THE DEVELOPMENT OF THE BARRED NEW HAMPSHIRE
AT THE UNIVERSITY OF BRITISH COLUMBIA

by

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ABSTRACT

A project in poultry breeding was undertaken to develop an autosexing breed of poultry that was suitable for both egg and meat production. A strain of New Hampshires that had been bred, selected and tested for production was used as foundation stock. To adapt the New Hampshire breed for autosexing, the barring factor was introduced from the Redbar, which had been previously developed at The University of British Columbia. A key for autosexing Barred New Hampshires was prepared by which a high degree of accuracy was obtained in sexing progeny that was 'pure' for the barring factor. Two distinct lines of Barred New Hampshires were developed, one bred by the Punnett and Pease method of maintaining 50% relationship to each of the parent breeds, and the other by the Hagedoorn method, of continually backcrossing to the superior parent breed to establish close relationship. The latter line was uniformly superior in characteristics associated with meat and egg production. A selection level was contrived for the Barred New Hampshires, including an arbitrary selection level for female breeding stock and, in addition, a selection index for males to head the breeding pens. In the third year of their development, the Barred New Hampshires excelled the basic New Hampshire breed in 'meat type' and persistency of egg production, were approximately equal in total egg production, egg weight, rate of growth and viability, but showed a higher incidence of broodiness. Fertility, hatchability and rate of feathering in the new autosexing breed were satisfactory. Further breeding will be required for purification and improvement of the breed.
ACKNOWLEDGMENT

The writer would like to thank Professor E. A. Lloyd, Head of the Department of Poultry Husbandry, for his constructive criticism and thoughtful direction throughout this project in poultry breeding.

To Mr. H. F. Ellis, foreman of the U.B.C. poultry plant, the writer is indebted for generous cooperation and assistance in connection with the many practical details involved in conducting the breeding experiments and recording the data.
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THE DEVELOPMENT OF THE BARRED NEW HAMPSHIRE

AT THE UNIVERSITY OF BRITISH COLUMBIA

I. INTRODUCTION

A project in breeding was undertaken to develop an autosexing breed of poultry that was adaptable for both egg and meat production. With respect to egg production the objectives included both number and weight of eggs. In order to develop a desirable type of meat bird it was necessary to consider such factors as early feathering, early maturity, rapid growth and premium meat quality.

With regard to the autosexing characteristic it has been shown by numerous investigators that it is possible to attain a high percentage of accuracy in distinguishing the sex of day old chicks of certain breeds of poultry by differences in down colour. Recently the report of Hill and Lloyd (1949) on the accuracy obtained with autosexing Redbars, suggested that the autosexing factor might be transferred to the closely related New Hampshire breed. Moreover, this breed was particularly suitable because of its wide popularity and commercial adaptability. Among other qualities, the New Hampshires are good layers, they mature and feather out
early, they are vigorous and are suitable, therefore, for either meat or egg production.

A certain amount of disappointment has been admitted in the performance of some strains of certain of the promising autosexing breeds. Because of these shortcomings very few have attained any degree of popularity to date. The Legbar is reported to give high egg production. (Hayhurst, 1948).

The reason for the economic failure of many of these breeds is not definitely known but it might be, that sufficient care in choosing the foundation stock was not exercised. Moreover, the subsequent inbreeding, practiced for the sake of pattern and color uniformity, may have brought together undesirable characteristics in the homozygous condition.

In this project special care was taken to secure the best possible foundation blood from the U.B.C. strain of New Hampshires in R.O.P. This strain possesses large body size, type, color, vigor and satisfactory egg production. It was decided to introduce the autosexing factor to the Barred New Hampshires from the Redbar. By using autosexing Redbar males on the New Hampshire females, it was possible to save the several generations of breeding and selection, that were necessary previously to develop the Redbar from the Barred Plymouth Rock and Rhode Island Red. Furthermore this procedure allowed the use of Hill and Lloyd's extensive data on the Redbars.
II. REVIEW OF PRINCIPLES OF AUTOSEXING

The term autosexing is used to describe a pure breed of poultry in which there is some characteristic difference between the down color or pattern of male and female chicks, which permits of their distinction at hatching time. The first breed of this type was developed by Punnett and Pease at Cambridge in 1929. They showed that, by combining the sex-linked gene for barring found in the Barred Plymouth Rock, with the autosomal gene for barring, present in the Campine, a pure breed would be obtained, in which the male chicks are differentially lighter in color than are the female chicks. They named this breed, Cambar. It is believed that its sex-linked color pattern results from the fact that the sex-linked gene for barring is an incompletely dominant inhibitor of pigmentation. Therefore in the male, the homogametic sex in poultry, two genes for barring will produce a lighter color of down in the chick than will the single gene present in the hemizygous female. A heterozygous male (Bb) is darker than the homozygous (BB) because the production of pigment in the down is less strongly inhibited in this case. The hemizygous female (B-) is darker than the heterozygous male because of the contributary effect of certain melanizing pigments elaborated by the ovary (Montalenti)(1934).

The normal sex dichromatism found in the Barred Plymouth Rock, which has been reported by Jerome, (1939),
and which gives a reasonably accurate measure of sex distinction in this breed, is accentuated in the Cambar by the presence of the autosomal gene for barring, contributed by the Campine. The gene for barring as found in the Barred Plymouth Rock, is regarded as restricting the black pigment to bars; for if the Barred Plymouth Rock did not have gene B, it would be a solid black color. According to Dunn (1923a) the barring effect in Plymouth Rocks, consisting as it does of alternate white and black bars, is dependent upon two sex-linked genes, one of which is B for barring pattern and the other a gene which prevents the development of buff in what would otherwise be the white bars of the barring pattern. When this second gene, known as 'silver' is absent, the barring pattern consists of black and gold bars rather than black and white bars.

If these two genes are transferred to a breed with some solid plumage color, other than black or white, a colored barring pattern results in which the bar gene's effect is to restrict complete development of the base color by superimposing upon it white bars. Thus, autosexing breeds can and have been developed from practically every solid colored variety of poultry, usually by making an initial cross with the Barred Rock to introduce barring and then conducting subsequent breeding along lines designed to standardize color and pattern.

The other known sex-linked factors in poultry may
also be utilized to differentiate sex at the day-old stage. These factors, according to Hutt (1949), are:

- Head streak
- Dilute
- Barred
- Inhibitor of dermal melanin
- Brown eye
- Light down
- Silver factor
- Slow feathering
- Naked

Other investigators suggest that genes for ear-lobe color and genes influencing the rate of maturity are also sex-linked (Warren 1929a). With the exception of the slow feathering factor, efforts to utilize any of these characteristics alone to estimate the sex of day-old chicks have not given reliable results. Since it is not economically efficient to maintain the slow feathering characteristic in a commercial breed of poultry, this factor is not a desirable one to use as a means of distinguishing sex. A homozygous slow feathering male crossed with a fast feathering female will give all slow feathering progeny; the reciprocal cross will give slow feathering male progeny and fast feathering female progeny. The latter cross therefore can be used for sex distinction, for at one day's age the primary and secondary flight feathers of a slow feathering chick are quite short, equal in length and quite pointed. The primaries of a fast feathering chick are nearly twice as long as the secondaries and more rounded in shape. In such a sex-linked cross it is the cockerel chicks who receive
the slow feathering characteristic. Since most cockerels in a dual purpose breed are marketed as table poultry, generally at the broiler stage (12 weeks) when slow feathering birds will not be completely feathered and the undesirable pin feathers will interfere seriously with the value of the carcass, such a cross is valuable only as a scientific curiosity.

The other sex-linked factors however, have been used in combination (Lamoreux 1941) to distinguish sex, or else have provided a useful means of checking the sexing accuracy of the barring factor. A method of sexing purebred Barred Plymouth Rock chicks by the appearance of the head spot, shank color, and general down color was reported by Jerome (1939) to be 95% accurate. Male chicks have a diffuse circular head spot while female chicks have an irregularly shaped head spot that stands out a clear white in contrast to the surrounding black. The shank color of the females is generally a combination of dark and light color. The blackish pigment extends down the shanks toward the toes and then is cut off abruptly. Male chicks have shanks of a uniform lighter shade, without contrasting color areas. The down color of males is generally lighter.

Essentially then, the problem in creating an auto-sexing breed of poultry, consists in transferring a bar gene, from a male of a barred variety (i.e. Barred
Plymouth Rock), to $F_1$ cross females, from dams of the desired foundation stock. These $F_1$ females will be pure or hemizygous for the barring factor. The $F_1$ males (heterozygous for barring) can then be mated to the $F_1$ females to give an $F_2$ generation of which 25% are hemizygous barred females, 25% are non-barred females, 25% are homozygous barred males and 25% are heterozygous barred males. To illustrate:

Barred Plymouth Rock male x Gold Campine female

\[
\begin{array}{c}
\text{BB} \\
\text{b-}
\end{array}
\]

\[
\begin{array}{l}
F_1 \\
F_2 \\
F_3 \text{ etc.}
\end{array}
\begin{array}{cccc}
\text{Bb} & \text{B-} & \text{25%} & \text{25%} \\
\text{50%} & \text{50%} & \text{25%} & \text{25%}
\end{array}
\begin{array}{c}
\text{BB} \times \text{B-} \\
\text{BB} \\
\text{100% Barred}
\end{array}
\]

Continued selection over several generations, on a best-to-best basis, of the pure barred stock, with the occasional introduction of heterozygous barred males, from different foundation stock, to hold down the inbreeding coefficient, will result in the autosexing breed. This was the method followed by Punnett and Pease, in developing the first autosexing breed, the Golden Cambar. The Redbars (Lloyd, Munro) were also bred by this procedure.
This method of breeding is subject to some criticism, for the high degree of inbreeding involved may lower the merit of the breed, by fixing undesirable genes in the homozygous condition. Furthermore, if one of the parent breeds is particularly desirable from an economic standpoint (better than average egg production or meat qualities), it is undesirable that the new breed be too far divorced from this parent type. An autosexing breed developed by this method will always be intermediate in type to the two parental breeds.

Consequently another method of developing an autosexing breed was suggested by the Dutch geneticist, Hagedoorn (1946). This method involves implanting barring on the present well-established breeds by back-crossing the F₁ and successive generation males onto females of the breed that it is desired to autosex. After six or seven generations, the barring is purified in the males with an inter-se cross. To illustrate:

Barred Plymouth Rock male x Brown Leghorn female

\[ BB \quad \text{b-} \]

\[ F_1 - F_6 \text{ heterozygous male} \times \text{Brown Leghorn female} \]

\[ Bb \quad x \quad \text{b-} \]

\[ F_6 \quad Bb \quad bb \quad B- \quad bb \]

\[ Bb \times \text{B-} \]

(Cont.)
This method of breeding results in an autosexing breed, carrying nearly 100% pure blood of the desired parent breed. Hagedoorn (1946) states that this is the only feasible method of developing a satisfactory autosexing breed of poultry. The first method has been successful in plant breeding, where self-fertilization may be employed, however poultry breeding, where self-fertilization is impossible, requires a different approach to meet its specific requirements. Hagedoorn has developed autosexing Barnevelders, Rhode Island Reds, Welsummers and Leghorns in this way. Certain autosexing breeds more recently developed in England have been derived by this procedure. As well as cutting down on the percentage of inbreeding and holding close relationship to the desired parent breed, this method has an added advantage in that autosexing chicks may be mass produced from ordinary females of the parent breed by using autosexing males on these females.

The two breeding methods referred to above have resulted in the four basic types of autosexing breeds in existence today:

(1) Those autosexing breeds in which type and
utility qualities are different from both the parental breeds. In this case, class outcrossing with the basic breed cannot be carried on without impairing the quality of the autosexing breed, although autosex distinction at hatching will not be impaired by such backcrossing. Examples of this type are the Cambar and the Dorkbar. (developed by method 1).

(2) Those autosexing breeds in which type and utility qualities are identical with one of the parent breeds. In this case, females may be mass-produced by back-crossing the autosexing males onto the appropriate basic breed without risk of impairing the clarity of sex distinction at hatching. The Legbar is an example of this type of autosexing breed. (developed by method 2).

(3) Those autosexing breeds in which type and utility qualities are different from both of the parent breeds and in which mass production of females by back-crossing is impossible because sex distinction at hatching is impaired. An example of this type of breed is the Buff-barred Wyandotte. The many shades of buff down interfere with sexing accuracy when backcrossing is attempted (developed by method 1).

(4) Those autosexing breeds in which type and utility qualities are identical with those of one of the parent breeds, so that a back-cross to the basic breed would not spoil the breed in this respect, but would impair sex
distinction at hatching. Examples of this type of breed are the Buffbar and the Brockbar. Again, the variation in buff downs interferes with sex distinction when backcrossing is attempted (developed by method 2).

