Please do not write on this and Return it in good condition. Write your answers on a Separate piece of paper

9

Animal Breeding

Key Terms

Accuracy
Across-breed EPD
Animal breeding
Breed
Breeding soundness examination
Breeding value
Contemporary group
Expected progeny difference (EPD)
F_1
Feed efficiency
Generation interval
Genetic correlation
Heritability
Maternal effect
Parent average
Percentile
Phenotypic value
Porcine stress syndrome
Possible change
Predicted transmitting ability
Predicted transmitting ability net merit dollars
Quality grade
Rate of gain
Reliability
Single-trait selection
Sire summary
Type production index
Ultrasonic scan measures

Learning Objectives

After you have studied this chapter, you should be able to:

- Define *animal breeding* and explain its contributions to animal science.
- Describe the general principles of animal breeding as it applies to beef cattle.
- Define *heritability* and *genetic correlations*.
- Explain how to use EPDs in beef cattle breeding.
- Describe the uses and benefits of a beef cattle sire summary.
- Describe the general principles of animal breeding as it applies to dairy cattle.
- Explain why associations among traits are so important to dairy cattle selection.
- Identify goals on traits of emphasis in dairy cattle selection.
- Describe the DHI system and explain its use in dairy cattle selection.
- List the ways in which swine genetic improvement is similar to and different from the other major species.
- Describe the difference in the way breeds influence the swine industry compared to the other industries.
- Describe the general principles of animal breeding as it applies to sheep.

INTRODUCTION

Animal breeding is the application of genetic principles to improve the efficiency of production of farm animals. It is a field that has contributed enormously to animal agriculture. By applying the principles of animal breeding, the productivity of all the food-producing species has increased. Much of that progress occurred in the last half of the 20th century because of the understanding of the nature of genetic variation, including at the molecular level, the increased application of the tools of the animal breeder to herds and flocks and the advent of sufficient computing power to deal with the complex mathematical models that are necessary to most fully identify superior individuals. Scientists have made remarkable progress in providing the tools to make improvements logically and systematically in the major food-producing species. For many reasons, animal breeding work on horses, goats, and the companion species has not achieved the same level of understanding. The primary reason is economic justification. It is hard to justify the same level of research directed to a species that is of lesser economic importance. Most of this research has been done at the land grant universities of the United States. Their mission and limited resources have dictated that the research be aimed in the direction that will net the greater good.

Animal breeding The use of biometry and genetics to improve farm animal production.

Animal breeding is a field that is changing, just as all science is changing. The tools of genetic engineering, such as marker-assisted selection and transgenics are enhancing the work of animal breeders, enabling genetic progress to occur much more rapidly. It is an exciting time in the history of genetic improvement as the tools of the molecular biologist are combined with the tools of the quantitative geneticist.

This chapter is divided into sections based on species. Each section discusses the tools and goals of animal breeding as directed at that species. Only beef cattle, dairy cattle, swine, and sheep are included because these are the species for which the techniques and applications are the most advanced and useful. The chicken is the only major exception to this statement. However, the application of animal breeding principles to the poultry industry is almost completely in the hands of the major breeding companies that dominate that industry. On a commercial basis, virtually no producer is involved in making breeding decisions. For this reason, poultry is excluded. The poultry breeder employs the same techniques that are discussed for other species and the progress during the last 50 years has been nothing short of astonishing.

BEEF CATTLE GENETIC IMPROVEMENT

The beef cow-calf producer is in business to produce beef as efficiently as possible. Modern breeding requires selecting for a balance of production performance (such as rate of gain) and end product merit (such as tenderness) to meet consumer expectations for eating satisfaction. Bull selection is a primary area in which producers can make directional change in their herd genetics. A wealth of performance information is available for what appears to be an endless list of traits.

The major areas of economic importance include reproductive efficiency, mature size, calf growth, maternal performance, and carcass traits. The level of production must be matched with available feed resources and the production environment. The design of the herd is not an easy task because very rarely is a successful breeding program designed around selection for a single trait. Fortunately, studies in animal breeding have quantified the genetic variation in beef cattle traits, so that beef cattle producers may use this information in producing better beef through designed breeding programs.

The following sections address key areas of genetic improvement in the beef cattle industry. Animal breeding principles are related to specific beef examples and current genetic selection tools are discussed.

Heritability

An understanding of the principles of heritability and genetic correlations for beef cattle traits is needed to better use the variety of selection tools and **breed** trait information that is available. Differences in traits measured in animal populations are the sum of genetic and environmental factors associated with those traits. **Heritability** indicates the proportion of the differences between individuals that is genetic. Heritability is not the same in every herd. It can vary between herds and within a herd if the management or the system of mating changes. Much research has been directed toward the study of heritability for various traits in beef cattle. Average heritability estimates from many studies for beef cattle are shown in Table 9–1. In general, reproductive traits tend to have low heritability (<0.20), growth traits tend

Breed Animals with common ancestry. They have distinguishable characteristics, and when mated with others of the breed, produce offspring with the same characteristics.

Heritability A measure of the amount of phenotypic variation that is due to additive gene effects. The proportion of differences between individuals that is genetic.

Table 9–1
HERITABILITY ESTIMATES FOR BEEF CATTLE

Trait	h^2
Birth weight	0.35
Weaning weight	0.30
Weaning score	0.25
Feedlot gain	0.45
Carcass grade	0.40
Fat thickness	0.33
Rib eye area	0.58
Marbling	0.42
Retail product %	0.30
Calving interval	0.08
Gestation length	0.35
Pasture gain	0.30
Yearling weight	0.40
Feed efficiency	0.38
Dressing %	0.38
Tenderness	0.55
Cancer eye	0.30

Source: Adapted from Cundiff, L.V. and K.E. Gregory. 1977. Beef Cattle Breeding. USDA Ag. Inf. Bull. 286 and Lasley, J.F. 1978. Genetics of Livestock Improvement. Prentice-Hall.

to have moderate heritability (0.20–0.40), and carcass traits tend to have fairly high heritability (>0.40).

Probably the most practical use of heritability is that it indicates the ease with which we can make genetic improvement through selection. As we can see from the published estimates of heritability in Table 9–1, it is much easier to show selection progress for growth and carcass traits than for reproductive traits. This has led some beef cattle producers to decide that reproductive traits should not be included in a selection program. However, this idea overlooks the fact that reproduction is the most important factor in the efficiency of most beef enterprises. The importance of traits associated with reproduction makes up for the low heritability, so reproduction should be considered for most selection programs.

Also, heritability indicates the proportion of the superiority in an individual or in a group of individuals that can be passed on to the next generation. This property is used to estimate breeding value. **Breeding value** is the value of an individual as a parent. The actual breeding value of an individual is never known, but it can be estimated from the performance of the individual and its relatives. Common information on relatives includes progeny, sire, dam, and sibling records.

Breeding value The worth of an individual as a parent.

Genetic Correlations

Very rarely are successful breeding programs based on **single-trait selection;** therefore, it is important to understand the genetic relationship between traits of interest. **Genetic correlation** refers to a situation in which the same or many of the same genes control two traits. The magnitude of genetic correlations may vary between −1 and +1. A genetic correlation of 0 indicates that different genes influence the two traits; thus the traits are uncorrelated. If the sign of the genetic correlation is positive, then the breeding values of the animals for the two traits tend to vary together. The reverse is true for a negative correlation.

Single-trait selection Selection for only one trait or characteristic.

Genetic correlation The situation in which the same or many of the same genes control two traits.

The absolute value of the correlation indicates the strength of the association between the two traits. When a genetic correlation exists between two traits, it means that the correlation does not equal 0. Rarely does this mean that the correlation is perfect at +1 or −1. For example, a genetic correlation of 0.10 is positive, but the magnitude of the correlation does not imply a strong genetic association between the two traits.

Feed efficiency Product (gain, milk, eggs, and so on) per unit of feed.

Rate of gain Pounds of gain per day over a specified period.

Knowledge of the magnitude of the genetic correlation between various traits is useful in a selection program. For example, **feed efficiency** is a difficult and expensive trait to measure. **Rate of gain** is a relatively easy and inexpensive trait to measure. A favorable genetic correlation exists between rate of gain and feed efficiency. Selection of sires can be directed toward rate of gain, which is easily measured. If the rate of gain is improved through selection, some improvement is expected in feed efficiency due to the favorable genetic relationship between the two traits. Genetic correlations are not always favorable. For example, selection for increased yearling weight has an adverse effect on calving difficulty. The fact that the genetic correlations are not perfect gives breeders the opportunity to try to identify sires that are exceptions to the unfavorable correlation.

Table 9–2 shows genetic correlations between growth and carcass traits. Some of these relationships may be beneficial if they are considered in a complete breeding program. As you can see, genetic correlations are seldom perfect. For example, many of the genes that control birth weight also control carcass weight in the same direction, as indicated by the positive genetic correlation of 0.60 in Table 9–2. Remember that the relationship is not perfect. Genetic correlations indicate what is likely to happen to one trait when selection is practiced for another trait.

To design the genetics of the beef animal for a particular production level, selection objectives must balance many traits of economic importance. Continued interest in carcass merit will result in an increase in multiple-trait selection practices in breeding programs. This makes information on the genetic correlations between carcass and other traits even more important.

Performance Information

To make genetic change in a desired direction, cow-calf producers have to know the current performance level of their herd. Through knowledge of beef cattle traits and their heritabilities, producers can use available selection tools to design a breeding program. The program should be designed with performance items in the plan

Table 9–2
GENETIC CORRELATIONS BETWEEN GROWTH AND CARCASS TRAITS

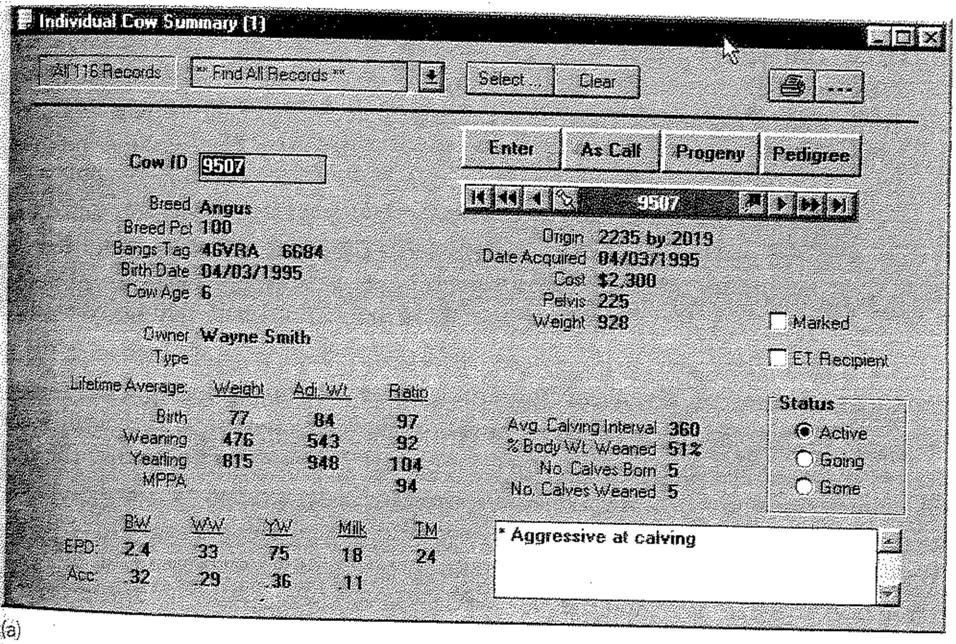
Trait	ADG^W	ADG^F	CAR	FAT	REA	MAR	SHR[1]
Birth weight (BW)	0.28	0.61	0.60	0.27	0.31	0.31	−0.01
ADG to weaning (ADG^W)		0.49	0.73	0.04	0.49	0.31	−0.05
ADG feedlot (ADG^F)			0.89	0.05	0.34	0.15	0.06
Carcass weight (CAR)				0.08	0.44	0.25	0.00
Fat thickness (FAT)					−0.44	0.16	0.26
Rib eye area (REA)						−0.14	−0.28
Marbling (MAR)							−0.25

[1] SHR 5 Warner-Bratzler shear.

Source: Adapted from Benyshek, 1988.

that address breeding, calving, weaning, yearling, carcass, and maternal breeding objectives.

