Breeding Problems With Sheep

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It is probable that sheep have been kept by man longer than any other class of domestic livestock. During this long period of domestication, certain breeds with outstanding characters have been developed. The best of them serve their purpose very well. From the practical standpoint there would seem to be less pressure for improvement in the case of sheep than in the case of other classes of livestock. Yet the sheepman would like to produce wool of a given character and quality with greater certainty; he would like to combine this with assured production of good-quality meat; he would like to be sure of getting high-milking ewes for the sake of a good lamb crop; and he is faced with the usual problems of diseases and weaknesses common to other livestock, plus some that are peculiar to his own field. He must consider also, especially, the matter of environment. From hot-house lamb production to the utilization of rugged ranges and of browse and forage unpalatable to most other classes of livestock, the sheep is called upon for a great variety of service to man.

The scientific worker, however, finds himself faced with a very great deficiency in genetic knowledge of practically all the economically important traits in sheep, including wool characters, meat characters, and milk characters. Also many of the available methods for measuring variations in the character and quality of sheep products are either inaccurate or inadequate to detect essential details. These two factors are responsible, to a large extent, for the lack of detailed records among existing flocks. The diversity of ideals peculiar to the American sheep industry—an outgrowth of variable market demands—adds to his difficulties. Under these circumstances, progress will naturally be slow. At the same time, the situation is a challenge both to the scientist and to the forward-looking elements in the industry. Some of the factors in the situation are discussed in this article.
Survey Shows That Most Research Is Concerned with Feeding and Management Problems

In connection with the cooperative survey of plant and animal improvement, questionnaires asking for information on sheep improvement were sent to the agricultural experiment stations in each of the 48 States. These questionnaires were composed of: (1) An introduction explaining the purpose of the survey and asking for information on the system of breeding, nature of active projects, kinds of data being recorded, and a list of breeders whose flocks have a reputation for purity of breeding; (2) a sheep sire card for wool on which space was reserved for data on year of birth, animal number, dam number, sex, birth and yearling weights, body type, and yearling fleece data, including number of days of growth, grease weight, clean weight, percentage of grease, length of staple, and fineness; (3) a sire card for mutton giving space for data on year, number, sex, parentage, birth and weaning weights, age weaned, live-animal score, carcass grade, and age slaughtered; and (4) a supplementary card for data on ration, pastures, health notes, and description of experimental methods.

These questionnaires were filled out in part and returned by 24 States. The remaining States either did not reply or returned the blanks with a note that no breeding experiments were being conducted with sheep.

Fifteen breeds were named in the reports for this survey, the more frequent being Rambouillet, Hampshire, Shropshire, and Southdown. Others were Dorset, Oxford, Cheviot, Suffolk, Corrie-dale, Romney, Ryceland, Australian Merino, Tasmanian Merino, Karakul, and the new tailless breed at South Dakota. Where station and college flocks are not separate, it is customary to keep three to five breeds, but where the station has a separate flock it is often of only one breed and rarely more than two. Often the sheep of the station flock are unregistered or of grade breeding.

The amount and nature of the data submitted varied considerably, as can be seen from an examination of table 1.

Table 1.—Type of data being recorded at the 24 State experiment stations replying to the questionnaire on improvement in sheep

<table>
<thead>
<tr>
<th>Kind of data</th>
<th>States recording</th>
<th>Kind of data</th>
<th>States recording</th>
<th>Kind of data</th>
<th>States recording</th>
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</thead>
<tbody>
<tr>
<td>Twinning</td>
<td>16</td>
<td>Fleece weight</td>
<td>19</td>
<td>Face covering</td>
<td>3</td>
</tr>
<tr>
<td>Vigor at birth</td>
<td>9</td>
<td>Weight of clean wool</td>
<td>5</td>
<td>Type</td>
<td>2</td>
</tr>
<tr>
<td>Weight at birth</td>
<td>14</td>
<td>Length staple</td>
<td>8</td>
<td>Abnormalities</td>
<td>7</td>
</tr>
<tr>
<td>Age when weaned</td>
<td>10</td>
<td>Fineness</td>
<td>7</td>
<td>Progeny test</td>
<td>3</td>
</tr>
<tr>
<td>Weaning weight</td>
<td>8</td>
<td>Uniformity of fleece</td>
<td>8</td>
<td>Inbreeding</td>
<td>3</td>
</tr>
<tr>
<td>Conformation</td>
<td>2</td>
<td>Kemp fibers</td>
<td>6</td>
<td>Line-breeding</td>
<td>5</td>
</tr>
<tr>
<td>Live-animal grade</td>
<td>1</td>
<td>Color of wool</td>
<td>2</td>
<td>Cross-breeding</td>
<td>2</td>
</tr>
<tr>
<td>Carcass grade</td>
<td>0</td>
<td>Horn character</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Grease weight of fleece, notes on number of young per ewe, and birth weight are the items most commonly recorded by the States that sent in reports. Only about one-third of these States regularly record anything on vigor of lamb at birth and weaning age and weight, or on length of staple, fineness of fiber, and uniformity of fleece. Weight of clean wool per fleece is obtained at five stations. Very little attention is being given to recording conformation, live-animal grade, carcass grade, color, type, face covering, and horns. The occurrence of abnormalities is being recorded at seven stations and the presence of kemp fibers in the fleece at six.