Some of the autosexing breeds which have been developed to date along with their varieties, parent breeds and originators are listed in Fig. 1. Several of these breeds were developed simultaneously at different institutions. In these cases all the investigators names are presented.
**Fig. 1 - AUTOSEXING BREEDS OF POULTRY**

<table>
<thead>
<tr>
<th>BREED</th>
<th>VARIETY</th>
<th>PARENT BREEDS</th>
<th>DEVELOPED BY</th>
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<tr>
<td>Cambar</td>
<td>Gold Silver</td>
<td>Gold or Silver Campine x Barred Plymouth Rock</td>
<td>Punnett and Pease</td>
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<tr>
<td>Legbar</td>
<td>Gold Cream Silver</td>
<td>Brown Leghorn x Barred Plymouth Rock</td>
<td>Punnett and Pease Hagedoorn</td>
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<tr>
<td>Brockbar</td>
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<td>Buff Plymouth Rock x Barred Plymouth Rock</td>
<td>Punnett and Pease</td>
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<tr>
<td>Dorkbar</td>
<td>Gold Silver</td>
<td>Silver Grey Dorking x Barred Plymouth Rock</td>
<td>Punnett and Pease</td>
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<tr>
<td>Redbar</td>
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<td>Rhode Island Red x Barred Plymouth Rock</td>
<td>Lloyd Munro Hagedoorn</td>
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<tr>
<td>Buffbar</td>
<td></td>
<td>Buff Orpington x Barred Plymouth Rock</td>
<td>Pease</td>
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<tr>
<td>Ancobar</td>
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<td>Ancona x Barred Plymouth Rock</td>
<td>Lamoreux and Jaap</td>
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<td>Oklabar</td>
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<td>Buff Wyandotte x Barred Plymouth Rock</td>
<td>Lamoreux and Jaap</td>
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<tr>
<td>Welbar</td>
<td>Gold Silver</td>
<td>Welsummer x Barred Plymouth Rock</td>
<td>Pease Hagedoorn</td>
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<tr>
<td>Brussbar</td>
<td>Gold Silver</td>
<td>Light Sussex x Legbar</td>
<td>Pease</td>
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<tr>
<td>Wybar</td>
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<td>Light Sussex, Brussbar x Silver Laced Wyandotte</td>
<td>Pease</td>
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<tr>
<td>Autosexing Barnevelder</td>
<td></td>
<td>Barnevelder x Barred Plymouth Rock</td>
<td>Hagedoorn</td>
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III. SEX DISTINCTION IN THE BARRED NEW HAMPSHIRE

Since New Hampshire and Rhode Island Red chick down patterns are similar, an autosexing key comparable to that used by Hill and Lloyd, for the Redbar breed (appendix xvi), was devised for the Barred New Hampshires. According to Byerly and Quinn (1936), the essential difference between the downs of the two breeds lies in the quantity of black pigment present. They found less black pigment in the New Hampshire chick downs. These investigators examined 1102 Rhode Island Red chicks; 47.5% carried black spotting or striping on the head or body. Of these, 84.9% were females. Of the non-spotted, non-striped chicks, 77.8% were males. They found that only 29.4% of 296 New Hampshire chicks carried striping.

Some strains of Rhode Island Red chicks carry considerably less spotting or striping than others. For example, Hays (1940) reported that 26.76% of 8713 Rhode Island Red chicks carried color markings. Only 10.16% of the males showed color markings in the down whereas 44.14% of the females showed spotting or striping.

Since the basic down patterns were known to be similar and because the first year Barred New Hampshire progeny carried a high percentage of Redbar blood, these chicks were sexed roughly according to Hill and Lloyd's key. They were handled along with the Redbar progeny available at the time and basic differences in the two breeds' down
patterns were noted. It was found that there was more spotting and striping in the Barred New Hampshire chicks than in the Redbar, 82.6% of this first generation showing dark markings, of which 72.6% were females. Although these results do not appear to agree with those of Byerly and Quinn, it seems probable that it might be a result of the wide variation in New Hampshire down color known to exist between different strains. The U.B.C. New Hampshires used in the original cross are uniformly darker than many strains of this breed and consequently carry sufficient dark pigment to account for the darker spotting and striping. The U.B.C. Redbars during the more recent years of their development were selected for absence of smutty undercolor and dark markings. More particularly during the 1946 breeding season, Hill and Lloyd succeeded in eliminating much of the very dark spotting and striping.

Approximately 70% accuracy in sexing the Barred New Hampshire chicks was procured in the early hatches of the first breeding season by use of the Redbar autosexing key. A Barred New Hampshire autosexing key was prepared by studying the down pattern of chicks killed and sexed, by examination of their gonads immediately following classification, and by thorough perusal of the descriptions of chicks, whose sex, as determined by secondary sexual characteristics, differed from that predicted by the key. This key with slight modifications was used by the writer
in all subsequent autosexing work.

According to this key as presented there are three major types of female down patterns and four types of male down patterns.

**BARRED NEW HAMPSHIRE AUTOSEXING KEY**

**A. Female Down Patterns:**

1. Wide dark brown or black head, back, and hip striping on a medium uniform brown base color. (see Plate IVB). This pattern generally also includes a dark pencil mark extending from the eye (see Plate VIIB).

2. Medium to light uniform brown all over body. No spotting or striping. (see Plate IVA)

3. Narrow black or brown head stripe on light uniform brown base color. (see Plate IVC). This pattern may include narrow black or brown median back stripe.

**B. Male Down Patterns:**

1. Uniform whitish-silver down (see Plate VC).

2. Silver or white head and white hip stripes on medium brown base color. (see Plate VA).

3. Silver head with broken black or dark brown head stripe, medium to dark brown body with light buff hip striping. (see Plate VB).

4. Wide, black head, hip, and back stripes on silvery white base color. The silver hip striping is very distinct. (see Plate VIB).
A cursory examination of this autosexing key indicates that although color differences are extreme between certain types of male and female chicks (Plate VII), the intermediate types included would be very difficult for the inexperienced to distinguish. Since the Barred New Hampshire breed was not developed to be merely a scientist's toy, dependent for its autosexing utility on very slight color differences, it became apparent that the more complicated intermediate type downs should be eliminated from the breed so far as possible. The first step in improving the clarity of sex distinction was to determine to what extent homogenous family differences in pattern existed. A thorough study was made of dam family differences. Examination of the records indicated that, in certain families, the male and female chicks were very dissimilar and hence very sexable, while in other families only slight differences in either relative uniformity or type of striping existed. It was obvious that breeding, for uniformity of sex differences, from the most sexable families was desirable. At the same time, stock from less sexable families would be maintained, for the purpose of contrast, in order to measure the gain in sexing accuracy. The best commercial stock was selected for the latter purpose.

It was found that the down of male chicks at the day old stage was dependent upon the homozygous or heterozygous condition of the barring and the head striping
genes. Homozygous male chicks were as a rule much lighter. These results agree with Jaap (1940) who, in studying New Hampshire and Rhode Island Red down colors found that BB chicks were much lighter than B chicks. One B gene did not produce any observable change in the basic down color; whereas homozygous male chicks carrying BB genes had definite head spots and a light silvery dorsal surface. The degree of dark pigment in the adult breeding stock was apparently expressed in the progeny as the degree of dark spotting or striping. In one particular family, all female progeny were type 1, 50% of the male progeny were homozygous type 2 and 50% were heterozygous type 4.
IV. EXPERIMENTAL: THE 1948 AND 1949 BREEDING SEASONS

A. Design of 1948 Breeding Pens

The first cross to develop the Barred New Hampshire breed was made in 1947. At that time, a pen of ten New Hampshire females were mated to a large, broad-breasted, well-barred Redbar male. Since this male was homozygous for the barring factor, the F₁ progeny consisted of 50% heterozygous barred males and 50% hemizygous barred females.

The stock from this cross were examined prior to the 1948 breeding season, and ten reasonably well-barred, vigorous pullets, and a precocious nicely marked cockerel, were selected for further breeding. Necessarily this male was a half brother to all the pullets. None of his full sisters were included in the pen.

The use of a half-sib mating was considered justifiable for the following reasons:

1. The inbreeding involved would facilitate purification of the Barred New Hampshire breed by establishing the barring characteristic in the homozygous condition in 25% of the stock.

2. It was necessary to save time wherever possible; this F₁ 'inter-se' provided the only available method of obtaining homozygous barred males to be used in the next (1949) breeding season.

3. Other crosses were planned, to introduce unrelated blood to guard the future development of the
breed against the dangers of excessive inbreeding. In the first cross an R.O.P. New Hampshire male was mated with the best available Redbar pullets. This male was 30 feathering, early maturing, A † meat type and came from a 265 egg dam. The second cross utilized a Redbar male x New Hampshire hens. The Redbar male used in this cross was well-barred and came from a highly sexable family. The New Hampshire females were from one of the top R.O.P. breeding pens. This cross was made relatively late in the breeding season, after the U.B.C. hatching was over, permitting the use of New Hampshire R.O.P. females.

These three crosses resulted in the following stock being available for the 1949 breeding season:

1. Homozygous Barred New Hampshire males from the $F_1$ 'inter-se'.
2. Heterozygous Barred New Hampshire males from:
   $F_1$ 'inter-se'
   New Hampshire male x Redbar females
   Redbar male x New Hampshire females
3. Hemizygous Barred New Hampshire females from:
   $F_1$ 'inter-se'
   Redbar male x New Hampshire females.

B. Design of 1949 Breeding Pens

Four breeding pens were set up for the 1949 breeding season, as follows:

Pen 7 -- was headed by the best 'meat-type' New Hampshire
male on the U.B.C. poultry farm. This male weighed 9.4 lbs. and was grade A 'meat-type'. He was 30 feathering, early maturing and came from a dam with a production record of 264. Mated to this male were 6 Barred New Hampshire hens, used in pen 23 the previous season. These hens had all produced progeny satisfactory from both the standpoint of autosexing and commercial quality. This cross doubled the concentration of New Hampshire blood in the progeny and produced heterozygous males of superior 'meat-type', used to maintain or improve 'meat-type' in subsequent matings. The non-barred female progeny produced were of no use in the further development of the Barred New Hampshire but were found to be excellent layers. Progeny of this cross segregated into two genotypes:

\[ bb \times B^- \]

\[ Bb, b^- \]

Pen 15 -- was headed by a heterozygous Barred New Hampshire male from 1948's pen 21. This bird was early maturing, 30 feathering, 9 lbs. in weight. He was very broad breasted and was in all ways an outstanding meat bird. He graded A †. His heterozygous genotype for barring was expressed as narrow white bars on a lustrous reddish bronze base. The barring was relatively even and uniform on all feathers. A full brother of this male, strikingly similar in type and handling quality, was reserved as a replacement. The females in pen 15 came from: (a) 1948's pen 23 and (b) Redbar male x New Hampshire female cross. In choosing the
females, emphasis was placed on their sexability as chicks, uniformity of barring, rates of feathering and maturity and body type. The type (b) females, while relatively late maturing and rather small in size, were included to preserve the superior 'blood line' from whence they came. Progeny segregated into four genotypes:

\[
\begin{align*}
Bb \times B- \\
BB, Bb, B-, b-
\end{align*}
\]

Pen 19 -- was headed by a homozygous Barred New Hampshire male from 1948's pen 23. This male was early maturing, fast feathering and grade A 'meat type'. He weighed 9 lbs. Mated to him were 10 Barred New Hampshire females from 1948's pen 23. No full sisters were used in the pen. The females were chosen on the basis of feathering, and handling qualities. This cross as well as providing the first pure-barred generation of the new breed, eventually resulted in a line of Barred New Hampshires developed by the original Punnett and Pease method that could be compared with other lines obtained by continually backcrossing to unrelated New Hampshire 'blood' (the Hagedoorn method) as is shown later.

\[
\begin{align*}
BB \times B- \\
BB, B-
\end{align*}
\]

Pen 21 -- was headed by a Homozygous Barred New Hampshire male from 1948's pen 23. This male was very evenly barred, grade A 'meat-type', and 9.1 lbs. in weight. He appeared early feathering and early maturing. Mated to this male
were 12 R.O.P. New Hampshire females from the best available
stock. These females all came from high producing families
who had exhibited low mortality. Progeny carried 75% New
Hampshire 'blood'. Two genotypes were possible in the
progeny:

\[ BB \times b^- \]

\[ Bb, B^- \]

C. Discussion of Progeny of 1948 and 1949

In the spring of 1948, 294 chicks were hatched
from pens 21 and 23 (see Fig. 2). The third cross made
(‘Redbar male New Hampshire females) was unsatisfactory,
since the late date of hatch (July 15), combined with a
severe attack of coccidiosis in the growing stock, produced
slow maturing, unthrifty birds. Only three pullets from
this hatch could be selected for future breeding purposes.

All birds were wing-banded, sexed and examined as
to rate of feathering at hatching time. Further, at 6, 10,
12, 16, and 24 weeks they were handled and classified as to
feathering, weight and meat grade.

1. Sexing Accuracy: 1948

By using the Redbar autosexing key (appendix (xvi)
in the first hatches and the newly devised Barred New
Hampshire autosexing key (page 15) in later hatches, an
accuracy of 84.2% was secured with the progeny of pen 21,
where two genotypes were possible, and 73.9% with the
progeny of pen 23, where four genotypes were possible (Fig. 2)
Fig. 2 - SEXING ACCURACY, RATE OF FEATHERING, MEAT GRADE AND DISTRIBUTION OF PROGENY FROM THE BARRED NEW HAMPSHIRE BREEDING PENS OF 1948 AND 1949.

<table>
<thead>
<tr>
<th>Year</th>
<th>Pen No.</th>
<th>Cross</th>
<th>No. of Progeny</th>
<th>Distribution of Progeny</th>
<th>Sexing Accuracy</th>
<th>% 30 Feathering</th>
<th>% A Meat Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>1948</td>
<td>21</td>
<td>New Hampshire male x Redbar hens bb x B-</td>
<td>89</td>
<td>Bb b-</td>
<td>84.2%</td>
<td>71.6%</td>
<td>83.1%</td>
</tr>
<tr>
<td>1948</td>
<td>23</td>
<td>Barred New Hampshire inter-se Bb x B-</td>
<td>205</td>
<td>BB Bb B- b-</td>
<td>73.9%</td>
<td>80.1%</td>
<td>68.2%</td>
</tr>
<tr>
<td>1949</td>
<td>7</td>
<td>New Hampshire male x Barred New Hampshire females. bb x B-</td>
<td>95</td>
<td>Bb b-</td>
<td>75.2%</td>
<td>82.3%</td>
<td>88.5%</td>
</tr>
<tr>
<td>1949</td>
<td>15</td>
<td>Heterozygous Barred New Hampshire male x Barred New Hampshire females. Bb x B-</td>
<td>69</td>
<td>BB Bb B- b-</td>
<td>70.1%</td>
<td>89.4%</td>
<td>72.1%</td>
</tr>
<tr>
<td>1949</td>
<td>19</td>
<td>Homozygous Barred New Hampshire male x Barred New Hampshire female. BB x B-</td>
<td>74</td>
<td>BB B-</td>
<td>92.6%</td>
<td>81.2%</td>
<td>63.7%</td>
</tr>
<tr>
<td>1949</td>
<td>21</td>
<td>Barred New Hampshire male x New Hampshire females. BB x B-</td>
<td>123</td>
<td>Bb B-</td>
<td>80.9%</td>
<td>74.6%</td>
<td>79.1%</td>
</tr>
</tbody>
</table>
Because of the lack of knowledge of any exact color pattern in the down of the Barred New Hampshires, in the earlier stages of their development, family differences had to be used to establish this key. Thus family groups were sexed independently. This practice allowed a higher percentage of accuracy than if only mass sight sexing had been employed. However, to be commercially successful, autosexing must be possible on a mass basis, thus in subsequent years family groups were purposefully mixed up before the sexing was done. Consequently sexing accuracy in the 1949 and 1950 progeny segregating into classes similar to pens 21 and 23 was not as high.