Performance programs come in many forms. Core programs begin at the ranch. Seedstock and commercial cow-calf producers have different needs. Seedstock producers sell breeding animals. Commercial cow-calf producers market calves to be finished for market. Also, herd size can influence the degree of detail that a producer is willing or able to assemble. Keep in mind that meaningful cow-calf records may be handwritten or computerized (Figure 9–1). The challenge is to choose performance records that are useful in making management decisions.



Cow ID 9507

Breed Angus
Breed Pct 100
Bangs Tag 46VRA 6684
Birth Date 04/03/1995
Cow Age 6

Owner Wayne Smith
Type

Origin 2235 by 2019
Date Acquired 04/03/1995
Cost $2,300
Pelvis 225
Weight 928

☐ Marked
☐ ET Recipient

Lifetime Average:	Weight	Adj. Wt.	Ratio
Birth	77	84	97
Weaning	476	543	92
Yearling	815	948	104
MPPA			94

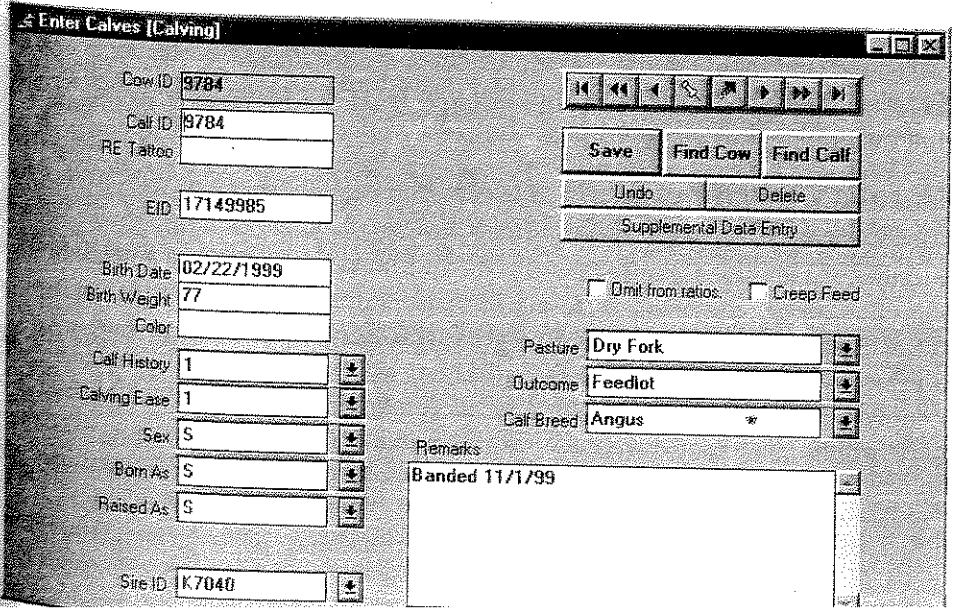
Avg. Calving Interval 360
% Body Wt. Weaned 51%
No. Calves Born 5
No. Calves Weaned 5

Status
● Active
○ Going
○ Gone

	BW	WW	YW	Milk	TM
EPD:	2.4	33	75	18	24
Acc:	.32	.29	.36	.11	

* Aggressive at calving

(a)



Cow ID 9784
Calf ID 9784
RE Tattoo

EID 17149985

Birth Date 02/22/1999
Birth Weight 77
Color
Calf History 1
Calving Ease 1
Sex S
Born As S
Raised As S

Sire ID K7040

☐ Omit from ratios
☐ Creep Feed

Pasture Dry Fork
Outcome Feedlot
Calf Breed Angus

Remarks
Banded 11/1/99

Figure 9–1 *(a) Cow summary report and (b) calf data entry form.* (Source: Cow Sense Herd Management Software, Midwest MicroSystems L.L.C. Used with permission.)

Seedstock breeders work closely with breed associations to develop extensive on-farm performance programs. Data collection and compilation are accomplished through strong ties between breeders and association personnel. Records across the country and, in some breeds, internationally, are used to generate genetic values for animals within a breed. Additional supplements to on-farm performance programs may include, but are not limited to, feedlot and carcass data collection programs and bull evaluation center data.

Commercial producers need an effective performance program that encourages the culling of inferior animals and selection of herd replacement breeding stock. Very rarely are effective selection programs based on single traits. Sire selection is the area in which commercial herds can place the greatest selection pressure. Commercial producers may rely on their seedstock "partners" to remove some of the guesswork in their bull selection and assist them in the use of specialized selection tools such as expected progeny differences (EPDs), discussed later in this chapter. Commercial cow herd and calf crop records are the nuts and bolts that assist producers in choosing the necessary bull power. Currently, a greater percentage of commercial and seedstock producers are forming stronger links to better understand performance progress and genetic tools from conception to carcass.

Sometimes commercial producers think they need EPDs on their crossbred cows to use EPDs. This is not true. The choice of sires has a tremendous impact on the genetic improvement of the herd. The producer does not need to have registered cows, or straightbred cows of one breed, to use EPDs as a sire selection tool.

A good understanding of the herd performance level for reproductive, growth, and maternal merit, and even carcass merit, is the first priority. Calving and weaning percentages, pregnancy percentage, pounds weaned per exposed females, calf death loss, and average mature cow size are examples of decision-making tools. The sire selections are then made using EPDs to move the herd genetically in the desired direction. Throughout history, geneticists have studied methods for use in identifying superior individuals in beef cattle populations. Sire selection has tremendous value to the beef cow-calf operation. Choices of herd sires not only have an impact on the resulting calf crops, but also affect the performance of the cow herd if daughters of the sires are kept as replacement heifers. Ideally, beef producers like to select sires of desirable genetic merit for genetic improvement in economically important traits. Selection of desirable genetics to match with a cow herd is a challenging task. Fortunately, the concept of breeding value provides beef producers an avenue to make useful selection decisions. The background on breeding value estimation leads to a better understanding of the merit of EPDs.

Genetic Evaluation, Breeding Value, and Expected Progeny Difference

Breeding value is used as an estimate of the transmitting ability of an animal. Breeding value, or genetic merit, is calculated from information on an individual's performance and the performance of progeny, sibs, parents, grandparents, and so on. The information comes from purebred breeders who report data to the national herd improvement program for their breeds. The combined information from all contributors provides a national database for the breed. A mathematical model called an animal model (AM) is used to predict breeding values. These values are then used to calculate the expected progeny difference.

Expected progeny difference (EPD) A prediction of the difference between the performance of an individual's progeny compared to all contemporaries for the progeny.

Half of the breeding value is equal to the **expected progeny difference.** The word *difference* implies a comparison. Thus EPDs let us compare or rank the superiority of individual animals. EPDs provide a prediction of future progeny performance of one individual compared to another individual within a breed for a specific trait. The EPDs are reported in plus or minus values in the units of measurement for the trait. For example, birth, weaning, and yearling weight EPDs are reported in pounds. In contrast, fat thickness EPDs are reported in inches.

Each individual member of a breed can have EPD values calculated for it. Age, sex of calf, or status as a parent are not limiting factors. Even a newborn calf can be assigned EPDs. It is possible to compare any two members of a breed, regardless of location. However, EPD values may be used to directly compare only those animals within a breed. The EPD values for a Hereford bull may not be compared against the EPDs for an Angus or Limousin bull.

Preferential mating of certain individuals does not bias the results. A genetically superior bull can be mated only to genetically superior cows and his EPD will not be inflated. This is accomplished by adjusting for the EPDs of the cows to which he is mated. Also, any genetic change within a breed for a particular trait is accounted for by adjusting for genetic trend. Thus comparisons may be made across generations of cattle. Young bulls with no progeny may be directly compared with older sires that have progeny.

Maternal genetic values, such as milk EPD, may be computed for the maternally influenced trait—such as weaning weight. EPDs are comparable across herds because mathematical models used to calculate EPDs account for differences in environment and management.

National Cattle Evaluations The first national sire summary was published in 1971 by a beef breed association. For the first time, bulls within a breed could be compared across herds, across regions of the United States, and across generations. All of the major beef breed associations today conduct national cattle evaluations (NCEs) and compute EPDs as a service to their breeders. These values are published and generally made available at least once a year.

Contemporary Group In the collection of beef cattle performance information, breed associations recognize that contemporary group definition is critical. A **contemporary group** is a group in which animals of a given sex and age, having similar treatment, are given an equal opportunity to perform. The basis of sound performance testing relies on correct identification of contemporary groups. Accuracy in estimation of genetic differences within a group of animals depends on the accuracy of grouping.

Contemporary group A group in which animals of a given sex and age, having similar treatment, are given an equal opportunity to perform.

Growth Trait EPDs

EPD values are most useful when two individuals are compared directly. For example, consider the following birth weight EPD example of two sires. Assume both sires are from the same breed, and the EPDs have equal accuracies:

	Sire A	*Sire B*
Birth weight EPD, lbs	+5	−2

The expected difference in the progeny of Sire A and Sire B for birth weight is 7 lbs. Sire A has an EPD of +5 and Sire B has an EPD of −2. On the average, we should expect the calves of Sire A to be 7 lbs heavier at birth than calves of Sire B, if all calves are managed the same and have dams of similar genetic merit. The predicted performance difference is 7 lbs. Because EPDs only allow the prediction of performance differences, not actual performance, it is not possible to estimate the actual birth weight average for these calves.

The following is an example for weaning weight. It describes a weaning weight difference in the progeny of two bulls:

	Sire A	*Sire B*
Weaning weight EPD, lbs	+25	−10

The expected difference in the progeny of Sire A and Sire B for weaning weight is 35 lbs. Sire A has an EPD of +25 and Sire B has an EPD of −10. On the average, we should expect the calves of Sire A to be 35 lbs heavier at weaning than calves of Sire B, if all calves are exposed to the same environmental conditions and are out of cows of similar genetic merit.

An example for yearling weight follows. It describes a yearling weight difference in the progeny of two bulls:

	Sire A	*Sire B*
Yearling weight EPD, lbs	+50	+10

The expected difference in the progeny of Sire A and Sire B for yearling weight is 40 lbs. Sire A has an EPD of +50 and Sire B has an EPD of +10. On the average, we should expect the calves of Sire A to be 40 lbs heavier as yearlings than calves of Sire B, if all calves are managed in a uniform manner and have dams of similar genetic merit.

Breed Average EPD and Base Year

It is frequently said that an EPD is a comparison to an average bull. This, unfortunately, is not true. A zero EPD represents the average genetic merit of animals in the database at the time when sufficient information existed to calculate EPDs. Therefore, it represents a historic base point, or base year. Some breed associations now set the base year to a particular year. If the breed has made any genetic change for a trait, the average EPD for the trait will no longer be zero. Breed associations publish the average EPDs in the sire summaries made available to the public. Information printed in the summaries should be examined carefully before individual EPDs are studied.

Accuracy

Accuracy The measure of reliability associated with an EPD. If little or no information is available, accuracies may range as low as 0.01. A high accuracy would be 0.99.

Accuracy is the measure of reliability associated with an EPD. Each EPD value should have an accuracy assigned to it. Accuracy is expressed as a value between 0 and 1. A high accuracy (>0.7) means a higher degree of confidence may be placed on the EPD, and the EPD value is not expected to change much as further information is gathered. A low accuracy (<0.4) means that the EPD may change a great deal as additional information is gathered. Nonparent animals have lower accuracy values because no progeny information contributes to their EPD. From a practical standpoint, the EPDs are used to select bulls for use in the herd, and accuracies help determine how extensively to use them. Some sale catalogs do not list accuracies with the EPDs. For young animals with no progeny data, such as yearling bulls, accuracies are generally low. They improve as the animal has offspring to contribute to the data from which its EPDs are calculated.

Possible Change

Possible change The measure of the potential error associated with EPD values.

Possible change is the measure of the potential error associated with EPD values. Many sire summaries are starting to include these values. Possible change is expressed as "+" or "−" in the same units as the EPD. These values quantify the amount a certain EPD may deviate from the "true" progeny difference. Accuracy and possible change values share a relationship. As more information is accumulated, accuracy increases and possible change diminishes. For a given accuracy, the "true" progeny differences of two thirds of all animals evaluated within a breed are expected to fall within the plus or minus possible change value. The following example illustrates this point:

Birth weight EPD = +2.0 lbs Accuracy = 0.90 Possible change = ±1.3 lbs

Of all of the animals with this EPD and accuracy, two thirds are expected to have "true" progeny differences between +0.7 and +3.3. These "true" differences have a much greater chance of falling toward the center of the range defined by the possible change value than falling close to the extremes.

