4-H MEMBER MANUAL

DAIRY SCIENCE

A Pacific Northwest Cooperative Extension Publication

Washington Oregon Idaho

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Your 4-H Dairy Science Project

SCIENCE IS INVOLVED in many areas of dairying. The 4-H Dairy Science Project emphasizes the "why's" of dairying. The information you learn here should help you with other dairy projects. You will learn some of the "why's" of selection, nutrition, milk secretion, and reproduction as well as "how to do it" aspects of working with your project animal or animals.

You may carry this 4-H Dairy Science Project in addition to your Dairy Animal Project. Or you may carry the 4-H Dairy Science Project alone. In either case, you should answer the questions and perform the suggested activities prepared for each section. Your project leader will give you a set of the exercises along with this bulletin.

You may want to do only one or two activities for some sections and then concentrate on other sections for more detailed study. Use your own initiative in preparing a dairy science exhibit or conducting a dairy science demonstration. In this way, you will benefit from the traditional 4-H "learning by doing."

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4-H DAIRY SCIENCE

HAVE YOU EVER WONDERED why a cow can eat green grass and yellow corn with the nutrients from these feeds going into red blood to produce white milk?

The answers to these questions are not completely understood, but we know that the cow is a remarkable creature. Her daily function involves as much pure science as anything found in nature.

"Science" is a word we see and hear frequently today. To some people it has taken on a magic meaning. People tend to associate science with electronics, atom bombs, space travel, and computers. Actually, science is simply a tool we use for discovering and organizing new facts about the universe in which we live.

Dairying has progressed from a "way of life" to a science. Many of the modern discoveries in related science fields such as genetics (breeding), chemistry, physics, and bacteriology are used in dairying. Today a dairy cow in the United States produces enough milk for about 30 persons. This is a tremendous increase over the amount produced by the family cow kept by our ancestors. The increase has been brought about largely by new developments in the fields of science.

This publication will show some of the areas where science plays a part in the function of the dairy cow. You may learn how to select an animal, how the animal grows, and how she digests feed and uses it for energy. You will discover how heredity works and what is involved in producing a new calf, milk formation, and in marketing a healthful product for human consumption.

SELECTING THE PROJECT ANIMAL

SELECTION OF A DESIRABLE ANIMAL is one of the most important steps to take in beginning a dairy project. A wise choice will give you much more pleasure and profit from your experience. It is just human nature that we get more satisfaction and have more pride in an animal that has a good appearance and produces a lot of milk. Therefore, you should consider both appearance and expected performance when choosing a dairy animal. Whether you place more emphasis on appearance (type) or expected performance (milk production) should depend on your plans.

Selecting on the Basis of Type

In selecting a good-looking dairy animal, study the uniform *Dairy Cow Score Card* published by the Purebred Dairy Cattle Association. From this you can learn about the ideal type cow of the breed and the different parts of the animal's body.

Also, learn the desirable features in the various parts of the body and where the parts are located. When selecting a dairy animal, look for the following features:

1. If she has calved, look for a capacious well-shaped udder, fastened securely to the body, with a level but well-halved floor and with teats that are squarely placed.
2. Well developed and large for her age with a deep, wide heart girth and a barrel that is long, deep and wide.
3. Withers that are refined and wedge shaped.
4. A neck that is long and lean with a clean-cut throat and dewlap.
5. Ribs that are wide apart and well sprung.
6. Thighs that are thin and incurving.
7. Legs that are strong, wide apart, straight, and squarely set under the body.
8. Back that is strong with a straight top line.
9. Rump that is long, nearly level, and wide with a smooth tail setting.
10. Head that is erect, clean-cut, wide between the eyes, with a large muzzle and bright, alert eyes. She should show the desired characteristics of the breed.

Selecting on the Basis of Milk Production

Unfortunately, you cannot look at a heifer and predict accurately how she will produce as a cow. This makes it necessary to study the pedigree carefully. A pedigree is simply an extended record of an animal's ancestry. In one sense it may be considered her family tree. However, in addition to containing the names and registration numbers of the sire (father), dam (mother), grandsires, and granddams of the animal, the pedigree contains varying amounts of information on each animal. This information can be used to predict the expected milk production of the animal you select.

