the poultry-breeder who has personal knowledge of the season, etc., who possibly discounts the diseases, the mishaps during the recording period, puts an entirely different interpretation on such family analyses —an interpretation of far greater value. George Odlum, the British Friesian breeder, put the point in a nutshell when he exclaimed, " For my own breeding records, I knock out this animal and that animal, but [in a twinkling aside to the audience] for publicity purposes I don't strike out anything."

In U.S.R.O.P., preliminary trap-nesting of thirty days is

Breeder's Name and Address	(a) Pullets on Farm	(b) Birds originally trap-nested for USROP entry	(c) Birds withdrawn during trial period	(d) Birds entered in USROP	(e) Individually pedigreed birds entered in USROP	(f) (g) Qualifying as USROP		(h) (i) (j) Qualifying Birds Which Laid			(k) (l) (m) Average of all Birds Entered			(n) (o) 1951 Single Male Matings		(p)	(q)
						Number	Percent	200 - 249 Eggs	250 - 299 Eggs	300 or more Eggs	Egg Production	Egg Weight oz. per doz.	Body Weight	Number	Females in Matings	Pullorum Class	Years in ROP
Coombs, J. O. and Son Sedgwick, Kansas	1,193	1,193	55	1,138	1,138	517	45.4	219	288	10	189	25.0	4.6	23	426	PP	23
Creighton Brothers Poultry Farm Warsaw, Indiana	65,000	6,000	553	5,447	5,447	2,049	37.6	1,256	748	45	171	25.5	4.6	96	2,400	PC	21
Del Rio Farm, George G. Haws Rt. 1, Box 460, Mesa, Arizona	1,100	63	7	56	27	10	17.8	-	-	-	*41.0	24.6	4.3	3	27	PP	5
Dembro Poultry Farm Sewell, New Jersey	10,000	1,947	14	1,933	1,933	1,288	66.6	552	661	75	206	25.7	4.6	32	625	PC	26
Dennis, F. A. Mansfield, Missouri	700	700	12	688	688	363	52.8	195	141	27	189	26.3	4.9	16	317	PC	15
Densmore Poultry Farm Box 267, Roanoke, Virginia	4,000	1,121	303	818	818	336	41.1	-	-	-	*55.3	25.2	4.2	12	259	PC	23
Dietz Poultry Farm Center Point, Indiana	600	500	-	500	500	280	56.0	164	111	5	194	26.7	4.7	5	100	PC	17
Down's Poultry Farm Romeo, Michigan	2,000	300	-	300	150	188	62.7	99	88	1	208	26.9	4.7	12	240	PC	25
Dublin Poultry Farm Dublin, Texas	1,000	1,000	-	1,000	232	663	66.3	-	-	-	*64.7	25.7	5.1	22	367	PC	13
Eberhardt Poultry Farm West Liberty, Illinois	1,800	335	8	327	327	98	29.9	64	34	-	151	26.1	4.4	7	126	PC	9
Edmonds, George W. Luverne, Minnesota	2,000	559	54	505	505	334	66.1	106	154	74	226	25.6	4.7	21	329	PP	13
Erath Egg Farm Stephenville, Texas	1,595	1,595	-	1,595	1,594	855	53.6	-	-	-	*64.4	25.2	5.1	25	206	PC	9
Feather Hill Farm Dade City, Florida	3,000	712	46	666	664	167	25.1	123	43	1	163	24.6	4.0	18	122	PC	5
Fletcher and Son Concord, North Carolina	2,200	612	72	540	538	330	61.1	94	171	65	215	25.5	4.7	12	180	PC	1
Fonk's Poultry Farm Kenosha, Wisconsin	1,500	550	-	550	550	118	21.5	83	33	2	137	26.4	5.2	10	211	PCd	11
Foreman Poultry Farm Lowell, Michigan	4,300	734	-	734	342	489	66.6	-	-	-	*82.7	25.1	5.3	-	-	PP	1
Fuzzydele Farms, Frank H. Ellis, III Elverson, Pennsylvania	1,547	1,047	-	1,047	1,047	339	32.4	-	-	-	*51.4	24.9	4.7	20	500	PC	16
Gasson's Poultry Farm Versailles, Ohio	8,041	2,399	565	1,834	1,834	1,497	81.6	339	900	258	250	26.5	5.0	32	701	PC	25

FIG. 28.—A page from U.S.R.O.P. Register 1950–51
(Column K. The numbers with asterisks are the year's percentage egg production of those flocks trap-nested only three days a week.)

permitted, and in some cases up to three months, when only whole families of candidates can be withdrawn.