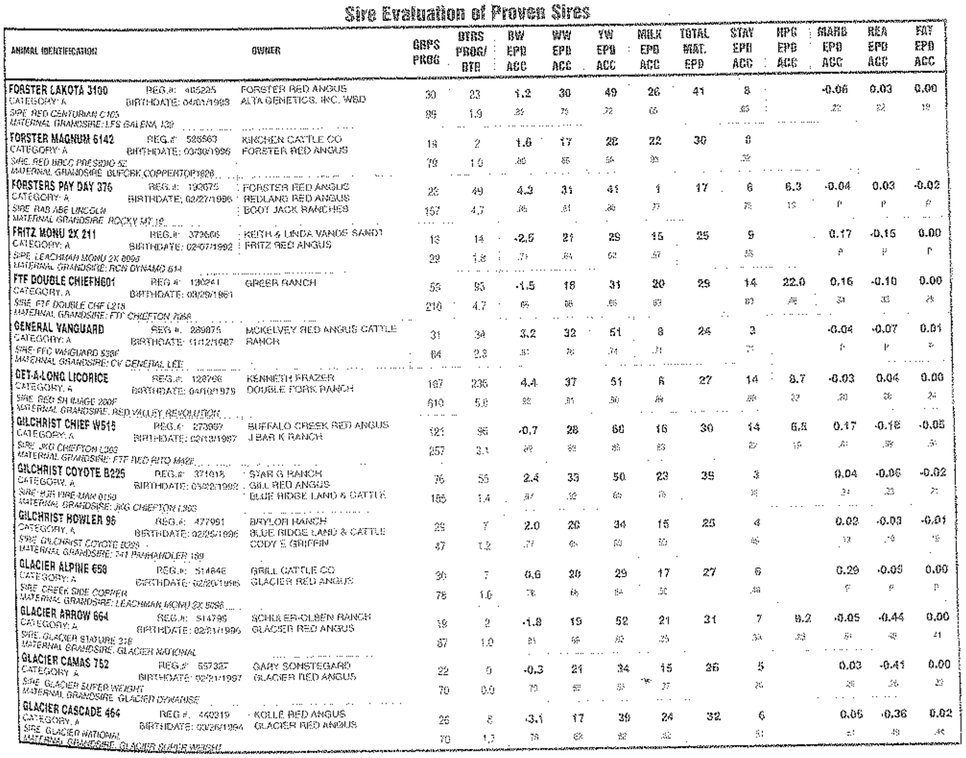
Also, one third of the individuals in the evaluation may have their "true" progeny difference values fall outside the range of +0.7 and +3.3. This means that one sixth of the individuals may have "true" values less than +0.7, and one sixth of the individuals may have "true" values more than +3.3.

Sire Summaries

Sire summary Genetic information published on sires available within a breed.

Sire summaries include a sampling of the available genetic material in each breed. Newly calculated and updated summaries for breeds that conduct national cattle evaluations are available online at least once a year and, in some cases, as frequently as weekly. Summaries include EPDs, accuracies, graphs of the average change in EPD for the particular breed, breed average EPDs, possible change values, and other useful materials. Descriptive material written at the beginning of each summary describes the format for reporting the EPDs.

Almost all sire summaries include birth weight, weaning weight, yearling weight, and milk EPDs (Figure 9–2). Many summaries currently include some characteristics that have a role in reproduction such as calving ease, gestation length,



Sire Evaluation of Proven Sires

ANIMAL IDENTIFICATION	OWNER	GRPS PROG	DTRS PROG/ DTR	BW EPD ACC	WW EPD ACC	YW EPD ACC	MILK EPD ACC	TOTAL MAT. EPD	STAY EPD ACC	HPG EPD ACC	MARB EPD ACC	REA EPD ACC	FAT EPD ACC
FORSTER LAKOTA 3100 REG.#: 405225 CATEGORY: A BIRTHDATE: 04/01/1993 SIRE: RED CENTURIAN C105 MATERNAL GRANDSIRE: LFS GALENA 139	FORSTER RED ANGUS ALTA GENETICS, INC. WBD	30 89	23 1.9	1.2 .89	30 .79	49 .72	26 .65	41	8 .65		-0.06 .22	0.03 .22	0.00 .19
FORSTER MAGNUM 6142 REG.#: 525563 CATEGORY: A BIRTHDATE: 03/30/1996 SIRE: RED BBCC PRESIDIO 52 MATERNAL GRANDSIRE: BUFORK COPPERTOP1828	KINCHEN CATTLE CO FORSTER RED ANGUS	18 79	2 1.0	1.6 .80	17 .65	28 .56	22 .39	30	8 .32				
FORSTERS PAY DAY 376 REG.#: 192075 CATEGORY: A BIRTHDATE: 02/27/1986 SIRE: RAB ABE LINCOLN MATERNAL GRANDSIRE: ROCKY MT 19	FORSTER RED ANGUS REDLAND RED ANGUS BOOT JACK RANCHES	23 157	49 4.7	4.3 .86	31 .81	41 .80	1 .77	17	6 .75	6.3 .13	-0.04 P	0.03 P	-0.02 P
FRITZ MONU 2X 211 REG.#: 373666 CATEGORY: A BIRTHDATE: 02/07/1992 SIRE: LEACHMAN MONU 2X 8095 MATERNAL GRANDSIRE: RCN DYNAMO 614	KEITH & LINDA VANDE SANDT FRITZ RED ANGUS	13 29	14 1.8	-2.5 .71	21 .64	29 .62	15 .57	25	9 .55		0.17 P	-0.15 P	0.00 P
FTF DOUBLE CHIEFN601 REG.#: 130241 CATEGORY: A BIRTHDATE: 03/29/1981 SIRE: FTF DOUBLE CHF L218 MATERNAL GRANDSIRE: FTF CHIEFTON 7068	GREER RANCH	53 210	93 4.7	-1.5 .89	18 .88	31 .85	20 .83	29	14 .83	22.0 .48	0.16 .34	-0.10 .33	0.00 .28
GENERAL VANGUARD REG.#: 289075 CATEGORY: A BIRTHDATE: 11/12/1987 SIRE: FFC VANGUARD 538F MATERNAL GRANDSIRE: CV GENERAL LEE	MCKELVEY RED ANGUS CATTLE RANCH	31 64	34 2.3	3.2 .87	32 .76	51 .74	8 .71	24	3 .71		-0.04 P	-0.07 P	0.01 P
GET-A-LONG LICORICE REG.#: 128766 CATEGORY: A BIRTHDATE: 04/10/1979 SIRE: RED SH IMAGE 200F MATERNAL GRANDSIRE: RED VALLEY REVOLUTION	KENNETH FRAZER DOUBLE FORK RANCH	187 610	236 5.0	4.4 .92	37 .91	51 .90	6 .89	27	14 .89	8.7 .32	-0.03 .20	0.04 .26	0.00 .24
GILCHRIST CHIEF W515 REG.#: 270997 CATEGORY: A BIRTHDATE: 02/18/1987 SIRE: JKG CHIEFTON L303 MATERNAL GRANDSIRE: FTF RED RITO M428	BUFFALO CREEK RED ANGUS J BAR K RANCH	121 257	96 3.1	-0.7 .89	28 .89	66 .85	16 .83	30	14 .82	6.5 .15	0.17 .40	-0.18 .39	-0.05 .51
GILCHRIST COYOTE B225 REG.#: 371016 CATEGORY: A BIRTHDATE: 05/22/1992 SIRE: BJR FIRE-MAN 0150 MATERNAL GRANDSIRE: JKG CHIEFTON L303	STAR G RANCH GILL RED ANGUS BLUE RIDGE LAND & CATTLE	76 185	55 1.4	2.4 .87	33 .82	50 .85	23 .75	39	3 .38		0.04 .34	-0.06 .33	-0.02 .21
GILCHRIST HOWLER 96 REG.#: 477991 CATEGORY: A BIRTHDATE: 02/25/1996 SIRE: GILCHRIST COYOTE B225 MATERNAL GRANDSIRE: 741 PANHANDLER 189	BAYLOR RANCH BLUE RIDGE LAND & CATTLE CODY E GRIFFIN	29 47	7 1.2	2.0 .77	20 .65	34 .63	15 .50	25	4 .46		0.02 .13	-0.03 .10	-0.01 .19
GLACIER ALPINE 658 REG.#: 514646 CATEGORY: A BIRTHDATE: 02/20/1996 SIRE: CREEK SIDE COPPER MATERNAL GRANDSIRE: LEACHMAN MONU 2X 5096	GRILL CATTLE CO GLACIER RED ANGUS	30 78	7 1.0	0.6 .78	20 .65	29 .64	17 .50	27	6 .38		0.29 P	-0.05 P	0.00 P
GLACIER ARROW 664 REG.#: 514795 CATEGORY: A BIRTHDATE: 02/21/1996 SIRE: GLACIER STATURE 216 MATERNAL GRANDSIRE: GLACIER NATIONAL	SCHLAEFER-OLSEN RANCH GLACIER RED ANGUS	19 87	2 1.0	-1.8 .81	19 .66	52 .60	21 .35	31	7 .33	9.2 .23	-0.05 .51	-0.44 .48	0.00 .41
GLACIER CAMAS 752 REG.#: 557327 CATEGORY: A BIRTHDATE: 02/21/1997 SIRE: GLACIER SUPER WEIGHT MATERNAL GRANDSIRE: GLACIER DYNAMISE	GARY SONSTEGARD GLACIER RED ANGUS	22 70	0 0.0	-0.3 .70	21 .59	34 .53	15 .37	26	5 .26		0.03 .28	-0.41 .26	0.00 .22
GLACIER CASCADE 464 REG.#: 440319 CATEGORY: A BIRTHDATE: 03/26/1994 SIRE: GLACIER NATIONAL MATERNAL GRANDSIRE: GLACIER SUPER WEIGHT	KOLLE RED ANGUS GLACIER RED ANGUS	26 70	8 1.7	-3.1 .78	17 .63	39 .62	24 .32	32	6 .51		0.05 .51	-0.36 .48	0.02 .46

Figure 9–2

Beef cattle *sire summary*. (Source: Red Angus Association of America, Denton, TX. Used with permission.)

heifer pregnancy, scrotal circumference, and stayability and carcass traits such as carcass weight, rib eye area, fat thickness, marbling score, and tenderness.

Maternal Trait EPDs

Maternal effects are an important consideration in evaluating beef cattle performance. Extensive studies have been conducted to quantify maternal effects for a variety of traits, particularly those measured during the preweaning growth period. In beef cattle, the dam makes at least two contributions to the offspring phenotypic value. **Phenotypic value** is the physical expression of the genetic makeup of an animal, such as a weaning weight. These contributions are the sample half of her genes passed directly to the offspring and the maternal effect she provides her calf. A **maternal effect** is defined as any environmental influence that the dam contributes to the phenotype of her offspring. The contribution of the dam is environmental with respect to the calf (mothering ability, milk production environment, and maternal instinct). The genetics of the dam allow her to create this environment for her calf. Maternal effects are important during the nursing period but have diminishing effects postweaning.

Phenotypic value A measure of individual performance for a specific trait.

Maternal effect Any environmental influence that the dam contributes to the phenotype of her offspring.

Milk EPD

Weaning weight is influenced by the genes for growth in the calf and the genes for milk (mothering ability) in the cow. There are separate EPD values for these two components. The weaning weight EPD evaluates genetic merit for growth and the milk EPD evaluates genetic merit for mothering ability. The milk EPD that results from the separation of weaning weight into growth and milk segments is, like any other EPD, fairly simple to use. It is the expected difference in weaning weight of calves out of daughters of a particular sire, due to differences in mothering ability. For example, consider the following two bulls:

	Sire A	*Sire B*
Milk EPD, lbs	+10	−6

Sire A has a milk EPD of +10; Sire B has a milk EPD of −6. The expected weaning weight difference, due to mothering ability alone, in calves out of daughters by the two bulls is 16 lbs. The 16 lbs are expressed in pounds of weaning weight, not pounds of milk.

