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SWINE BREEDING

FOREWORD

Genetic improvement in swine can be obtained only by improving the inheritance of the breeding animals. This is accomplished by discarding animals of inferior inheritance and by making the best possible use of those with superior inheritance. From the many selection and breeding methods the swine producer must choose the combination most useful in his program. An effective choice requires some knowledge of the genetic principles involved and some appreciation of the specific purposes that each may be expected to serve. An effective choice also requires that the producer have a clearly defined goal.

Most commercial producers agree that improvement means an increase in the efficiency with which pigs convert feed into carcasses of high quality; in other words, improvement in weaned litter size, vigor, rate of growth, efficiency of feed utilization and carcass quality. Improvement in terms of these traits should, therefore, be the goal of breeders of purebred swine for it is their responsibility to supply improved seed stock to the industry. Indeed, it is more than a responsibility; it is an economic necessity for otherwise they cannot hold the confidence of their customers.

This publication is intended primarily for the producers of either purebred or commercial swine who are seriously concerned with swine improvement and are prepared to give real study to the problems involved.

CONTENTS

SWINE BREEDING

H. T. FREDEEN[1]
Experimental Farm, Lacombe, Alberta

Breeding, feeding and management are the three fundamental ingredients of swine production. No one of these is sufficient in itself. Superior breeding stock can fulfill their genetic potential only under adequate levels of feeding and management. Conversely, superior feeding and management can be fully effective only if applied to pigs of good genetic potential. This publication outlines principles of selection and breeding that can contribute to genetic improvement of swine.

The most important traits in swine are litter size, vigor or livability, rate of growth, efficiency of feed utilization and carcass quality. The fact that these are inherited is shown by the differences in performance that exist between breeds, between strains within breeds, and between litters within a strain. But environment, that is differences in feeding, housing and management, also exert a profound influence upon these traits. The success of the individual breeder depends upon his skill in distinguishing between the genetic and environmental portions of the differences he observes within and between herds. The ability to recognize with sureness the extent to which environmental differences mask true genetic differences and the ability to use selection and breeding practices that make the most constructive use of inherited differences are the art and science of swine breeding.

Swine breeding operations are conducted in two main phases. One is the breeding of pedigree swine, the other the breeding of commercial pigs. Breeders of pedigree swine are responsible for developing improved strains to serve as seed stock for the commercial industry. From the available breed-strains, the commercial producers must seek those that, when bred pure or in specific cross combinations, will economically produce high-quality bacon hogs, under their conditions. The selection and breeding practices most appropriate to these two phases of breeding operations are discussed under separate headings.

BREEDS

For registration in Canada, breeds of swine must be approved by the Canadian National Livestock Records Board. This board consists of representatives of all livestock breed associations in Canada and of the Canada Department of Agriculture. For information on any breed, old or new, write the Director,

[1]Geneticist and Head, Livestock Section.

Canadian National Livestock Records, Ottawa.

Eight breeds of swine were registered in Canada in 1960. Most numerous was the Yorkshire, which accounted for 64 percent of the total registrations. Table 1 indicates the changes in status of the various breeds between 1950 and 1960. Before 1950 the Yorkshire was the only white bacon breed registered in Canada. In 1962, with the introduction of the Landrace in 1954 and the Lacombe in 1958, there were three.

Table 1.—Numbers of Swine of Various Breeds Registered in Canada in 1950 and in 1960

Breed	1950		1960	
	No. registered	Percentage of total	No. registered	Percentage of total
Yorkshire	34,210	87.6	26,533	59.2
Landrace	—	—	12,956	28.9
Lacombe	—	—	2,214	4.9
Tamworth	2,987	7.6	1,524	3.4
Large Black	—	—	803	1.8
Wessex	—	—	484	1.1
Berkshire	1,390	3.6	294	0.7
Duroc Jersey	304	0.7	29	0.1
Hampshire	36	0.1	—	—
Chester White	147	0.4	—	—
Poland China	—	—	—	—
TOTAL	39,074		44,837	

The popularity of the white breeds in Canada may be due, in part, to the trade discrimination against the colored hair and "seedy" belly often found in the carcasses of dark-haired breeds. But of equal or greater importance is the fact that the white breeds have shown superior carcass quality combined with equal or better rate and economy of gain under Canadian conditions. Table 2 shows the differences in performance between the Yorkshire, Landrace and Lacombe. It also shows that very few litters of other breeds have been tested.

Table 2.—Performance of Various Breeds in R.O.P. Testing of Swine in Canada, 1959 and 1960

Breed	No. of litter groups tested	Age at slaughter	Pounds of feed for 100-lb. live gain	Total carcass score
Yorkshire	1,625	185	352	76
Landrace	321	182	364	78
Lacombe	418	170	340	76
Tamworth	6	189	381	50
Wessex	6	187	—	66

Carcass score is a fairly reliable indicator of commercial grade. Scores over 70 indicate a large percentage of grade A carcasses but grades fall quickly as carcass scores decline below 60.

Yorkshire

The Yorkshire originated in Yorkshire and surrounding counties in England and was imported to Canada early in the development of our swine industry. It has the same ancestral background as the Large White and the latter breed is registrable in the Yorkshire herd book. Since introduction into Canada, however, the Yorkshire has developed a characteristic type that distinguishes it from the Large White.

The Yorkshire is a prolific breed and the sows have good milking and mothering ability. Carcass quality, growth rate and feed economy are generally good. It is an excellent crossing breed.

The Yorkshire and Large White, despite their common ancestry, differ genetically and provide some hybrid vigor when crossed. The Large White has been tested under Canadian conditions and, though strain differences have been demonstrated, it has generally proven somewhat inferior to the Yorkshire in carcass quality and equal or slightly superior in rate of gain.

Landrace

The Landrace originated in central Europe and has been selectively bred in the Scandinavian countries for many years. The marked improvement made by the Danes led to an importation of 23 Danish Landrace by the United States Department of Agriculture in 1934. This importation served widely in the development of new breeds in the United States. In 1950 a number of Landrace were released to the public, and private breeders in both the United States and Canada established Landrace herds. These have been increased by importation of Swedish and Norwegian Landrace strains. Improved Danish strains have not been available because of the strict export embargo maintained by that country.

The rapid expansion of the Landrace breed in Canada has delayed adoption of constructive breeding programs. Nevertheless, the breed has an international reputation and constructive breeding efforts by Canadian breeders will ensure the Landrace a prominent place in the industry. A move to incorporate performance as a requirement of registration was made at the 1962 annual meeting of the Canadian Landrace Association.

The breed is prolific, the sows are good milkers and the better strains perform well in the feedlot. In carcass quality the Landrace is equal to the Yorkshire. Extensive tests in the United States indicate that it is an excellent crossing breed.

Lacombe

The Lacombe, the first breed of swine of Canadian origin, was developed by the Canada Department of Agriculture at the Experimental Farm, Lacombe. It resulted from a breeding program begun in 1947 with a foundation of the Danish Landrace, Chester White and Berkshire. The aim was to develop a pig that would yield a high-quality carcass when bred pure and give hybrid vigor when crossed with the Yorkshire. The breed was selected on the basis of performance in each generation during its development. The main performance traits considered were weaned-litter size, weaning weight, growth rate and carcass quality. The contributions of the parent breeds to the new breed were: Landrace, 56 percent; Berkshire, 23; and Chester White, 21. In physical appearance it resembles the Landrace parent most closely.

Lacombe females were first released to the public in 1958. The breed is selectively registered by requiring minimum standards of performance in growth rate, feed efficiency and carcass quality before pigs can be accepted for registration. These standards have contributed to the performance record of the Lacome (Table 2).

Placid temperament, good mothering ability, high-quality carcasses and excellent growth rate are characteristics of the breed. It performs well in crosses with the Yorkshire.

Tamworth

The Tamworth is a red breed and, like the Yorkshire, originated in England. The breed has not been tested extensively under Record of Performance in Canada but tests conducted to date indicate that the breed does not equal the Yorkshire in carcass quality. The Tamworth is generally considered to be less prolific than the white breeds previously described. Valued for its hardiness and vigor, the Tamworth may, if carefully selected, contribute usefully to commercial cross-breeding operations.

Berkshire

The Berkshire, a black breed with white points, originated in England. One of the first breeds imported to Canada, the Berkshire proved popular and at the turn of the century was the most numerous breed in this country. In recent years its popularity has declined, largely because it did not perform nearly as well as the Yorkshire under testing and because of the objection to black hair and "seedy belly" in bacon.

In prolificacy, the Berkshire is about midway between the white breeds and the Tamworth. The breed has a high reputation for milking ability, uniformity of back fat and fullness of ham. Berkshires are easy feeders and perform well in crosses.