The majority of errors in sexing the progeny of the pen 21 cross were made with males from dark colored dams. In these cases, the single barring gene did not lighten the down to any degree and the male chicks were very similar to the b- females. Furthermore brown or black head striping and spotting was found in many males of the Barred New Hampshire breed whereas according to the Redbar Key, these birds would be classified as females. Sight sexing in the pen 23 cross was difficult even on a family basis because of the four possible genotypes. The 25% BB males and the 25% B- females were classified accurately but the 25% Bb males were in many cases mistaken for females and the 25% b- females varied so considerably in pattern that many were incorrectly sexed.
2. Sexing Accuracy: 1949

The Barred New Hampshire autosexing Key was improved in 1949; 92.6% accuracy in autosexing the pure barred progeny from pen 19 was obtained by its use. All sexing was done on a mass basis. Fig. 2 presents the sexing accuracy in the four 1949 breeding pens. Similar to 1948, the majority of mistakes in sight sexing were again made in the case of heterozygous males from dark colored dams. In several families the heterozygous male chicks had the broad dark head and back stripes, typical of the female color pattern, combined with a silver head and broad white hip stripes, typical of the male color pattern. To promote clarity of sex distinction in chick down color families of this type were eliminated from future breeding work. The accuracy in pen 21, (80.9%) was high considering the fact that all progeny carried only one gene for barring. However, the New Hampshire females used in this cross were relatively light and uniform in color while the Barred New Hampshire male was light and clearly barred. Consequently there was less chance of confusion by the expression of excessive dark pigment in the down of the progeny.

3. Fertility and Hatchability

The Fertility and Hatchability of Barred New Hampshire eggs set in 1949 was computed by hatches, by pens (sires) and by dams. It was relatively satisfactory throughout the breeding season, except in pen 15 (see Fig. 3)
Fig. 3— FERTILITY AND HATCHABILITY OF 1949 BARRED NEW HAMPSHIRE PROGENY

<table>
<thead>
<tr>
<th>Pen #7 Hatch</th>
<th>% Fert.</th>
<th>% Hatch.</th>
<th>Pen #15 Hatch</th>
<th>% Fert.</th>
<th>% Hatch.</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>92.7</td>
<td>76.3</td>
<td>#1</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>#2</td>
<td>94.1</td>
<td>75.5</td>
<td>#2</td>
<td>88.6</td>
<td>51.3</td>
</tr>
<tr>
<td>#3</td>
<td>93.5</td>
<td>89.7</td>
<td>#3</td>
<td>86.1</td>
<td>77.4</td>
</tr>
<tr>
<td>#4</td>
<td>97.1</td>
<td>55.9</td>
<td>#4</td>
<td>89.8</td>
<td>43.2</td>
</tr>
<tr>
<td>Total:</td>
<td>93.3</td>
<td>74.03</td>
<td>Total:</td>
<td>80.7</td>
<td>54.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pen #19 Hatch</th>
<th>% Fert.</th>
<th>% Hatch.</th>
<th>Pen #21 Hatch</th>
<th>% Fert.</th>
<th>% Hatch.</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>93.1</td>
<td>42.6</td>
<td>#1</td>
<td>86.3</td>
<td>77.7</td>
</tr>
<tr>
<td>#2</td>
<td>95.3</td>
<td>70.5</td>
<td>#2</td>
<td>89.8</td>
<td>67.6</td>
</tr>
<tr>
<td>#3</td>
<td>92.7</td>
<td>65.8</td>
<td>#3</td>
<td>88.6</td>
<td>88.9</td>
</tr>
<tr>
<td>#4</td>
<td>92.2</td>
<td>61.0</td>
<td>#4</td>
<td>85.1</td>
<td>92.5</td>
</tr>
<tr>
<td>Total:</td>
<td>93.4</td>
<td>59.9</td>
<td>Total:</td>
<td>87.6</td>
<td>78.05</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hatch</th>
<th>% Fert.</th>
<th>% Hatch.</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>83.8</td>
<td>63.7</td>
</tr>
<tr>
<td>#2</td>
<td>91.4</td>
<td>67.4</td>
</tr>
<tr>
<td>#3</td>
<td>90.2</td>
<td>78.3</td>
</tr>
<tr>
<td>#4</td>
<td>90.7</td>
<td>62.7</td>
</tr>
</tbody>
</table>

TOTAL % FERTILITY: 89%

TOTAL % HATCHABILITY: 68%
Furthermore, hatchability was low in eggs from Hatch 4 (pen 7, 15 and 19) which were in the same incubator. Air circulation was faulty in this incubator and consequently eggs did not hatch satisfactorily. That lack of vigor in parent stock was not a factor is evidenced by the results of the first three hatches.

Rate of Feathering

A relatively high percentage of the Barred New Hampshire progeny of 1948 and 1949 were 30 feathering.\(^1\) (see Fig. 2). The pen 15 progeny of 1949 were 89.4% 30 feathering. Fig. 4 shows the actual segregation of birds with respect to this characteristic. Out of 328 birds classified as to feathering, 79.5% were 30 feathering in 1949. Results indicate that all the males used were pure for this character and that the mixed feathering came from certain females. Only 30 feathering males were selected for future breeding work. Insofar as was possible with the limited numbers the same standard was applied to females. However, in many cases it was necessary to use 20 feathering females because of their other desirable characteristics.

Meat Grade

The number of Barred New Hampshires qualifying as A meat grade was high during 1948 and 1949\(^2\) (Fig. 2). The best meat birds on the U.B.C. poultry farm in 1949 were the Barred New Hampshire males from pen 7. 88.5% of these

\(^1\)For a discussion of the feathering classification, see page 69.
\(^2\)For a discussion of meat grade classifications, see page 70.
## Classification of Feathering

1949 Barred New Hampshire Progeny

<table>
<thead>
<tr>
<th>Pen No.</th>
<th>Number Hatched</th>
<th>Number Classified</th>
<th>30 feathering</th>
<th>20 feathering</th>
<th>1 M.T.</th>
<th>1</th>
<th>1-2</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>95</td>
<td>90</td>
<td>72</td>
<td>11</td>
<td>5</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>69</td>
<td>56</td>
<td>50</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>74</td>
<td>68</td>
<td>55</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>21</td>
<td>123</td>
<td>114</td>
<td>84</td>
<td>9</td>
<td>12</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Totals:</td>
<td>361</td>
<td>328</td>
<td>261</td>
<td>25</td>
<td>22</td>
<td>8</td>
<td>10</td>
<td>2</td>
</tr>
</tbody>
</table>

%  
- 79.5%  
- 7.6%  
- 6.7%  
- 2.4%  
- 3%  
- 0.6%
birds were graded A. The rate of growth (weight at 12 weeks) and meat grade of all the Barred New Hampshire young stock of 1949 is compared with other U.B.C. breeds in Fig. 5. The New Hampshires averaged heaviest at 12 weeks (2.66 lbs.), the Barred New Hampshires were slightly lighter (2.54 lbs.). However, the average meat grade of the Barred New Hampshires (74.12% A) was higher than other breeds. At maturity the Barred New Hampshires of 1949 were very satisfactory in meat quality. Fig. 6 presents the 'meat-type' classification of the mature Barred New Hampshire stock prior to the 1950 breeding season. The market grades and 'meat-type' of the R.O.P. Barred New Hampshire and New Hampshire females after 245 days in production is given in Fig. 7.
Fig. 5 - AVERAGE WEIGHT AT 12 WEEKS AND PERCENT A MEAT GRADE OF BARRED NEW HAMPSHIRE, NEW HAMPSHIRE, RHODE ISLAND RED AND BARRED PLYMOUTH ROCK GROWING STOCK ON U.B.C. POULTRY FARM IN 1949.

<table>
<thead>
<tr>
<th>Hatch</th>
<th>Barred New Hampshire</th>
<th>New Hampshire</th>
<th>Rhode Island Red</th>
<th>Barred Plymouth Rock</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.54</td>
<td>2.68</td>
<td>2.34</td>
<td>2.54</td>
</tr>
<tr>
<td>2</td>
<td>2.56</td>
<td>2.71</td>
<td>2.37</td>
<td>2.52</td>
</tr>
<tr>
<td>3</td>
<td>2.52</td>
<td>2.61</td>
<td>2.29</td>
<td>2.51</td>
</tr>
<tr>
<td>4</td>
<td>2.57</td>
<td>2.64</td>
<td>2.38</td>
<td>2.50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hatch</th>
<th>% A Meat Grade</th>
<th>Hatch</th>
<th>% A Meat Grade</th>
<th>Hatch</th>
<th>% A Meat Grade</th>
<th>Hatch</th>
<th>% A Meat Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>76.1%</td>
<td>2</td>
<td>64.1%</td>
<td>3</td>
<td>42.7%</td>
<td>4</td>
<td>55.6%</td>
</tr>
<tr>
<td>2</td>
<td>72.7%</td>
<td>2</td>
<td>65.8%</td>
<td>3</td>
<td>43.9%</td>
<td>4</td>
<td>52.9%</td>
</tr>
<tr>
<td>3</td>
<td>72.8%</td>
<td>2</td>
<td>64.9%</td>
<td>3</td>
<td>40.9%</td>
<td>4</td>
<td>53.8%</td>
</tr>
<tr>
<td>4</td>
<td>74.9%</td>
<td>2</td>
<td>70.1%</td>
<td>3</td>
<td>45.9%</td>
<td>4</td>
<td>56.1%</td>
</tr>
</tbody>
</table>

Total
<table>
<thead>
<tr>
<th>Hatch</th>
<th>Total Av. Wt. at 12 weeks lbs.</th>
<th>Total A Meat Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.54</td>
<td>74.12%</td>
</tr>
<tr>
<td></td>
<td>2.66</td>
<td>66.22%</td>
</tr>
<tr>
<td></td>
<td>2.34</td>
<td>43.35%</td>
</tr>
<tr>
<td></td>
<td>2.51</td>
<td>54.60%</td>
</tr>
</tbody>
</table>

Total Hatch
Fig. 6 — "MEAT TYPE" CLASSIFICATION OF MATURE BARRED NEW HAMPSHIRE MALES AND FEMALES MADE PRIOR TO 1950 BREEDING SEASON - JAN. 1950

<table>
<thead>
<tr>
<th>Grade</th>
<th>Number</th>
<th>%</th>
<th>Grade</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>A‡</td>
<td>10</td>
<td>20.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>21</td>
<td>43.7</td>
<td>A</td>
<td>20</td>
<td>34.5</td>
</tr>
<tr>
<td>A⁻</td>
<td>14</td>
<td>29.2</td>
<td>A⁻</td>
<td>22</td>
<td>37.9</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>93.7%</td>
<td></td>
<td>51</td>
<td>87.9%</td>
</tr>
<tr>
<td>B</td>
<td>4</td>
<td>8.3%</td>
<td>B</td>
<td>7</td>
<td>12.1%</td>
</tr>
<tr>
<td></td>
<td>49</td>
<td></td>
<td></td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0</td>
<td>0</td>
<td>C</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
### Fig. 7 - Market Grades and Average Weight of Barred New Hampshire and New Hampshire (R.O.P.) Hens After 245 Days in Production June 19, 1950.

**Barred New Hampshire**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>{ A+</td>
<td>12</td>
<td>28.57%</td>
</tr>
<tr>
<td>A</td>
<td>18</td>
<td>42.86%</td>
</tr>
<tr>
<td>{ A-</td>
<td>5</td>
<td>11.9%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>83.33%</td>
</tr>
<tr>
<td>B</td>
<td>7</td>
<td>16.67%</td>
</tr>
<tr>
<td></td>
<td>42</td>
<td></td>
</tr>
</tbody>
</table>

Range in wts. 4.8 - 7.0  
Average weight: 5.7

**New Hampshire**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>{ A+</td>
<td>52</td>
<td>22.90%</td>
</tr>
<tr>
<td>A</td>
<td>94</td>
<td>41.40%</td>
</tr>
<tr>
<td>{ A-</td>
<td>48</td>
<td>21.10%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>85.42%</td>
</tr>
<tr>
<td>B</td>
<td>32</td>
<td>14.5%</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>.1%</td>
</tr>
</tbody>
</table>

Range in wts. 4.1 - 8.5  
Average weight: 5.8
V. FACTORS FOR MEAT AND EGG PRODUCTION

The most popular and profitable breeds of poultry of today are those that have been bred and selected for both meat and egg production. In this connection it is significant that, in British Columbia, the four most common breeds are the New Hampshire, the Rhode Island Red, the Barred Plymouth Rock and the White Leghorn. The first three, which are dual-purpose breeds, now equal the White Leghorn in production, although the latter has been bred mainly for egg production. Furthermore, male birds of the dual-purpose breeds help to supply the demand for the different types of poultry meats. Males of the egg breeds, like the Leghorn, beyond the light broiler stage, are of less value as meat birds.

In the formation of the Barred New Hampshire the objective was to produce an improved dual purpose breed, that would be very close to the parent New Hampshire in production qualities and carry the plump, meaty breast of the best U.B.C. Redbars. The first step in a poultry breeding project, such as the development of a new breed, is to decide upon the characteristics that are to be incorporated into the breed and then to construct a satisfactory selection index. In order to prepare such an index, it is necessary to evaluate the economic importance and heritability of the characteristics concerned, and know approximately the number and nature of the genes that
control the expression of each characteristic.