In the main, this survey of experiment station practice may be summarized as having the following features:

1. Most of the research has been directed toward problems in feeding and management, little of it having concerned breeding, except for cross-breeding and the genetics of special traits.

2. The breeding practices followed have generally been much the same as those used by currently successful sheepmen.

3. There is much variation in the characteristics measured and in the ways of measuring and recording them.

LITTLE USE MADE OF LINE-BREEDING OR INBREEDING

The system of breeding used with college and experiment station flocks varies considerably, but only a few institutions use a definite system of line-breeding or inbreeding. Three stations report the use of inbreeding, five report a more or less definite line-breeding policy, and two report studies in cross-breeding. The remaining stations use a more or less changeable system, which may include inbreeding, line-breeding, and outcrossing over a period of years.

Seven stations definitely mention the use of selective breeding in their flocks, but it is not apparent from the reports whether this selective breeding may at times include some close matings. A very common system is to choose as good individuals as possible for rams, with some attention to the excellence of the ram's sire and dam or other close relatives. At most stations it is required that the rams be unrelated to the flock in which they are to be used.

A few stations consistently purchase rams from one flock or one family. This involves some line-breeding but rarely very much. A very few deliberately practice line-breeding to certain outstanding individual rams. This does not often go close enough to produce lambs with an inbreeding coefficient much above 16 percent. A very few others stated that when they have a ram with unusually good progeny, they do not hesitate to inbreed closely to him, using him on his daughters, sisters, and dam if these are still in the flock. Presumably such close inbreeding is not continued with the next ram unless it, too, proves to be unusually good. Hence such a breeding policy might be characterized as outbreeding with occasional spurts of close inbreeding.

Only three stations reported the use of the progeny test as a part of their program. This fact seems at first sight to indicate that there is a widespread opportunity for sheep improvement through application of the progeny test, combined with selection and breeding for the fixation of the various characters. Nearly all college and most station flocks are too small, however, to permit the simultaneous progeny testing of several rams. There are exceptions, notably the
flocks at the United States Sheep Experiment Station, Dubois, Idaho, the Texas Station Rambouillet flock, and the Montana Station flock, which are large enough for progeny testing. The Massachusetts Station reports a definite project on ways to use the progeny test. This project is being conducted in cooperation with the Bureau of Animal Industry, United States Department of Agriculture.

The most significant fact coming out of the survey is the widespread lack of data submitted on more than a single generation of breeding. Under such circumstances it is not only impossible to make anything approaching a satisfactory genetic analysis to determine the extent of progress toward purity of germ plasm for

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given character and quality with greater cer-
tainty; he would like to combine this with assured
production of high-quality meat; he would like to be
sure of getting high-milking ewes for the sake of a
good lamb crop; and he has to meet all the usual
problems of diseases and weaknesses. The scientific
worker finds himself faced with a great deficiency in
knowledge of the way these important characters are
inherited. They have not been studied partly because
so much of the experimental work has been done by
practical breeders who could not afford to risk unfa-
vorable results and who were hampered by breed
traditions and the pressure of their associates. The
scientist should not be confined by the same restric-
tions, and in a forward-looking program he would be
free to make his analysis of inheritance as the first
step to building up a combination or synthesis of
economically desirable traits.

certain characters, but also it is difficult to form an opinion on the
amount of effort the experimenters are making in this direction. It
seems probable that some stations have on hand much more pertinent
data than their reports indicate. Lack of time, shortage of assistance,
and the unusual nature of the request may have prevented the making
of full reports.

A more nearly adequate analysis of the situation at some future
time may reveal that more progress has been made toward purity of
germ plasm than this chapter indicates. As is shown in figure 1, many
elements of individuality affecting both the judge and the sheep
enter into the show record which is so widely used as a basis for selec-
tions. But the show-ring system is a purely arbitrary one. The
judge frequently must make many compromises in his own mind and
there is nothing left to posterity by which future breeders may know what combination of traits made the winner. This obstacle must be removed before the science of genetics can play any significant role in the further improvement of sheep. In fairness to both the show-ring system and the geneticist who finds the show record inadequate, it must be admitted that some of these traits may never be reducible to mathematical expression.