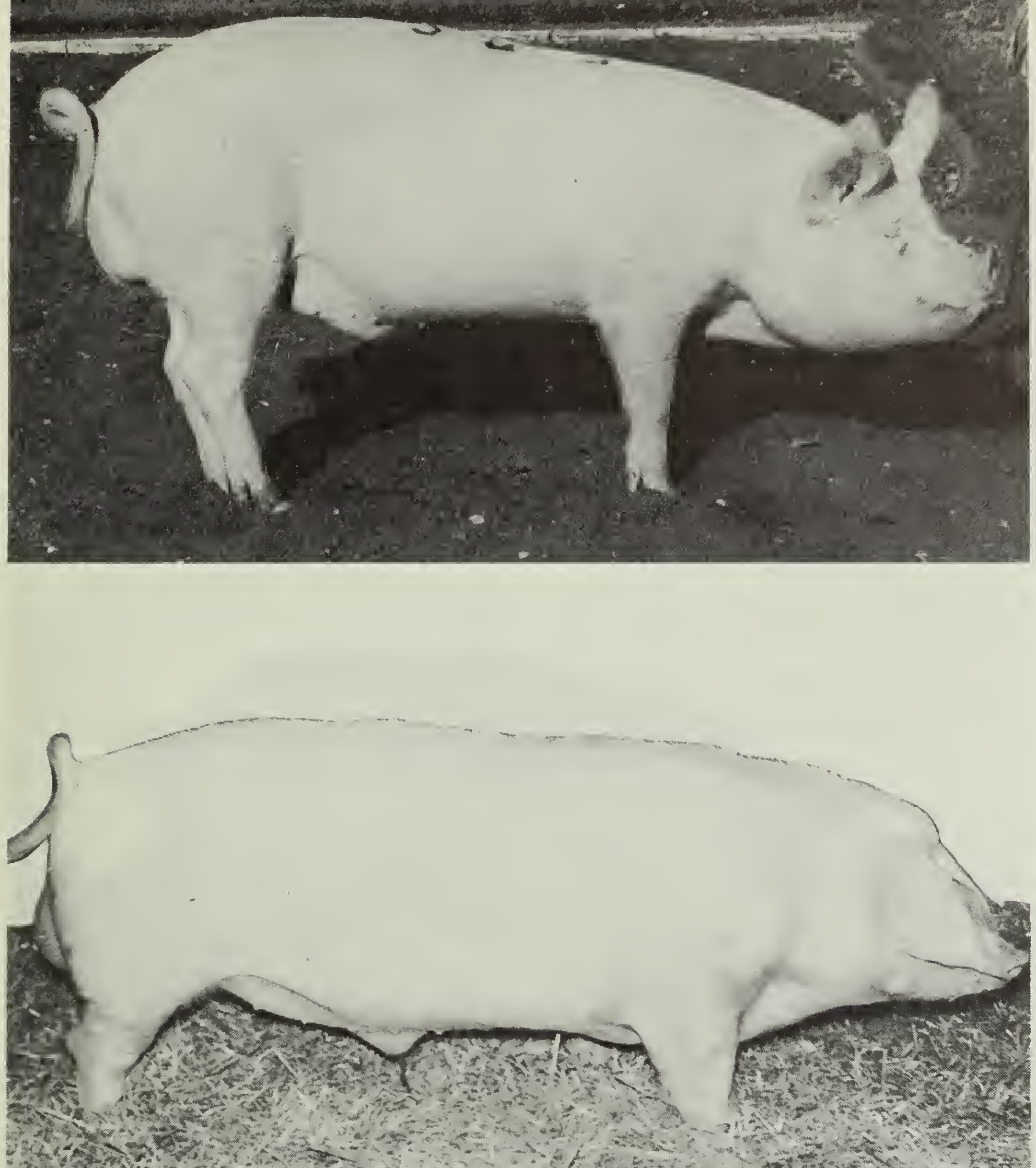
Large Black

The Large Black also originated in England. The fact that it was not represented there by a breed society until 1899 indicates its relatively recent origin. The first importation of the breed to Canada was made about 1920. Large Blacks have not been R.O.P.-tested in Canada.

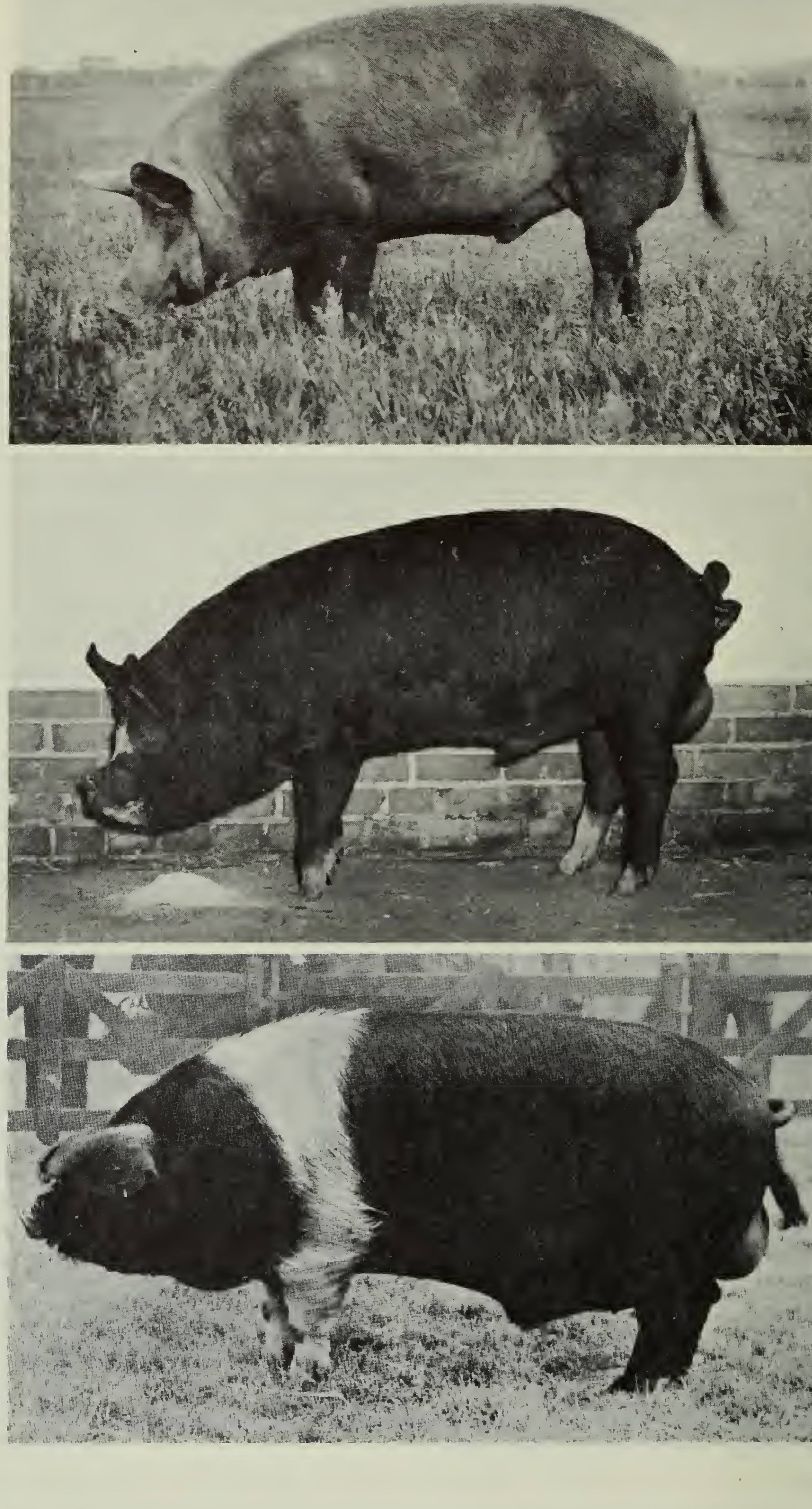
Wessex Saddleback

The Wessex Saddleback is black with white forelegs and a continuous belt of white hair over the shoulder. It was developed in the region of the county Hampshire in England and exportations to the United States in the early eighteen hundreds provided the foundation for the Hampshire breed in that country. The first importations to Canada were made in 1956.

In England, this breed is considered an excellent grazer with a reputation for hardiness. R.O.P. tests of the breed in Canada have not been impressive.



Typical boars of three breeds. Top to bottom: Yorkshire, Landrace, Lacombe.



Typical boars of three breeds. Top to bottom: Tamworth, Berkshire, Wessex Saddleback.

Nonbacon Breeds

The Duroc, Hampshire, Chester White and Poland China are not recognized as bacon breeds in Canada. Except for the Duroc, they have not been represented in registrations of recent years.

The distinction between bacon and nonbacon, or lard, breeds is based largely on differences in carcass length, bacon breeds being longer. In addition, bacon breeds produce carcasses with a higher ratio of lean to fat. Since 1930 there has been a gradual development of "meat-type" strains in the lard breeds in the United States. Some strains have been considerably improved in lean content of the carcass. These strains have not been tested under Canadian conditions.

New Breeds and Inbred Lines

A number of new breeds, each based on a hybrid foundation featuring at least one bacon breed, have been developed in the United States. Because these breeds have been inbred they are often referred to as inbred lines and their herd books are maintained by the Inbred Livestock Registry, St. Paul, Minnesota. Full information on each of these breeds may be obtained from the Registry.

These new breeds include the Minnesota No. 1, Minnesota No. 2, Montana No. 1, Maryland No. 1, Beltsville No. 1, Beltsville No. 2, San Pierre, and Palouse. The San Pierre was developed by the United States Department of Agriculture at Beltsville and the Palouse at Washington State College. Origins of the other breeds are indicated by their names. Except for the Palouse, all of these breeds are colored. They have not been tested to any extent in Canada.

INHERITANCE IN SWINE

Genetics is often viewed as a mysterious process—one so complex that it cannot be applied in everyday breeding operations. At the same time, a purebred pig is expected to conform to breed standards in color and general type. Desirable traits are looked for in a herd sire with the hope that his offspring will resemble him. This expectation that "like begets like" is as old as the practice of livestock breeding and is known to be founded squarely and surely on the laws of inheritance formulated in the science of genetics. Knowledge of a few relatively simple principles of inheritance will dispel the mystery of genetics and make it a useful and dependable tool in the hands of the swine breeder.

Genes

The basis of inheritance is the invisible unit called the gene. The development of all of an animal's characteristics is controlled by genes, of which many are found in every cell of the body. The genes are organized in pairs within each cell. In reproduction the germ cells divide in half in such a way that each sperm or egg cell carries a single gene from each of the many pairs present in the original cell. In fertilization, which follows mating, two reproductive cells—a sperm from the male and an egg cell from the female—unite, thereby restoring the normal paired condition of the genes. This ensures that every gene pair of every animal is made up of one gene contributed by that animal's sire and the other by the dam. In other words, the male and female parents each contribute half of the genes in their progeny.