Successful U.S.R.O.P. pullets are a highly selected lot, and consequently unreliable material for the progeny testing of U.S.R.O.M.

Although in theory this edifice of improved poultry-breeding is built on breeding from progeny-tested stock, U.S.R.O.M., in practice few such matings of old cocks and hens are made. The viability of such stock is poor, as are fertility and hatchability, and it is generally found that the breeder is concentrating on the sons and daughters of his proven stock.

It is most significant that Americans are having grave doubts over their R.O.P., which are illustrated by the following quotation of the Committee's Report on re-examining the R.O.P. Programme, Kansas, Feb. 1952.

" It was agreed that it is very difficult to combine an efficient breeding programme and an accurate testing programme, as is attempted in R.O.P., where the same birds are used for both purposes. An example of the conflict is that while it might be desirable to withdraw up to 90 per cent of the birds under traps in a breeding programme, there should be no withdrawals in a testing programme. It was the opinion of the committee that the breeders should have more freedom in breeding methods, but that the stock produced should be properly evaluated. It was agreed that the present methods of evaluating performance are not adequate, and that for many breeders a random sample test would more accurately reflect the potential performance of the breeder's stock. The random sample test could be set up to give more freedom in breeding methods and procedures."

It is a great step forward that this committee of the leading United States geneticists and poultry-breeders should recommend in 1952 random sample testing as the only rational method of testing strains of poultry, as recommended by Hagedoorn at the Ottawa Poultry Congress, 1927.

In 1935 U.S.R.O.P. was started as a democratically organised, officially sponsored poultry-stock improvement scheme. The leading poultry geneticists and breeders believed they knew the best way to breed better poultry, and so they devised this

breeding scheme to conform to their ideas. In 1952 these same men have decided that they do not know the best way of breeding poultry; they cannot help but take notice that the top places in the laying trials are crowded by non-R.O.P. breeders and that the majority of leading R.O.P. breeders feel they could make more rapid breeding progress if they were free of many of the provisions of R.O.P. There is consequently a strong movement to liberalise the breeding requirements of R.O.P., a movement to allow the breeder to follow whichever new breeding scheme appears to be most efficient for his own particular circumstances. At their National Plans Conference at Dallas in June 1952 the Breeding Committee of R.O.P. unanimously voted for random sample testing (on an optional basis) for all R.O.P. breeders. This is a revolution, in that henceforth R.O.P. breeders entering in the random sample tests will be evaluated by their entries at such tests, and the production of their R.O.P. candidates will not be published. Henceforth breeders can concentrate purely on achieving a genetic stock improvement, instead of, as hitherto, paying much attention to the showing put up by their trap-nested pullets (R.O.P. candidates) in the official register.

I believe that this unanimous vote at Dallas is the beginning of the end of Government-sponsored registration schemes, as I cannot conceive a liberalised R.O.P. scheme open enough to include all the modern methods of poultry selection, sire group testing, hybridisation, short-term testing (Lerner),[1] strain and breed cross testing, reciprocal recurrent selection,[2] and of course a new crop of promising genetic ideas which are just round the corner (Chapter Forty-four).

The American poultry-breeding industry illustrates how the large constructive breeder has all the advantages over the small man, irrespective of whether they are inside or outside the registration scheme. In Britain we have the position of the Poultry Stock Improvement Committee, anxious apparently to get a similar registration scheme going, and as a consequence encouraging many small breeders to start trap-nesting their

1 Sib-test selection.
2 One day a week trap-nesting as a sire test.

flocks. The scale of operation of these small breeders is such that when they start trap-nesting, they are starting pedigree breeding, they are starting individual selection (one of the least efficient methods of stock improvement) at great labour and expense, because they are working on an insufficient scale for progeny testing. Today most pedigree poultry-breeders in the United Kingdom find that the commercial first-cross pullet chick is their paying line and that the market for high-priced pedigree stock is so limited, that it does not justify the prohibitive costs of pedigree-breeding today.

In Britain several large hatcheries have started large constructive poultry-breeding projects, which in the course of a few years, when these organisations have genetic control of the female as well as the male side of their matings, will result in a big rise in the quality of British poultry stocks.