The sheep-breeding projects now being carried on at the various agricultural experiment stations are shown in the following tabulation:

**Sheep-breeding and some related projects at the agricultural experiment stations and the United States Department of Agriculture**

- **Florida**: Columbia sheep performance investigations.
- **Georgia**: Sheep breeding for Georgia conditions.
- **Idaho**: Black spotting in Rambouillets; turned-in eyelids (entropion) in lambs—a study of the inheritance; overshot jaw (prognathism) and undershot jaw (brachygnathism) in sheep—an inheritance study.
- **Kentucky**: The introduction of purebred sheep; to establish a flock of purebred sheep consisting of four breeds—Cheviot, Hampshire, Shropshire, and Southdown.
- **Maryland**: Breeding of new flocks suitable for early-lamb production.
- **Massachusetts**: Cooperative sheep project with the Bureau of Animal Industry—a record-of-performance study; physiology of reproduction—incidental studies of the scrotal reactions to temperature relative to the testes and anterior pituitary hormones.
- **Michigan**: The improvement of wool production in Rambouillet and other breeds of sheep.
- **Minnesota**: A study of the embryological development of the sheep.
- **Mississippi**: A study of the inheritance of the factor for time of weaning with sheep; a study to determine the relative value of Corriedale, Hampshire, and Southdown breeding in the sheep-production program of Mississippi.
Montana: Inheritance of size, form, and productive capacity of range ewes; heredity as a factor in the determination of twinning in Rambouillet sheep.

Nebraska: Sheep breeding.

Nevada: Methods of producing more and better lambs in Nevada range flocks.

New Hampshire: Fertility and milk production of sheep.

North Carolina: A study of the changes in meat and wool characteristics resulting from the use of purebred rams on native ewes.

North Dakota: A study of the inheritability of wool by market grades; a study of ewe-lamb breeding.

Ohio: Straight breeding versus cross-breeding of Merino ewes.

Oklahoma: Effect of nutrition on the physiology of reproduction of sheep; correlation studies of wool and the behavior of various factors in inheritance.

Pennsylvania: Hot-house lamb production.

South Carolina: A genetic study of the inheritance of the early-lambing character.

South Dakota: Breeding of Karakul sheep; crosses with other breeds to develop quality of Karakul lamb fur; tailless sheep; combining the unit characters of the fat-rumped Siberian sheep, which is tailless, with those of the Rambouillet.

Texas: Inheritance of the polled characters in fine-wool sheep; cytological and hybridization studies with sheep and goats; a study of the inheritance of skin folds on Rambouillet sheep.

West Virginia: Breed as a factor in sheep production and quality of products produced.

Wyoming: Breed studies with Hampshire sheep; breeding western ewes for wool and lamb production; Australian Merino wool—(1) the effect of Wyoming climate on the wool of Australian Merino rams, (2) the prepotency of Australian Merino wool in crosses of Australian Merino rams on Rambouillet ewes.

**Sheep-breeding projects of the Bureau of Animal Industry, United States Department of Agriculture**

Sheep-breeding investigations of performance in lamb and wool production with Merinos, Rambouillets, Corriedales, and Columbias on the range, and with Hampshires, Shropshires, Southdowns, Corriedales, and Dorsets under farm conditions.

Sheep-breeding investigations of performance in fur production with Karakuls.

The development of breeds and strains of sheep suitable to southwestern ranges and to the economic requirements of sheepmen.

**Breeding projects in which sheep take a prominent part**

California (Davis): Vitamin A in relation to reproduction in sheep.

Iowa: The comparative amount and kind of inbreeding and other breeding practices which have been used in producing the pure breeds of livestock and uses of these findings in further improvement of breeding stock.

Missouri: Physiology of reproduction in farm animals.

**TEN YEARS’ RECORDS IN TEXAS**

The Texas Agricultural Experiment Station returned more data than any other in the United States. It is apparent that during the last 10 years very complete data on weights, type, and wool characters have been systematically recorded in such a manner that daughter-dam comparisons for the offspring of different sires are easily made in the Texas Station’s Rambouillet flock. Data on wool characters were reported for both ram and ewe offspring sired by six different rams used in the flock since 1924. In one case records on 63 daughters by one ram were available, although only 15 were from dams having yearling records on clean wool, shrinkage, and staple length, and 22 from dams having a record on fineness of fiber.

Two of the six rams were outstanding in that they sired daughters averaging longer staple, heavier clean-wool fleeces, and lighter shrinking fleeces of finer wool than their dams. One of these rams was bred by the experiment station and the other was purchased as a lamb from a leading Rambouillet breeder. Since the period of their use—
1922–27 and 1924–27—the endeavor to locate superior sires has been continued. During the past several years increased attention has been given to the discovery of such valuable sires within the station flock. This is a desirable procedure, because when one is located there will be available a set of records that may make the identification or development of the next one an easier task.

The Texas Station also reports an interesting case of inheritance of the polled character in Rambouillet sheep. Eight rams of polled breeding have been tested and two have been found to be homozygous for the polled character.

RECORDS OF PRIVATE BREEDERS

The incompleteness of the data received from most of the experiment stations made it impractical to go ahead with the original plan of sending similar questionnaires to those private breeders reported by State workers as having flocks wherein superior germ plasm may exist. The request for names brought in a total of only 54, representing all breeds of sheep. Many of the State workers explained, however, that there might be other flocks in the State just as valuable but unknown to them. There was a distinct hesitancy to discriminate by naming only the flocks they happened to know. This situation is due largely to the fact that no method has ever been set up in any State for measuring merit in all flocks of sheep. The nearest approach to anything of the kind is the few attempts by breeders to record the weight and grade of fleece produced by their best sheep, not by the flock as a whole.