Combined Maternal EPD

The combined maternal EPD (sometimes called maternal weaning weight) reflects both the milking ability transmitted to daughters and the direct weaning growth transmitted through daughters to their calves. Here is an examples:

		Weaning Weight Maternal	
	Weaning Weight EPD	*Milk EPD*	*Combined EPD*
Bull A	+20	+12	+22
Bull B	+4	+6	+8

$$\text{Combined (Bull A)} = 1/2\,(20) + 12 = 22 \text{ lbs}$$

$$\text{Combined (Bull B)} = 1/2\,(4) + 6 = 8 \text{ lbs}$$

Bull A has a direct weaning weight EPD of +20 lbs, which expresses the ability of the bull to transmit weaning growth directly to his progeny. On the average, calves sired by Bull A should be 16 lbs heavier at weaning than calves sired by Bull B, assuming both bulls are mated to a comparable set of females and the calves are exposed to the same environmental conditions. The 16-lb difference in future progeny performance is due to genes for direct weaning growth.

The milk EPD for Bull A (+12) is the contribution to his daughter's calves solely through transmission of genes for mothering ability. Sire A has a milk EPD of +12; Sire B has a milk EPD of +6. The expected weaning weight difference, due to mothering ability alone, in calves out of daughters by the two bulls is +6 lbs.

The combined EPD for Bull A (+22) is computed by taking half the weaning weight EPD plus all of the milk EPD. The +22 lbs reflects both the milking ability transmitted to daughters and the direct weaning growth transmitted through the daughters to their calves. In a similar fashion, the combined EPD for Bull B is half times the weaning weight EPD plus the milk EPD, or +8 lbs. An average 14-lb difference between the combined EPDs for the two bulls (22−8=14) would be expected to be the difference in weaning weight of calves out of the daughters of the two bulls. The difference reflects the milking ability of the daughters and the direct weaning growth transmitted through daughters to their calves.

Carcass EPD

Carcass trait EPDs are an additional performance tool that is becoming more available each year. Many of these EPDs are generated from progeny carcass data for various sires within a breed. Generating EPDs for sires within a breed can be an expensive project because carcass data on close relatives, particularly progeny, must be captured. When collecting data on progeny of sires for genetic evaluation, it is most desirable to have at least 25 progeny per sire, although this may be difficult to achieve. For carcass trait EPDs, a simple comparison of two bulls within a breed is conducted, as shown in Table 9–3. Look at the difference in EPDs between the bulls. On the average, future calves out of Bull A will have 50-lb heavier carcass weights, 0.40 sq. in. larger rib eye areas, and 1% greater retail product percentage than calves sired by Bull B. Future offspring of Bull B will have a fourth higher marbling score than calves out of Bull A.

Ultrasonic scan measures can be used to evaluate carcass merit as well as actual measurements on carcasses. Some breeds present separate EPDs for ultrasonic measurements and for actual carcass measurements. The fact that these EPDs can differ can be disconcerting and, increasingly, these two sources of measurement are combined to form a single EPD for each of the measures of carcass merit.

Ultrasonic scan measures Measurements of body tissues taken with ultrasound waves.

Table 9–3
ANGUS CARCASS EPD EXAMPLE

EPD	Breed Average	Bull A	Bull B	Difference
Carcass weight, lbs	+5.95	40	−10	50
Marbling score	+.05	−.10	.15	.25
Rib eye area, sq. in.	+.12	.40	.00	.40
Fat thickness, in.	−.003	.00	.00	.00
% Retail product	+.10	.5	−.5	1%

Source: Dolezal, 1999. Used with permission.

Mature Size

Mature size is an important issue in the beef industry today. Size is composed of closely related measures of weight and height; however, the relationship among these traits is not clearly understood. Studies of mature size in beef cows have estimated lifetime growth curves for weight through maturity. Other reports have considered the influence of body size on the biological efficiency of cows.

Genetic prediction of mature size may allow beef cattle breeders to make a directional change in the mature size of their cow herd or to emphasize uniformity of cow size for a particular production environment. Studies of the genetic components of mature size have addressed weight and height at maturity separately by trait, rather than as a composite measure.

Mature weight and height are highly heritable traits. For example, heritability estimates in Angus cattle are 0.49 for weight and 0.87 for height in mature cows. Heritabilities of this magnitude indicate that selection for these traits would be effective. In other words, if beef producers wanted to make changes in the height and weight of the cow herd, they would select sires of replacement heifers using some guidelines for desirable size for the herd production environment. Also, it is important to consider that the genetic correlation between mature weight and height is strong and positive. Large genetic association between these two traits suggests that selection for increased height would be associated with increased cow weight. Some beef breeds have incorporated cow size data into a genetic evaluation for the creation of mature cow size EPDs. Ideally, selection would be in favor of smaller birth weights, larger weaning and yearling weights but smaller mature size. Bending the growth curve in this manner can be difficult but success in this endeavor would have a strong positive effect on overall production efficiency.

USE OF EPDS

Use of EPDs for Selection in Seedstock Herds

Purebred producers know that they need to use EPDs in their breeding programs. Competitors are using them and genetic change is happening. Care needs to be exercised when making selection decisions. Type fads have caused some problems in the past when single traits were emphasized. Similar, or worse, problems may arise if a single performance trait is emphasized. For example, if the members of one breed association begin to emphasize yearling weight and ignore all other characteristics, several concerns may result. Birth weight would be expected to increase, with the attendant calving difficulty. Mature size should also increase, perhaps to the point where the functionality of the cow herd would diminish. This could also lead to problems in reaching desirable **quality grade** at an acceptable weight. Each trait has a set of drawbacks, if changes are carried to an extreme. The availability of EPDs would make such extremes easier to reach, if breeders chose blindly to emphasize a single trait.

Quality grade Scale that indicates quality and value of the carcass such as *prime*, *choice*, and so on.

A more balanced selection program is certainly desirable. Some producers recommend choosing herd sires that have high yearling weight EPD, high milk EPD, and low birth weight EPD. Because these three characteristics are sufficiently different from one another, the difficulties from extreme changes in any one of them would be unlikely to result. Such a program, along with careful consideration of the various reproduction and carcass merit EPDs should result in a balanced program of improvement.

Purebred producers are not only the users of EPDs, but they also provide the data used in calculating EPDs. Producers are strongly encouraged to provide complete, accurate records on all calves born each year. Complete, accurate recordkeeping is the only way that useful EPDs can be calculated.

Use of EPDs for Selection in Commercial Herds

Commercial producers should make maximum use of available EPDs when considering purchases of breeding stock. Seedstock producers should be providing such information on all cattle that are for sale. Again, a balanced program of trait selection is desired.

A commercial producer has a first responsibility of choosing the appropriate breed, or breeds, for his or her program. Once breeds are chosen, examination of what is needed in replacement breeding stock is in order. Some recommendations for commercial scenarios are shown in Table 9–4.

Each of these recommendations should be followed with an awareness of the prevailing environmental conditions. Rougher conditions probably dictate avoidance of very high EPDs for growth or milk, and even more care to avoid high birth weights. Growth EPDs should be geared to the desires of the potential buyers. Again, traits for which there are no EPDs as yet can also be important. Traits associated with reproduction certainly fall into this category. Commercial producers should demand that bulls have passed a **breeding soundness examination.** The cow herd of the seller should be examined for regularity of calving.

Breeding soundness examination Physical examination to determine the readiness of an individual for breeding purposes.

EPDs within a breed are directly comparable between herds. Therefore, if a commercial producer has more than one source of breeding stock, he or she can compare the genetic merit of the different sources. Unfortunately, EPDs cannot be compared between breeds. A bull with a low birth weight EPD from a large mature size breed may sire calves that are heavier than those from a bull with a high birth weight EPD from a moderate sized breed. A low birth weight EPD does not guarantee a minimum of calving difficulty if the choice of breeds is incorrect.

Pedigree Estimated EPDs

After the first of each year, sale catalogs prepared for production sales and full of information on potential herd sires become available. Many sale catalogs contain EPDs for the bulls offered for sale. Data on some bulls appear in catalogs with limited

Table 9–4
RECOMMENDATIONS FOR EPDS FOR VARIOUS COMMERCIAL SCENARIOS

Use of Individual	Breed	Birth	Weaning	Yearling	Milk[1]
Terminal sire on mature cows	Large carcass	Not too high	High	High	Not relevant
Bull to use with heifers	Small to medium size	Low	Moderate	Moderate	Consider if keeping heifers
Sire replacement heifers	Medium size maternal	Low to moderate	Moderate to high	Moderate to high	Varies

[1] Selection decisions involving milk EPD should take into consideration the production environment and feed resources available for the cow herd.

Source: Buchanan et al., 1993, p. 84.

or no EPD information. This may be particularly true for young bulls that have not had their performance information included in the breed genetic evaluation. Bull buyers may use a quick and easy procedure to compute "pedigree EPD" values for young bulls with no EPDs. Pedigree EPDs can be computed provided there is access to EPDs on the animals in the pedigree of the young bull. By using the EPDs on animals in the young bull's pedigree and the knowledge of how breeding value is transmitted from generation to generation, pedigree EPDs can be computed.

Every calf has received a random sample of half of the sire's genes and a random sample of half of the dam's genes to combine into its genetic makeup. Parents of the calf have received their genetic makeup in the same fashion, with half of their genetic makeup contributed by each of their parents. By understanding this halving nature of inheritance, the EPDs on parents and grandparents in the pedigree of a young bull may be used to compute pedigree EPDs.

Some breed associations have an "interim EPD" program based on pedigree information to provide EPDs on young animals that have not had an opportunity to have their individual performance included in the most recent national cattle evaluation for the breed. Many sale catalogs may already provide the pedigree EPD for convenience.

Across-Breed EPDs

Currently, most EPDs are used only on a within-breed basis. They are calculated for the specific breed; therefore, the EPDs are only useful for direct comparisons of future progeny performance for cattle within that breed. The across-breed EPD concept (AB-EPD) has been actively investigated since the late 1980s. Commercial bull buyers using more than one breed of bull are particularly interested in having this EPD option. The methodology for accomplishing AB-EPDs on a national scale is not yet perfected. To compare cattle of different breeds, additional information is required. This information includes (1) mean breed differences in the environments of interest; (2) the base year, or zero EPD point, for the breeds of interest; and (3) the expected effects of heterosis (or hybrid vigor) for matings between the breeds of interest. Breed comparison data from the U.S. Meat and Animal Research Center are the best resources available to date. Breed adjustments to make across-breed EPD comparisons are computed annually at this research station.

EPDs and Crossbreeding

Planning a crossbreeding system first relies on the choices of breeds, followed by the use of within-breed EPDs as selection tools for performance traits. To assist beef producers in their choices of breeds, studies have tried to group or categorize breeds into general biological types. Perhaps the most famous and extensive of these studies involves the Germ Plasm Evaluation study conducted at the U.S. Meat and Animal Research Center (USMARC) at Clay Center, Nebraska. Table 9–5 lists 25 different sire breed groups that were evaluated in calves out of Hereford and Angus dams or calves out of the two-breed cross (F_1) dams. The breed groups illustrate relative differences (X = lowest, XXXXXX = highest) in growth rate and mature size, lean-to-fat ratio, age at puberty, and milk production. Increasing numbers of Xs indicate relatively higher performance levels and older age at puberty.

F_1 Two-breed cross animals.

Table 9–5
BREEDS GROUPED INTO BIOLOGICAL TYPES FOR FOUR CRITERIA[1]

Breed Group	Growth Rate and Mature size	Lean-to-Fat Ratio	Age at Puberty	Milk Production
Jersey (J)	X	X	X	XXXXX
Longhorn (Lh)	X	XXX	XXX	XX
Hereford-Angus (HAx)	XXX	XX	XXX	XX
Red Poll (R)	XX	XX	XX	XXX
Devon (D)	XX	XX	XXX	XX
Shorthorn (Sh)	XXX	XX	XXX	XXX
Galloway (Gw)	XX	XXX	XXX	XX
South Devon (Sd)	XXX	XXX	XX	XXX
Tarentaise (T)	XXX	XXX	XX	XXX
Pinzgauer (P)	XXX	XXX	XX	XXX
Brangus (Bn)	XXX	XX	XXXX	XX
Santa Gert. (Sg)	XXX	XX	XXXX	XX
Sahiwal (Sw)	XX	XXX	XXXXX	XXX
Brahman (Bm)	XXXX	XXX	XXXXX	XXX
Nellore (N)	XXXX	XXX	XXXXX	XXX
Braunvieh (B)	XXXX	XXXX	XX	XXXX
Gelbvieh (G)	XXXX	XXXX	XX	XXXX
Holstein (Ho)	XXXX	XXXX	XX	XXXXX
Simmental (S)	XXXXX	XXXX	XXX	XXXX
Maine Anjou (M)	XXXXX	XXXX	XXX	XXX
Salers (Sa)	XXXXX	XXXX	XXX	XXX
Piedmontese (Pm)	XXX	XXXXXX	XX	XX
Limousin (L)	XXX	XXXXX	XXXX	X
Charolais (C)	XXXXX	XXXXX	XXXX	X
Chianina (Ci)	XXXXX	XXXXX	XXXX	X

[1] Increasing number of Xs indicates relatively higher values.