Taking the Sterling, Thornber and W. D. Evans' hatcheries, with an annual output approaching 20 million chicks, the progeny-testing projects of their hatcheries do not fit in with nor are they likely to tie up with the British P.S.I.P.; yet the genetic improvement resulting from the breeding-schemes of these larger hatcheries is likely to be many times more effective than any genetic improvement resulting from P.S.I.P.

In the period between the proof stage and publication of this book, Dr. Rupert Coles, head of the Poultry Section of the British Ministry of Agriculture, has announced that, subject to the approval of the industry, the breeding provisions of the Poultry Stock Improvement Plan are to be revolutionised and that random sample testing is to be adopted. Our poultry industry should give wholehearted support to these far-reaching proposals.

Chapter Forty-four

Laying Trials and Random Sample Testing

ON both sides of the Atlantic laying trials have been very popular. They have been well supported by pedigree poultry-breeders, who have looked on them as a shop-window by which the customer could gauge the productivity of the breeder's poultry. On the east of the Atlantic at such trials the poultry are housed intensively in deep-litter pens. In the United Kingdom laying trials the poultry are housed in small poultry-houses, and each entry have access to a small permanent patch of grass. The entry at laying trials is of necessity small, consequently the results are a worthwhile guide to a breeder's merit only when notice is taken of a breeder's position in the trials over a period of, say, five years. The modern tendency is for awards to be given to the breeder who is consistently at or near the top for a number of years. These trials in no way consist of a representative sample of a breeder's flock. Such trials also give some scope to the breeder with a flair for picking laying-test winners. Most breeders will try to send progeny, the result of a repeat mating, of proved success, in this great battle of wits. In Britain the permanent grass pens can carry a most uneven distribution of poultry parasites, which militates against the statistical significance of the trial, and from this aspect the United States small, deep-litter pens are probably preferable. The British National laying trial is of forty-eight weeks' duration, which should be remembered

when comparison is made with United States laying trials, which are mainly of fifty-one weeks' duration. At the British National, after the first eight weeks, no egg under 2 oz. is credited to the entry for the purpose of the competition. This emphasis on the large egg is a double-edged weapon. In Britain for ten years producers of large eggs have not been paid for this size increase. From the breeder's angle, strains of poultry laying large eggs frequently give poor hatching results.

From a comparison of British and United States laying trials it would appear that the United States hen has been bred to lay more eggs than has the British hen, but if a comparison is made of the average weight of eggs laid by the well-bred United States hen and the weight of eggs laid by the well-bred British hen, the difference is less marked.

During the 1947–48 season, over sixteen laying trials in the United States, where management varies from good to bad, the ten leading competitors entered 949 pullets which averaged hen-housed 249·9 eggs per pullet in fifty-one weeks. Mortality in this analysis was 9·4 per cent. These are remarkable production figures.

Hagedoorn, a voice in the wilderness, recommended a poultry sampling trial in 1923 (see Poultry Congress Papers, Ottawa, 1927) as the only rational treatment for laying trials. One such trial was started in Holland, but proved short-lived.

The Americans have now followed up this line: California started a random sampling test in 1947.

Cornell started such a laying trial in 1950. This trial is of great interest, because at Cornell, Hutt has been carrying out research on the genetic resistance of poultry to leucosis.

The regulations of this trial stipulate that a random sample of eggs be taken. The intention is that each sample shall be a fair and honest sample of what any buyer of the grade of chicks would receive. A disinterested person designated by the test management takes the sample and seals the box. The eggs are hatched at the test.

All light-breed chicks are brooded in three groups, all heavy-breed chicks in three other groups during the first eight weeks. Each sample of chicks is distributed equally among its respective groups.

For two weeks the chicks are brooded in close proximity to a flock of mature hens known to be infested by leucosis at an age when they are susceptible to the disease. All pullets reared are housed. No culling or selection is done except to pick out any males. Accidental deaths or missing pullets are not counted as mortality. Record is kept of each entry of eggs laid and feed consumed each month. Eggs are graded for size and samples of eggs are broken for egg-quality tests. Egg production is recorded up to 500 days from date of hatch—a method which gives a premium to early-maturing stock. Every effort is made to have environmental factors identical for all chicks.

The price of fifty pullet chicks as given in the entrants' current price list is charged against the entry, as well as all feed consumed during laying.