For the above reasons a review was made of the genetic background and commercial importance of the main economic characteristics (meat and egg qualities) of the fowl.

A. Meat Qualities

The important characteristics of birds that affect meat quality are divided into five categories, namely, - (1) rate of growth, (2) body size, (3) conformation and amount of meat, (4) rate of feathering, and (5) freedom from defects.

(1) Rate of growth:

Rapid growth is of the utmost importance to the broiler producer who desires a well-fleshed plump type of bird at the earliest possible age. It is of lesser importance to the producer of roasting fowl, since Waters (1937) showed that the inherited rate of growth during the first few weeks has little or no bearing on final body size. This is supported by the work of Jaap and Morris (1937) who, in working with the growth rates of White Leghorns and Barred Plymouth Rocks, found that growth to eight weeks is a separate entity not necessarily associated with mature body weight. Moreover, Lerner and Asmundson (1938) showed that the decreased early growth rate found in late hatched chicks, as compared with the faster growth of early hatched chicks of the same strain, leads to
compensatory growth among the later hatched chicks in later growth stages. Kempster, too, in 1941 showed that young stock whose growth rate had been retarded by hot weather, in the early period, attained, by more rapid growth later, a weight normal for their strain. In this regard, Heuser and Norris (1934) found that, in four lots of chicks on diets containing different levels of protein, growth during the period of most rapid development, i.e. from hatching to ten weeks, was directly proportional to the amount of protein included in their diet. By lowering the protein content, they were able to slow the growth rate. At 29 weeks of age, however, the lots that failed in early growth had made up their deficiency.

Asmundson and Lerner (1933) suggested that differences in rates of growth are determined by multiple genes. Later, in 1938, these investigators found evidence of sex-linkage in growth rate in the Rhode Island Red x White Leghorn crosses, reported by Warren in 1930. The latter merely concluded from his data that such cross-breeding provides a stimulus which accelerates growth during the first few weeks. Asmundson and Lerner (1942) studying the relationship between growth of shanks and body weight in turkeys, found that large broadbreasted turkeys had relatively shorter legs than other smaller strains. Their data indicated that differences in the rate of growth of the body had a greater influence on the pro-
portion of length of the shank to body weight at 32 weeks
than differences in the rate of growth of the shank.

(2) **Body size:**

The importance of large body size in poultry meat
birds should not be underestimated. For either broiler or
roaster production, a large, compact, well-fleshed carcass
is desirable. Differences in body size in the fowl, as in
other species, depend upon a great many different genes, the
exact number of which has not been determined. For this
reason mass selection, on a basis of largest birds, seldom
results in stock that equal the parents in size. Generally
a large array of intermediates are produced. Early inves­
tigations into the genetics of body size (Punnett and
Bailey, 1914) suggested that it was controlled by four pairs
of genes with cumulative effects. Waters in 1931 reported
that the differences he observed between Leghorns and
Brahmas in size, could be accounted for by two pairs of
genes, with major effects; each gene responsible for an
increase of 500 grams in heterozygotes and 1000 grams in
homozygotes. Maw (1935) presented evidence for a sex-
linked gene that depressed body size. In 1941 Hutt, Cole
and Bruckner showed that body size can be effectively in­
creased by proper breeding methods. They increased by 7%
the mean mature weight of their White Leghorns in four
generations of selection, while simultaneously directing
selection toward laying capacity, egg size and disease
resistance. To date three hereditary variations in size have been sufficiently studied to indicate that they are caused by single genes. One of these is the sex-linked reduction of size, another, an autosomal recessive dwarfism, accompanied by various pathological conditions and the third, a sex-linked recessive dwarfing.

(3) **Body conformation and amount of meat**

Selection geared to high quality poultry meat production aims at a plump and broad-breasted carcass with a minimum percentage of offal and bone and a maximum dressing percentage of high quality meat. The extensive experimental work and publicity undertaken recently in the United States (Chicken of Tomorrow Contest\(^3\)), to provoke interest in the production of better broilers, provides an example of the importance the poultry industry now attaches to securing improved types of meat poultry to satisfy the market. It is worthy of note, that, in Canada increased attention is being given to establishing meat grades under the inspection of the Dominion Department of Agriculture. Under Dominion government regulations, all dressed poultry that is shipped between provinces or exported, is carefully graded. While not compulsory in all local trade, a very considerable portion of Canadian poultry meat has been brought under this control. Through the cooperation of the provincial and dominion governments,

\(^3\)Sponsored by the Great Atlantic and Pacific Tea Company, as an incentive to the production improved 12-week old broilers.
poultry meat is now graded, under Dominion Standards, in large centres like Vancouver and Victoria and to a considerable extent by trade and market organizations.

The body of the ideal meat bird is heartshaped and compact, providing the greatest number of desirable cuts when carved for the table. It is reasonably fine in bone, with thin pliable skin. The short broad head and neck and stout well-curved beak, relatively broad at the base are associated with the compact body. The shoulder is broad and rather flat on top; the back is broad with the width well carried back to the rump of the bird. The breast is moderately deep, wide, full and round. When great depth is obtained, there is danger that the breast will be poorly fleshed. A long straight keel is desirable. The legs are relatively short, thick and set well apart to give the body adequate width. Minimum sized wings are desired since little meat comes from this source.

Little is known concerning the inheritance of the type form described above. Kopec (1927) made reciprocal crosses between White Leghorns and Buff Orpingtons and measured in the $F_1$ and $F_2$ generations, several body dimensions. He found depth of thorax and length of sternum to be inherited independently. Maw and Maw (1938) took five measurements of shape on the progeny of three Barred Plymouth Rock sires, who varied in size. Progeny of the smallest sire were smallest in all five dimensions, while the progeny of the largest sire were greater in length and
breadth of back, in depth of body at the front and in length of shank but not in length of keel. The sire that was intermediate in weight produced both sons and daughters that were less in all dimensions but keel length. Maw and Maw suggest that keel length is governed by a single gene. Lerner, Asmundson and Cruden (1947) studied progeny of a randomly selected New Hampshire breeding flock with respect to body weight, shank length, keel length and breast width at 12 weeks of age. They found the heritability of these four characters to be respectively, 50, 50, 30, and 30 per cent. They found negative correlations between keel length and breast width, suggesting that attempts to improve both simultaneously will, to a small degree, exercise a pull in opposite directions. They suggest that a more serious difficulty facing the breeder is the positive correlation that exists between body weight and shank length. Selection for increased body weight and a reduced shank simultaneously will largely cancel each other. It seems apparent that considerable progress in breeding for improved body type is possible if a program of careful selection for each of the desired characteristics is followed with careful attention to the various heritabilities and correlations.

(4) Rate of feathering:

Early, full, fast feathering is necessary in a good strain of broilers to allow the birds to dress out well at twelve weeks of age without undesirable pin feathers.
It is not so important for roaster production but even in this case, early feathering young stock, under natural conditions, are better protected against adverse weather conditions and more capable of avoiding predators. Early information on the genetics of feathering came from Serebrovsky (1922), who discovered that fast feathering was sex-linked. This was verified by Warren in 1925. Autosomal genes, preventing the full expression of (k) the fast feathering factor, were discovered by Warren (1933) and Jones and Hutt (1946). These two recessive autosomal mutations are known as retarded (t\textsuperscript{3}) and tardy (t). Together with the normal factor T, they form a series of multiple alleles. Retarded is less abnormal than tardy. The full genotype for normal rapid feathering male chicks is kkTT, for females k-TT. Warren and Payne (1945), working with four lots of New Hampshire chicks, found that those with rapid feathering were consistently heavier at twelve weeks of age. They suggest that gene k may accelerate the whole organism. Hays and Sanborn (1942), demonstrated a dominant autosomal gene influential in producing good back feathering at eight weeks in Rhode Island Reds. Many strains of Rhode Island Reds show the bare-back characteristic. Darrow (1942) reported that variations in the degree of early feathering in sex-linked early feathering strains of heavy breeds may occur. He found the variations to be expressed in the number of secondaries apparent at hatching time and at the age when feathers appeared on the tail and back. He refers
to the factor as an autosomal recessive modifier of sex-linked early feathering. This modifier depresses the number of secondaries at hatching and delays tail feather and even body feather growth. He suggests that the broiler producer should concentrate on selection for a high number of secondaries. More recently, the work of Hill (1949-1950) suggests that additional inhibiting factors may be involved. He found feathering in the U.B.C. Rhode Island Reds very complex and not readily explained by the action of three genes.

5. Freedom from Defects

To grade out well at market time, a poultry carcass must be free from such defects as crooked breast, breast blisters, and off colored and hairy skin. A crooked breasted fowl, no matter how heavy and broad breasted, is invariably graded down. It is not definitely known whether crooked breastedness is genetically controlled, nutritional or environmental (caused by sharp roosting poles or premature roosting). It seems highly likely that this condition may result from a combination of these causes, for, on the U.B.C. poultry farm, as on others, it occurs somewhat sporadically in certain families and to different degrees during different years.

The cause of breast blisters is not definitely established, but the condition is more prevalent in angular breasted birds with a poor covering of feathers. A measure
of control may be secured over this condition by selection for plumpness in the breast and fast feathering, as evidenced by the decline of this condition at U. B. C.

A smooth light cream-colored or light pink skin, free from hairs and deep follicles is preferred in the meat market. This type of skin has been controlled to a large measure by selection.

B. EGG QUALITIES

In 1948, out of a total value of $258,000,000 for Canadian poultry products, eggs represented $171,000,000 or roughly 65%. In 1949, out of a total production of $251,000,000, eggs were valued at $146,000,000 or roughly 58%. During the same period, poultry meats climbed in value from $87,500,000 in 1948 to $104,000,000 in 1949.4

While the value of the poultry meat industry in Canada is rapidly increasing, it can be seen that egg production is still of paramount importance to poultry economy. To secure efficiency in egg production, number, size and quality of eggs must be given proper consideration.

It is usual to think of annual egg production as chiefly influenced by five factors, namely: (1) age at first egg, (2) rate of production, (3) broodiness, (4) winter pause, and (5) persistency of production. This arbitrary classification is merely a convenient means of breaking down the multifactorial complex of genes, governing fecundity,

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4 Dominion Bureau of Statistics, Department of Trade and Commerce, "Production of Poultry and Eggs, 1949".
into more measurable terms. Undoubtedly, factors affecting body size, growth rate, egg size, metabolic rate, and the secretion and elaboration of sex hormones are concerned as well.

In this project consideration was given to the general genetic background of egg production and stress placed upon the factors of, (1) total production, (2) intensity of production, (3) egg weight, and (4) incidence of broodiness.

1. General Genetic Background of Egg Production

There has been a great deal of research on the inheritance of egg production during the last 35 years. The initial work of Pearl (1912), suggested that the differences in egg production, observed between individual birds, resulted from the action of two pairs of genes, one autosomal, the other sex-linked. Goodale and Macmullen (1919) concluded that two pairs of genes, both autosomal, were operative in determining a bird's production. They presented evidence to show that Pearl's data could also be interpreted on this basis.

Hurst (1921) postulated individual genes as controlling production during different seasons of the year, with a recessive gene controlling high autumn production. Goodale and Sanborn (1922) concluded that the first year's egg record was the sum of genetic variation in five factors, namely; age at first egg, rate of lay, broodiness, winter
pause and persistency of production. That individual genes
account for the observed segregations of these factors was
first proposed by Hays (1924). Punnett (1930) presented
evidence showing that no sex-linkage was involved.

More recently, the attention of investigators
has been focused on the heritability of egg production and
the gains that may be realized by progeny test selection.
Munro (1936) found the heritability of annual egg production
to be 20 or 25%. Munro, Bird and Hopkins (1937) estimated
heritability at 31%. Gutteridge and O'Neil (1942) reported
that egg production was influenced to a much greater degree
by environment than by heredity. Lerner and Taylor (1943)
found the heritability to be 23%. Later Lerner and Cruden
(1948) reported the heritability of accumulative egg pro-
duction as constant through the year and equal to 33%. In
1948 Schoffner and Sloan reported the heritability of egg
production, (derived from a study of 751 dam-daughter pairs)
as 34%. Comstock, Bostain and Dearstyne (1947) present
several estimates of heritability, ranging from 16% - 47%.

In light of the above investigations, it seems
reasonable to assume that from one quarter to one third of
the total variation found in egg production is genetically
controlled. The average of the above estimates, 31.3%,
provides a reasonably accurate measure of the heritability
of egg production. This figure was used in constructing
the Barred New Hampshire selection index.
The average production of hens still alive at the end of a laying year gives the breeder little information unless it is based on the proportion of the original number of birds involved. The "hen-day" average, determined from the cumulative average of monthly or weekly records during the year, will be high if poor layers have been culled regularly, much lower if they have not. Similarly, productivity may be computed from the proportion of the flock which lay 200 or more eggs in a year. However, this is not a true figure if the families showing poor prospects in the first three months are then excluded from the original number, as permitted in the Canadian R.O.P. scheme. Unfortunately these forms of measuring egg production have resulted in excessively high records being reported, until the average poultryman is led to expect much higher productivity from the average hen than she is capable of achieving. As a measure of economic value, the "production index" or "hen-housed average," which is the total number of eggs laid by the flock or family during the test period, divided by the original number of birds, is a more useful figure. However, the production index is influenced as much by mortality as by laying ability and so its use over a period of years as a measure of the improvement in egg production, effected by selection, is of dubious value unless the mortality has been constant during that period. To give a complete picture of the production of the Barred New Hampshires the following figures are reported: first, the
average production of hens that completed a full year in the laying house, second, the average percent mortality of all birds housed and third, the intensity of production.