Source: Cundiff et al., Beef Improvement Research Federation Symposium, 1993, p. 130.

DAIRY CATTLE GENETIC IMPROVEMENT

Dairy producers have been leaders in genetic improvement. Many commonly known techniques for evaluating genetic merit have been derived and tested initially on dairy cattle records. One advantage the dairy industry has is the focus on a limited number of economically important traits. Traditionally, milk yield has been the primary driver in trait emphasis for profitability. Yet very rarely are effective breeding programs based on a single trait. Dairy producers are challenged to balance traits of economic importance to address some of the following goals:

- Achieve profitable milk yield levels.
- Monitor milk composition.
- Generate profitable replacement animals that are productive under the stress of high production levels.
- Sustain and improve cow longevity in the herd.

The following sections address key areas of genetic improvement in the dairy cattle industry. Animal breeding principles are related to specific dairy examples and current genetic selection tools are discussed.

Heritability Estimates

An understanding of the heritability and genetic correlations for dairy cattle traits is necessary to take advantage of the variety of selection tools and breed trait information available. Studies in animal breeding have quantified the genetic variation in dairy production, so producers may use this information to be more profitable through designed breeding programs. Although much emphasis is placed on milk yield and its impact on profitability, it is important to review the heritabilities of other commonly known dairy production traits. As discussed earlier, the most practical use of heritability is that it indicates how easily we can make genetic improvement through selection. However, one should not overlook more lowly heritable traits, such as the reproductive complex. These traits are highly influenced by environment and management but significant differences between individuals can still exist.

Table 9–6 presents heritability estimates for dairy production parameters compiled from various research reports. In general, most reproductive traits tend to have low heritability (<0.20); yield traits tend to be moderately heritable (0.20–0.40); and composition traits and weights tend to have fairly high heritabilities (>0.40). Keeping in mind the earlier discussion, and viewing the heritabilities, one can see that it is relatively easy to change mature weight or wither height through selection. To improve reproductive efficiency or longevity, the dairy cattle breeder must take advantage of all the genetic tools available.

Associations Among Traits

Genetic correlation refers to a situation in which the same or many of the same genes control two traits. Table 9–7 presents phenotypic and genetic correlations between milk yield and other production characteristics. Phenotypic correlations are

Table 9–6
HERITABILITY OF VARIOUS TRAITS IN DAIRY CATTLE

Trait	Heritability
Milk yield	0.30
Milk fat yield	0.30
Protein yield	0.30
Total solids yield	0.25
Milk fat %	0.50
Protein %	0.50
Persistency	0.40
Peak milk yield	0.30
Milking rate	0.40
Gestation length	0.40
Birth weight	0.40
Mature weight	0.50
Wither height	0.50
Conception rate	0.05
Reproductive efficiency	0.05
Calving interval	0.10
Productive life length	0.08
Feed efficiency	0.35
Mastitis resistance	0.10
Overall type score	0.20
Dairy character score	0.20
White coat color (Holsteins)	0.90

Source: Wilcox, 1992, p. 3. Used with permission.

Table 9–7
GENETIC CORRELATIONS BETWEEN MILK YIELD AND OTHER TRAITS

Trait	Correlation with Milk Yield	
	Phenotypic	Genetic
Fat yield	0.69	0.45
Protein yield	0.9	0.81
Fat %	−0.35	−0.35
Protein %	−0.35	−0.30
Type score	0.29	0.00
Stature	0.11	−0.01
Strength	0.12	0.07
Dairy character	0.50	0.68
Foot angle	0.00	−0.24
Rear legs (set to hock)	0.02	0.14
Pelvic angle	0.04	0.19
Fore udder attachment	−0.09	−0.47
Rear udder height	0.12	−0.13
Rear udder width	0.16	0.09
Udder depth (distance from floor of udder to ground)	−0.27	−0.64
Medial Suspensory ligament	0.14	0.12
Front teat placement	0.02	−0.12
Productive life length	0.15	0.08
Mastitis susceptibility (somatic cell score)	−0.10	0.20

Source: Adapted from Buchanan et al., 1993, p. 96. Updated according to Cole *et al.*, 2010.

correlations between two traits that producers actually measure or see; thus a combination of genetics and environment plays a role in expression of the trait, such as weight or height. Genetic correlations are more difficult to visualize.

Knowledge of the magnitude of the genetic correlation between various traits is useful in a selection program. The magnitude of genetic correlations may vary between −1 and +1. A genetic correlation of 0 indicates that different genes influence the two traits; thus, the traits are uncorrelated. For example, selection based on milk yield has little or no effect on front teat placement (Table 9–7).

The absolute value of the correlation indicates the strength of the association between the two traits. When a genetic correlation exists between two traits, it means that the correlation does not equal 0. Rarely does this mean that the correlation is perfect at +1 or −1. For example, a genetic correlation of 0.20 between mastitis susceptibility and milk yield is positive, but the magnitude of the correlation does not imply a strong genetic association between the two traits. Therefore, selection based on milk yield does not significantly increase the susceptibility to mastitis.

The sign (+/−) of the genetic correlation indicates the relationship between traits (i.e., how selection for one affects the other). If the sign of the genetic correlation is positive, then the breeding values of the animals for the two traits tend to vary together. The reverse is true for a negative correlation. Therefore, if selection is for increased performance in one trait, performance in the other trait will likely decrease. For example, the percentage traits for composition (fat % and protein %) tend to be negatively associated with milk yield. However, yield traits (fat and protein) tend to be highly correlated in a positive direction with milk yield, both phenotypically and genetically.

Consideration of the relationship between traits can be very beneficial if they are considered in a complete breeding program. Again, the tabular values reveal that genetic correlations are seldom perfect. For example, many of the genes that control dairy character also control milk yield in the same direction, as indicated by the positive genetic correlation of 0.68 in Table 9–7. The relationship is not perfect. The fact that genetic correlations are not perfect provides breeders with the opportunity to try to identify sires that are exceptions to the unfavorable correlation. Again, genetic correlations give us an indication of what is likely to happen to one trait when selection is practiced for another trait. The magnitude of the correlation suggests how closely traits will vary together.

Goal Setting and Trait Emphasis

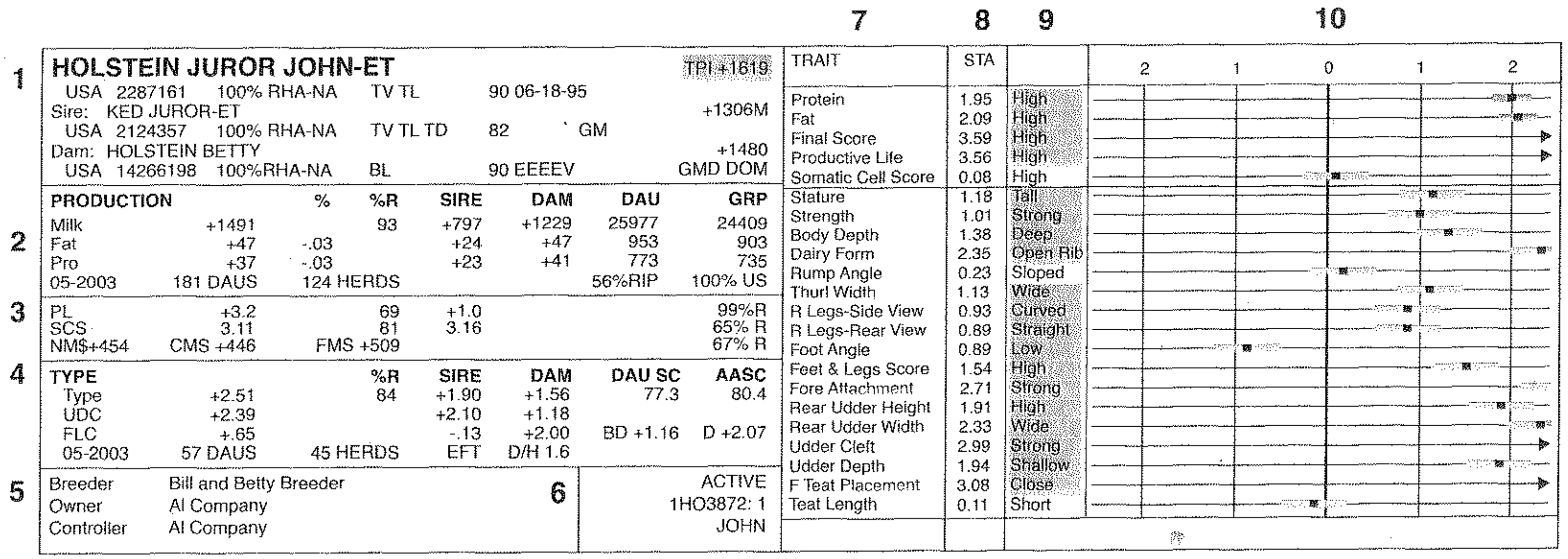
The genetic improvement program for every dairy herd must have goals to design the cow herd with the genetics for making a profit. Milk yield and composition are important economic considerations. Within-herd genetics and production performance must be evaluated and scrutinized through effective recordkeeping. Also, access to genetically superior animals outside the herd through the use of artificial insemination is critical. Before deciding whether selection should be practiced for a particular trait, consider the following:

- Can the trait of interest be accurately measured?
- What is the heritability for the trait? Is genetic progress through selection possible?
- Will selection for this trait contribute to income (directly or indirectly)?

Most producers begin planning a well-founded breeding program through basic use of: (1) Dairy Herd Improvement Association (DHI) records and (2) semen purchase of bulls with genetic superiority for economically important traits.

Trait emphasis should be balanced with respect to the heritability of the trait, genetic correlations among traits, the reliability of the information, and economic importance of the trait. This is no small task considering there are national genetic evaluations for about 30 traits (Figure 9–3). U.S. dairy geneticists have attempted to simplify selection decisions for dairy farmers by properly weighting all the traits into the Net Merit Dollar Index (NM$). Similar indexes have been developed by breed associations, such as the Total Performance Index (TPI) by the Holstein Association. The traits in these indexes are properly weighted for the average or most typical dairy producer to maximize profit on a commercial dairy. Individual dairies may want to change emphases depending on their management systems and goals. Low-input grazing herds put more emphasis on reproductive traits and feet and legs and less emphasis on milk production. Also, smaller cows tend to make more efficient grazers than large cows.

Producers who sell breeding stock put more emphasis on fancy type traits. The so-called eye appeal of the animal seems to influence price in the sales ring much more than the animal's genetics for milk production. For dairy producers with aspirations of developing a great show cow, most emphasis needs to be placed on final score type, stature, dairy form, and the udder traits. Dairy producers must be careful in selecting their goals in that the genetics of a show animal is quite different from the genetics needed to produce milk most efficiently.