At the end of the test, "income" is determined by subtracting cost of chicks and feed from "returns" for eggs and market poultry.

I have given details of this random sample laying trial at Cornell University because I believe we can no longer afford to pursue our own laying trials along present lines. Our orthodox trials were conceived before statisticians took an interest in genetics, in the days when individual selection and pedigree breeding were held in high esteem.

The poultry-breeders of North America feel that they now want to be free of the shackles of the breeding provisions of R.O.P.; they want to be free to adopt any of the many new ideas of poultry-breeding. They believe that the quality of their stock must be evaluated by random sample tests, which must be instituted as soon as possible to cover all breeders over their vast continent.

The college geneticists in the U.S., many of whom have always been sceptical of the breeding provisions of R.O.P., welcome this revolution. They argue that at the Colleges they have not the facilities or numbers to indulge in satisfactory work in poultry population genetics. Under the new set-up the practical progressive breeder can launch out on many of the new ideas, unshackled by R.O.P., the college geneticist can co-operate, advise and study the results objectively, knowing that the progress or lack of progress made by

such breeders will be accurately assessed over the years in the random sample tests, where his stock will be tested against every other breeding scheme.

In England we are fortunate in that we have not started official registration of poultry in our P.S.I.P. We can therefore conveniently scrap Foundation Stock Breeders Grade which has never been brought into action, and Breeders Grade with its archaic provisions, and in its place institute as soon as possible random sample testing, the only logical way of evaluating the quality of a breeder's stock.

Historically it is interesting to record that the whole nucleus breeding system recommended in this book is one of holding random sample tests of the progeny of each breeding cockerel on the breeder's own premises. The Commercial Section at the English National Egg-laying Test has in effect been a random sample test in operation in England for many years. In view of the revolution in ideas in North America I suggest that all the British laying trials be converted rapidly into random sample tests.

This random sample testing has come to the forefront so suddenly that there is insufficient knowledge of the best way of putting these ideas into practice. As with all new ideas, its application and adaptation will have to be constantly improved as experience is gained.

The hybridisation of poultry has been based on random sample testing, and so Henry B. Wallace has much experience in what is involved. The following are his suggestions for official random sample testing in the U.S.:—

" 1. Twenty test locations.

2. Seventy-five pullet chicks started per entry in each location.

3. Every entry in each location.

4. Each entry replicated twice in each location, twenty-five pullets housed per replicate.

5. Each entry should be obtained from stock being sold in a minimum volume of 100,000 chicks of identical grade or *variety* (Hy-Line # 152 would be a variety by my definition).

6. Locations should be started at a progressively later date, so some are January hatched and some late May. All should be kept on test for fifty weeks after the overall flock averages 50 per cent production; or for fifty weeks after the flock is 180 days old.

7. It would be best to hatch the test chicks in one place after obtaining the hatching eggs directly from a breeder flock producing the variety. Obtaining *chicks* would be much less desirable.

8. Cockerel chicks should be destroyed.

9. In general, the 1951–52 rules of the California Random Sample Test seem satisfactory for measuring performance.

10. Various feeding programmes should be followed at the twenty test locations in proportion to the programmes most commonly used in the State. (In any one test, of course, only one programme should be followed.)

11. No trap-nesting.

12. Each kind of chicken should be reared separately, so all costs and all income can be allocated fairly. (See California rules.)

13. If the test locations have more space than requested by commercial entries, then they should accept experimental entries of stock which is planned for later commercial production, if good enough."

Chapter Forty-five

The Poultry Breeder's Catalogue

POULTRY-BREEDERS make a habit of producing an annual catalogue for the promotion of sales of their poultry-breeding stock. These catalogues are usually expensively produced and well-illustrated brochures. They consist mainly of the pedigree matings for the coming hatching season, giving the egg production and egg-size of some selected hens in their pullet year. The catalogue also lists the numerous prizes gained in the numerous laying trials. It is really of extremely little value to a prospective customer, because the information is all relevant to selected individuals. What a customer really wants to know is the hen-housed egg average of a breeder's pullet flock and the mortality from such an unculled flock, if he is to assess the value of the poultry stock. From a breeder's point of view, such figures are frequently difficult to produce, because he often does not carry his whole flock of pullets through eleven months of egg production. Earlier in this book I have made a case for a six-month progeny test May to November. Most breeders also pursue a programme of constant culling of individuals in the flock. A few British breeders have started to produce such hen-housed egg averages. When they start this innovation they should be specific, stating whether the record is from date of first egg.