2. INTENSITY OF PRODUCTION

A high intensity (rate of lay) results in a greater net financial return per bird. Hays and Sanborn (1927b) report that two dominant genes, I and I\(^1\), control intensity. Hens carrying gene I alone have an average winter clutch size greater than two, but less than 2.6. Gene I\(^1\) gives a clutch size of about 2.6. Both genes together increase the clutch size to 3 or more eggs throughout the winter season. They found no sex linkage was involved. Hays (1930) reports linkage between I\(^1\) for high intensity, and gene A, for small egg size.

A measure of rate of laying that has been employed by some investigators, Knox, Jull and Quinn (1935), Godfrey and Jull (1936) among others, is the number of eggs laid from the time that laying commences to March 1st, the production being expressed as a percentage of the total number of days involved. Lerner and Taylor (1936) suggest that if the rate of lay is controlled by the same genes throughout the year, the logical method of determining rate, is to exclude from the calculations all pauses in production. Therefore, intensity of production in the Barred New Hampshires was computed by expressing the number of eggs laid from the first egg to June 1st, as a percentage of the number of days involved, with all pauses excluded.
3. **EGG WEIGHT**

Egg weight is important commercially because the top Canadian egg grade arbitrarily calls for eggs weighing 24 oz. to the dozen. Poultry breeders are forced to select for breeding purposes, families laying eggs weighing two ounces or more. There is no encouragement to breed for egg size much in excess of 2 ounces, since no premium is paid the producer of very large eggs. Furthermore, exceedingly big eggs do not hatch well and are not suitable for shipping in standard cases.

Like most quantitative characters, an unknown number of genes is involved (Hutt, 1949). In view of the ease with which egg size may be raised by selection, Hutt suggested that genes affecting egg size may be fewer in number than those determining fecundity, viability, and other physiological characters. Hutt and Bozivich (1946) reported that no sex-linkage was involved in the inheritance of egg size. Conversely, Ghigi (1948) found evidence of sex-linkage in White Leghorn x Sonneratti reciprocal crosses. That egg size is highly heritable and may be effectively improved by breeding was demonstrated by Snyder (1945). He found egg size in several generations of Barred Plymouth Rocks to vary considerably, down to 52 gm. Selection by the progeny test raised average egg size to 60 gm, in two years and maintained it at that level for five years. Waters (1943) reported figures of 46%, 55% and 74% for the heritability of this characteristic. Lerner and Taylor (1943) found a
heritability of 46%. Schoffner (1948), estimating heritability from a ten egg sample taken during the month of April, found the heritability to be 60.7%. Comstock, Bostian and Dearstyne (1947) report figures ranging from 46-84%. Lerner, Cruden and Taylor (1949) found the heritability of early egg weight to be 44%. The average of the above figures, 56.5%, was used in construction of a selection index.

4. BROODINESS

Successive periods of broodiness throughout the year interfere seriously with egg production. It has been shown by several investigators that one or two attenuated periods of broodiness during a laying year may have very little effect on the total number of eggs laid. Lanson (1948) reported that hens with broody tendencies frequently lay at a higher rate than those without the maternal instinct. However, if a bird remains broody for too long or has successive periods of broodiness, she tends to lose weight and condition. For many reasons, not the least of which is avoidance of the bother of "breaking up clucking hens", the broody characteristic is considered detrimental to efficient poultry production and is selected against accordingly.

According to Goodale, Sanborn and White (1920), broodiness is due to complementary genes, non-broody breeds lack one of these or carry an inhibitor of both. These complementary genes, called arbitrarily A and C, together, in either the homozygous or heterozygous state, produce broodiness. Because of the different degrees of broodiness
encountered in various breeds of poultry, it is believed that the genes controlling this character may have additive effects. Axelsson (1933-34) suggested that complementary factors, partly sex-linked and partly autosomal, were in control of broodiness. Further evidence of sex-linkage was presented by Warren (1942) and later Kaufman (1948), studying Polish Greenleg x White Leghorn reciprocal crosses, suggested that broodiness depends on one pair or more sex-linked factors and on one pair or more of autosomal complementary factors. She suggests that non-broody hens lack either the sex-linked factor or the autosomal factor or both and that contradictory results from earlier investigations may have been caused by different combinations of the sex-linked and autosomal factors in different breeds and strains.

Riddle, Bates and Lahr (1935) showed that broodiness is induced by prolactin. Injections of artificially prepared prolactin stimulate "setting". Kaufman assumes that the faculty of periodical secretion of prolactin is controlled by the sex-linked factors, the autosomal factors being involved in the inheritance of the constitution of the organism (ability to answer to the hormone). She suggests that the higher incidence of broodiness generally found in cross-breds may be produced by an alternation of the hormonal balance.

Broodiness is characteristic of the Asiatic breeds and is found to some degree in all breeds derived from them. Barred Plymouth Rocks, Rhode Island Reds and
New Hampshires all exhibit broodiness to varying degrees. Goodale (1920) demonstrated that broodiness could be effectively reduced by selection, as is the case with most undesirable dominant characteristics. In five years he lowered the proportion of broody birds in a flock of Rhode Island Reds from 91% to 19%. The number of broody periods per broody hen was reduced from 5.4 to 1.9. A search of the literature indicated that nothing has been written on the heritability of broodiness.

C. VIABILITY

In the evaluation of the economic qualities of commercial poultry, viability, or disease resistance, may be an important factor. For example, the progress that is made in the direction of increased production may be nullified by an excess of mortality. A good illustration of such a condition, arose in this province in 1930, when a prosperous industry was threatened by a sudden and disastrous attack of paralysis in high producing breeding flocks. In the previous ten year period remarkably rapid progress had been made in breeding for increased egg production and several world's records established. Since that time efforts have been made to regain the lost ground by selection for disease resistance. A further complicating factor in the control of mortality has been the increase in the incidence of the various sporadic diseases within recent years.
The two important phases of the problem of selection for viability are the relative roles played by heredity and environment on the health of the bird. Through studies of the influence of heredity by progeny tests, it was found that great variations in disease resistance existed in different strains of poultry. Some results in experiments demonstrating the feasibility of reducing mortality by breeding are presented in Fig. 8 (After Hutt, 1949).

### FIG. 8 SOME RESULTS IN EXPERIMENTS DEMONSTRATING THE FEASIBILITY OF REDUCING MORTALITY BY BREEDING

<table>
<thead>
<tr>
<th>Investigator</th>
<th>Breed</th>
<th>Period of selection</th>
<th>Length of Test period</th>
<th>Mortality, per cent, in Original unselected population</th>
<th>Latest generation reported</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marble (1939)</td>
<td>Barred Rock</td>
<td>1933-1937</td>
<td>150 to 515 days</td>
<td>48.7#</td>
<td>24.6</td>
</tr>
<tr>
<td>Marble (1939)</td>
<td>White Leghorn</td>
<td>1933-1937</td>
<td>150 to 515 days</td>
<td>39.8#</td>
<td>20.1</td>
</tr>
<tr>
<td>Sturkie (1943)</td>
<td>White Leghorn</td>
<td>1935-1940</td>
<td>365 days from first egg</td>
<td>89.0</td>
<td>27.0</td>
</tr>
<tr>
<td>Bostian and Dearstyne (1944)</td>
<td>White Leghorn</td>
<td>1939-1941</td>
<td>30 to 360 days</td>
<td>23.3</td>
<td>11.2</td>
</tr>
<tr>
<td>Bryant (1946)</td>
<td>White Leghorn</td>
<td>1940-1944</td>
<td>140 to 525 days</td>
<td>25.0</td>
<td>17.1</td>
</tr>
<tr>
<td>Hutt and Cole (1947)</td>
<td>White Leghorn C</td>
<td>1936-1945</td>
<td>42 to 500 days</td>
<td>66.8</td>
<td>22.4</td>
</tr>
<tr>
<td>Hutt and Cole (1947)</td>
<td>White Leghorn K</td>
<td>1936-1945</td>
<td>42 to 500 days</td>
<td>66.8</td>
<td>19.9</td>
</tr>
</tbody>
</table>

*Days of age  
#Includes those removed "for health".
Progress in breeding for disease resistance is slow at the best since the breeder is faced with the problem of selecting for this characteristic and for egg production, at the same time, along with such factors as egg size, rate of feathering and maturity and breed type. The complexity of the situation is accentuated by the fact that these characteristics are inherited on a quantitative basis. Furthermore, certain linkage relationships may interfere with the implantation of the desirable genes in the individual.

According to Hutt (1949) and others the variations in viability of breeds could result from any of the following causes:

1. Linkage of lethal or semi-lethal genes, or genes causing physiological deficiencies, with those determining breed characters, e.g., Dunn's lethal linked with recessive white. Some of these might reduce the heterozygotes viability.

2. Genes for physiological characters incorporated, either deliberately or unwittingly, as determiners of the breed, e.g., rapid feathering, non-broodiness, and low requirements of thiamine and manganese in Leghorns.

3. Disproportion or abnormality of structure, e.g., extremely short legs in Dark Cornish, abnormally large crests or combs, frizzled plumage.

4. Effects in the heterozygotes of lethal genes unwittingly adopted as breed characters, e.g., the creeper mutation in the fowl and crest in the duck.
Robertson and Lerner (1949) point out that in a population where no artificial selection is applied, there exists a natural selection differential for viability, since birds with a genotype for low viability will have a lower chance of surviving to become parents of the next generation than the birds with a genotype for high viability. Lerner and Taylor (1943) reported the heritability of viability to be 13%, while Lush, Lamoreux and Hazel (1946) found it to be 8%. Robertson and Lerner (1949) corroborated the 8% figure.

D. HATCHABILITY AND FERTILITY

To ensure economical chick production, it is essential that poultry breeding stock give a high percentage of fertility and hatchability. Although many of the causes of low fertility and hatchability are environmental, i.e. inadequate nutrition, adverse weather conditions and incompetently managed incubation, there are certain genetic factors concerned. It has been shown that certain strains of White Wyandottes consistently give very low fertility (Hutt 1940). Again, the percentage of inbreeding in a flock has been shown to affect both fertility and hatchability (Waters, 1938). Waters reported the following five year averages for fertility and hatchability:

<table>
<thead>
<tr>
<th></th>
<th>Fertility</th>
<th>Hatchability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inbred stock</td>
<td>83.6%</td>
<td>72.1%</td>
</tr>
<tr>
<td>not inbred</td>
<td>75.9%</td>
<td>80.8%</td>
</tr>
<tr>
<td>top cross</td>
<td>85.7%</td>
<td>85.8%</td>
</tr>
</tbody>
</table>
Hays and Sanborn (1939) report that one major gene (H) is concerned in high hatchability. This gene is transmitted equally by males and females and has a cumulative effect. The three general classes of birds with respect to high hatchability are: (1) HH birds, which if mated to either HH of Hh males give hatching records of 85% or more; (2) Hh birds which usually have a hatchability range from 55% to 84% and may produce no hatchable eggs; and (3) hh birds which generally range in hatchability from 0 to 54%.

Schoffner and Sloan (1948), studying 84 sire groups and 396 dam-daughter comparisons and 1129 daughters, found the heritability of hatchability to be 16%.
VI. SELECTION INDEX FOR THE BARRED NEW HAMPSHIRE

In this study an attempt has been made to develop a selection index, or a numerical expression of "over-all" breeding value. Selection may be practiced in three ways. The first method is to select for one characteristic at a time until it is improved, then select for a second and so on. The second method is to cull simultaneously but independently for each of the several characteristics considered to be of importance. In other words, to establish arbitrary culling levels for certain characteristics, below which all individuals are culled, no matter how superior they may be in other characteristics. The third method is to establish a total score or selection index to measure net merit, by which those with the highest total scores are used for breeding purposes. The first method is the slowest for reaching a total objective. The second method has the practical advantage, which may be important under some circumstances, in that culling on each characteristic may be done whenever that characteristic develops, without waiting to score later developing characteristics. The third method, i.e. selection index, is more efficient than the method of independent culling levels because it permits unusually high merit in one characteristic to compensate for slight defects in another. The efficiency of such an index will be lowered if too many characters are included in the selection program. When a selection index is used, some
of the advantage of culling on independent levels may be realized by culling the very worst in each undesirable characteristic when it develops and leaving doubtful cases to be decided later by a selection index. The principles behind the construction of a selection index, designed to make maximum improvement, are those of multiple regression, where it is desired to predict as accurately as possible an unknown or "dependent" variable from two or more known "independent" variables. The dependent variable is the bird's net genetic merit or breeding value; its characteristics under consideration are the independent variables. The information required for each characteristic is as follows:

1. The average amount which a given variation in that characteristic raises or lowers the net phenotypic merit of the animal (economic importance).

2. Heritability of each characteristic.

3. Genetic correlations between that characteristic and the others.

4. Phenotypic correlations between that characteristic and the others.

The genetic correlation between two characteristics in the same bird can be measured by observing a large number of pairs of closely related birds and correlating characteristic "x" in one member of the pair with characteristic "y" in the other. This procedure requires
large numbers and the estimates have high sampling errors. The environmental correlations between two characteristics can be formulated by correlating the two characteristics on the same bird and subtracting the genetic correlation. However, the few studies made to date indicate that if the economic importance and the heritability of the characteristic concerned are known with rough accuracy, the efficiency of an index based on them will not be much altered by the intercorrelations between the variables, although their relative importance may be altered.