At the present time there is an exceedingly wide gap between the system of records actually kept by breeders and the system that would be required to prove progress and indicate the existence of superior germ plasm for the various characters in sheep. There cannot be any real genetic evaluation of the flocks reputed to be superior until this gap has been at least partly bridged. To what extent this can be done remains to be seen, but it is a complex problem for the experimenter, the breed associations, and the breeders to solve.

TWO KINDS OF SUPERIORITY

Probably in no class of domestic livestock are there so many variations of economic importance as there are in sheep. Not only are there two main groups represented by the mutton and wool breeds, respectively, but among the wool breeds there is a great variety of characters, each of which plays an economically significant role. In the composite of all these characters there are some antagonisms, and seldom or never would the extreme expression of all characters be seen in one individual. For instance, the long fiber of the Lincoln, the fineness and crimp of fiber of the Merino, the skin folds of the Rambouillet, and the extreme mutton conformation of the Southdown do not occur together.

In addition to the wool and conformation characters of the two contrasting types of sheep, the wool and the mutton types, a third group of inherent factors affecting the production of milk and butter-fat are important constituents of superior germ plasm. This group of factors has received almost no attention from the geneticist, but indirectly it probably receives considerable attention from sheep breeders. Success in raising superior lambs is so dependent on the milk production of the ewe that any consideration of superior inheri-
Hampshire ewe no. 56319, on the left, and five successive generations of her female descendants. They were 13, 11, 9, 6, 3 years and 1 year old, respectively, on the day these individual pictures were taken at Beltsville, Md. During her lifetime, in 11 lambings this ewe produced 15 lambs and raised 13 of them.

The need for more knowledge of inheritance in sheep

Sheep breeding has always been an important part of animal husbandry but has not yet been practiced to any significant extent as a means of determining the exact hereditary constitution of the species. Although considerable experimental breeding work has been done and many observations having some genetic significance have been made, in only a relatively few cases do these studies concern the characters of economic importance in sheep. Furthermore, so many uncontrolled factors frequently affect the expression of the characters that exact interpretation of their genetic basis is impossible or at best can be made in general terms only.

The various breeds of sheep have been developed by practical breeders to meet their varied needs, and there is so much variation in these breeds that it is easily possible to change the characteristics of a given strain by selection alone. This situation is not an obstacle to further research because the breeder or producer is not the one who is going to do the genetic research. Recognition of the fact that the breeder cannot afford to engage in scientific studies with the chance that some of the results will be unfavorable does not mean that the scientific investigator has to be limited in the same way. One trouble in the past has been that many of the experimenters were practical breeders, and were somewhat hampered by their own breed traditions and the pressure of their associates.
The line is noted for its hardihood and longevity. Considering that these ewes did not produce lambs before they were 2 years old and that the average usefulness of a Hampshire ewe is between three and four lambings, it is doubtful if such a record could often be achieved, if attempted.

It is clear that the breeder and the geneticist are concerned with the same problems, but they approach them in different ways. One wants to build up combinations of traits that will give him the best sheep for his particular purpose; the other wants to find out how the various traits are inherited. Obviously, the latter is the sound way to approach the problem from the scientific standpoint, but the approach has usually been the other way around for all of our domestic animals.

It is not the intention here to discuss all the experiments that have been conducted on inheritance in sheep. They cover a fairly wide range, including color, fleece characters, ear length and form, horn growth, tail length and form, number of mammae, fecundity, anatomical abnormalities, mutton conformation, and hybridization studies. A résumé of the work up to 1925 has been made by Roberts and Crew; and a list of all the important articles up to 1929 was published by the Imperial Bureau of Animal Genetics, Edinburgh, Scotland, in 1931. It seems necessary to discuss here only the characters of economic importance because they are the ones with which the present survey was primarily concerned.

One of the few experiments on measurements of mutton form and its genetic basis was carried on at the New Hampshire Agricultural Experiment Station by Ritzman. The genetic aspect of the work involved crosses on a small scale between Rambouillet and Southdown breeds. The first-generation animals were usually intermediate in mutton conformation between the two parents. In the second generation after the cross there was strong evidence of segregation. The evidence obtained indicates clearly that multiple factors are concerned and that a large second-generation population must be raised before the parental types are recovered.

In a similar study in England involving Merino and Shropshire sheep, Mackenzie and Marshall also found a complex genetic situation in the inheritance of conformation as related to mutton production. It is evident from their results that there was considerable variation in the inheritance carried by the parental stocks, since the characteristics of the first-generation hybrids were somewhat variable although, on the average, intermediate between those of the parents. The second-generation hybrids showed slightly more variability but
not enough segregation to give concrete evidence on the nature of the inheritance involved. The results show that the hereditary differences between the fine-wool and the mutton breeds used are many, and a satisfactory analysis of the situation will require not only large numbers of breeding animals but animals of reasonably homozygous composition to start with.