Genetic and Environmental Variation

As was stated in the introduction, much of the difference, or *variation*, one sees among animals is inherited. This is because different animals have different gene combinations which have their own specific effects on development. This variety in the genes of different animals produces what is known as *genetic variation.*

Genes are not the only source of differences between animals. Poor feeding can certainly influence development; so can disease, or extremes in weather. These factors, along with all the other items of management that affect the animal, are called environmental factors and lead to variation that is known as *environmental variation.* This variation, unlike that due to inheritance, cannot be transmitted from one generation to the next. But it does confuse the genetic picture and therefore is a hindrance to effective selection.

Either kind of variation, or a combination of the two, may lead to the superiority of one animal over another. In genetic superiority, the better animal carries more favorable genes. In environmental superiority the better animal has received more favorable feeding and management. The total variation observed will therefore be partly genetic and partly environmental. Since only the genetic portion is of value to genetic improvement, the breeder must try to choose for breeding animals that carry the best genes. He must be able to distinguish between animals that are superior genetically and those that are good looking simply because they were raised in a favorable environment.

The study of methods of recognizing animals of superior breeding worth and of using these in breeding to achieve genetic improvement is the science of animal breeding. This science has claimed the attention of research people for many years. The following section describes their findings in a way that will be useful to the practical swine breeder.

Single-gene Inheritance

There are in pigs one or two (and only one or two) situations for which environment can be completely disregarded; in other words, all of the variation observed is due to genetic differences. A good example is hair color. It isn't hard to tell a black pig from a white one; nor can one make a black pig white by changing the environment. Thus differences in environment do not complicate the genetic interpretation of color differences among pigs. There is, however, a genetic complication that must be understood. This complication is known as *dominance.*

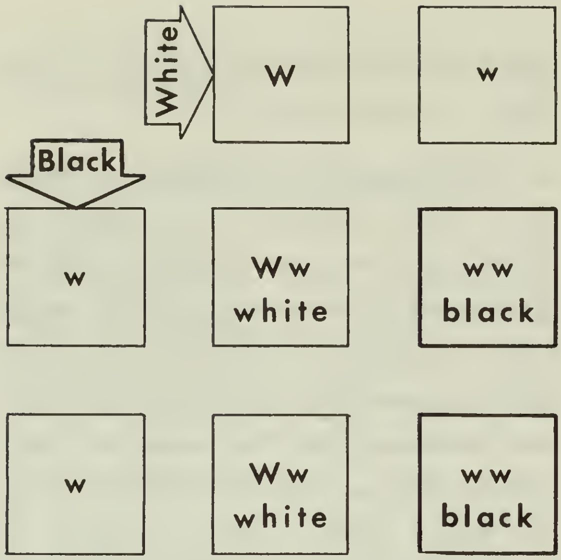
Dominant genes leave no doubt about their presence. The gene for white hair in the pig is dominant and whenever the gene pair controlling the pig's hair color includes one the pig will be white regardless of the gene with which it is paired. Genes that express themselves only in the absence of a dominant gene are called *recessive* genes. They will produce their effect only when paired with an identical recessive gene. In the pig, the gene for black hair color is recessive. Thus a pig will be black only if both members of the gene pair are "black" genes.

A single example will illustrate the important fact that an animal can carry a recessive gene without showing it. Purebred Yorkshires are expected to be genetically pure for the dominant "white" gene and purebred Berkshires are genetically pure for the recessive "black". When these breeds are crossed, the offspring must receive a dominant white gene from the Yorkshire parent and a recessive black gene from the Berkshire parent. Since white is dominant, these crossbred progeny will be white but all carry the recessive black gene. In genetic terms, they would be "heterozygous" for the color genes. When these offspring are used for breeding, half of their reproductive cells will carry the gene for dominant white and half will carry the gene for recessive black. If the white crossbred pigs are mated back to the Berkshire, half of the resulting progeny will be black. Some black progeny could also be produced by the mating of the two white crossbreds since each is capable of transmitting the black gene. In such a case, a black pig will have been produced by two completely white parents. Such a pig does not, in so far as color is concerned, differ in any way from any other black pig. His occurrence is simply a normal consequence of dominance and recessiveness.

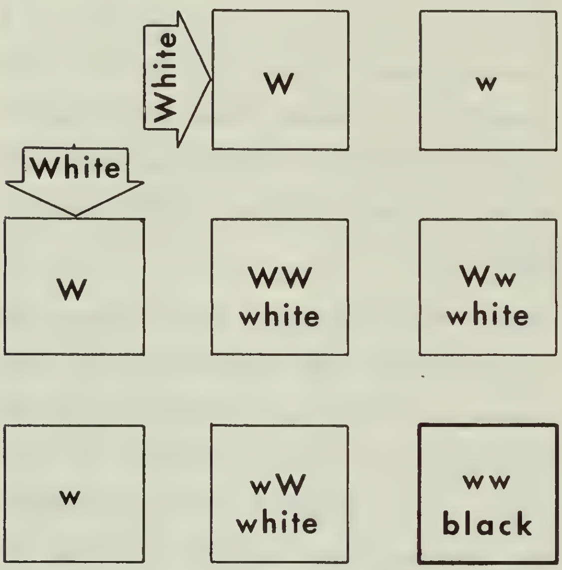
The foregoing remarks do not apply to skin color, the genetics of which is much more complex. Further, even the example of hair color is restricted to the black color of the Berkshire. It does not apply in the same simple fashion to the black of other breeds.

In discussing the inheritance of single-gene traits, symbols are useful for identifying the genes that are present. Dominant genes are denoted by capital letters and their recessive "mates" by the corresponding small letters. Thus the dominant gene for white is identified by W and the recessive black by w. Since genes occur in pairs an animal that is genetically pure for white will be WW and the reproductive cells it produces all carry the gene W. Similarly, an animal that is black will be ww and all of its reproductive cells carry the gene w. A heterozygous animal will be Ww and, though it is white, half of its reproductive cells will carry the dominant white W and half carry the recessive black w.

When two animals are mated, the reproductive cells produced by one parent combine at random with the reproductive cells produced by the other. The simplest way to visualize the consequences of this random assortment is to draw a "checkerboard" with two rows and two columns. Head each column with the two genes of one parent and each row with the two genes of the other parent. Now carry into each of the squares in the checkerboard the two appropriate genes, one from the column and one from the row. The four classes that result represent the genetic types produced by the mating.



Mating a white heterozygote (Ww) with a black (ww) will produce only two kinds of offspring, heterozygous white pigs (Ww) and black pigs (ww) in equal numbers.



Mating two white heterozygotes (Ww) will produce three kinds of offspring, the pure white (WW), the heterozygous white (Ww) and the pure black (ww). These will be in the ratio of 1:2:1. However, because of dominance there will be only two colors, white and black, in the ratio of 3:1.

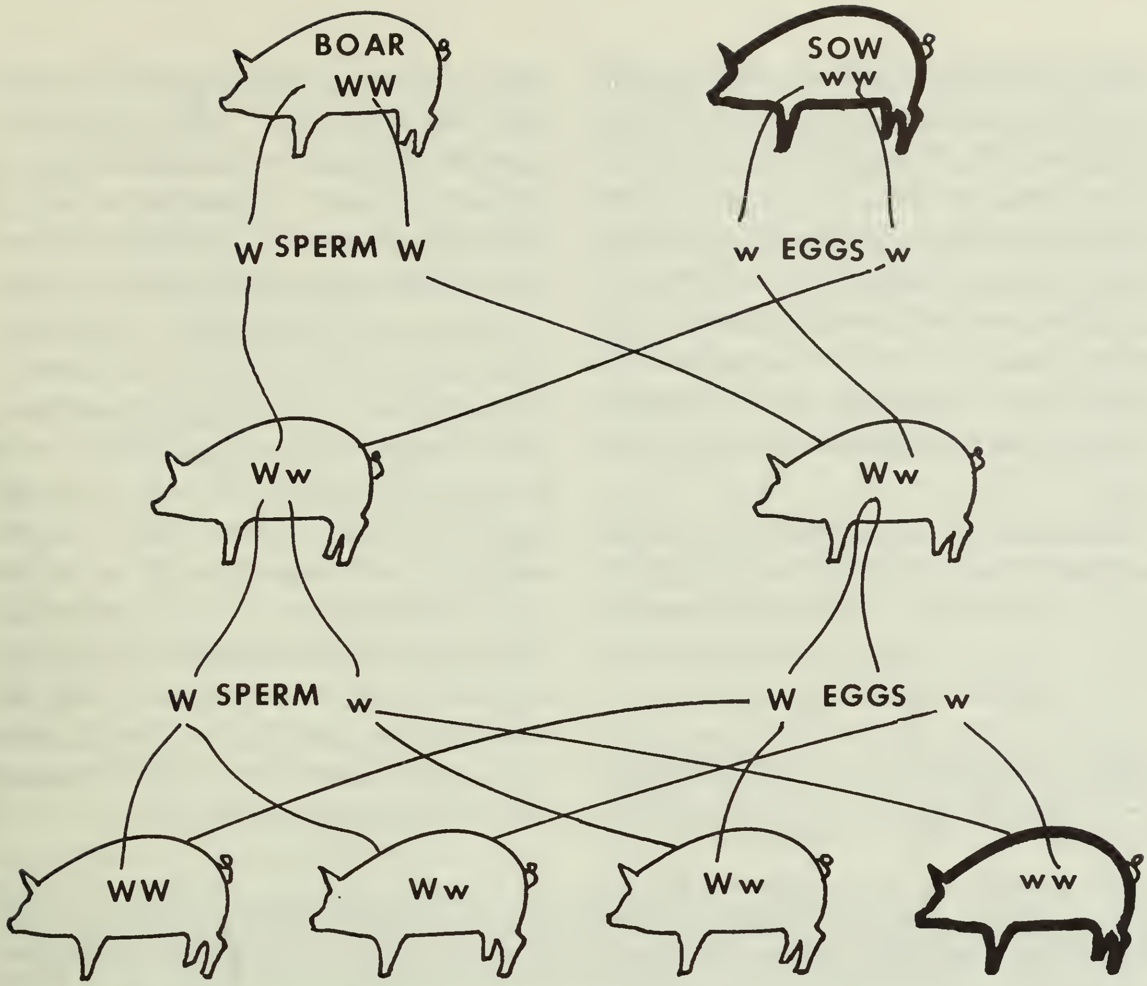
Dominance may be a mixed blessing. A commercial producer who wishes to use a female herd of mixed color to produce white market pigs need only buy a purebred sire of a white breed. Such a sire is pure for the dominant white and will produce only white pigs. However, dominance is an obstacle to the breeder who wishes to rid a herd completely of the recessive black since the heterozygous animals will appear identical to those that are genetically pure for white.