Production records on the animal being selected are more important in predicting future performance than any other information contained on the pedigree. So you might think of the pedigree as the recommendations that an animal might use when applying for a job.

Fifty percent of the inheritance of the animal comes from the sire and 50% comes from the dam. This is shown in Figure 1. On the average, each of the four grandparents contributes 25% to the genetic make-up of the individual animal. Therefore, the animal's production performance should be closely related to the performance of its ancestors. This justifies a very careful study of the animal's pedigree, especially the information on the sire and dam, in order to have some idea as to the milk production you can expect.

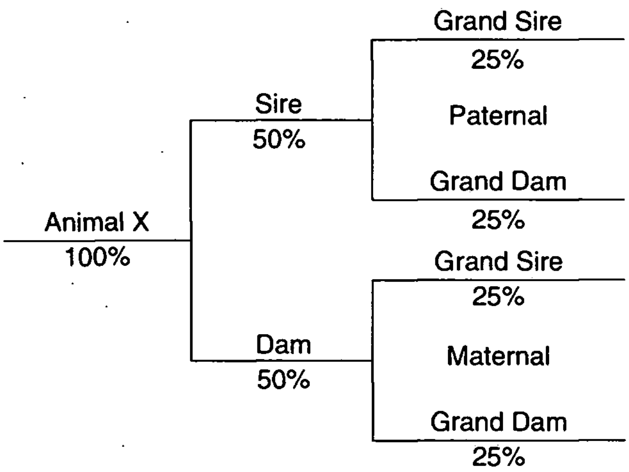


FIG. 1—A. Pedigree form showing the average genetic contribution made by each ancestor to Animal "X."

Points of importance on the pedigree to consider carefully are:

1. *Milk and butterfat records on the animal being selected.* Of course, these records will not be available for heifers. However, if the animal has calved, her milk production records will be more important in selecting for production than the records on any other animal listed on the pedigree.
2. *Transmitting ability of the sire (traits passed on to his offspring).* The sire doesn't give milk so he will have no production records. His transmitting ability will be shown through the milk, butterfat, and protein production performance of his daughters.

Several important transitions have occurred relative to how we make genetic evaluations of sires since our first attempts in the 1930s. Each change has been due to development of more accurate statistical methods and the availability of more sophisticated computing equipment. Originally, sires were evaluated by comparing the production of a sire's daughters to their dams. If his daughters showed a production increase over their dams, the sire received credit for the increase. However, if his daughters produced less, he was blamed for the decrease. This system, though a beginning, was subject to question because it was possible to bias a proof through culling, controlling feeding, and by manipulations of other management factors. Daughter averages did not take into account variations in production due to season, geographical area, or herd so the proof could not be widely trusted when applied to many herds throughout the country.

In 1962 the Herdmate Comparison (HMC) was adopted by USDA-DHIA. This improved method attempted to overcome many of the biases inherent in the older Dam-Daughter comparison. This system compared a sire's daughters to their herdmates. In 1974, the sire proving method was changed once again to the USDA-DHIA Modified Contemporary Comparison(MCC). The change to this system made sire proofs much more accurate and made it possible for a dairyperson living in one section of the country to use a sire from far away with a higher degree of confidence.

The system expresses the transmitting ability of a sire on a nationwide basis and predicts the average production of his future daughters above or below breed average herdmates. The measure is a PTA (Predicted Transmitting Ability for milk (PTA milk), fat (PTA fat), fat percentage (PTA%), and protein (PTA protein).

The more widely a sire is used in herds throughout the country, the more reliable his PTA will become. The percent reliability (%Rab.) is a measure of the degree of confidence of the PTA milk, PTA fat, PTA%, PTA protein. You should have greater confidence in the proof of a sire with 90% reliability than one with a 30% reliability even though the proofs were nearly the same with respect to PTA.