THE SITUATION IN THE MUTTON BREEDS

Just as the consumer eats large quantities of meat from dairy breeds of cattle, so also will he eat large quantities of lamb and mutton produced by the wool breeds of sheep, so long as wool production occupies a place of importance in American agriculture. This has a relation to superior germ plasm for meat production in the sense that economic pressure makes it desirable to produce both milk and meat or wool and meat in the same herd or flock. In the future this pressure may increase with changing economic conditions, but genetically the problem is one of combining important economic characters. However, there is the possibility that combinations in relatively pure genetic form may already have been made by breeders, and if so their identification is a matter of great importance.

The principal mutton breeds of sheep in the United States are the Hampshire, Shropshire, Oxford, and Southdown. The Lincoln, Cotswold, Corriedale, Dorset, Cheviot, Romney Marsh, Leicester, and Suffolk are numerically of much less importance. Since these breeds include both the medium- and long-wool classes, there is considerable variation in the combinations of heredity involved. In actual practice both wool and mutton characters must be dealt with simultaneously, but for purposes of genetic discussion each is treated separately.

The problem of superior germ plasm relative to meat production among these breeds is similar to that in swine and beef cattle in that it concerns fertility, general vigor, rapidity of gain, economy of feed utilization, and conformation. Also, the difficulty of measuring genetic variations in these characters is just as acute among sheep as among the other classes of animals, and the comments made in the sections of this Yearbook which deal with these other classes apply here also. Broad, well-muscled backs and loins, plump legs, and uniformity of finish, combined with high fertility, constitute much of the mutton ideal. This condition has been approached in many of the mutton breeds of today, but the great amount of intra-breed variation and the rapid rate at which animals degenerate in the hands of unskilled breeders are conclusive evidence of the lack of genetic purity for the economic traits of form and function.

The question, in popular language is, where do we go from here with the specialized mutton sheep?

The stage is hardly set for the curtain to rise; the instruments have to be tuned to a standard before the overture can begin. In other words, the breeder does not yet have the information necessary to identify the superior germ plasm in his flock, and the experimenter must find that information. While variations in body proportions and size can be measured with available instruments, the real genetic significance of these is not yet clear. There is urgent need for research on this problem to ascertain what data can be effectively applied in a breeding program.
The work dealing with improvement in mutton qualities carried on in the Department has shown the futility of collecting data based entirely on human judgment. This is particularly true when several different points of conformation are being considered at one time. Committee scoring of type, condition, back, rump, and leg, and the use of these scores in progeny testing and selective breeding, have served only to maintain the average grade for each characteristic at a certain level. What actual measurements might replace such judging and be more effective can only be guessed at present; but by using as a starting point work already done, such as that on physical measurements and inheritance of size and conformation carried on at the New Hampshire and Wyoming Stations, the experimenter should be able to make some progress in determining what kind of data can be obtained that will be reliable and useful.

THE SITUATION IN THE WOOL BREEDS

A strict separation of breeds of sheep into two arbitrary classes, wool breeds and mutton breeds, is not possible because both meat and wool are used in the case of every domestic sheep of importance in this country. The only exceptions among domestic sheep are the woolless breeds known as Blackhead Persian and Barbados. It is usual to divide the various breeds into three classes based on the length and fineness of the wool fibers. Thus, we have the fine-wool, the medium-wool, and the long-wool classes. Such a classification includes the breeds kept primarily for mutton as well as those raised for wool. When the term "wool breed" is used, it usually implies one of the breeds kept primarily for fine wool, such as the Rambouillet and Merino, while the term "mutton breed" designates a breed that excels in mutton quality rather than wool. For example, the Hampshire, Southdown, Shropshire, and Oxford breeds would be included in the latter class, yet all produce both mutton and wool, and the separation into two groups is an arbitrary one. The third, or long-wool group, includes such breeds as Lincoln, Leicester, Cotswold, and Romney Marsh, and these are also of the mutton type.

It is useful to know the kind of wool produced by different animals, and a list of the more common breeds, showing the wool characteristic of each, is given in table 2.

Some breeds may be said to occupy an intermediate position similar to that occupied by dual-purpose cattle bred to produce good-quality beef plus an amount of milk somewhat intermediate in quantity between that of the specialized dairy and the beef breeds. The statements made in the section on dual-purpose cattle on the difficulty of handling two such divergent characters apply broadly to many breeds of sheep. The fact that breeders give more attention to wool or to mutton makes for genetic instability for the two characteristics. The result, genetically, is an alternate building up and tearing down of heterozygous combinations of hereditary material.