Identification of heterozygous animals, though usually not important for color, may be desirable for certain types of defective conditions. Inherited defective conditions are usually recessive and all heterozygous animals will appear normal. Thus the appearance of a defect of genetic origin in a litter is usually proof that *both parents* were heterozygous. Further, the normal litter mates of a defective pig may also carry the undesired recessive gene.

Heterozygous animals can be identified by mating tests. The quickest test is provided by mating the suspected heterozygote with a pig that shows the undesired trait. Such a pig would, of course, be pure for the recessive genes. However, this method is rarely practical and the more useful procedure is to attempt to mate heterozygous animals together. This simply requires the mating of litter mates or close relatives— in other words, inbreeding. If an undesirable recessive gene is present in the herd, inbreeding increases the likelihood that pigs with the undesired gene are mated.

There is a widespread belief that defects such as ruptures and ridglings are of rather simple genetic origin. This is now known to be at least partly false.

Detailed studies of these defects have shown that their inheritance is complex and that they may also be produced by



Random combinations of genes in progeny from pure white and black pigs.

poor nutrition, by accidents, and by other causes that are not genetic (see pages 34 to 35 for a more detailed discussion of defects). Consequently, the appearance of defective pigs in a litter may indicate environmental rather than genetic deficiencies. This does not mean that the possibility of a genetic basis for defects can be ignored. However, a final conclusion should not be reached until more conclusive evidence has been obtained through use of one of the mating tests described.

Many-gene Inheritance

The simple type of inheritance just described applies to very few traits in swine. In fact, traits of economic importance appear to be controlled by many pairs of genes. To further complicate the picture, they are also influenced by a variety of environmental factors. Thus, in considering the inheritance of these traits it is necessary to take into account both the *genetic variation* and the *environmental variation.* This is most simply illustrated by considering the trait of carcass length.

Carcass length is determined partly by number of vertebrae, which varies from 27 to 30, and partly by the size of each vertebra. Hence, length must be influenced by many gene pairs, each affecting the process of skeletal development. Each gene pair may have a small effect but when these are added together for all of the gene pairs the total results can be large. The effect of one gene pair may also counteract the effect of another.

Carcass length is also influenced by environment. Inadequate rations or disease may retard growth, thus limiting the extent to which the genes can express themselves. To recognize and control all of the factors affecting gene action would be difficult, perhaps impossible. Yet effective breeding and selection practices require some knowledge of the average effects of *genetic variation.* This knowledge is obtained by calculating what is known as the *heritability* of each trait.

HERITABILITY, simply defined, is that portion of the variation due to inheritance. Heritability of 50 percent means that, *on the average,* half of the variation is genetic and half is caused by environment. This simple definition is not perfect—complications are discussed later—but it is safe to assume that heritability indicates the proportion of the total variation that will respond to selection. In other words, knowledge of heritability makes it possible to predict the *average* rate of improvement expected from a given selection program.

Estimates of heritability for several important traits are given in Table 3. These figures are averages combined from many sources. The carcass traits of length, backfat and loin area are highly heritable. These traits can be measured with considerable accuracy and they respond well to selection. Growth rate and efficiency of feed use are influenced to a greater extent by environment and have intermediate heritability. Litter size and weaning weight have low heritability.

Table 3.—Heritabilities of Some of the Important Traits in Swine

Trait	Heritability, %
Litter size at birth	10
Litter size at weaning	7
Average weaning weight	8
Growth rate—weaning to 200 lb.	40
Feed efficiency	30
Carcass length	50
Carcass fat	55
Carcass lean	60

The word *average* must be emphasized. Heritabilities are averages estimated from a very large quantity of information. Genetic gains predicted from these estimates can be expected only on the same basis of the broad average. They will not apply in every individual case. Gains may be greater or less than predicted. Environment—feed, disease, weather, etc.—will also differ from one year to the next and may mask true genetic changes. For these reasons, failure to obtain the predicted genetic gains in any one year may be expected.

Selection

To most breeders, selection means keeping certain animals for breeding and culling others that do not measure up to the desired standards. But this is only part of the picture; controlling the number of offspring produced by each breeding animal is also part of selection. For example, if two boars are selected for breeding in a herd, the boar that serves the greatest number of females has the greatest opportunity of leaving offspring that may in turn be used for breeding. Thus by controlling breeding use it is possible to give greater selection emphasis to certain animals.

Breeding animals produce superior offspring only if they give them superior genes. Therefore, genetic improvement requires that the animals selected for breeding carry more than the average number of favorable genes. As a guide in the selection of such animals the breeder may use the performance of the individual, the performance of its litter mates, progeny, or other close relatives, or a combination of this evidence. The choice between these alternatives depends upon the heritability of the trait for which selection is being practised.

Before discussing this aspect of selection it is desirable to emphasize the importance of a consistent selection program. Genetic improvement of a herd takes time. If goals are continually changing, little progress will be made. The desired results can be obtained only by taking as the goal something that is basically sound and selecting consistently toward this goal year after year and generation upon generation.

Selection for traits of high or intermediate heritability.—For highly heritable traits, selection on the basis of the individual's own performance will permit the most rapid genetic improvement. This applies to fat thickness, a trait that can be measured on the living animal by means of a probe. Length and carcass lean, both highly heritable, can be measured with accuracy only after slaughter. For these traits it is necessary to use the performance of litter mates in selection.

The use of heritability estimates in predicting genetic gains may be illustrated by carcass length. Consider a herd in which all litters have been carcass-tested and have averaged 30.0 inches in carcass length. Suppose that, from *within* this herd the boar selected for breeding was from a litter that averaged 31.0 inches and the gilts were from litters averaging 30.6 inches. If carcass length was controlled completely by inheritance, the length of the offspring would be the average of the parental litters, that is

$$\frac{31.0 + 30.6}{2} = 30.8$$

or 0.8 inches above the original herd average. But carcass length is only 50 percent heritable so that only 50 percent of this gain may be expected. In other words the progeny should average 30.4 inches in length. Notice the statement that the parents were selected from *within* the herd. This ensures that all animals are compared under the same environmental conditions. Had the boar been chosen from a different herd there would be difficulty in deciding how much of his superiority was genetic and how much was due to different conditions of feeding and management.

Growth rate and feed efficiency are of intermediate heritability. For these traits, the most useful form of selection is one that combines the performance of the individual with that of its litter mates. Prediction of the rate of genetic improvement expected from a given selection program would be done in a manner similar to that described above for carcass length.

Improving traits of low heritability.— Litter size and weaning weight are of great importance in swine production. Their low heritability (Table 3) indicates, however, that selection for them may not be particularly rewarding. That this is actually the case has been verified by research. Selection experiments have shown that ordinary methods of selection offer little promise for improvement of these traits. Moreover, selection techniques that may prove successful are so complex that they cannot be used in practical breeding programs.

Fortunately, there is an alternative genetic method for improving litter size and weaning weight. This method is based on the genetic phenomenon known as *heterosis*, or *hybrid vigor*, and depends upon the crossing of breeds or strains that combine well.

HETEROSIS is the phenomenon responsible for the superior vigor, thrift, and growth rate frequently observed in crossbred pigs. This superiority is not due to chance. It is an expression of rather complex genetic mechanisms that produce their effects only through specific gene combinations. Since heterosis is obtained by crossing, the improvement is not permanent and each cross must be evaluated on its own merits.

"Nicking" ability—in other words the ability to produce heterosis—cannot be estimated by a simple procedure comparable to heritability. However, two principles are useful in predicting potential crossing performance.

- The amount of heterosis depends upon the performance trait. In general, it is large for traits of low heritability and small for traits of high heritability.
- The amount of heterosis produced depends upon the genetic dissimilarity of the parents. It is expected to be large when the parents are unlike in their heredity and small when the parents have similar inheritance.

Parents chosen from different breeds will be less alike in their genetic background than parents of the same breed. Thus breed crosses are expected to provide greater heterosis than crosses between strains within breeds. However, the fact that breed crosses give highly variable performance emphasizes the importance of breed strains. It is known that specific strain crosses within a breed will be superior to other crosses within the same breed. Similarly, a specific strain of one breed may perform best only when crossed with a specific strain of another breed. The search for superior crossing combinations will be rewarding only if strains with established levels of performance can be identified and maintained within each breed.

A breed strain may be defined as a group of animals more closely related to each other than they are to the rest of the breed. This requirement, however, is not sufficient in itself. The animals of a true strain must also have genetic likeness—they must resemble each other and they must give uniform and predictable breeding results. This likeness can be obtained only by following the mating system known as inbreeding.

In summary, these are the known facts of inheritance in swine:

- All important performance traits are controlled by inheritance.
- Environmental effects can mask true genetic differences; hence the most reliable genetic comparisons are those made within the herd.
- Heritability estimates provide a reasonably reliable basis for pre-

dicting the average genetic gain expected from a consistent selection program.

- Traits of high heritability respond well to consistent and continuous selection.
- Traits of low heritability do not respond to practical selection procedures. However, improvement in these traits can be obtained by use of crossing, either of breeds or of strains within breeds.
- Distinct breed strains that can be identified and perpetuated provide the only sound basis from which to develop a useful breed cross.