HOLSTEIN JUROR JOHN-ET TPI +1619

USA 2287161 100% RHA-NA TV TL 90 06-18-95
Sire: KED JUROR-ET +1306M
USA 2124357 100% RHA-NA TV TL TD 82 GM
Dam: HOLSTEIN BETTY +1480
USA 14266198 100%RHA-NA BL 90 EEEEV GMD DOM

PRODUCTION		%	%R	**SIRE**	**DAM**	**DAU**	**GRP**
Milk	+1491		93	+797	+1229	25977	24409
Fat	+47	-.03		+24	+47	953	903
Pro	+37	-.03		+23	+41	773	735
05-2003	181 DAUS	124 HERDS				56%RIP	100% US
PL	+3.2		69	+1.0			99%R
SCS	3.11		81	3.16			65% R
NM$+454	CMS +446	FMS +509					67% R

TYPE			%R	**SIRE**	**DAM**	**DAU SC**	**AASC**
Type	+2.51		84	+1.90	+1.56	77.3	80.4
UDC	+2.39			+2.10	+1.18		
FLC	+.65			-.13	+2.00	BD +1.16	D +2.07
05-2003	57 DAUS	45 HERDS		EFT	D/H 1.6		

Breeder Bill and Betty Breeder
Owner AI Company
Controller AI Company

ACTIVE
1HO3872: 1
JOHN

TRAIT	STA	
Protein	1.95	High
Fat	2.09	High
Final Score	3.59	High
Productive Life	3.56	High
Somatic Cell Score	0.08	High
Stature	1.18	Tall
Strength	1.01	Strong
Body Depth	1.38	Deep
Dairy Form	2.35	Open Rib
Rump Angle	0.23	Sloped
Thurl Width	1.13	Wide
R Legs-Side View	0.93	Curved
R Legs-Rear View	0.89	Straight
Foot Angle	0.89	Low
Feet & Legs Score	1.54	High
Fore Attachment	2.71	Strong
Rear Udder Height	1.91	High
Rear Udder Width	2.33	Wide
Udder Cleft	2.99	Strong
Udder Depth	1.94	Shallow
F Teat Placement	3.08	Close
Teat Length	0.11	Short

1 Identification Pedigree Block
2 Production Summary Block
3 Additional Genetic Information Block
4 Type Summary Block
5 Ownership Block
6 NAAB Data Block
7 Trait Name Block
8 Standard Transmitting Ability (STA) Block
9 Biological Extreme Block
10 Trait Profile Block

Figure 9–3

How to read Holstein sire information. (Source: Holstein Foundation. Used with permission.)

GENETIC EVALUATION PROCEDURES

DHI System

Much of the genetic improvement in milk production in the United States is attributable*in part to good use of performance records through the Dairy Her Improvement (DHI) system. Data obtained monthly through the DHI productio testing and management system provide producers with detailed reports on the current status of their herd. These records are also compiled nationally through the U.S Department of Agriculture (USDA) to calculate genetic evaluations for sires.

The DHI system of genetic evaluation consists of comparing sire daughter with contemporaries in the same herd. Superior sires are chosen based on thei ability to pass specific traits to their offspring. Initially, young bulls are chose based on superior pedigree value. These genetics are then randomly mated to cow across various locations for production of daughters. These daughters' records ar compared with their contemporaries to allow the calculation of estimated geneti transmitting ability of the bull.

Animal Model

The USDA-DHI Animal Model Genetic Evaluation compiles lactation yield information for milk, fat, protein, somatic cell score, productive life, and pedigree or relationships among animals. For a cow's lactation record, sources of variation such a management group, genetic merit, permanent environment, and herd by sire interactions are considered. Specific effects of age, length of lactation, and milkings pe day are adjusted prior to analysis. The animal model procedure produces predictions of the breeding (genetic) value of an animal. Breeding value is defined as the value of an individual as a parent. Parents transfer a random sample of the genes to their offspring. Breeding value gives an estimate of the transmitting ability of the parent. Some basic values generated from the evaluation are as follows:

Predicted transmitting ability Half the breeding value.

PTA—One-half the breeding value is equal to the **predicted transmitting ability** (PTA). The PTA implies a comparison. Thus, PTAs allow us to compare or rank the superiority of individual animals. PTAs provide a prediction of future progeny performance of one individual compared to another individual within a breed for a specific trait.

Reliability A measure of accuracy in dairy records.

REL—**Reliability** (%R) is the measure of accuracy, or the amount of information in an evaluation.

Parent average The average PTA of the parents of a dairy cow.

PA—**Parent average** (PA) is the average PTA of the sire and dam of the individual in question. If a parent is unknown, an unknown-parent group effect is used.

Predicted transmitting ability net merit dollars An economic index that measures relative lifetime profit of a dairy cow.

PTANM$—**Predicted transmitting ability net merit dollars** (PTANM$) is an economic index. PTANM$ combines evaluations for milk, fat, protein, somatic cell score, productive life, udder composite, feet and leg composite, size, daughter pregnancy rate, calving ease, and stillbirth rate. It is a measure of relative lifetime profit.

Producers benefit from the extensive herd summary reports provided by DHI. Herd analysis and management reports include production, reproduction, genetics, udder health, and feed cost information. Figure 9–4 illustrates the identification and genetic summary portion of a sample DHI report. This report is useful in verifying the number of replacement and producing animals in the operation. As one might expect, the usefulness of DHI records is enhanced by a higher percentage of identified animals.

Identification and Genetic Summary

Age group	Number animals	Average age	NUM. identified by		Number ID. changes	NO. animals with PTA$/PA$	Average PTA$ / PA$	
			Sire	Dam			Animal	Sire
0-12	62	6	62	62		58	+108	+187
13+	66	18	66	66		61	+97	+163
Replacements	128	12	128	128		119	+103	+175
1st lact	34	23	34	30	2	34	+84	+140
2nd lact	30	36	28	26		28	+73	+122
3+ lacts	58	59	51	44		49	+52	+87
All lacts	122	43	113	100	2		+68	+114
% Identified (producing females)			93	82				

Herd PTA$ option
MFP

	Genetic profile of service sires		
	Proven A.I. sires	A.I. young sires	All other sires
% of herd bred to	75	20	5
Number of bulls used	5	12	3
Average PTA$ or PA$	+200	+216	+10
AV. percentile rank (net merit)	83	90	0

Figure 9–4
Sample DHI report. (Source: Dairy Records Management Systems. Used with permission.)

The PTA$ and PA values are presented for cows within the herd, as well as their sires. Values are calculated using the USDA Animal Model Genetic Evaluation procedure. PTA$ in this report is the economic value of the PTAs for milk, fat, and protein. An increase in cow and sire PTA$ from younger to older cows is an indication of within-herd genetic progress.

Sire Selection

With sire selection playing an important role in genetic improvement, dairy producers spend a great deal of time studying bull proofs given in sire summaries. Figure 9–3 shows a sample data summary for a Holstein sire. Perhaps the best application of genetic evaluations involves the comparison among sires. An example comparison of data on two Holstein sires from a summary is shown in Table 9–8.

The TPI value is a **total performance index**. This multiple trait approach calculated by the Holstein Association combines PTAs (protein, fat, type), udder composite, feet and legs composite, somatic cell score, productive life, daughter pregnancy rate, dairy form, daughter calving ease, and daughter stillbirth rate. It provides a ranking of sires on their ability to transmit a balance of traits. Net merit dollars (NM$) is the economic index calculated by the USDA as an index of relative lifetime profit.

Total performance index
Index used by the Holstein Association to rank sires on their ability to transmit a balance of traits.

Table 9–8 shows that yield comparisons between the two sires favor the future offspring of Superior Brett over Average Jake. For example, if daughters of these bulls are housed in the same herd as contemporaries and are managed alike, the expected difference in milk, fat, and protein yield would be 495, 37, and 8, respectively, in favor of Superior Brett. However, protein percentage would tend to favor Average Jake, illustrating a negative association between these two traits in this example. From an economic standpoint, Sire Brett is still on top with respect to NM$ and TPI values. In this example, the reliabilities (%R) are similar for both bulls, indicating similar accuracies. If the %R values were largely different, decisions on how extensively to use a young sire (low %R) would be needed. A low accuracy bull is not bad; he is

Table 9–8
COMPARISON OF DATA ON TWO HOLSTEIN SIRES

	Superior Brett	Average Jake	Difference
TPI™	+1618	+1430	+188
PTA			
M (milk)	+1850	+1355	+495
F (fat)	+88	+51	+37
P (protein)	+55	+47	+8
PTA%			
F (fat %)	+0.09	+0.09	0
P (protein %)	−0.01	+0.06	−0.07
% R (reliability of PTAM and PTAF)	78%	80%	−2%
PTA			
NM$ (net merit dollars)	+470 (69%R)	+407 (65%R)	+63
SCS (somatic cell score)	+3.40 (57%R)	+3.10 (57%R)	+0.30
PL (productive life)	+1.1 (42%R)	+0.2 (40%R)	+0.9
T (type—final score)	+1.58 (75%R)	+1.30 (72%R)	+0.28
%DBH (difficult births in heifers)	9% (71%R)	7% (72%R)	+2%

Source: Dolezal, 1999. Used with permission. Modified to August 2000 base change.

part of the new genetic information for the breed. Reliability values are expected increase as more daughter records contribute to the bull's proof.

The somatic cell score (SCS) PTA is a tool that allows producers to select bu based on their ability to sire daughters with lower rates of mastitis. Somatic cells a body cells. When found in milk, they indicate damage to the udder that is caused l mastitis. Research indicates that single-trait emphasis for higher milk yield is associat with increased incidence of mastitis. This is not a perfect relationship. Not all hi production sires have associated rates of mastitis in daughters. Heritabilities used l the USDA are 0.10 for SCS and 0.30 for milk production. This suggests that gene change to reduce mastitis is slow. In the previous example, the SCS of Sires Brett ar Jake's daughters are expected to differ on the average by 0.3 (3.40 − 3.10 = 0.3). Tl PTASCS should be viewed as a selection tool, rather than as a sole selection criterio to optimize total economic merit.

To continue to increase the genetic potential of the herd, follow a few basic rul

- Use an index such as net merit dollars to weight properly the production and no production traits to maximize total economic merit.
- Use 7 to 10 sires per herd per year.
- Select sires from the top 10% based on an index such as NM$ or TPI.
- Use elite genomically tested young sires on at least a portion of the herd.
- Use sires with 70% reliability or higher.
- Consider calving-ease bulls for heifers.
- After sires have been selected, individually mate animals to lower average inbree ing in offspring.

SWINE GENETIC IMPROVEMENT

Genetic improvement programs are a primary focal point for today's swi industry. The high reproductive rate and short **generation interval** in swi allow rapid genetic progress for economically important traits. In recent year

Generation interval The average age of parents when their offspring are born.

the swine industry has followed some of the patterns set by commercial poultry production. Much of the pork produced today originates from corporate swine production systems, which are vertically integrated from conception to consumer. This leads to an interesting structure for modern pork production, which contains seedstock breeders, commercial swine producers, and corporate production units.

The National Swine Improvement Federation (NSIF) and National Pork Producers Council (NPPC) are key organizations for documentation on swine genetic resources. The NSIF and NPPC, as well as other agencies, have historically sponsored "Guidelines for Uniform Swine Improvement Programs." Seedstock and commercial swine producers, corporate operations, researchers, and extension personnel utilize this publication. The guidelines give details on the use of uniform procedures for measuring and recording swine performance data.

The NPPC is a member organization of NSIF. The NPPC's mission is to make pork production successful and profitable from the production segment to the ultimate consumer. This council works closely with producers, researchers, and extension personnel, and has swine industry ties.

Performance Information

Efficient pork production relies on objective data collection for economically important traits, breeding value estimation, and planned selection decisions. Key areas include the reproductive complex, growth rate and efficiency, and carcass traits. With the high reproductive rate in swine, extensive evaluation of female reproduction is critical. Data include birth records, litter size (number farrowed alive and dead), farrowing ease scores, litter weight at weaning, and reproductive soundness. On the male side, reproductive soundness data are collected on boars for libido, mounting, mating ability, and semen evaluation. Herd reproductive measures include pigs per sow per year; pregnancy, farrowing, and weaning rate percentages; live pigs per litter; and mated female to service boar ratio.

Growth rate and feed efficiency are evaluated extensively in the swine production system. Economically important measures include days to 250 lbs, average daily gain (ADG), and feed efficiency. Body composition and carcass merit are important to producers as well as to the ultimate consumer eating experience. Data collected include backfat thickness (live), carcass fat depth, loin eye area, pounds of lean pork, and loin muscle color, firmness, and marbling.

Visual appraisal is important in swine breeding programs as it is in many other species. For swine, feet and leg soundness along with underline soundness may be scored; these areas affect production and reproduction success.

Porcine stress syndrome (PSS) is tracked in swine populations. This condition has genetic control at a single locus and is identified as a homozygous-recessive genotype. Pigs under stressful conditions exhibit blotchy skin color and heavy breathing, and they can die from this condition. Phenotypic differences between normal and PSS pigs are that PSS individuals appear more muscular and shorter bodied. The ham area may appear more rounded and circular, along with prominent loins and rumps. Fortunately, the PSS animals can be identified by a blood test or Halothane anesthesia test. Those individuals with the condition should be culled.