In the U.S., where breeders have been progeny testing poultry for improved egg production for many years, some breeders are publishing most informative and valuable catalogues.

COCKEREL–PULLET MATINGS, 1948

Pen.	Dam.	No. in family.	Average.		Eggs in 365 days from 1st egg.	Number completing 365 days.
			50th Egg weight.	200th Egg weight.		
1	H1407	17	58·3	61·5	254·3	12
	H1629	20	61·4	67·7	261·0	19
2	H1773	28	60·8	64·3	255·8	25
3	H1107	20	62·8	64·1	283·3	18
	H1123	16	58·0	59·7	293·8	15
4	H1704	14	59·8	64·2	252·5	12
	H1825	16	59·4	62·4	263·0	14
5	H1110	23	57·9	58·6	264·7	20
6	H1357	13	57·4	61·3	288·3	10
	H1587	15	58·1	65·4	264·3	13
7	H 376	26	59·0	63·1	276·2	23
	H1195	18	57·2	63·6	281·7	14
	H1463	21	61·4	63·1	260·4	20
8	H1302	10	60·0	62·8	294·4	7
9	H 439	14	61·8	64·3	272·0	13
	H 985	13	61·0	65·0	249·6	13
11	H 182	16	63·8	64·5	224·6	13
	H 510	14	59·9	63·7	255·2	12
12	H1371	8	64·6	65·2	242·6	8
	H1517	15	58·3	60·2	222·6	14
13	H 404	16	56·8	60·4	278·2	15
	H1038	18	56·2	59·1	268·4	17
14	H1428	17	58·5	60·4	244·6	17
	H1665	19	57·2	60·5	273·4	17
15	H 43	24	57·0	62·8	261·6	20
	H 425	17	57·3	61·6	229·5	12
16	H 441	18	55·5	60·5	250·0	16
	H 552	13	58·9	64·3	253·8	13
	H 697	14	56·0	63·0	231·9	12
17	H 218	14	61·0	65·3	284·7	9
	H1351	17	60·1	62·0	263·3	14
	H1422	19	58·3	63·8	272·8	17
18	H 146	13	58·4	61·3	263·1	10
	H 313	11	58·2	63·7	261·5	9
	H 403	20	58·3	63·1	239·5	13
	H1548	19	56·6	58·8	281·6	17
19	H1334	19	59·5	62·1	259·3	18
	H1807	12	59·6	65·0	259·6	9
20	H1079	11	58·1	59·5	298·2	9
	H1333	16	57·6	60·2	286·1	13
	H1362	20	58·5	60·5	290·4	17
	H1512	23	56·2	59·7	293·9	18
	H1514	24	55·1	57·2	281·4	23
21	H 11	11	60·5	63·0	239·3	9
	H 730	22	56·7	60·2	258·7	19
	H 742	10	59·7	62·7	289·5	8
	H1533	15	58·2	61·4	267·3	14
22	H 97	14	60·2	64·6	277·0	11
	H 397	21	62·2	65·6	271·3	15
	H1159	24	59·1	62·9	279·2	22
23	H 49	14	59·5	64·6	237·1	14

FIG. 29.—Average egg weight and egg number of the 94 families of pullets of the 1948 hatch carried intact from March 24, 1948 to December 1, 1949. (See page 234.)