PEDIGREE BREEDING

Purebred swine are registered in Canada by the Canadian National Livestock Records, Ottawa. To register purebreds, breeders must apply for specific herd letters to be used in identifying all purebreds farrowed as their herd property. The white breeds and the Tamworth must be identified by tattoo markings consisting of the registered herd letters in one ear and the individual pig number together with the designated year letter in the other. Other breeds are identified by tattoo or ear tag. Whichever method is used, the pigs must be identified when under eight weeks of age and before they are weaned. Each breeder must keep a private record with all particulars of his breeding operations and this must be made available on request to officials of the breed association, the Canada Department of Agriculture, and the Canadian National Livestock Records. Failure to comply with regulations can result in pigs being ineligible for registration.

Details of eligibility for registration are established by the individual breed association, that is, the Canadian Swine Breeders Association representing the Yorkshire, Tamworth, Berkshire, Hampshire, Chester White, Wessex Saddleback, Duroc, Poland China, and Large Blacks, the Canadian Landrace Association, and the Canadian Lacombe Breeders Association. "Purity" of ancestry is required by all breed associations but there are important breed differences in registration standards (see the section on breeds, pages 5—11).

Breeders of pedigree swine are responsible for providing improved seed stock to the industry. Indeed, since the industry provides the final market for pedigree breeding stock this is more than a responsibility; it is an economic necessity. To the commercial producer, swine improvement has only one meaning, that is, an increase in the overall efficiency with which pigs convert feed into carcasses of the most desirable quality. By directing their breeding and selection procedures toward this goal, breeders of pedigree swine will gain and hold the confidence of their market.

The choice of breed and of strain within breed are important in establishing a pedigree herd. As was shown previously, breeds differ in their performance potential. Likewise, strains within a breed may differ greatly. Establishing and maintaining a good pedigree herd is costly and a breeder must be sure of his chosen breed and strain before he ventures into pedigree breeding.

The question of herd size should be considered early in the planning of pedigree breeding operations. A one-sire herd poses certain problems in the selection of replacement sires. Selection of all breeding stock from within a herd of this size is not generally advisable as the rate of inbreeding becomes excessive. However, the practice of selecting replacements from other herds carries with it the possibility of introducing disease. It also makes difficult the evaluation of genetic potential since differences in feeding and management between herds will tend to confuse the genetic picture. This will be discussed more fully in a later section (pages 23 to 28). Loss of the boar in a one-sire herd may be disastrous. It is not an easy matter to replace a good herd sire. These problems may be minimized by increasing herd size to the point where at least three or preferably more herd sires can be maintained.

Mating Systems for Pedigree Herds

Mating systems for pedigree herds are classified broadly as outbreeding, the mating of unrelated animals within a breed, or inbreeding, the mating of related animals. These two systems take four reasonably distinct forms.

Outbreeding has been the preferred mating system in the breeding of pedigree swine. It may be a corrective mating system in the sense that successive replacement boars are selected with a view to strengthening herd performance in specific traits where a previous sire has been weak.

An outbreeding program requires a minimum of advance planning. The question of where to go next arises only when a replacement boar is required. It can be solved by selecting an outstanding boar from a herd that has the desired level of performance. The major limitation of outbreeding as described above is the variability observed among the offspring of an outbred boar. Consistent breeding results cannot be expected.

Strain crossing is a special form of outbreeding in which replacement sires for the herd are obtained from two or more distinct breed strains according to a regular sequence. It is generally planned around strains that, in trial matings, have been found to "nick" or combine well. Strain crossing makes use of hybrid vigor within a breed. A strain cross involving continued use of two specific strains could produce low levels of inbreeding.

Strain crossing in Canada is limited by the scarcity of distinct strains within the various breeds. Breed strains that do exist are largely the product of regional isolation. For example, the Yorkshire strain known as the Island Yorkshire resulted from breeding within the stock on Prince Edward Island. However, very few individual breeders in any region in Canada have attempted to create and maintain their own distinctive strains by consistent selection within their own herds.

Inbreeding, the mating of related animals, may range from intense to mild depending on the relationship between the mated pair. The most intense inbreeding results from matings between parent and offspring or between litter mates. Deliberate inbreeding is generally avoided because of the belief that it will cause a decline in vigor and performance. To some extent this belief is correct. Usually, rapid inbreeding is accompanied by a decline in merit. The observation that some strains are affected more than others simply illustrates the fact that inbreeding promotes genetic purity for all inherited traits, favorable and unfavorable, present in the strain.

Some swine breeders see in these facts the very elements that can make inbreeding a powerful tool for improving their herds. Through skilful use of a selective inbreeding program they can critically examine the general strengths and weaknesses of their strains, reject individuals revealed as genetically inferior, and promote genetic uniformity for desired performance traits among the animals that remain.

LINEBREEDING is a relatively mild form of inbreeding in which the objective is to maintain a high degree of relationship to one ancestor of particular merit. Linebreeding has been used successfully in the development of uniform and reasonably true-breeding strains.

Choice of systems.—In planning a breeding program, the breeder of pedigree swine must consider the present and future requirements of his market. Progressive breeders are keenly aware of the trend toward planned crossbreeding in commercial production. They recognize that the full benefits of crossbreeding will not be realized until there exist a number of genetically distinct strains within each breed. They also realize that these strains must be reasonably prepotent for economically important performance traits. Understanding of these facts provides a sound basis for choosing a suitable mating system for the pedigree herd.

Neither outbreeding nor strain crossing by itself will produce genetically distinct breed strains that meet adequately the requirement of prepotency. To develop and maintain such strains requires the use of a carefully controlled inbreeding or linebreeding program. This does not mean that outbreeding or strain crossing will serve no useful purpose. Strain crossing in particular has a place in the multiplication of breeding stock for use by commercial producers. If the strains chosen for crossing are distinct genetically, if they combine well, and if they have high performance for traits of economic importance, this mating system should produce vigorous females that give good performance in commercial herds. But the important responsibility of pedigree breeders is to develop and maintain distinct breed strains. The breeding program recommended for this purpose is developed in the following section.

Development of breed strains.—The actual breeding program for strain development would probably include intense and mild inbreeding as well as outbreeding. As a first step in the formation of a breed strain there is much to commend one generation of close inbreeding, preferably brother-sister matings, among the animals selected as the herd foundation. Results from these matings should reveal any genetic deficiencies in the stock and, at the same time, indicate the traits in which the strain may excel. If the results encourage further development of the strain, the progeny from the initial close inbreeding could be retained for breeding. Future matings would feature mild inbreeding (linebreeding) designed to maintain a reasonably close relationship to the outstanding individuals of the strain. Replacement sires would be selected from within the herd. Periodic outcrossing by introduction of female breeding stock or the use of boars from a related herd might be used to correct specific faults observed in the strain.

At this point a word of caution seems desirable. Rapid inbreeding is not desirable in this breeding program. A slow increase in relationship will allow greater opportunity to eliminate undesirable traits before they become fixed in the herd. Moreover, high levels of inbreeding will not guarantee that the herd will give wholly predictable breeding results. The breeding program described, however, has greater promise than the alternatives now known.

HERD SIZE will influence the success of this breeding program. One- or two-sire herds will probably inbreed too rapidly if closed. For such herds, to follow the breeding program described would require that replacement boars be brought in from related herds. This invites the introduction of disease and selection is difficult because environmental differences between herds tend to confuse the genetic picture. However, herds with at least three herd sires can, if judgment is exercised in planning of matings, be closed successfully to outside stock with no cause for concern that inbreeding will be excessive. To justify the maintenance of three service sires requires that the herd have at least 15 mature females. Annual breeding of an equal number of gilts would be desirable to permit preliminary progeny test evaluation of potential replacement sires. This scale of operations, large by present-day standards, may not be considered feasible by many pedigree breeders. An alternative is for three or more breeders with one-sire herds to pool their breeding programs with the view of producing a single strain. This would require that they consider their several herds as one closed breeding unit.

Many breeders may consider that an average of five sows to a boar does not make efficient use of the herd sire. For certain types of swine production this view is correct. However, the first concern of the pedigree breeder must be the efficient appraisal of the breeding worth of his herd sires. He should also test as many boars as possible to permit the selection of sires that can contribute to genetic improvement of his own herd. An average of five litters per sire is adequate for this purpose, and on this basis 15 breeding females can justify the maintenance of three boars.

Selection in Pedigree Herds

Selection is the process of deciding which animals shall be permitted to become parents. Saving those of superior merit and culling those that are inferior provides the basis for genetic improvement.

To have real meaning to the swine industry, selection must be based on performance traits that have economic significance. Further, selection must be concentrated on relatively few traits; it will be inefficient if spread over many. The traits of economic importance in swine production include litter size, vigor and livability, growth rate, efficiency of feed utilization, and carcass quality. The emphasis given to each of these in selection is a decision for each individual breeder. This decision should be based on the immediate need for improvement of one or more specific traits and the known facts of inheritance of each trait.

The genetics of these traits was discussed in a previous section page (16). There it was shown that litter size at birth and at weaning, the latter being a measure of vigor or livability, have low heritability. These traits are not expected to respond to practical selection procedures and selection for them may not be particularly rewarding. However, it was also shown that growth rate, efficiency of feed utilization, and carcass quality are of high heritability. These traits will respond to consistent selection practised generation upon generation. Accordingly they should be emphasized in selection procedures.

Type also requires some attention. The more important features of type are physical soundness, vigor, and teat number, in other words, those qualities that contribute to the potential durability and breeding life of the animal. Type may also include conformation in terms of market suitability, that is, length, minimum fat, and fullness of ham. It should not include breed "fads" nor should conformation, except where its component parts are definitely associated with carcass quality, take precedence over the more important traits of economic importance outlined in previous paragraphs. Several of the components of type are heritable and should be considered after selection for the major traits has been completed.