The breeder benefits from the flexibility or heterozygous nature of his breeding stock in two ways: (1) He is able to change the characteristics of the stock in a comparatively short time and can thus follow, with some lag, changes in market demand for wool and mutton. (2) Probably in many cases the stock has greater vigor because of the heterozygous combinations that result from the system of breeding employed. Of course some breeders even go so
far as to cross-breed deliberately in order to maintain greater vigor and change the characteristics of their flocks rapidly. This is no doubt the quickest way to get these results if the right strains are available for crossing; but with the present knowledge of inheritance relative to both wool and mutton, the strains that will “nick” advantageously can be located only by the method of trial and error. Such cross-breeding may be the means of bringing together desirable heredity that can be concentrated into true-breeding superior strains. For example, in 8 years’ comparison with ewes of four breeds, the Columbia breed, developed in the Department of Agriculture from a cross involving Rambouillet ewes and Lincoln rams, produced more wool and the lambs reached a greater weight at weaning time than was the case with the other four breeds.

Table 2.—A list of wool classifications, grouped according to fineness of wool, of the more common breeds of sheep, together with a description of the kind of wool each produces and some of the uses to which it can be put in the manufacture of cloth

<table>
<thead>
<tr>
<th>Breed</th>
<th>American grades of wool</th>
<th>Numerical grades of wool</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Merino and Rambouillet</td>
<td>Fine and half blood</td>
<td>58's and finer</td>
<td>Used in making fine dress goods and flannel</td>
</tr>
</tbody>
</table>
| Southdown              | Half and three-eighths blood combing and clothing (chiefly three-eighths blood clothing) | 58's and 60's in the half blood; 50's in the three-eighths blood | The half-blood wool is used mostly for fine dress goods, the three-eighths blood for the manufacture of cloth such as serges, twills, whipcords, herringbones, and other materials used for coatings and linings.
|                        |                                                              | 58's in the three-eighths blood; 48's and 50's in the quarter blood | Used mostly in the manufacture of suitings. |
| Corriedale, Dorset, Hampshire, Shropshire, Suffolk | Usually quarter blood combing (that is, the course side of medium wool) | 48's and 50's.                                  | Do.                                        |
|                        |                                                              | 46's and 48's.                                   | The quarter blood is used in the manufacture of suitings, and the low quarter blood is used in making such materials as heavy overcoats, blankets, and carpets. |
| Cheviot                | Quarter blood and low quarter blood combing (that is, the coarse side of medium and the fine side of coarse wool). | 46's and 48's.                                  | Used mostly in the manufacture of heavy overcoats, blankets, and carpets. |
|                        |                                                              | 40's and 48's.                                  |                                           |
|                        |                                                              | 38's, 44's, 40's, and 30's; a small percentage produces finer than 40's. |                                           |
| Oxford                 | Low quarter blood, common and braid.                         |                                                 |                                           |
| Cotswold, Leicester, Lincoln, Romney Marsh. |                                                 |                                                 |                                           |

The production of wool was the primary purpose of the American sheep industry until about the last decade of the nineteenth century. Since then the market demand for lamb and mutton has developed so that all commercial sheep producers are striving to include excellent mutton qualities in the wool type as well as in the mutton type. At the same time the yield of wool per sheep has also increased, until now the average annual fleece weight in the United States is about 8 pounds, whereas a century ago it was only about 2 pounds.

Yardsticks Needed for Wool

There is a widespread opinion that the measurement of the wool production of a sheep is a simple matter and that wool characters can be easily and quickly determined in exact mathematical units.
This is quite contrary to the facts. Although the technique of measuring variations in wool characters is far more advanced than it is for mutton, much still remains to be done both in the refinement of methods and in their adaptation to practical use by experimenters and sheep breeders. There is no standardized procedure for accurately measuring length of fiber, and as yet there is no accurate measure of crimp sufficiently rapid for practical use even by research workers. Nineteen of the twenty-four experiment stations reporting data make records of fleece weight, but only five of these obtain the weight of clean wool. Also, only about one-third of the stations record length of staple, fineness, and uniformity of fleece.

Within recent years much progress has been made toward perfecting methods and devices for measuring important characteristics of fleeces and physical properties of wool. At present, some are of practical use only for the experimenter, but others have been so simplified that they are available to flock owners who wish to study

**Figure 3.** - A, Device for holding fibers for cutting extremely thin cross sections of opaque fibers for making detailed study of structure, or for fineness studies. Microscopic sections can be prepared in 15 minutes as compared with 2 days by old methods. Fibers are pushed into the slot by a tongue on the movable slide a. The plunger h then pushes the fibers through the slot to the extent desired, and a sharp safety-razor blade is used to make a clean slice. The plunger is aimed with the slot to a ten-thousandth of an inch. B, A photomicrograph of a portion of a thread from a piece of men's suiting appearing to be all wool, but found to be a mixture of wool and delustered rayon.
Figure 4.—Photomicrographs of a cross section of wool: A, Very fine and reasonably uniform wool from a grand champion fleece grown on a grade Rambouillet ewe; B, very fine wool from a first-prize registered Rambouillet ewe fleece; C, very uniform but coarse wool from a registered Rambouillet ram fleece; D, very uniform wool from the fleece of a registered Merino ewe; E, wool greatly lacking in uniformity from a first-prize fleece grown on a purebred Merino ewe. All X 500.
the fleeces of their breeding animals with more precision than can be done by touch or with the unaided eye. Among the latter is an instrument, perfected in the Department's animal fiber research laboratory, for making cross sections of fibers arranged as they occur naturally in the fleece (fig. 3, A). Photographic projections, such as shown in figure 4, are then made of these fibers showing their relative and actual size and shape, and their internal and surface structure as well, when the device illustrated in figure 3, A, is used. Their distribution as they grew is also clearly shown.