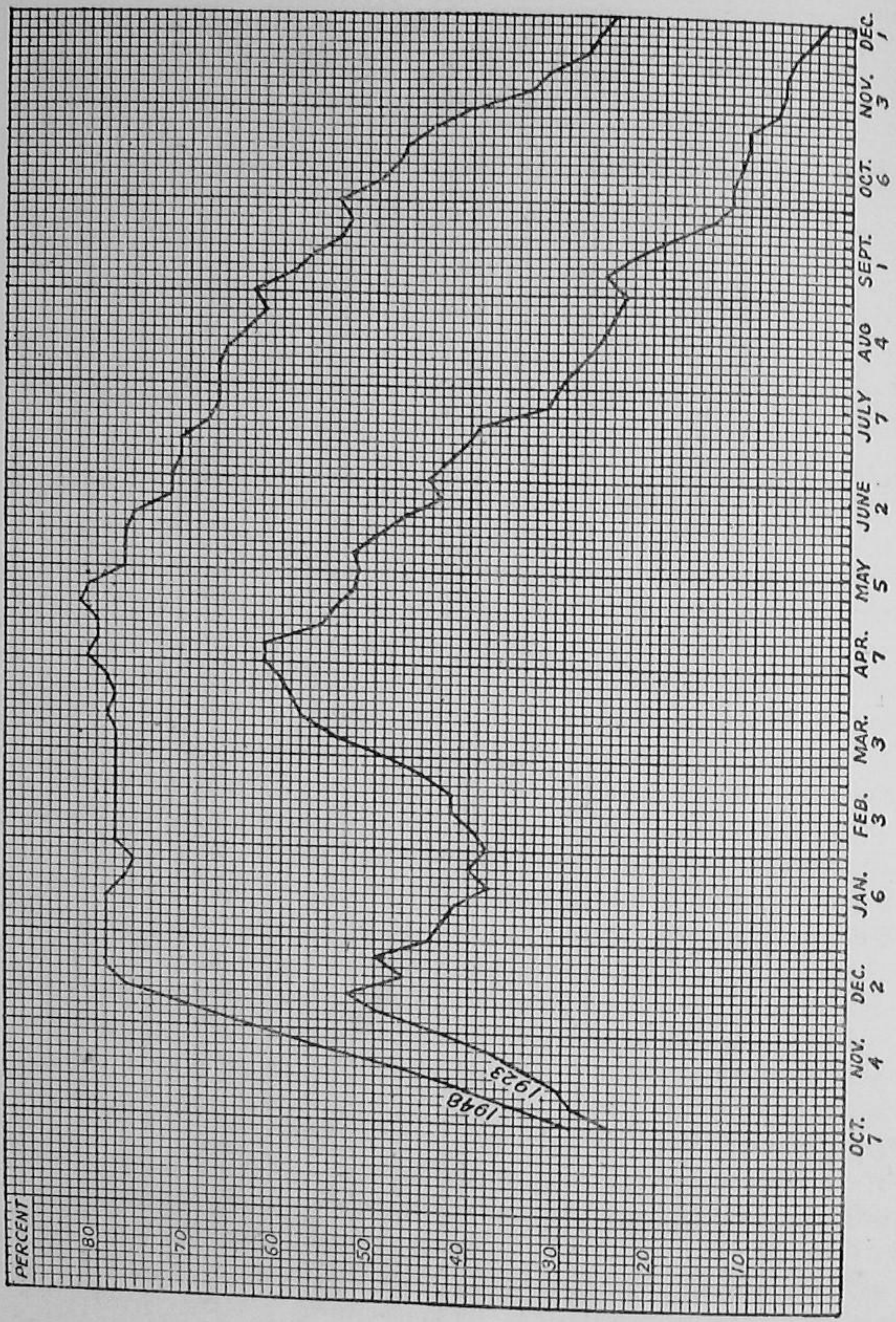


FIG. 30.—See page 234.