Selection of breeders during 1950 was accomplished by combining the selection index method and the arbitrary culling levels method. An arbitrary level that all prospective breeder's must meet was devised for all characteristics. In addition to this, a selection index, based on available information on heritability and importance, was constructed. The selection index was used in choosing males to head the various breeding pens. The selection pressure could not be as intense in choosing female breeding stock, since numbers were relatively small. All birds qualifying for breeding purposes were required to meet the following standards, both on an individual and a family basis:

1. Average annual egg production of 200 or more eggs.

2. Average egg size of 24 oz., or better, to the dozen.
3. Not more than two periods of broodiness.
4. Average laying house mortality of less than 10%.
5. Average of 70% fertility.
6. Average of 60% hatchability.
7. Average of 70% grade A "meat type."
8. Average of 70% 30 feathering

In addition, the birds were required to be clearly barred, A "meat type", weigh 8½ lbs. in the case of the male, and 5½ in the case of the female, and be free of standard disqualifications. Furthermore, males selected to head the breeding pens were chosen by applying a selection index to their families based on the following five characteristics:

(1) Annual egg production
(2) Meat grade
(3) Viability
(4) Hatchability
(5) Egg weight

The selection index used was computed from the following arbitrary estimates of commercial importance and the known heritabilities:

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Heritability</th>
<th>Assigned Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg production</td>
<td>31.3%</td>
<td>5</td>
</tr>
<tr>
<td>&quot;Meat type&quot;</td>
<td>40%</td>
<td>4</td>
</tr>
<tr>
<td>Viability</td>
<td>9.7%</td>
<td>4</td>
</tr>
<tr>
<td>Hatchability</td>
<td>16%</td>
<td>3</td>
</tr>
<tr>
<td>Egg weight</td>
<td>56.5%</td>
<td>2</td>
</tr>
</tbody>
</table>

s = 156.5 E + 160 M + 38.8 V + 48 H + 113 W

The weights required here are less than the standard for the breed (see appendix xi), because pullets and cockerels were in most cases used for breeding purposes.
VII. EXPERIMENTAL: THE 1950 BREEDING SEASON

A. Design of Breeding Pens

The high degree of accuracy obtained (92.6%), in autosexing the pure barred progeny from pen 19, the only 1949 breeding pen to produce only homozygous barred males and hemizygous barred females, was considered encouraging in view of the limited knowledge of down color patterns in chicks of the new breed. The other matings made in 1949 were not expected to produce easily sexed progeny, since four genotypes for barring were possible in most of the offspring. Because of the progress made in fixation of pure barred chick down patterns, the 1950 breeding pens were planned in a way designed to emphasize economic characteristics. One pen was set up to produce pure barred stock, to provide a check on autosexing accuracy and to maintain stock at the 50% New Hampshire 'blood' level. The other pens were selected, not only for improvement in economic qualities, but also, for increase in the degree of relationship to the New Hampshire breed. This latter procedure was particularly desirable since previous results showed that stock from matings continually back-crossed to New Hampshires, came closer to the desired standard. Since a high coefficient of inbreeding has been shown to lower vigor in many cases, the inbreeding coefficient was kept as low as possible by employing unrelated New Hampshire 'blood' in a variety of matings. This procedure does not give sexable stock because of the number of possible variations in the genetic
makeup for barring. However, when the economic standard is attained, it will be a comparatively simple procedure to purify barring by the method suggested by Hagedoorn.

Available breeding stock included:


4. Yearling Barred New Hampshire females, which had qualified under R.O.P.


Five pens were set up, the males heading the pens being chosen by the arbitrary standards devised for the Barred New Hampshire breed (page xi) and the selection index. All females were required to meet the arbitrary standards to qualify. The matings, along with some data on the birds as individuals, the level of New Hampshire "blood" they carried and the expected segregation of progeny, are discussed below.

Pen 6 was headed by a homozygous Barred New Hampshire male from pen 15 of 1949. This male was graded A in "meat type" and weighed 9.2 lbs. He was 30 feathering and uniformly barred. He had several sisters in the 1950 R.O.P. entry.
Mated to this male were twelve, yearling Barred New Hampshire hens, all of whom had qualified under R.O.P. the previous year. The progeny test indicated that they carried genes for fast feathering, rapid growth, viability and good body type. These hens were all clearly barred and Grade A "meat type." None had exhibited more than two broody periods.

Since the male and the females carried 50% New Hampshire blood, the progeny carried the same level. Chicks autosexed with a high degree of accuracy since only the two distinct types, BB and B- were possible.

\[
BB \times B- \\
BB \quad B-
\]

Pen 13 was headed by a heterozygous Barred New Hampshire male from pen 7 of 1949. This male was exceptionally well barred, he weighed 9.3 lbs. and was graded A- "meat type". He was mated to twelve R.O.P. New Hampshire females, all of grade A "meat type" with good handling qualities. They were representative of the best U.B.C. New Hampshire families. As far as could be determined, they were fast feathering and early maturing. Since the male carried 75% New Hampshire "blood" and the females 100%, the progeny were of the 87\(\frac{1}{2}\)% level. The method used to develop this line of New Hampshires is that of Hagedoorn, i.e. continuous back-crossing to New Hampshire stock. They present a direct comparison to Pen 6, developed by the original
Punnett and Pease method. In 1950 it was possible to compare these two methods as regards economic qualities. The comparative figures for egg production, "meat type", viability, etc. are presented in fig. 9.

Autosexing was difficult to apply to the progeny of this pen, since one half the chicks were non-barred and the others carried just one B gene each.

\[ Bb \times b^- \]

\[ Bb, bb, B-, b^- \]

Pen 18 was headed by a homozygous Barred New Hampshire male from Pen 19 of 1949. This male weighed 9.0 lbs., was graded A "meat type" and was early maturing. He proved to be 20 feathering, although he was included in the pen under the assumption that he was 30 feathering. At certain stages of development it is almost impossible to distinguish 20 and 30 feathering. Mated to this male were 12 selected R.O.P. New Hampshire females; they were all grade A "meat type" and averaged 5.4 lbs. in weight. Since the male carried 50% New Hampshire "blood" and the females, 100%, the progeny were of the 75% level. This line was developed by use of a slight modification of the Hagedoorn method, since the male came from the pure barred mating of 1949, which was being maintained at the 50% level.

Sexing accuracy was low in this cross since, although only two classes of offspring were possible, Bb and B-, these both contained only one gene for barring. The effect of the single gene on the chick down pattern is often
**Fig. 9 -- COMPARISON OF ECONOMIC QUALITIES IN THE TWO LINES OF BARRED NEW HAMPSHIREs**

**LINE A**
Produced by crossing at the 50% level of New Hampshire "blood". The figures given in each case are those for the most recent generation (i.e., egg production refers to progeny of 1949, hatchability to 1950 progeny).

<table>
<thead>
<tr>
<th>LINE A</th>
<th>LINE B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Produced by crossing at the 50% level of New Hampshire &quot;blood&quot;.</strong></td>
<td><strong>Produced by continuous backcrossing to pure New Hampshire stock.</strong></td>
</tr>
<tr>
<td>203.1</td>
<td>240.6</td>
</tr>
<tr>
<td>25.6 oz./doz.</td>
<td>25.5 oz./doz.</td>
</tr>
<tr>
<td>20%</td>
<td>0%</td>
</tr>
<tr>
<td>29.2%</td>
<td>19.7%</td>
</tr>
<tr>
<td>6%</td>
<td>4%</td>
</tr>
<tr>
<td>88.7%</td>
<td>92.1%</td>
</tr>
<tr>
<td>79.6%</td>
<td>78.1%</td>
</tr>
<tr>
<td>70.1%</td>
<td>89.8%</td>
</tr>
<tr>
<td>1.9 lbs.</td>
<td>2.3 lbs.</td>
</tr>
<tr>
<td>Average egg size</td>
<td>Average egg size</td>
</tr>
<tr>
<td>Laying house mortality</td>
<td>Laying house mortality</td>
</tr>
<tr>
<td>% broodiness</td>
<td>% broodiness</td>
</tr>
<tr>
<td>Mortality to 12 weeks</td>
<td>Mortality to 12 weeks</td>
</tr>
<tr>
<td>% fertility</td>
<td>% fertility</td>
</tr>
<tr>
<td>% hatchability</td>
<td>% hatchability</td>
</tr>
<tr>
<td>% A meat grade</td>
<td>% A meat grade</td>
</tr>
<tr>
<td>Average weight at 10 weeks</td>
<td>Average weight at 10 weeks</td>
</tr>
</tbody>
</table>
very similar.

BB x b-

Bb, B-

Pen 24 was headed by a heterozygous Barred New Hampshire male from pen 7 of 1949. This male weighed 8.9 lbs. and was graded as A in "meat type". He was evenly barred, early maturing and 30 feathering. He was mated to twelve Barred New Hampshire pullets from Pen 21 of 1949. These pullets were all entered in R.O.P., were uniformly barred, averaged 5.7 lbs. in weight and all grade A "meat type". They were pure for early, fast feathering, as far as could be determined and with two exceptions were early maturing. The last mentioned pullets were exceptionally well-marked birds. Since both the male and the females carried 75% New Hampshire "blood", the progeny were of the same level.

Autosexing was difficult since four classes of progeny were produced, BB, Bb, B-, b-.

BB x B-

BB bb B- b-

Pen 26 was headed by a heterozygous Barred New Hampshire male from pen 21 of 1949. This male weighed 9.0 lbs. and was graded A in meat type when he was placed in the breeding pen. Later he lost somewhat in weight and fleshing due to injuries received in fighting. He was nicely barred, early maturing and 30 feathering. He was mated to 13 Barred New Hampshire females, 11 from 1949's pen 19 and two from pen 15. These females were fairly uniformly barred and 30
feathering. Several were late maturing and did not produce hatching eggs for the first hatch. Consequently the number of progeny was considerably lower than hoped for. The male carried 75% New Hampshire "blood", the females 50%, the progeny 62½%. Sexing was difficult since four genotypes were produced, BB, Bb, B-, b-.

\[ Bb \times B- \]
\[ BB, Bb, B-, b- \]

RESULTS OF 1950 BREEDING SEASON

Eggs from five 1950 Barred New Hampshire breeding pens were set in three different lots. The first hatch came off on March 20, the second on April 4, and the third on April 18th. All chicks were R.O.P. wing-banded, sexed and classified as to rate of feathering at hatching time. Weak birds were killed and sexed by examination of their gonads. Fig. 10 shows the number of progeny by hatches and by pens in 1950.

**Fig. 10**

<table>
<thead>
<tr>
<th></th>
<th>Pen 6</th>
<th>Pen 13</th>
<th>Pen 18</th>
<th>Pen 24</th>
<th>Pen 26</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hatch 1</td>
<td>31</td>
<td>53</td>
<td>62</td>
<td>32</td>
<td>18</td>
<td>196</td>
</tr>
<tr>
<td>Hatch 2</td>
<td>36</td>
<td>30</td>
<td>24</td>
<td>30</td>
<td>12</td>
<td>132</td>
</tr>
<tr>
<td>Hatch 3</td>
<td>63</td>
<td>57</td>
<td>45</td>
<td>59</td>
<td>13</td>
<td>237</td>
</tr>
<tr>
<td><strong>Total</strong>:</td>
<td><strong>130</strong></td>
<td><strong>140</strong></td>
<td><strong>131</strong></td>
<td><strong>121</strong></td>
<td><strong>43</strong></td>
<td><strong>565</strong></td>
</tr>
</tbody>
</table>
The numbers of chicks killed because of weakness, spraddle legs or general unthriftiness at hatching time are listed below:

Hatch 1 -- 8; Hatch 2 -- 16; Hatch 3 -- 10.

The number is abnormally high for Hatch 2, (12%); not due to low vigour of stock but to certain mechanical difficulties in incubation.

1. HATCHABILITY AND FERTILITY

The fertility and hatchability of the Barred New Hampshires were computed by hatches, by pens (sires) and by dams. The figures are not presented for the second hatch, for reasons as explained above. Fig.11 shows the percentage fertility and hatchability by pens and by hatches.

2. SEXING ACCURACY

The percentage of accuracy in autosexing was computed for each dam and for each sire. The "dam" figures, with few exceptions, are relatively uniform within each pen because the progeny segregate in the same classes with respect to barring. Fig.12 presents the percent accuracy for each pen.

Similar to the results of 1949, the pen pure for barring (pen 6) gave a high percentage of accuracy, while the other pens in which several types of progeny were produced, gave a much lower percentage of accuracy. Sexing accuracy in pen 26 was unexpectedly high. This, however, could not be considered significant because of the low number of progeny involved.
Fig. 11— FERTILITY AND HATCHABILITY OF 1950 BARRED NEW HAMPSHIRE PROGENY

<table>
<thead>
<tr>
<th>Pen #</th>
<th>Hatch #1</th>
<th>% Fert.</th>
<th>Hatch #3</th>
<th>% Hatch.</th>
<th>Total:</th>
<th>% Fert.</th>
<th>Hatch #1</th>
<th>% Hatch.</th>
</tr>
</thead>
<tbody>
<tr>
<td>#6</td>
<td>78.2</td>
<td>77.5</td>
<td>93.9</td>
<td>80.7</td>
<td>88.7</td>
<td>79.6</td>
<td>87.9</td>
<td>71.9</td>
</tr>
<tr>
<td>#13</td>
<td>91.8</td>
<td>79.1</td>
<td>92.5</td>
<td>77.02</td>
<td>92.1</td>
<td>78.1</td>
<td>89.0</td>
<td>71.7</td>
</tr>
<tr>
<td>#18</td>
<td>93.8</td>
<td>70.5</td>
<td>88.5</td>
<td>83.3</td>
<td>91.1</td>
<td>76.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#24</td>
<td>90.4</td>
<td>68.0</td>
<td>94.7</td>
<td>65.5</td>
<td>93.3</td>
<td>66.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#26</td>
<td>75.7</td>
<td>64.3</td>
<td>75.4</td>
<td>52.0</td>
<td>75.5</td>
<td>58.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TOTAL: 89.9% 71.8%
### Autosexing Accuracy in 1950 Barred New Hampshire Progeny

<table>
<thead>
<tr>
<th>Pen No.</th>
<th>Cross</th>
<th>Number of Progeny</th>
<th>Distribution of Progeny</th>
<th>Level of New Hampshire Blood</th>
<th>Sexing Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>homozygous barred New Hampshire male x barred New Hampshire females</td>
<td>130</td>
<td>BB, B-</td>
<td>50%</td>
<td>89.1%</td>
</tr>
<tr>
<td></td>
<td>BB x B-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>heterozygous barred New Hampshire male x New Hampshire females</td>
<td>140</td>
<td>Bb, bb, B-, b-</td>
<td>87.5%</td>
<td>65.7%</td>
</tr>
<tr>
<td></td>
<td>Bb x b-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>homozygous barred New Hampshire male x New Hampshire females</td>
<td>131</td>
<td>Bb, B-</td>
<td>75%</td>
<td>56.2%</td>
</tr>
<tr>
<td></td>
<td>BB x b-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>heterozygous barred New Hampshire male x barred New Hampshire females</td>
<td>121</td>
<td>BB, Bb, B-, b-</td>
<td>75.5%</td>
<td>78.3%</td>
</tr>
<tr>
<td></td>
<td>Bb x B-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>heterozygous barred New Hampshire male x barred New Hampshire females</td>
<td>43</td>
<td>BB, Bb, B-, b-</td>
<td>62.5%</td>
<td>81.4%</td>
</tr>
<tr>
<td></td>
<td>Bb x B-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3. FEATHERING, RATE OF GROWTH, BODY WEIGHT AND "MEAT TYPE"

All Barred New Hampshire young stock were examined at six and ten weeks of age. At these times, their sex, feathering, rate of growth, weight and "meat type" (body proportions and amount of meat) were recorded. The feathering data are presented in fig. 13. An explanation of the nomenclature used to describe the type of feathering is offered below.