Porcine stress syndrome
Genetic defect in which pigs are heavily muscled but have poor carcass quality and may die when subjected to stress.

Genetic Parameters

Heritability indicates the proportion of the superiority in an individual or in a group of individuals that can be passed on to the next generation. This property is used

Table 9–9
HERITABILITY ESTIMATES OF TRAITS IN SWINE

Trait	Heritability, %
Pigs born alive	10
Pigs weaned	10
Litter birth weight	30
Individual birth weight	20
Adjusted 21-day litter weight	15
Feed efficiency	30
Days to 230 lbs	35
Average daily gain	40
Average daily feed intake	24
Dressing percent	30
Backfat probe	40
Loin muscle area	47
Carcass lean percent	48
Age at puberty	32
Ovulation rate	39
Rebreeding interval	23

to estimate breeding value. The actual breeding value of an individual is neve known. It can be estimated from the performance of the individual and its relatives. Common information on relatives includes progeny, sire, and dam records. Table 9–9 pre-sents heritability estimates and correlations for som economically important traits. Growth and carcass measures are moderately t highly heritable. The magnitude of these estimates indicates that selection fo these traits will be effective. The heritability estimates for traits like pigs bor alive and pigs weaned are lower and will be more difficult to make progres through selection.

Breeding Value and Expected Progeny Difference

Parents transfer a random sample of their genes to their offspring. Breedin value gives an estimate of the transmitting ability of the parent. Half of th breeding value is equal to the expected progeny difference (EPD). The word *dif* *ference* implies a comparison. Thus EPDs let us compare or rank the superiorit of individual animals. These concepts were explored in the beef cattle improve ment section. The same principles and assumptions apply for swine geneti evaluations.

Swine Breeds

Unlike the beef industry, fewer swine breeds have had a large impact on commercia swine production. Within these breeds, extensive evaluation of superior individu als has taken place. Specialized sire and dam lines have been developed using thes evaluations. Subsequent commercial crossbreeding systems are designed for efficien pork production. Today's swine industry is strongly focused on genetic evaluatio of performance data among and within breeds. For example, the NPPC has been in strumental in leading and supporting genetic evaluation programs. Examples includ the Terminal Sire Line National Genetic Evaluation and the Maternal Line National Genetic Evaluation Programs.

An interesting angle to the swine industry is that many times the actual breed composition of a particular breeding line is not known. This approach was patterned similarly to commercial poultry production. Commercial units rely on the seedstock producer choices or corporate genetic selections to set the genetics of their animals. Private companies employ geneticists to carefully evaluate all production aspects of their base genetics. Hybrid boars and sows are developed with protected rights to the actual genetic makeup of breeds and individuals within breeds.

The swine industry capitalizes on the advantages of heterosis, particularly maternal heterosis benefits for reproduction. Crossbred sows are used in rotational crossbreeding systems, as well as the maternal side of the terminal cross programs. Research on hybrid boars has indicated that these sires have increased libido, structural soundness, and improved conception rates. Market offspring produced may express 100% of the individual heterosis, as long as the breeds are different for sire and dam lines in the crosses.

Selection index application is very common in the swine breeding programs. Index approach may be directed toward maternal, paternal, or general improvement strategies. Index equations allow the simultaneous evaluation of two or more traits. Traits are weighted based on their economic value and the overall selection objectives for the breeding population. The index accounts for economic value, but also heritability, genetic and phenotypic correlations, and the phenotypic variation for the respective traits. Specific indexes are designed for maternal lines, emphasizing reproductive performance as expressed in litter size and 21-day litter weight. Additional production traits may be included. On the sire, or paternal side, post-weaning traits are important, as well as days to 250 lbs and backfat thickness. Feed conversion emphasis is included in the index through genetic correlations between the other traits.

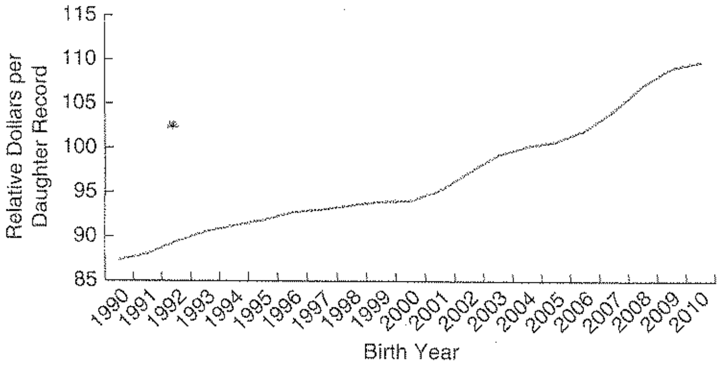
Many times, maternal and paternal lines developed through index selection are combined into a terminal crossbreeding system in which distinct lines are crossed to produce market pigs. No replacements are generated from this system. In contrast, a general selection index is used in more rotational crossbreeding systems. Equal value is given to reproductive and production traits, since individuals in this system must serve as a sire and a dam. A rotational system generates its own replacements.

Breeds from other countries have been studied to determine if specialized genetics would benefit commercial hog production. Perhaps the most well-known quest is that of the Chinese breeds of swine. These breeds are of great interest because of their high reproductive rate (9–17 pigs born alive) as well as early puberty advantages. However, limiting factors associated with these breeds are low growth rate, poor conformation, and excessive fat deposition. Four main breeds are Meishan, Fengjing, Jiaxing Black, and Erhualian. Future developments in pig genome research may identify specific genetic material that these breeds may contribute to future reproductive advances.

Stages

A well-known performance resource in swine genetic evaluation is *STAGES* (Swine Testing and Genetic Evaluation System). This system evaluates the genetic superiority of swine using a statistical methodology similar to that of the beef and dairy industries. The U.S. swine breed associations use the program, which was developed jointly by Purdue University and USMARC. STAGES incorporates

Figure 9–5
Genetic trend for Yorkshire sow productivity index (SPI).
(Source: Purdue University, 2007.)



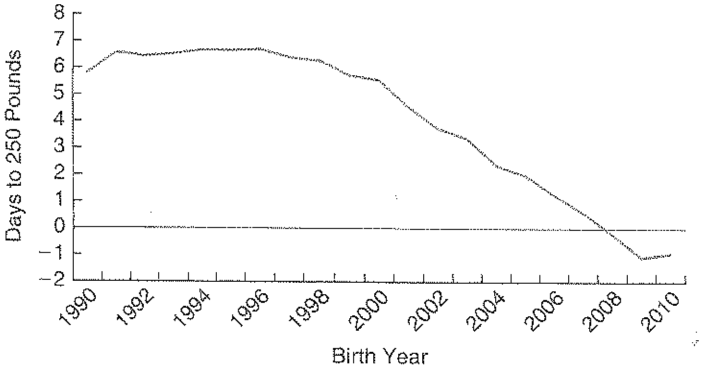
performance information on individuals, progeny, and collateral relatives, as well as the use of relationships among these animals, to generate breeding values (and ultimately within-herd EPDs). For example, postweaning and reproduction analyses are conducted on a within-herd basis. Breeders rely on performance information collected from on-farm programs, national breed tests, and progeny tests to generate within-herd EPDs for animals.

Also, a STAGES national evaluation is run for specific herds to generate across-herd EPDs. Across-herd genetic evaluations to compare animals in different herds within a breed are used to identify the best genetic material nationally. Also, centrally tested boars have been evaluated nationally by this approach. For selection decisions, the seedstock breeders use these data in conjunction with their within-herd evaluation of breeding prospects. Commercial producers rely heavily on the progress of their seedstock suppliers to capture the value of these genetic evaluations.

An example of another index is the sow productivity index (SPI), used to select litters with future replacement gilt candidates. The index includes EPDs with reproductive emphasis. Weighting factors are placed on the EPDs for number of pigs born alive, litter weight, and number weaned relative to the economic value for the trait. Figure 9–5 illustrates the genetic change that has taken place in the Yorkshire breed for SPI (including reproductive traits only).

Figure 9–6 shows the genetic trend lines for days to 250 lbs. In this case, negative EPD values are more desirable, so the change over time is in a negative direction. Thus, the time it takes an animal to reach 250 lbs has been shortened genetically.

Figure 9–6
Genetic trend for days to 250 lbs in Yorkshire swine.
(Source: Purdue University, 2007.)



SHEEP GENETIC IMPROVEMENT

The sheep producer is in the business of producing two products, lambs and wool, as efficiently as possible. The major areas of economic importance to the sheep producer are lamb growth, prolificacy, and, in some areas, wool quality and quantity. However, the tools are not the same for sheep breeding and genetic improvement as they are for the other major meat breeds. EPDs have only been available for sheep since 1986 and are not yet as useful as they are for the other species. In addition, artificial insemination is rarely used in the sheep industry. This makes gaining genetic progress through the widespread use of superior sires less of an influence on the industry. The following sections discuss the key areas of sheep breeding and genetic improvement available to the sheep producer.

Breed and Breed Types

To understand sheep genetic improvement and breeding systems, it is first necessary to understand something of the genetic diversity of sheep breeds. Breeds of sheep available in the United States can range from fine-wool breeds, to long-wool breeds, to hair breeds. These breeds can range in mature size from 100 lbs to over 400 lbs, and average from one lamb per ewe per year to over three lambs per ewe per year. Some breeds lamb year-round; most lamb only in the spring of the year. With this degree of genetic diversity available to the sheep producer, selection of the breeds utilized in a commercial operation is crucial to the success and profitability of the operation. The appropriate choice depends on the geographic location, feed conditions, weather conditions, and goals of the operation.

For simplification and ease of understanding, the breeds are grouped together and classified. They can be classified by face color (black face versus white face) or by wool type (fine wool versus long wool versus hair). However, the most common classification is by use, based on the major function of the breed in common mating systems: ewe breed, dual-purpose breed, and ram breed (Figure 9–7).

Ewe Breeds Ewe breeds are generally the fine-wool, white-faced breeds and those that were developed from crosses of the fine-wool breeds (Rambouillet, Merino) with long-wool breeds (Lincoln, Border Leicester), or the highly prolific breeds (Finnsheep, Romanov). The breed most widely seen in commercial flocks in the United States is the Rambouillet or Rambouillet cross; the term most generally used for these range ewes is the Western ewe or Western White-face ewe.


(a) (b) (c)

Figure 9–7
Sheep breeds are often classified by use of the breed. The pictured breeds of sheep are examples of the different breed classes: (a) ewe breed, Rambouillet; (b) ram breed, Shropshire; and (c) dual-purpose breed, Corriedale.

Ram Breeds Ram breeds are the meat-type breeds used primarily as terminal sire on the ewe breeds or dual-purpose breed to increase lamb gain and carcass quality fo market lamb production. The ram breeds are noted for size, fast growth, and carcas quality. The two most widely used ram breeds in the United States are the Suffol and Hampshire breeds, with the Dorset, Shropshire, Oxford, and Southdown breed used in some instances.

Dual-Purpose Breeds The breeds classified as dual purpose are those that ca be used as either ewe breeds or ram breeds, depending on the environment an production goals of the operation. These are breeds that are not only noted fo milk production, mothering ability, and twinning rate, but also exhibit some o the characteristics noted in the ram breeds such as better growth rate and carcass quality. Examples of dual-purpose breeds are the Dorset, Columbia, an Corriedale.

Selection

Heritability An understanding of the heritability of important traits (low, moderate, high) in sheep production is needed to better understand the use of selectio and mating systems in the sheep operation. Simply stated, the heritability of a trai describes how easily genetic improvement can be made. The variation in a trait i made up of genetic and environmental components. Heritability is the proportion o difference among animals for a trait (e.g., milk production) due to genetic difference rather than environmental factors. This is important because geneticists are intereste in the portion that is transmissible from parent to offspring. Strictly defined, heritability is the ratio of additive genetic variance to total phenotypic variance. This is important to genetic improvement because breeding value depends heavily on additiv genetic variance. If variation does not exist, then progress through selection canno be made.