Studies of representative fleeces made with this device have revealed some details that the unaided eye is unable to judge accurately.
Density, crimp, luster, and other factors influence eye judgment, and a predominance of fibers of one fineness seems to attract the eye from fibers of widely different fineness and therefore causes the observer to misjudge the average fineness of the sample. By using the device it has been found that first-prize fleeces of the wool breeds frequently have much greater uniformity with respect to size of fiber than grand-champion and reserve grand-champion fleeces of the same breed at the same show.

It appears that the prevalent method of judging fleeces at shows is a relatively superficial one when it comes to the essential details fundamental to real differences in quality. Judging fleeces by touch and with the unaided eye does not detect sufficient detail for the result to be useful in breeding for fleeces of greater uniformity. Much lack of progress in breeding with this objective during the past decade is due to the fact that the measures employed are not exact enough to record essential variations in the several characters involved. For instance, in fur-breeding studies with Karakul sheep, progress has been retarded by the lack of physical measures of such important characters as curl and luster. A purebred Karakul lamb skin is shown in figure 5.

Physical Properties Versus Hereditary Basis

There are few conclusive data to show the mode of inheritance of the important characteristics of wool. However, there is a considerable amount of literature dealing with observations made on some aspects of sheep breeding or wool inheritance. For instance, in The Bibliography on the Biology of the Fleece, by Crew, 434 citations are given, although an examination of the titles shows that only about one-third deal with breeding.

Many of the studies reported concern characters other than length, fineness, crimp, percentage of grease, etc. Much effort seems to have been expended on statistical analysis of the interrelationships existing between the physical properties of wool and various other sheep characters. For instance, density, character, and weight of fleece, fineness of fiber, length of staple, percentage of grease, age of sheep, body weight, and mutton type have been studied by many workers who have determined the degrees of association between such characters.

This is the sort of situation that comes from the accumulation of data and their subsequent analysis to discover the relations existing between the various characters involved. No matter how exact the results may be, however, they deal with only one generation, and this is their weakness from the breeding standpoint. Although such a study confined to one generation is necessary and desirable from certain standpoints, it will never contribute anything to our knowledge of genetics, and what we now need to do is to make a study of each variable as it appears in successive generations. Only in this way can we determine how the various wool characters are affected by heredity.

One must not be misled into thinking that the mode of inheritance of the various characters will be quickly and easily determined. On the contrary, this will probably be a slow and tedious process. The small amount of work that has been done to date on the inheritance of wool characters shows clearly that multiple factors are concerned,
and that there is a widespread lack of dominance among the various
genes involved. A careful and reasonably complete genetic analysis
of each character would be valuable to both the geneticist and the
breeder. In making this analysis, one of the first things necessary
will be the development of strains that are to a large extent true in
their breeding for certain characters. This is a job for the experi-
menter rather than the practical breeder because the process is cer-
tain to be an expensive one.

But while the experimenter is doing this, perhaps contributions of
some value can be made by analyzing data on a generation basis
rather than an annual basis. Such a change would make possible the
construction of pedigrees that would give the important characteris-
tics of each ancestor. Thus the various traits could be followed from
one generation to the next. Only in a relatively few cases is this pos-
sible at the present time.

There is a feeling, however, that unless it can be shown that keeping
individual records for wool would bring enough increased profits to
balance the extra cost, it will never meet with favor among breeders.
This should stimulate the research worker to develop a method that
will make the breeder’s part of the work easier and more practicable.
In the meantime, care should be exercised to keep experimental pro-
cedures within proper bounds and not to mislead the wool grower into
changing his system for one that may bring him decreased returns.
He depends on his profits for a living, and up to this time his own
methods have served reasonably well for this purpose.

SOME SELECTED REFERENCES ON SHEEP AND WOOL

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———

ROBERTS, J. A. F.

——— and CREW, F. A. E.

——— and WHITE, R. G.

——— and WHITE, R. G.

RUSSELL, S. F.

SPENCER, D. A., HALL, M. C., MARSH, C. D., and others.