30 -- Early, full and fast feathering. At six weeks, birds carrying the genes for 30 feathering are completely covered by feathers. The primaries and secondaries of the wings are well-developed and rounded in shape and the tail feathers are well grown.

20 -- Early fast feathering. In this case the modifier of early feathering possibly has been responsible for retardation of complete wing feather development. The secondaries are pointed in shape and fewer in number. Furthermore the feathering on the sides of the body is incomplete.

1. -- Modified early, patchy feathering. No tail development is found in birds of this type. The wings have well-developed primaries, small retarded secondaries and are bare over the coverts. The back has a narrow band of feathers down the spine.

1-MT -- Number 1 with a tail of medium length.

2. -- Similar to Number 1, except that the wings are completely devoid of feathers over the coverts and the back is frequently bare. This is a common condition in Rhode
Island Reds.

Intermediate 1-2 -- Birds of this class are intermediate between 1 and 2. They generally have a very narrow ridge of feathers down the centre back.

Rate of Feathering

The percentage of birds showing 30 feathering in 1949 and 1950 was approximately the same. (see Fig. 4) and Fig.13) 79.5% of the stock showed 30 feathering in 1949, 81.9% in 1950. It was disappointing that no appreciable gain was made with this important characteristic. However, the high percentage achieved in 1949 made additional gains very difficult to obtain. Furthermore the classification of feathering was more stringent in 1950 since additional information (Hill, 1950) was utilized. It appears that the male used in pen 18 could not have been pure for 30 feathering because of the large percentage of his offspring in the lower classifications. The percentage of mixed feathering occurring in the other pens came only from certain females, indicating that the males were pure, the females not. These families would be discarded from further breeding work.

The weights at 10 weeks and the "meat type" or grade classifications are given in Fig. 14. The meat type categories are a convenient way of expressing body proportion and percentage of meat. An explanation of the terms used is provided below:

A - Birds falling into this category are comparatively
### Fig. 13

#### CLASSIFICATION OF FEATHERING

**1950 BARRED NEW HAMPSHIRE PROGENY**

<table>
<thead>
<tr>
<th>Pen No.</th>
<th>Number Hatched</th>
<th>Number Classified</th>
<th>30 feathering</th>
<th>20 feathering</th>
<th>1 M.T.</th>
<th>1</th>
<th>1-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>130</td>
<td>125</td>
<td>110</td>
<td>13</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>140</td>
<td>129</td>
<td>106</td>
<td>17</td>
<td>5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>131</td>
<td>126</td>
<td>84</td>
<td>21</td>
<td>17</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>24</td>
<td>121</td>
<td>102</td>
<td>97</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>43</td>
<td>26</td>
<td>19</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>565</strong></td>
<td><strong>508</strong></td>
<td><strong>416</strong></td>
<td><strong>59</strong></td>
<td><strong>25</strong></td>
<td>5</td>
<td>3</td>
</tr>
</tbody>
</table>

| %       | 81.9%          | 11.6%             | 4.9%          | .9%           | .6%    |   |     |
Fig. 14 - AVERAGE WEIGHT AT 10 WEEKS AND PERCENT A MEAT GRADE OF BARRED NEW HAMPSHIRE, RHODE ISLAND RED AND BARRED PLYMOUTH ROCK GROWING STOCK ON U.B.C. POULTRY FARM IN 1950.

<table>
<thead>
<tr>
<th>Hatch</th>
<th>Barred New Hampshire</th>
<th>New Hampshire</th>
<th>Rhode Island Red</th>
<th>Barred Plymouth Rock</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.0</td>
<td>1.9</td>
<td>1.7</td>
<td>1.9</td>
</tr>
<tr>
<td>2</td>
<td>1.9</td>
<td>1.9</td>
<td>1.6</td>
<td>1.7</td>
</tr>
<tr>
<td>3</td>
<td>2.1</td>
<td>2.0</td>
<td>1.7</td>
<td>1.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hatch</th>
<th>% A Meat Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>80.9%</td>
</tr>
<tr>
<td>2</td>
<td>78.3%</td>
</tr>
<tr>
<td>3</td>
<td>74.9%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hatch</th>
<th>Total Avg. Wt. at 10 Weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.0</td>
</tr>
<tr>
<td>2</td>
<td>1.93</td>
</tr>
<tr>
<td>3</td>
<td>1.66</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hatch</th>
<th>Total % A Meat Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>77.8%</td>
</tr>
<tr>
<td>2</td>
<td>66.7%</td>
</tr>
<tr>
<td>3</td>
<td>48.9%</td>
</tr>
</tbody>
</table>
broad-breasted, long-keeled with relatively short stout legs. They carry a high proportion of meat.

B -- Birds classified B, are of a more narrow breasted type, the keel is shorter and the bird as a whole does not carry so much meat. Broad-breasted birds with a slightly crooked keel bone may be classified as B.

C -- Birds that are very sharp in breast conformation or generally thin and out of condition. Birds with very badly malformed breasts will be classified as C.

For the sake of more exact information on superior 'meat-type', the additional classifications of A* and A- are generally used in making field notes. A* birds are superior A's, and A- birds tend to a slightly sharp breast. With maturity, these birds nearly always develop into good A's. Similar sub-sections are utilized for classifying B birds. In the chart presented, for the sake of convenience, the market grade data are presented as percentage of the birds falling into the A, or desired, classification.

Meat characteristics:

Body size and rate of growth of the Barred New Hampshires was increased slightly in 1950. In 1949 the males and females averaged 2.54 lbs. at 12 weeks, as compared with figures of 2.66 for the New Hampshires, 2.34 for the Rhode Island Reds and 2.51 for the Barred Plymouth Rocks. See Fig. 5. While these weights do not compare favourably
with those generally achieved by pure broiler producers, they serve to indicate the Barred New Hampshires' rank as a meat breed. Weights and growth rates of all poultry stock on the U.B.C. farm tend to fall slightly below normal for the strains, because of the crowded conditions necessitated by the volume and variety of stock. Furthermore the ration fed is a commercial growing ration, and not a highly concentrated broiler ration fed for forcing purposes. It would be highly undesirable, for example, to force young pullets on a highly concentrated ration. The percentage of birds falling into A meat grade class are also shown in Fig. 5. The Barred New Hampshires were significantly above all other breeds in this characteristic.

Increasing the percent of New Hampshire blood, selecting for broad-breastedness, and early maturity paid off in 1950 (Fig 14) the Barred New Hampshire young stock were the heaviest of all breeds on the farm and had the largest proportion of birds graded A meat type. Again the weights in all breeds are below normal due partly to a slight set-back from coccidiosis and partly to overcrowding.

4. Freedom from defects:

The 1950 Barred New Hampshire progeny were almost completely free from defects, such as crooked breasts and breast blisters. Only nine birds were recorded out of all handled (508) as having any degree of crooked breast. No breast blisters have been reported to date (July, 1950).
5. Egg Production

Egg production in the Barred New Hampshire R.O.P. entry increased from the 1949 average of 196.6 eggs to 209.1 in 1950. That this increase was partly environmental is illustrated in Fig. 15, which shows an increase in average egg production of the Barred New Hampshires and two other U.B.C. R.O.P. breeds in 1949 and 1950. These three breeds were all trapnested, housed and maintained under identical conditions. The records of the latter two breeds are presented for comparative purposes, since it was desirable to discover how the Barred New Hampshire ranks in competition with other commercial breeds. In studying these records, it is important to note that all the birds were used for class demonstration purposes, constantly being disturbed and handled. Such treatment was bound to interfere to some degree with their general health and productivity. Moreover, the variety of breeds and large numbers maintained on the U.B.C. poultry plant complicates feeding and management to some degree. Consequently, these records are not likely to indicate the true genetic worth of the strains in question.

The first records extend over a 365 day period, beginning in October, 1948 and ending in September, 1949. The second year's records are 365 day estimates based on the period extending from October 1949 to June 1, 1950. A conversion factor of 1.6 was used to bring the production in this 228 day period to the annual figure. It has been
Fig. 15 -- I. AVERAGE ANNUAL EGG PRODUCTION AND MORTALITY IN THREE U.B.C. BREEDS DURING 1949 AND 1950.
II. INTENSITY OF LAY DURING 1950.

<table>
<thead>
<tr>
<th>BREED</th>
<th>1948-1949</th>
<th>1949-1950</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AVERAGE EGG PRODUCTION</td>
<td>MORTALITY</td>
</tr>
<tr>
<td>Barred New Hampshire</td>
<td>196.6</td>
<td>14.3%</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>202.2</td>
<td>10.5%</td>
</tr>
<tr>
<td>Rhode Island Red</td>
<td>187.9</td>
<td>11.6%</td>
</tr>
</tbody>
</table>

*The 1949 figures are converted from the R.O.P. 305 averages to 365 estimates; the 1950 figures are converted from 228 averages to 365 estimates.*
demonstrated that partial records, particularly those extending over the winter period, are statistically accurate. Lerner (1947) showed that the most efficient index for selection places 1.66 more emphasis on production before January than on production after January.

6. Intensity of Lay

The intensity of lay was computed for each of the three breeds. The rate of lay in each case, as presented in Fig. 15 is the total number of eggs from first egg to June first, expressed as a percentage of the number of days involved -- with all pauses excluded. The Barred New Hampshires exhibited a higher intensity than the other breeds even though their total production did not equal that of the New Hampshires. This was due to the higher percentage of broodiness in the Barred New Hampshires.

7. Mortality

Laying house mortality in the three U.B.C. breeds for 1949 and 1950 is presented in Fig. 15. A conversion factor of 1.25 was used to bring the percent mortality in 1950 to a 365 day basis. This factor was devised from an examination of all laying house mortality records on the U.B.C. poultry farm during the year 1949-1950.

8. Egg Weight

Egg weight in the Barred New Hampshire has been satisfactory since their initiation. Attention has been given to this factor in each year's breeding program. The
average egg weight in 1950 to date is 26.4 ozs. per dozen. This figure is well above that necessary for the Grade A classification.

9. Broodiness

As expected on the basis of the cross-breeding involved, the Barred New Hampshires have shown a higher incidence of broodiness than any of the other U.B.C. breeds. Broodiness was a particularly serious problem in the 1949 R.O.P. entry, 50% of the birds showing one or more periods of broodiness. (see Fig. 16). This record compared unfavorably with U.B.C. strains of the other breeds, since 19% of the New Hampshires were broody, 15.5% of the Rhode Island Reds and 19% of the Barred Plymouth Rocks.

In 1950, it was found that the incidence of broodiness had been reduced to some extent. Fig. 17 compares the total percentage of broodiness in 1949 and 1950 in the new breed. Furthermore it became apparent when the records of the two lines of Barred New Hampshires were studied that the line carrying the highest percentage of New Hampshire "blood" showed less broodiness than the 50% line (see Fig. 9). This was considered to be due to segregation of the complementary factors governing broodiness. It is obvious that considerable selection against the broody tendency must be done in the future, and that the practice of backcrossing to New Hampshire stock can be a considerable help in curtailing this characteristic. That the high
Fig. 16—Illustrating the Relative Percentage of Broodiness found in four U.B.C. R.O.P. breeds. The percent of Broodiness is subdivided into the two classes: 1-2 broody periods, and three or more broody periods.
Fig. 17 - REDUCTION IN PERCENT OF BROODINESS IN R.O.P. BARRED NEW HAMPSHIRE PULLET FROM 1949 TO 1950
incidence of broodiness found in the Barred New Hampshire stock did not seriously impair total production is illustrated by Fig. 18 which compares the total percent broodiness and total survivor production in three U.B.C. breeds.

The figures for broodiness in 1950 are computed on a seven month basis and converted to an annual figure by use of a conversion factor of 1.4. This factor was devised from a study of the records of broodiness in all breeds at U.B.C. The study indicated that 60% of the annual broodiness occurs during the first seven months of production.
Fig. 18 -- ANNUAL EGG PRODUCTION COMPARED WITH AVERAGE PERCENT ANNUAL BROODINESS IN THREE U.B.C. R.O.P. BREEDS (1949-50)

TOTAL PERCENT BROODINESS

- Rhode Island Reds
- New Hampshires
- Hampbars (Barred New Hampshire)
A project in poultry breeding was undertaken to develop an autosexing breed of poultry that was suitable for both meat and egg production. A strain of New Hampshire that had been bred, selected and tested for production was used as foundation stock. This breed had proved to be superior to the Barred Plymouth Rocks and Rhode Island Reds in the production of meat and eggs at U.B.C. To adapt the New Hampshire breed for autosexing, the barring factor was introduced from the Redbar, previously developed at The University of British Columbia.

In the earliest stages of development, Barred New Hampshire chicks were sexed by using the autosexing key developed by Hill and Lloyd for the Redbar breed. Because of differences in the male and female down patterns of the Redbar and the Barred New Hampshire chicks, a new key for autosexing Barred New Hampshire chicks was devised. According to this key, as presented, there are three major types of female down patterns and four types of male down patterns.