Measuring and Recording Performance

Accurate written records are absolutely essential to an effective selection program. Even where few traits are involved, dependence on memory alone can lead to many costly errors. At the same time, record keeping takes time and should be limited to the items of most importance. Minimum records are listed below:

A. Identification and Litter Record
   1. Pig number
   2. Sex
   3. Birth date
   4. Sire and dam
   5. Service date of dam
   6. Total number born
   7. Litter size at weaning, by sex

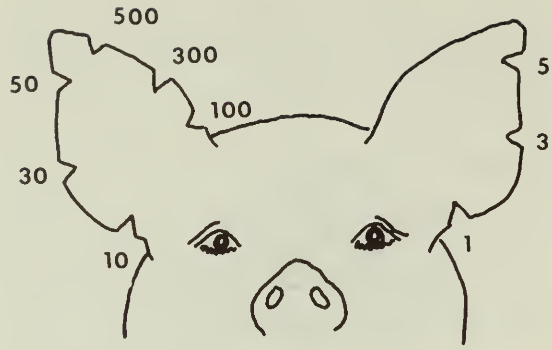
B. Individual Record
   1. Teat number
   2. Weaning weight
   3. Disposal date, weight and age
   4. Disposal cause
   5. Market grade if sold to slaughter

C. Special Records
   1. Performance testing

Identification.—The records listed under this heading meet the minimum requirements established by Canadian National Livestock Records for registration and must be maintained by all breeders of pedigree swine. At the same time, these records are essential to any swine breeding operation, for without this minimum information all subsequent records are meaningless.

Individual marking of each pig, the basis of any record system, is readily accomplished by ear notching. Notching pliers, highly suitable for this operation, may be obtained from most livestock supply companies. Notching should be done within a few hours after birth. A sharp V-shaped notch is preferred. This gives a distinct mark that will not interfere with ear development.

A system of numbering by notches is illustrated on page 24.

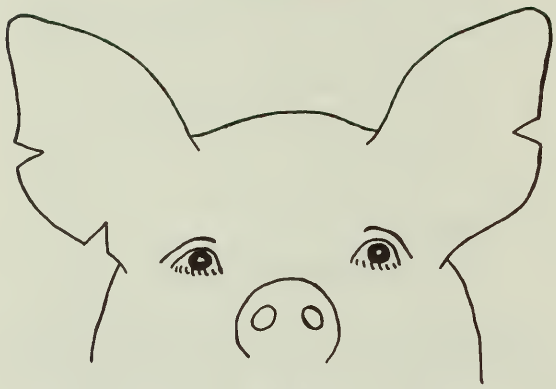


An ear-notching system for identifying individual pigs. The right ear is used to identify each litter, the left ear to identify the individual pig in the litter.

In either ear the units position is nearest the head, the "three" position at mid ear, and the "five" position near the tip. A combination of notches will provide all other numbers. For example,

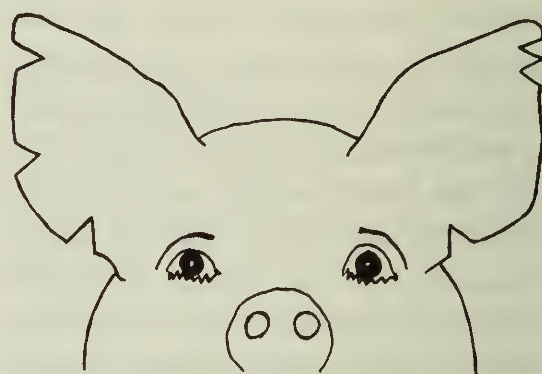
2=1+1	8=3+5
4=1+3	9=1+3+5
6=1+5	10=no notches
7=1+1+5	11=1+5+5

Various combinations are illustrated below. Reading this system of notching requires very little practice.



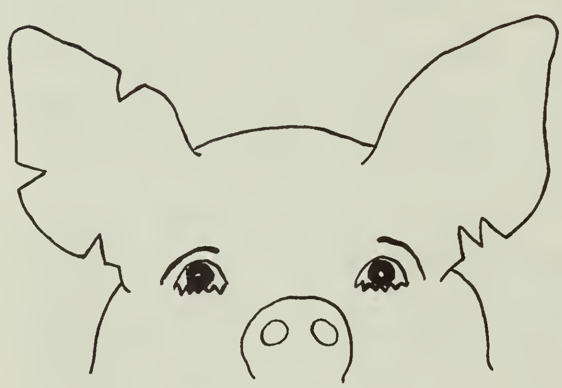
NO.43

4TH LITTER, 3RD PIG



NO.091

9TH LITTER, 11TH PIG



NO.342

34TH LITTER, 2ND PIG

NO.620

62ND LITTER, 10TH PIG

Examples of ear-notching combinations to identify individual litters and pigs.

The large numbers have greatest application in large herds but they are also useful in smaller herds, where consecutive years may be assigned different blocks of litter numbers for easy identification of pigs of any age. The method illustrated will individually identify all pigs in a total of 99 litters. This can be expanded to 999 litters by using the upper edge of the left ear in the same manner.

Purebred pigs intended for registration must be individually identified by tattoo markings at an age under eight weeks and before they are weaned. In tattooing, care must be taken to prevent injury that may lead to the condition known as "cauliflower ear." A recommended practice is to tatto toward the outer edge of the ear and along the length of the ear between the large veins and cartilage folds. If done correctly, the identification will remain legible for the duration of the animal's life.

The tattoo number should be identical with the number notched into the pig's ear. This will often eliminate the necessity for reading tattoos.

b. Individual Performance—Proper identification at birth makes possible the recording of individual performance. The number of teats should be checked and recorded before the pigs are weaned. The number of functional teats cannot be determined at this age but normal appearance and uniform spacing of the nipples are essential. Both sexes must be checked; boars with teat or mammary deficiencies may transmit these to their progeny. Sex is recorded at this time along with remarks concerning abnormalities of any kind. Failure to maintain complete records on these items will be detrimental to breeding progress.

Total weight of the litter taken at or near weaning provides necessary information on the nursing and mothering ability of the dam. Although the weight of each pig is not essential, such information may be useful for early culling or as a check against future development.

After weaning and before the time comes for selection, pigs may be sold for breeding or slaughter or they may die. The cause and date of such disposal should be recorded. This provides valuable information on the average merit and vigor of each litter. Market grade and age of pigs shipped to slaughter will also furnish a guide to the quality and growth potential of the litter.

At least once each year the progeny records should be summarized for each sow and each sire used in the breeding herd. Comparison of these progeny records provides a basis for sound decisions concerning culling and replacement of breeding stock.

R. O. P. Testing—The Canada Department of Agriculture administers a testing program known as the Record of Performance Policy for Purebred Swine. It is open to all breeders who own at least five registered females and one registered boar of a breed recognized in Canada. The essential feature of the test is the feeding of a litter group of four pigs on a standard ration from weaning to market weight (200 pounds). At slaughter, carcass measurements are made and the average rate of gain, feed efficiency, and carcass quality of the test group are reported to the breeder.

Although the R.O.P. test provides a progeny test for both the sire and the dam, it is essentially a test of a mating. It provides a litter-mate record, or a "sib-test" of the remaining members of the litter and of all future litters produced by the same mating. This point cannot be stressed too strongly. If test results are below average, the mating should not be repeated and the litter mates should be discarded. Boars and sows whose progeny have performed poorly for growth rate, feed efficiency, or carcass quality should be culled. Conversely, matings that give above-average performance for these traits should be repeated so as to multiply stock that have superior genetic potential. This practice will lead to the most rapid propagation of desirable breeding stock.

Breeders may also measure the growth rate of pigs by home testing under uniform conditions. Useful carcass information can be obtained on the live animal by probe measurements of fat thickness over the shoulder, back and loin. Such testing will identify the best litters in the herd and the outstanding boars and gilts from these litters should be used as replacement breeding stock.

One probing technique requires the insertion of a thin metal ruler through a small skin incision made with a sharp knife. Fat tissue offers little resistance to the ruler so that, with a little experience, the firmness of the muscle underlying the fat will be recognized readily and thus the depth of fat measured. Probing may also be accomplished by use of the "lean meter", a device developed by the University of Purdue. This instrument consists of a slender needle which is directed through the surface fat tissue and records electrically the depth at which the underlying lean is contacted. With experience, either technique will prove accurate. The average for three to six probes about evenly spaced along the back will provide a reasonable measure of carcass fatness. To provide valid comparisons, pigs must be of the same age or stage of development when probed.

Use of Records in Selection

Performance records are used for culling inferior stock and for selecting replacements. Selection and culling are, of course, opposite sides of the same coin. Inferior animals are discarded or culled; those that remain are automatically selected for breeding use. Conversely, the best may be selected and the remainder culled. The following paragraphs outline first the culling of mature breeding stock and then the selection of replacements from among young gilts and boars.

CULLING of mature stock means discarding animals that, because of age or performance, are not an asset to the herd. Parents that have produced superior progeny should be retained. Comparison of progeny performance will be made from the sow and sire progeny summaries mentioned earlier. The R.O.P. test is the best basis for evaluating the performance of each breeding animal in the herd and every breeder of pedigree swine is well advised to submit to test the first litters produced by each boar or gilt added to his herd. Early testing will establish whether replacement stock can transmit to their offspring the desired levels of performance. Those that cannot should be culled immediately.

What emphasis should be given to size and weight of the litter at weaning? Selection for them is unlikely to be rewarding because of their low heritability, but can they be ignored completely? The answer is no! Sows with poor reproductive performance should not be tolerated in any herd. Although litter size and weight will have little value in the selection of replacement gilts and boars, these traits can be useful in the culling of sows. Herd efficiency will be improved by eliminating females that, for any of a variety of reasons, fail to produce litters of satisfactory size and weight. Breeding a few more females than are actually required will permit the early culling of those that have a poor breeding or farrowing record.