Average heritability estimates for various traits are shown in Table 9–10. I general, reproductive traits tend to be low in heritability (<0.20), growth traits ten to be moderately heritable (0.20–0.40), and carcass and fleece traits tend to sho high levels of heritability (>0.40). The most practical way to understand the us of heritability is in the selection process. The higher the heritability of a trait, th quicker improvements can be made through selection for that trait. Reproductiv traits such as prolificacy are lowly heritable and, therefore, sheep breeders see ver little progress when selecting for twinning rate. That is why other methods are use to increase twinning rate in the ewe flock. However, the carcass traits have very hig heritabilities and selection progress can be noted from one generation to the nex very quickly when selecting for the carcass traits. The growth traits are moderate i heritability and selection for these traits will show good genetic improvement fro generation to generation.

Selection for growth traits. Growth traits are of economic importance to shee operations. Because growth traits show moderate levels of heritability, selectio programs that emphasize growth traits can show good genetic improvement fro generation to generation. Selection for growth is most important in the ra breeds. These individuals are the predominant sires used for commercial marke lamb production and their main contribution to the lamb crop is growth rate an carcass merit. Increased growth rate allows producers to market lambs at an earlie age or at heavier weights. In the sheep industry, the most important growth trai is weaning weight.

Weaning weights are influenced by not only growth rate of the lamb, but ag of the ewe, type of birth, and method of rearing of the lamb. Selection for growt

Table 9–10
HERITABILITIES OF VARIOUS TRAITS

	Percent		Percent
Reproductive Traits		**Carcass Traits**	
Ewe fertility	5[1]	Carcass weight	35
Prolificacy[2]	10	Weight of trimmed retail cuts	45
Scrotal circumference	35	Percent trimmed retail cuts	40
Age at puberty	25	Loin eye area	50
Lamb survival	5	12th rib fat thickness	30
Ewe productivity[3]	20	Dressing percent	10
Growth Traits		**Fleece Traits**	
Birth weight	15	Grease fleece weight	35
60-day weight	20	Clean fleece weight	25
90-day weight	25	Yield (%)	40
120-day weight	30	Staple length	55
240-day weight	40	Fiber diameter	40
Preweaning gain: birth–60 days	20	Crimp	45
Postweaning gain: 60–120 days	40	Color	45
Dairy Traits			
Milk yield	30		
Fat (%)	30		
Protein (%)	30		
Fat yield	35		
Protein yield	45		

[1] May increase to 10% in ewe lambs and in ewes bred in spring.
[2] Lambs born per ewe lambing.
[3] Pounds of lamb weaned per ewe exposed.
Source: *Sheep Production Handbook*, 1996, p. BRD-61. Used with permission.

rate simply by using lamb weaning weight may not be effective unless some of these common nongenetic factors are adjusted for. Weaning weights should be adjusted for age of lamb, sex, type of birth, method of rearing the lamb, and age of the dam. These adjustments and an example of the calculations are shown in Table 9–11.

National Sheep Improvement Program (NSIP)

Expected progeny differences are widely used in the beef, dairy, and swine industries, but are just in the infancy stages in the sheep industry. The National Sheep Improvement Program (NSIP), initiated in 1986, was designed to provide both the purebred producer and the commercial producer with a performance recording and genetic evaluation program. The NSIP evaluates maternal traits, growth traits, wool traits, and is developing carcass traits.

The NSIP uses the standard set of adjustment factors shown in Table 9–11 for the adjustment of weaning weights. In most breeds, the genetic evaluations are done on a within-flock basis until the database grows large enough to have sufficient ties to have across-flock genetic evaluations. Across-flock ties occur when related individuals are in two or more flocks. Genetic ties normally occur through the rams rather than the ewes because of the high number of progeny per ram and the movement of rams or sons of rams from flock to flock. The breed associations using across-flock genetic evaluations through NSIP are the Polypay, Suffolk, Columbia, Dorset, Hampshire, Katahdin, Romney, Rambouillet, and Targhee breeds.

Table 9–11

MULTIPLICATIVE ADJUSTMENT FACTORS FOR ADJUSTING LAMB PREWEANING AND WEANING WEIGHTS TO A COMMON AGE OF DAM, LAMB SEX, AND LAMB TYPE OF BIRTH-REARING

		Type of Birth-Rearing					
Sex	Ewe Age	1–1	2–1	2–2	3–1	3–2	3–3
Ewe	1	1.13	1.29	1.38	1.40	1.51	1.80
	2 or over 6	1.08	1.19	1.29	1.28	1.38	1.54
	3–6	1.00	1.10	1.19	1.18	1.27	1.36
Ram	1	1.02	1.15	1.21	1.23	1.31	1.53
	2 or over 6	0.98	1.08	1.17	1.16	1.25	1.38
	3–6	0.91	1.00	1.08	1.07	1.15	1.23
Wether	1	1.10	1.25	1.33	1.36	1.45	1.72
	2 or over 6	1.05	1.16	1.26	1.25	1.35	1.50
	3–6	.98	1.08	1.16	1.15	1.24	1.33

Adjustment factors are from the Report of the NSIP Technical Committee, 1986. Weights are adjusted to a single ewe lamb from a 3- to 6-year-old ewe equivalent. Adjustment factors are to be used on preweaning and weaning weights taken at approximately 30, 60, 90, or 120 days of age. Before applying adjustment factors, actual weight must be adjusted to the same age for each lamb using one of the following two equations:

1. If birth weight is available:

$$\text{Age adjusted wt.} = \left[\frac{\text{actual wt.} - \text{birth wt.}}{\text{age when weighed}} \times \text{adjustment age(days)}\right] + \text{birth wt.}$$

2. If birth weight is not available:

$$\text{Age adjusted wt.} = \frac{\text{actual weight}}{\text{age when weighed}} \times \text{adjustment age(days)}$$

Final adjusted weight is given by multiplying the age adjusted weight by the appropriate adjustment factor. Example: A ewe lamb born as a triplet and reared as a single from a 7-year-old ewe weighed 7 lbs at birth and 66 lbs at weaning when 93 days of age. What is her adjusted 90-day weight?

$$\text{Age adjusted wt.} = \left[\frac{66 - 7}{93} \times 90\right] + 7 = 64 \text{ lbs}$$

$$\text{Final adjusted 90 day wt.} = 64 \times 1.28 = 82 \text{ lbs}$$

Lamb born in litters of greater than three should use the triplet adjustment factors. Lambs born as singles and reared as twins should use the twin–twin (2–2) adjustment factors and lambs born as singles or twins and reared as triplets should use the triplet–triplet (3–3) adjustment factors.

Source: *Sheep Production Handbook*, 1996, p. BRD-63. Used with permission.

Heterosis in Sheep Breeding

All of the meat-producing species rely on crossbreeding to improve productivity. However, the sheep industry has used crossbreeding systems very effectively for decades. Crossbreeding systems in sheep involve mating ewes and rams of different breed or breed crosses to produce offspring that are superior (due to heterosis) in performance to that of either of the parent stock. Systematic crossbreeding systems are advantageous because they utilize heterosis.

Heterosis, or hybrid vigor, for a trait is defined as the superiority of the crossbred individual relative to the average performance of the purebreds included in the

Table 9–12
AVERAGE HETEROSIS EFFECTS IN THE CROSSBRED LAMB[1]

Trait	Level of Heterosis (%)
Birth weight	3.2
Weaning weight	5.0
Preweaning daily gain	5.3
Postweaning daily gain	6.6
Yearling weight	5.2
Conception rate	2.6
Prolificacy of the dam[2]	2.8
Survival: birth to weaning	9.8
Carcass traits	approximately 0
Lambs born per ewe exposed[1]	5.3
Lambs reared per ewe exposed[1]	15.2
Weight of lamb weaned per ewe exposed[2]	17.8

[1] From the review by Nitter, G. 1978. Breed utilization for meat production in sheep. *Animal Breeding Abstracts* 46: 131–143.
[2] Purebred ewes mated to a different breed of ram to produce crossbred lambs.
Source: *Sheep Production Handbook*, 1996, p. BRD-28. Used with permission.

cross. In general, crossbred individuals tend to be more vigorous, fertile, healthier, and grow faster than the average of parental stock that make up the cross. Traits that are lowly heritable show high levels of heterosis. Reproductive traits are a good example of a lowly heritable trait that shows high levels of heterosis. Moderately heritable traits show moderate levels of heterosis, such as the growth traits. Highly heritable traits such as fleece and carcass traits show little hybrid vigor. Average heterosis effects for the crossbred lamb and crossbred ewe are shown in Tables 9–12 and 9–13, respectively. The total effect of heterosis on the crossbred lamb is 17.8%; the effect of heterosis on the crossbred ewe is 18%. These advantages make it imperative for the sheep producer to use crossbreeding systems to improve the economic efficiency of the commercial sheep operation.

Table 9–13
AVERAGE HETEROSIS EFFECTS IN THE CROSSBRED EWE[1]

Trait	Level of Heterosis (%)
Fertility	8.7
Prolificacy	3.2
Body weight	5.0
Fleece weight	5.0
Lamb birth weight	5.1
Lamb weaning weight	6.3
Lamb survival: Birth to weaning	2.7
Lambs born per ewe exposed	11.5
Lambs reared per ewe exposed	14.7
Weight of lamb weaned per ewe exposed	18.0

[1] From the review by Nitter, G. 1978. Breed utilization for meat production in sheep. *Animal Breeding Abstracts* 46: 131–143.
Source: *Sheep Production Handbook*, 1996, p. BRD-29. Used with permission.

SUMMARY AND CONCLUSION

Animal breeding is a discipline that takes the principles of genetics and applies them to practical selection and management systems. The goal is to produce the best animals for the conditions in which they will be produced. The cow-calf producer is in the business of producing beef as efficiently as possible. The techniques used and the selections made for breedings must balance production performance and end-product merit. EPDs are a tool to assist in this process. A wealth of information is available to use. The challenge is to identify the combinations of genetics and environment that is most profitable and competitive. Similar tools are readily available to the dairy producer. Extensive data collected through the DHI system has allowed rapid genetic progress to be made in economically important traits. Availability of PTAs provides a challenge for producers to evaluate the economic importance of each trait and to keep current with new technologies. A well-known performance resource for swine breeders to use in selection is the Swine Testing and Evaluation System. This system evaluates the genetic superiority of swine using mixed-model technology similar to that of the beef and dairy industries. Sheep producers have a similar program in place called NSIP. However, this is a new program compared to the other species. It is less developed because there are fewer sheep and fewer participating sheep producers. Sheep producers use selection and crossbreeding but have less information with which to work.

STUDY QUESTIONS

1. Define animal breeding. Why is animal breeding more important as a discipline now than it was 50 years ago? Have all species of livestock benefited from animal breeding research? Why or why not?
2. Speculate on ways in which biotechnology and genetic engineering will make animal breeding a more useful science.
3. What are the major areas of economic importance in beef cattle breeding?
4. Define *heritability.* Describe the difference in heritability among growth traits, reproductive traits, and carcass traits in beef cattle.
5. Why is understanding genetic correlations important in beef cattle breeding? Describe such a relationship between two traits.
6. Why is it important for a beef cattle producer to know the performance of his or her herd? What are some types of performance programs? How do breed associations help?
7. What is an EPD? Define it in relation to breeding value. For what traits can EPDs be calculated? What animals within a breed can have EPDs calculated?
8. What is a contemporary group? Why is this important?
9. What does it mean for EPDs within a breed to be standardized? What is a base year?
10. Define and explain the value of *accuracy* and *possible change.*
11. What is a maternal effect in beef cattle? What are its components? What is milk EPD? What is weaning weight EPD? What is combined maternal EPD?
12. Describe the difference in the use of EPDs in the selection of seedstock herd compared to selection in a commercial herd.
13. In what situation might it be advantageous to calculate estimated EPDs from pedigree information? What would you expect the accuracy of such EPDs to be?
14. Speculate on the value of across-breed EPDs. What are the problems in calculating these values?
15. Name some major goals for dairy cattle genetic improvement. How much more or less complicated does the use of heritability estimates seem in dairy cattle compared to beef cattle? Is the definition of heritability the same?
16. What are some traits that a producer could expect his herd to make rapid improvement in through the application of sound animal-breeding techniques? Little progress?
17. What does it mean when we say that "genetic correlations are seldom perfect"?
18. Describe the value of DHI in dairy cattle breeding programs.
19. What are some traits that are difficult to measure and include with susceptible accuracy in breeding programs?
20. Define these terms: *predicted transmitting ability, reliability, parent average, predicted transmitting ability dollars,* and *percentile ranking.*