**BARRED NEW HAMPSHIRE AUTOSEXING KEY**

**A. Female Down Patterns:**

1. Wide dark brown or black head, back, and hip striping on a medium uniform brown base color. (see Plate IVB). This pattern generally also includes a dark pencil mark extending from the eye (see Plate VIIIB).
A. Female Down Patterns - Cont.

2. Medium to light uniform brown all over body. No spotting or striping. (see Plate IVA).

3. Narrow black or brown head stripe on light uniform brown base color. (see Plate IVC). This pattern may include narrow black or brown median back stripe.

B. Male Down Patterns:

1. Uniform whitish-silver down (see Plate VC).

2. Silver or white head and white hip stripes on medium brown base color. (see Plate VA).

3. Silver head with broken black or dark brown head stripe, medium to dark brown body with light buff hip striping. (see Plate VB).

4. Wide, black head, hip, and back stripes on silvery white base color. The silver hip striping is very distinct. (see Plate VIB).

By the use of this key a high degree of accuracy was obtained in sexing progeny of the pens in which both the males and female chicks were 'pure' for the barring factor. From other matings in which progeny varied as to their genotype for barring, a lower degree of accuracy was obtained. Although distinctive color differences exist between certain extreme types of male and female chicks, the variety of intermediate types produced made sexing difficult. For this reason, a study of family differences
in pattern was made and only the most 'sexable' families included in subsequent breeding plans. The down color of males at the day old stage was found to depend on the homozygous or heterozygous state of genes responsible for barring and striping. Homozygous male chicks were generally very light, with pronounced whitish hip stripes, whereas the heterozygous males from the same families were darker in body down color with dark striping superimposed on a silver head.

The first cross to develop the Barred New Hampshire breed was made in 1947, when a pen of New Hampshire females were mated to a Redbar male. Subsequent breeding procedure included 'inter-se' matings of half-siblings and back crosses to unrelated New Hampshire stock. Genetic diagrams of all matings used in the development of the Barred New Hampshires are presented below.

<table>
<thead>
<tr>
<th>Year</th>
<th>Pen No.</th>
<th>Parents</th>
<th>Progeny</th>
</tr>
</thead>
<tbody>
<tr>
<td>1947</td>
<td>6</td>
<td>BB x b-</td>
<td>Bb, B-</td>
</tr>
<tr>
<td>1948</td>
<td>23</td>
<td>Bb x B-</td>
<td>BB, Bb, B-, b-</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>BB x b-</td>
<td>Bb, B-</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>bb x B-</td>
<td>Bb, b-</td>
</tr>
<tr>
<td>1949</td>
<td>7</td>
<td>bb x B-</td>
<td>Bb, b-</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>Bb x B-</td>
<td>BB, Bb, B-, b</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>BB x B-</td>
<td>BB, B- 1st gen. 'pure' barred progeny</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>BB x b-</td>
<td>Bb, B-</td>
</tr>
</tbody>
</table>
Two distinct lines of Barred New Hampshires were developed, one bred by the Punnett and Pease method of maintaining 50% relationship to each of the parent breeds and the other by the Hagedoorn method of continually backcrossing to the superior parent breed to establish close relationship. In 1950 when these two lines were compared with regard to the more important economic characteristics, the latter line was found to be uniformly superior.

In addition to selection for down color differences between the sexes, during the first two years of development, attention was given to such economic qualities as egg production, 'meat-type', rate of feathering, and viability. Following the satisfactory results obtained by the use of the autosexing key on the pure barred progeny of 1949, attention was focused on the improvement of economic qualities. A selection level was contrived from information available on the inheritance of factors associated with meat and egg production. This standard included an arbitrary selection level for female breeding stock and in addition a

<table>
<thead>
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<th>Year</th>
<th>Pen No.</th>
<th>Parents</th>
<th>Progeny</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950</td>
<td>6</td>
<td>BB x B-</td>
<td>BB, B- 2nd gen. 'pure' barred progeny.</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>Bb x b-</td>
<td>Bb, bb, B-, b-</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>BB x b-</td>
<td>Bb, B-</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>Bb x B-</td>
<td>BB, Bb, B-, b-</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>Bb x B-</td>
<td>BB, Bb, B-, b-</td>
</tr>
</tbody>
</table>
selection index for males as follows:

\[ s = 156.5 E + 160 M + 38.8 V + 48 H + 113 W \]

In the third year of the development of the Barred New Hampshire, they excelled the basic New Hampshire breed in 'meat-type' and persistency of egg production, were approximately equal in total egg production, egg weight, rate of growth and viability, but showed a higher incidence of broodiness. This later was to be expected on the basis of the crossbreeding involved, and is subject to further selection. Fertility, hatchability and rate of feathering were satisfactory in the Barred New Hampshires. Further breeding will be required for purification and improvement of the breed.
APPENDIX A

PLATE I  - HOMOZYGOUS BARRED NEW HAMPSHIRE MALE

Wide white barring, due to "double dose" of barring gene, on deep reddish bronze background. This male weighs 9.17 lbs. and his broad breast, long keel and well fleshed sides and back make him an admirable table bird.

PLATE II  - HETEROZYGOUS BARRED NEW HAMPSHIRE MALE

The fine-ringlet barring, typical of the heterozygous male, is clearly shown here. The bird is a deep red-bronze color with narrow white bars superimposed. This male weighs 9.25 lbs. Note extremely broad breast and back, typical of this new breed and indicative of fine market quality.

PLATE III  - HEMIZYGOUS BARRED NEW HAMPSHIRE FEMALE

White barring is superimposed on the basic buff color. The dark flecks on the neck feathers as well as the black-tipped tail feathers, reflect her New Hampshire ancestry. The shape also is typical of the New Hampshire female. This hen laid 231 eggs, averaging 26.6 ounces per dozen during her first year in the laying house.
PLATE IV - THE THREE TYPES OF BARRED NEW HAMPSHIRE FEMALE CHICK DOWN PATTERNS

A. Medium to light uniform brown down. No spotting or striping.

B. Wide dark brown or black head, back and hip striping on a medium uniform brown base color. This pattern generally also includes a dark pencil mark extending from the eye. Female downs of this type give 100% sexing accuracy.

C. Narrow black or brown head stripe on light uniform brown base color. This pattern may include a narrow black or brown back stripe. Females of this type are often difficult to distinguish from males of Plate IV B.

PLATE V - BARRED NEW HAMPSHIRE MALE CHICK DOWN PATTERNS

A. Silver or white head and white hip stripes on medium brown base color. This type of male is easily sexed.

B. Silver head with broken-black or dark brown head stripe, medium to dark brown body with light buff hip striping. Easily confused with females of Plate IV C.

C. Uniform whitish-silver down. Easily sexed.

PLATE VI - BARRED NEW HAMPSHIRE MALE CHICK DOWN PATTERNS

Three barred New Hampshire male chicks. Types A and C are similar to Plate V, A and C.

B. Wide black head, hip and back stripes on silvery white base color. The silver hip striping is very
PLATE VI - Cont.

distinct. This type of male is heterozygous for the barring gene and came from a family carrying a large amount of dark pigment. The homozygous male from this mating is seen in Plate V, B.

PLATE VII - BARRED NEW HAMPSHIRE MALE AND FEMALE CHICKS

The optimum dichromatism is seen in this picture. Males and females of these types give 100% sexing accuracy.

A. The male.

B. The female.
B STANDARD FOR BARRED NEW HAMPISHRES

ECONOMIC QUALITIES: General purpose fowl for egg and meat production. Color of skin, yellow; color of egg shell, brown.

Disqualifications
One or more entirely white feathers showing in outer plumage. (See General Disqualifications and Cutting for Defects.)

STANDARD WEIGHTS

Cock ............ 9 lbs.  Hen ............ 6\(\frac{1}{2}\) lbs.
Cockerel ...... 8 lbs.  Pullet ........ 5\(\frac{1}{2}\) lbs.

SHAPE OF MALE

COMB: Single, medium size, well developed, set firmly on head, perfectly straight and upright having five well-defined points, those in front and rear smaller than those in center; blade smooth, inclining slightly downward, but not following too closely the shape of the neck.

BEAK: Strong, medium in length, regularly curved.

HEAD: Medium in length, fairly deep; inclined to be flat on top rather than round. Face smooth, full in front of eyes, skin fine in texture.

EYES: Large, full, prominent, set high in head.

WATTLES: Moderately large, uniform, free from folds or wrinkles.

EAR LOBES: Elongated-oval, smooth, setting close to head.

NECK: Medium length, well-arched, hackle abundant flowing well over shoulders, fairly close feathered.

\* American Standard of Perfection
WINGS: Fairly large, well-folded, carried horizontally and close to body, wing fronts covered by breast feathers; primaries and secondaries broad and overlapping in natural order when wing is folded.

BACK: Long, very broad its entire length, forming a gradual concave sweep to tail.

TAIL: Medium length, well spread; carried at an angle of 45° above horizontal. Sickles, medium length, extending well beyond main tail; lesser sickles and coverts, medium length, broad; main tail feathers broad and overlapping.

BREAST: Very deep and full; proportionately very broad and well rounded.

BODY AND FLUFF: Body, medium length, very broad, deep, well rounded, keel, long, extending well to front at breast. Fluff, full.

LEGS AND TOES: Legs set wide apart, straight when viewed from front; lower thighs, plump and muscular, of medium length; toes of medium length, straight, well spread.

PLUMAGE: Feather character of broad, firm structure, overlapping well and fitting tight to body.

SHAPE OF FEMALE

COMB: Single small to medium in size, well developed smooth texture, firm at base having five well defined points, those in front and rear smaller than those in center.

BEAK: Medium length, regularly curved.

HEAD: Medium length, fairly deep, flat on top; face, smooth,
HEAD - Cont.
full in front of eyes; skin, fine in texture.
EYES: Large, full, prominent, set well up in head.
WATTLES: Medium size, well developed, well rounded.
EAR LOBES: Elongated-oval, smooth, setting close to head.
NECK: Medium length, arched, tapering from shoulders to
head, close feathered.
WINGS: Large, well folded; carried nearly horizontal;
fronts covered by breast feathers; primaries and secondaries
broad and overlapping, in natural order when wing is folded.
BACK: Long, very broad its entire length, forming a
gradual concave sweep to tail.
TAIL: Medium length, moderately well spread, carried at an
angle of 40° above horizontal. Main tail feathers broad
and overlapping.
BREAST: Very deep and full, well rounded.
BODY AND FLUFF: Body, long, very broad and deep, well
rounded; keel, fairly long extending well to front at
breast. Fluff, full.
LEGS AND TOES: Legs set wide apart, straight when viewed
from front; lower thighs, medium length, closely feathered,
smooth; shanks, medium length, smooth; toes, medium length,
straight, well spread.
PLUMAGE: Feather character of broad, firm structure, over-
lapping well and fitting close to body.
COLOR OF MALE

COMB, FACE, WATTLES AND EAR-LOBES: Bright red.

BEAK: Reddish horn.

HEAD: Plumage, brilliant reddish-bay, each feather crossed by regular, white bars; the white and red bars to be of approximately equal width, in number proportionate to the length and width of the feathers, and to extent throughout the length of the feathers in all sections of the fowl except in the wings and tail where black feathers are permitted. The main tail feathers, black, sickle feathers, rich, lustrous greenish black; coverts, lustrous greenish black edged with deep chesnut red.

EYES: Bay.

LEGGS AND TOES: Lower thighs, medium chesnut red, shanks and toes, rich yellow tinged with reddish horn. Slate color in legs is not a disqualification.

Undercolor of plumage in all sections, very light salmon or white. Smokiness, however, is not a defect.

COLOR OF FEMALE

COMB, FACE, WATTLES AND EAR-LOBES: Bright red.

BEAK: Reddish horn.

EYES: Bay.

PLUMAGE: Reddish Buff, each feather crossed by regular, white bars; the white bar being approximately one half the width of the dark bar, the bars in all sections of the fowl shall be in numbers proportionate to the length and breadth
PLUMAGE: - Cont.

of the feathers; lower neck feathers distinctly tipped with black. Main tail black edged, primary coverts of wing black edged with medium red.

LEGS AND TOES: Lower thighs, light chestnut, shanks and toes, rich yellow tinged with reddish horn. Slate not to be considered a disqualification.

Undercolor of plumage in all sections very light salmon or white. Smokiness, however, is not a defect.
FEMALES

1. **Head** -- uniform, unbroken and light, medium or medium to dark brown color with one of the following:
   (a) **Back** -- uniform and light, medium or medium to dark brown color -- 7 percent.
   (b) **Back** -- broad, central and medium to dark brown back stripe with or without two narrower parallel hip stripes and sometimes black margins -- 2 percent.

2. **Head** -- faint to distinct and light, medium or dark brown stripe passing over the crown of the head of the chick and down the top of the neck with one of the following:
   (a) **Back** -- uniform and light, medium or medium to dark brown color -- 26 percent.
   (b) **Back** -- broad central and medium to dark brown back stripe with or without two narrower parallel hip stripes and sometimes black margins -- 16 percent.

MALES

3. **Head and Back** -- generally lighter down color, the darkest showing light to medium brown with one or more of the following characteristics:
MALES - Cont.

(a) **Head** -- white spot -- 12 percent

(b) **Head** -- mottled -- 4 percent

(c) **Back** -- mottled -- 6 percent

(d) **Back** -- two silvery white stripes -- 16 percent.

4. **Head** -- markings faint to distinct, diffused and light to medium brown stripe (linear T or I shaped) broken off on the crown and often in the form of a horseshoe -- down color comparatively uniform and light or light to medium or mottled.

(a) **Back** -- mottled down -- 3 percent

(b) **Back** -- two silvery white stripes -- 2 percent

(c) **Back** -- comparatively uniform and light or light to medium brown down color -- 2 percent.

5. **Head and Back** -- very light color with no clear markings -- 6 percent.
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