One word of caution concerning the culling of boars. Many excellent boars are culled each year for no reason other than excessive weight. Replacing a proven sire with an unknown young boar is often an unnecessary gamble. With careful attention to ration to minimize weight, adequate exercise to keep him active, and use of a crate for breeding gilts, the useful service life of a top-quality sire can be extended greatly.

One other aspect of culling also should be mentioned. Many breeders sell their top-quality gilts and boars, believing that this is good business and believing for some strange reason that they themselves can get along with the second best. In terms of improving their own herds this is bad business. The only sure way to herd improvement—and thus to breed improvement—is to retain the best in the pedigree herds and to ruthlessly cull all inferior animals.

SELECTION means choosing superior individuals to replace those that have been culled. The first principle here is to seek replacements only from litters that have performed well, preferably litters that have given high performance when tested on R.O.P. Whether R.O.P. records are available or not, the litter mates should have grown rapidly and produced top market grades. Uniform high performance among the members of the litter is very desirable. The second principle is to choose from these superior litters, individuals that are outstanding in weight for age, vigor, strength of feet and legs, teating, and general conformation. Visual appraisal of conformation can be complemented by probe measurements of fat depth.

The selection of a boar is of great importance and every available record should be utilized fully to ensure the best possible choice. A young, unproven boar must be evaluated on his own as well as his litter-mate performance. Seek the best pig from the best-testing litter sired by a boar whose progeny by other matings have been of uniformly high performance. The qualities of a herd sire will make a lasting impression on a herd. Undesirable traits introduced by using an inferior sire may take years to erase.

Selection within the herd.—The desirability of making selections from within the herd has already been emphasized. This practice will improve the accuracy of selection by limiting the extent to which environmental differences obscure or mask genuine genetic differences. For this same reason, gilts or boars being compared for selection should be about the same age and should have been developed under uniform feeding and management. It is also important to make final selections when the boars and gilts are at or near market weight. Appraisal at much lighter or much heavier weights is not a satisfactory guide to potential market acceptability of their offspring.

Within-herd selection is generally applicable to the choosing of replacement gilts. It also applies to the selection of boars for herds being developed as closed strains.

Selection between herds.—Under many circumstances, breeding stock must be selected from outside herds. Because of environmental differences, comparisons between herds are not reliable unless the pigs have been tested under the same conditions. The only way such tests can be made is through the R.O.P. testing policy.

Reports of R.O.P. tests may be used for identifying superior herds and the best litters within those herds. Replacement boars should be sought from among the litter mates of such litters or from a litter of the same mating. Beware of a boar whose sire has limited test information or whose progeny have shown considerable variability. Beware also of a herd that lacks uniformity among its brood sows. Breeders who follow a constructive and consistent breeding and selection program will have developed strong sow herds with great uniformity of character and performance. It is from such breeders that replacement boars should be chosen.

Every practical breeder knows that, regardless of the selection method used, there will be disappointments. A boar or gilt may fail to transmit to its offspring the outstanding qualities for which it was selected. Even a satisfactory mating may prove less than satisfactory when repeated. Such experiences do not invalidate the selection procedures outlined. However, they do emphasize the need for consistent selection generation after generation, every generation being thoroughly proven through a comprehensive testing and recording program.

In summary, these are the principles of a constructive breeding program:

- The goal of the program must be the production of breeding stock improved for traits of economic importance to commercial producers.
- Selection of genetically superior breeding stock is essential to improvement. Selection must be accompanied by ruthless culling of inferior stock.
- Selection must be consistent, generation after generation.
- Accurate written records provide the only sound basis for consistent selection.
- The first requirement of good records is a marking system for identifying each pig very soon after birth.
- To be most effective, selection must be concentrated on a minimum number of traits. Items of high economic importance that respond to selection should be emphasized.
- The accuracy of selection is greatly increased by making comparisons within the herd.
- Planned use of a mild inbreeding program is necessary for development of a true-breeding or prepotent strain.
- Prepotency for desired performance traits requires that the inbreeding program be accompanied by selection.

COMMERCIAL SWINE BREEDING

The performance traits important in commercial swine production are identical with those described under pedigree breeding, namely, weaned litter size, vigor, rate of growth, efficiency of feed utilization, and carcass quality. However, the goal in pedigree production is to develop foundation stock that will transmit improved performance to their offspring, whereas commercial production is concerned primarily with the economic production of quality market pigs. This difference in objectives means that the selection and breeding practices recommended for commercial production differ in certain respects from those recommended for producing purebred swine.

A basic requirement of successful commercial breeding operations is a sow herd capable of weaning large, vigorous litters. The choice of mating system is of vital importance to development of such a herd.

Mating Systems for Commercial Herds

There is abundant scientific and practical evidence to show that maximum litter size, weaning weight, and vigor are most likely to be obtained by taking advantage of the genetic phenomenon known as hybrid vigor. Thus, a hybrid female can be expected to wean larger, more vigorous, stronger pigs than can be expected from her parental breeds or strains. For this reason, crossing is now generally recognized as the best breeding procedure for commercial production. But the benefits of crossbreeding cannot be obtained simply by scrambling breeds or breed strains together. The basis for success must be a carefully planned, systematic program designed to maintain a high level of hybrid vigor in the brood sows as well as in their offspring. Of the six mating systems that are of specific use to the commercial producer, four involve the crossing of breeds.

OUTBREEDING means the mating of unrelated animals within a pure breed. This common method involves the use of registered boars on sows of the same breed. Successive herd sires are usually chosen to correct specific faults observed in the herd. Consequently, outbreeding is likely to yield variable results. It does not usually result in hybrid vigor.

STRAIN CROSSING, a less common form of outbreeding, depends upon the existence of distinct strains within the breed. Systematic crossing of quality strains that have been found to "nick," or combine, well can provide reasonably consistent performance. A more complete discussion of outbreeding and strain crossing may be found in the section describing breeding systems for pedigree herds.

A breed strain may be defined as a group of animals more closely related to each other than they are to the rest of the breed. However, this requirement is not sufficient in itself. The animals of a true strain must also have genetic likeness—they must resemble each other and they must give uniform and predictable breeding results. This likeness can be obtained only by following the mating system known as inbreeding.

The SINGLE CROSS, another common method, is best defined as the mating of a purebred or high-grade sow of one breed with a purebred boar of another breed. All offspring are marketed, and replacement boars and females are purchased from an outside source.

In CRISSCROSSING, boars from two breeds are used alternately. In each generation, replacement females are retained from the current crop of gilts and mated to a boar of the breed opposite to that of their sire. When foundation stock is chosen for a crisscross program, the females should be of the most prolific breed.

In Rotational crossbreeding, boars of three or more breeds are used in an ordered and planned sequence. It provides a greater potential for hybrid vigor than does crisscrossing. The initial cross should utilize purebred females of the most prolific breed. In subsequent generations, replacement gilts are retained from within the herd.

Crisscrossing and rotational crossbreeding are relatively straightforward. They permit the selection of replacement females from within the herd so that purchase of breeding stock is limited to boars. In small herds a new boar must be purchased each time replacement females are retained. Herds of sufficient size to use two or more boars will not have this problem. In either mating system, the use of nonwhite boars in the program will eventually lead to the production of a certain proportion of colored pigs.

In Repeated three-way crossing, hybrid females of a specific two-breed cross are mated to boars of a third breed. All three-breed offspring, male and female, are marketed. Replacement females must always be of the original two-breed cross. If the third breed is white, this program will usually guarantee white market pigs regardless of the colors of the breeds contributing to the hybrid dam. The repeated three-way cross produces pigs more nearly uniform in vigor, growth, and carcass quality than the other forms of systematic crossbreeding.

Choice of mating systems.—More hybrid vigor can be expected from breed crosses than from crosses of strains within breeds. Thus the choice of mating systems is likely to be between the four breed-crossing systems described.

The single cross makes no use of the hybrid female for litter production. For this reason, single crossing is not the answer to a sound crossbreeding program.

Crisscrossing and rotational crossbreeding are popular breeding systems because they do not require the purchase of replacement gilts. However, their application in small commercial herds is limited by the fact that, to avoid inbreeding, a new herd sire must be purchased each time replacement gilts are saved. Moreover, with these breeding systems, the females are always related breedwise to the boar with which they are mated. This does not permit maintenance of the highest possible levels of hybrid vigor in the female breeding stock.

The repeated three-way cross does not have this deficiency. Also, as was stated before, this breeding system will produce pigs of greater uniformity than the other crossbreeding procedures. One practical limitation is the fact that separate purebred herds must be maintained for each of the three breeds chosen for crossing. However, some breeders are now specializing in the production of hybrid gilts for use in repeated three-breed crosses and the future is likely to bring a considerable expansion in this phase of the industry.

Breeders who specialize in producing hybrid females for use in repeated three-way crosses usually maintain herds of one or both of the pure breeds that are crossed to produce the hybrid gilts. In this way they control the production of the foundation breed strains and can adopt selection and breeding methods that will improve the performance of the hybrid gilts

they offer for sale. Only by controlling the foundation breed strains is it possible to produce hybrid females that will give dependable, high-quality breeding performance.

The obvious question at this point is what three breeds should be used. There appears to be little choice in this matter. The only breeds that can be recommended in Canada are the Yorkshire, Landrace and Lacombe. This is partly because of the market preference for white pigs. More importantly, however, these breeds are R.O.P.-tested in large numbers annually and breeding stock with proven performance for growth rate and carcass quality is available. All other breeds are tested rarely and effective selection of quality breeding stock is difficult.