WOOD, T. B.
Appendix

Some Workers Identified with Sheep Improvement at State and Federal Experiment Stations

Alaska, College: G. W. Gasser.
Arkansas: W. R. Horlacher.
Idaho, Moscow: C. W. Hickman, J. E. Nordby.
Illinois, Urbana: W. G. Kammlade, E. Roberts.
Kansas, Manhattan: R. F. Cox, H. L. Ibsen.
Kentucky, Lexington: E. S. Good, L. J. Horlacher.
Louisiana, Baton Rouge: M. G. Snell.
Maryland, College Park: B. E. Carmichael, K. G. Acker.
Nebraska, Lincoln: M. A. Alexander.
Nevada, Reno: F. W. Wilson, C. E. Fleming.
New Mexico, State College: J. H. Knox, K. W. Parker.
Ohio, Wooster: D. S. Bell, M. A. Bachtell, C. S. Plumb.
Oklahoma, Stillwater: W. L. Blizzard, O. S. Willham.
Oregon, Corvallis: O. M. Nelson.
South Carolina, Clemson College: L. V. Starkey, E. G. Godbey.
Tennessee, Knoxville: Moses Jacob, C. C. Planey.
Texas, College Station: J. M. Jones, B. L. Warwick, A. K. Mackey, W. H. Dameron.
West Virginia, Morgantown: E. A. Livesay, C. V. Wilson, B. F. Creech.

Field stations:
- Dubois, Idaho: Stanley L. Smith, John A. Stochr.
- Middlebury, Vt.: Earl B. Krantz.
- Beltsville, Md.: M. B. Potts, V. L. Simmons, J. O. Grandstaff.

United States Department of the Interior, Bureau of Indian Affairs, Fort Wingate, N. Mex.: J. M. Cooper, Herbert King, Jr.
DISTRIBUTION OF PUREBRED, REGISTERED MERINO SHEEP BY STATES, CENSUS OF 1930.

Ohio is the banner Merino State, having 39.61 percent of the purebred, registered sheep of this breed. Texas is second with 30.78 percent of the Merinos. About 25 percent of them are in the seven States—Iowa, Pennsylvania, Michigan, Missouri, Oregon, New York, and West Virginia—and the remaining 5 percent are sparsely scattered over the other 39 States.

DISTRIBUTION BY STATES

0.00 TO 0.49 PERCENT
0.50 TO 0.99 PERCENT
1.00 TO 4.99 PERCENT
5.00 TO 9.99 PERCENT
10.00 TO 19.99 PERCENT
20.00 TO 29.99 PERCENT

FIGURE 6.—Distribution of purebred, registered Merino sheep by States, census of 1930.

DISTRIBUTION OF PUREBRED, REGISTERED RAMBOUILLET SHEEP BY STATES, CENSUS OF 1930.

Texas leads in the production of Rambouillet sheep, having 28 percent of the total, and Utah with 27 percent nearly ties with Texas as the breeding ground for this western fine-wool breed. Montana has 10 percent and Wyoming 5 percent of the Rambouillets. About 92 percent of the sheep of this breed are in the 11 far Western States and Texas. Ohio with 2.62 percent is the only State in the eastern half of this country that has more than a fraction of 1 percent of the Rambouillets.
FIGURE 8.—Distribution of registered, purebred Southdown sheep by States, census of 1930. Kentucky leads in Southdowns with 39.20 percent. Tennessee follows with 15.18 and West Virginia with 11.57 percent. These three States, therefore, have nearly two-thirds of all the Southdowns.

FIGURE 9.—Distribution of purebred, registered Shropshire sheep by States, census of 1930. The eight States that lead in Shropshires are Michigan, Missouri, Iowa, Ohio, Oregon, Minnesota, Indiana, and Illinois in the order named. These eight States have 64 percent of all the Shropshires. About three-quarters of all the Shropshires are in the northeast quarter of the United States, lying north of the southern boundaries of Missouri, Kentucky, and Virginia and east of the western boundaries of Minnesota, Iowa, and Missouri.
DISTRIBUTION BY STATES

<table>
<thead>
<tr>
<th>Percentage Range</th>
<th>Color</th>
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<tbody>
<tr>
<td>0.00 to 0.49</td>
<td>Light gray</td>
</tr>
<tr>
<td>0.50 to 0.99</td>
<td>Medium gray</td>
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<tr>
<td>1.00 to 4.99</td>
<td>Dark gray</td>
</tr>
<tr>
<td>5.00 to 9.99</td>
<td>Very dark gray</td>
</tr>
<tr>
<td>10.00 to 19.99</td>
<td>Black</td>
</tr>
</tbody>
</table>

Figure 10.—Distribution of purebred, registered Hampshire sheep by States, census of 1930. The States that lead in the production of Hampshire sheep are Idaho with 19.59 percent, Oregon 14.21, Montana 7.51, Colorado 6.25, Washington 5.83, Kentucky 5.13, California 4.68, and Utah 4.47 percent. Two-thirds of the Hampshires are in the 11 far Western States and Texas.

Figure 11.—Distribution of registered, purebred Oxford sheep by States, census of 1930. Michigan leads in Oxford sheep with 21.32 percent. Oregon is second with 11.69 percent, followed by Illinois 9.22, Iowa 7.92, Wisconsin 6.47, Indiana 6.05, and Ohio 5.18. The five East North Central States and Iowa have more than half of all the Oxfords.