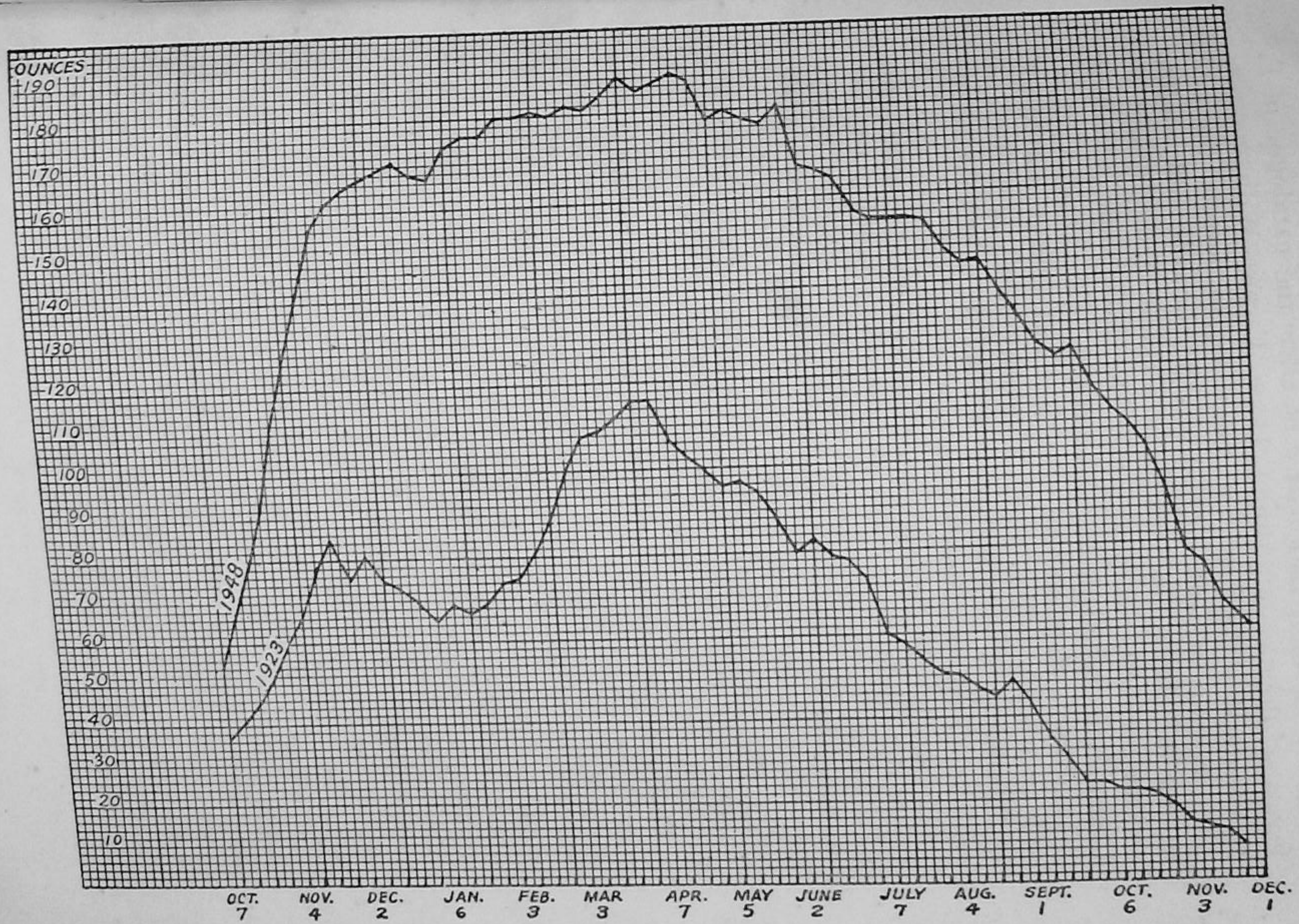


FIG. 31.—See page 234.

Possibly the most informative of all is the catalogue of E. Parmalee Prentice of Mount Hope Farms, Williamstown, Massachusetts. Prentice has been no orthodox breeder. After six years of pedigree breeding dairy-cattle and poultry he saw the obvious inconsistencies of such methods, and he had the prescience in 1922 to take Dr. H. Goodale, a leading United States geneticist, into his employ.

The Mount Hope annual catalogue has always started off with an article of a fresh aspect of poultry-breeding written by Dr. Goodale. In 1950 this article is headed "Three-hundred-egg Flocks for Every Poultry man".

On page 231 the average production and mortality of each family is published. In 1948, of ninety-four families carried for a full year, forty-six averaged 270 or more eggs per pullet. No British breeder can produce records at all comparable with those of these ninety-four families.

On page 232 is a graph of breeding progress which shows the Mount Hope pullet flock laying an average daily production of 78 per cent for twenty-two weeks.

Page 233: this graph should be compared with the graph on page 232. By gaining a genetic increase in egg-weight, this story of progress becomes all the more an impressive advertisement of the results than can be achieved when scientific methods are applied to animal-breeding.

Dr. Goodale completes the story of breeding progress with a photograph of a proven sire Mount Hope Haddon. This cock had the distinction of siring eighty daughters with an average production of 289 eggs weighing 25 oz. to the dozen. Of these eighty daughters thirty-six laid 300 eggs or more in 365 days from the first egg.

In a year when the British poultry-man believes he is efficient when he reached a 200-hen-housed egg average from his flock, the Mount Hope catalogue should shatter these illusions and provide an illustration of the potentialities of the breeder working in close collaboration with the geneticist. The figures also show that Dr. Goodale was not indulging in day-dreams when he headed his article "Three-hundred-egg Flocks for Every Poultryman".

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