Selection in Commercial Herds

Selection is just as important to the commercial producer as it is to the breeder of purebred pigs. In certain respects it may be even more complex for it requires the evaluation of breeds and breed strains not only in terms of their own merits but also in terms of their combining ability

Selection of foundation strains.—Breeds and breed strains differ in their crossing potential. Thus the first and most vital selection decision will be the choice of foundation strains that can offer the greatest "nicking", or combining, ability. Though crossing potential cannot be predicted in advance, the search for superior crossing combinations will be guided by the following three principles:

- The opportunity for hybrid vigor is greatest when the genetic relationship between the chosen strains or breeds is least. For this reason breed crosses are expected to be superior to strain crosses within a breed.
- The strains chosen for crossing within or between breeds must have established satisfactory levels of performance for the economically important performance traits of weaned litter size, vigor, growth rate, efficiency of feed utilization, and carcass quality.
- The chosen strains should be reproducible; in other words, there should be some assurance that breeding stock of the strains will be similar in performance from one year to the next.

Hybrid vigor is not important for carcass traits. Consequently, acceptable carcass quality of the crossbred progeny can be ensured only by selecting parental strains proven in this regard. The breed strains chosen as the foundation for a crossing program should also have proven ability for growth rate. The most valid basis for evaluating these traits is R.O.P. test information. Additional records maintained by breeders of pedigree herds may be useful if sufficiently detailed. Information on litter size, mothering ability, physical soundness, and vigor can be obtained only from examination of the herd and the herd records.

Selection of foundation animals.—Choice of breed strains is an important first step in planning a crossing program. Equally important is the choice of the individual foundation animals. Foundation stock should be above average for all the traits of economic importance. In particular, in the selection of gilts emphasis should be given to potential reproductive performance and boars should be outstanding individuals with proven litter-mate or parental performance for growth rate and carcass quality.

Evaluation of crossing potential.—The initial cross between the chosen foundation breed strains will indicate crossing potential for feed-lot performance and carcass quality. Information may also be obtained on preweaning vigor and survival. However, preweaning performance can be limited by the mothering ability of the purebred dam, and the real test of the crossing potential of the chosen strain will not be made until the crossbred gilts are used for breeding. These gilts, because of their own hybrid vigor, are expected to have superior mothering ability and should wean larger, heavier, and stronger litters than their dams. Thus the real test of "nicking", or combining, ability of breed strains is made by evaluating the reproductive performance of the hybrid female.

Measuring and Recording Performance

Records are essential to success in commercial swine breeding. Sound evaluation of potential crossing performance of breed strains can be made only by careful use of records. Dependence on memory alone can lead to costly errors.

For a detailed description of records and their use in selection see pages 23 to 28. The ear notching system described there can be simplified so that all pigs in a litter are marked with a single notching pattern that identifies litter only. Such identification is an essential part of records.

Evaluation of crossing potential or of replacement breeding stock in a commercial herd requires the following records:

- Litter number—each litter identified by its own ear notch
- Identification of both sire and dam
- Date of farrowing
- Number of pigs born
- Number of pigs weaned
- Total weaning weight of litter

The following information should be recorded for each pig in a litter:

- Disposal date and cause—death, market, or breeding use
- Age at slaughter
- Slaughter grade
- Probe measurement (page 26) of back fat thickness at market weight.

Use of records in evaluating combining ability.—The real test of combining ability is provided by the reproductive performance of the hybrid female. Records on litter size at birth, survival to weaning, and weaned weight of the litter have specific value in evaluating the "nicking", or combining, ability of the breed strains chosen for the crossing program. Should the hybrid females of the chosen cross prove unsatisfactory in these traits a different choice of foundation breed strains will be desirable.

Crosses between individual animals from good bacon breeds may occasionally produce disappointing carcasses. If the crossbreds have performed well for other traits, crossing of the breeds should not be discontinued. Quality in the crossbreds is largely determined by the carcass merit of the individual animals entering the cross and can be improved by selection of boars and replacement gilts that have superior litter-mate records for carcass quality and are themselves of superior conformation.

Litter records of each breeding sow should be summarized annually. All items of performance should be considered and sows whose litters have not performed well in terms of number marketed, growth rate, and carcass should be culled. A few extra gilts should be bred annually so that unsure breeders or those that produce or wean small litters can be culled immediately.

Selecting replacement gilts.—The desirability of maximum hybrid vigor in the breeding females has already been emphasized. Thus, hybrid gilts selected for breeding should have above-average hybrid vigor—in other words, strong vigorous gilts with good weight for age. Further, gilts should be chosen from litters that are uniformly superior in these traits. They should be physically sound, show good udder development, have at least 12 and preferably 14 well-spaced teats of normal appearance, and have desirable conformation in terms of length, ham development, and leanness. These requirements of gilt selection are applicable to all systems of breeding.

Selecting replacement boars.—Planned crossbreeding programs require the systematic purchase of replacement boars. In selection of such boars, outstanding performance for growth rate, efficient feed utilization and carcass quality should be required. The accuracy of selection will be greatly improved if boars are chosen from herds that have given consistently high performance when tested under the R.O.P. policy. The individual boar should have desirable conformation, vigor, physical soundness, and good weight for age. Final selection is best made when the boar is about market weight.

Color Inheritance

Color is important to the producer of commercial pigs because of market discrimination against pigs with black hair or skin. Purebred Yorkshires, Landrace, and Lacombes are expected to be genetically pure for white. When crossed either with each other or with the Berkshire they should produce white offspring. The Tamworth, in crosses with the white breeds, may produce a few sandy-colored or red and white pigs. Black and white spotted pigs or a "blue roan" color may result when the white breeds are mated with the Large Black, Hampshire, or Wessex breeds.

Pigs of the colored breeds when crossed with each other will produce nothing but colored offspring. If they are crossed with white crossbred pigs that have one colored parent, about half of the offspring will be colored.

Use of a colored breed in a crisscrossing or rotational crossbreeding system will lead eventually to the production of colored pigs. Use of one or two colored breeds in the repeated three-way cross will not produce colored market pigs if the purebred boar used on the hybrid females is from a white breed.

In summary, these are the essential features of a constructive breeding program for commercial swine production:

- High sow productivity in terms of weaned litter size and vigor is essential to efficient commercial production.
- The most promising method for obtaining this goal is planned use of the genetic phenomenon known as hybrid vigor.
- Hybrid vigor is obtained by crossing distinct breeds of strains. Be-

cause the potential for hybrid vigor increases as the genetic relationship between the parent strains decreases, crosses between breeds are expected to be superior to crosses between strains within a breed.

- The full benefits of hybrid vigor will not be obtained until the hybrid female is used for breeding.
- The crossbreeding system used should be systematically planned to maintain a high level of hybrid vigor in the sows and in their offspring. The repeated three-breed cross is expected to give results superior to those obtained from other crossing systems.
- Breeds and breed strains will differ in their crossing potential. Since "nicking", or combining, ability cannot be predicted, superior crossing combinations must be identified by means of test crosses.
- Breed strains chosen as the foundation for a crossing program should have proven ability for growth rate and carcass quality and the specific animals selected should be of high individual merit.
- Successful crossbreeding requires advance planning of a systematic program and adherence to the plan.

ABNORMALITIES

Several abnormal or defective conditions occur in pigs. Some of these may be corrected by minor surgery. Others cannot be treated successfully and may seriously interfere with normal performance of the animal. At one time these conditions were thought to be completely controlled by inheritance and culling of all defective animals and their parents was recommended for "cleaning up the herd." Modern genetic knowledge on this subject indicates that this view was extreme. Though inheritance is involved in certain cases, other cases are of nongenetic origin and may more properly be termed "accidents of birth."

Knowledge on this question is far from complete, but the characteristics described in the following paragraphs are at present considered to be at least partly heritable. Pigs exhibiting any of the listed abnormalities should be culled, even if they have been made to appear normal by means of corrective surgery. Culling is suggested also for breeding animals that produce more than the occasional defective pig. Inbreeding is the method most likely to reveal the presence of undesirable inherited characteristics in the breeding herd.

RUPTURE, or scrotal hernia, is a condition in which one or more loops of the intestine pass through the inguinal ring into the scrotum. Minor surgery at the time of castration can correct this condition and produce a normal barrow. Inguinal rupture is seldom seen in females.

NAVEL RUPTURE, or umbilical hernia, occurs when the intestine passes through the abdominal wall at or near the navel. It is not uncommon and may be predisposed by a navel infection which weakens the abdominal wall at this site. It may be corrected by early surgery.

RIDGLING, or cryptorchid, pigs are males in which one or both of the testicles have failed to descend normally into the scrotum. Surgery may be used to alter a ridgling to a normal barrow.

Hermaphrodites, or intersexes, have a combination of male and female reproductive organs. Externally such animals appear to be female. The retained testicles may be removed surgically. Allied with this condition is one called "upturned vagina." It would be more correctly described as "upturned vulva." Females exhibiting this abnormal condition are usually, if not always, nonbreeders.

Atresia ani, or closure of the anal canal, may be corrected by surgery. For obvious reasons this condition must be recognized and treated very shortly after birth.

Inverted nipples are relatively common. This is a condition in which the teat canal is held inwards, so that normal milk flow is prevented. The teat lines of gilts—and boars—should be examined carefully when the pigs are selected for breeding to ensure that this condition does not exist. At the same time the number of normal teats, their evenness of spacing, and the incidence of rudimentary teats should be considered. A female cannot be expected to do a satisfactory job of nursing her litter unless she has an adequate number of well-spaced, functional teats. Well-spaced nipples of normal appearance are equally important in the boar, for his inheritance will contribute to the udder development of his female progeny.

Leg weaknesses of both genetic and nutritional origins are common in pigs. Usually these do not impair feed-lot performance but they may substantially reduce the duration of useful service from breeding animals. For this reason, leg weakness of any kind should not be tolerated in prospective breeding stock.

Other abnormal conditions of obscure origin include cleft palate, hydrocephalus, "amputated" limbs, blindness, hairlessness, and rigid forelimbs. Several of these conditions are known to be caused or duplicated by nutritional deficiencies.

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