An updated USDA-DHIA Sire Summary is published in January and July of each year and is available to dairypersons who are on DHI testing programs. In addition, all of the artificial breeding organizations publish the latest proofs for their sires and each of the dairy breed registry associations publish the USDA Sire Summaries for their breed.

3. *Milk butterfat, and protein records of the dam.* Not all cows with production records will have protein records reported; however, this form of testing is being done more frequently and may gain greater importance as more milk is marketed on a protein component basis.
4. *Cow index of the dam.* We have had a measure of the transmitting ability of the dam (other than her own production records) since 1974. Cow Indexes tend to have lower reliability than do Sire PTA largely because of the number of daughters in several herds that might be attributed to a single sire versus the limited number of daughters a cow may have.
5. *Transmitting ability of the paternal and maternal grandsires.*
6. *Milk, butterfat, protein records and cow indexes of the paternal and maternal granddams.*

Pedigrees may be confusing in some instances. For example, if the dam of the animal being selected has no production records, you may find some "filler" material inserted under her name. You may find a statement of her lineage such as, "traces 6 times to the great sire "_____" or "her maternal sister was first place at the _____ Fair," etc.

Any information on the pedigree which does not give evidence of an animal's own production performance, type trait information, or transmitting ability should be viewed as "filler" material. This could include such items as high sale prices, show ring winnings, performance achievements of close relatives, etc. These items might make interesting reading; however, they won't tell you much about the animal's own production or type.

It's the Parents Who Count

As shown earlier the sire and dam each contribute 50% of the offspring's inheritance and their influence will be much greater on an animal's performance than any of the other ancestors. With this fact in mind greater emphasis should be placed on the records of the sire and dam when selecting a young animal. An outstanding animal listed far back in the pedigree is not apt to have a significant influence on the animal's performance (see Figure 1).

Make a very careful study of the pedigree. A quick scanning of a pedigree and looking for any kind of information isn't enough.

Type of Production?

Ideally, it would be desirable to select dairy animals with high expected production and possessing sound functional type traits. This isn't always possible and you will have to make some choices. In considering animals that are to be kept as a foundation for a herd you will want to place heavier emphasis on production records than on type classification and show records.

Type Selection Considerations

Although production traits must be emphasized, you should also be cognizant of the importance of sound functional type traits in dairy cattle.

Herd classification for type has been used for many years. In the early stages of development, classification was an attempt to evaluate an animal's conformation more accurately than was being done in the show ring (the earliest type evaluation of all). The animal to be evaluated was compared to the ideal of the breed and given a score on the major type breakdown (dairy character, body capacity, mammary system, general appearance). A perfect score was 100. Type classification brackets were used: Excellent for scores 90 and higher; Very Good, 85 to 89; Good Plus or Desirable, 80 to 84; Good or Acceptable 75 to 79; Fair 65 to 74; and, Poor 64 points and lower.

This program evolved into a Descriptive Type Traits program where up to 16 type traits were rated by code numbers from being desirable to acceptable to undesirable. This system was somewhat more accurate and objective than the earlier type appraisal systems. The descriptive system proved to be a valuable tool for dairy farmers who wished to select service sires from those available in the AI studs.

The descriptive type system made it possible to develop a formula to calculate a PTAT (Predicted Transmitted Ability Type) which has become another tool for dairy farmers striving to improve the quality of their cattle.

The most recent and accurate system of type trait appraisal to evolve is the Uniform Type Traits Appraisal program. The National Association of Artificial Breeders (NAAB) appointed a committee in 1977 to review the then current type classification systems and to design a new program to provide the type trait information needed to increase the rate of genetic progress in dairy cattle conformation. There was a strong push to work with all dairy breed associations to implement such a system on an industry-wide basis. The system that has come into widespread use is sometimes referred to as a Linear Traits Appraisal System. All of the breed associations have adopted the system; however, some breeds have chosen to change the program in some breakdowns so we do not have breedwide uniformity as was so strongly recommended.

The NAAB Committee developed the system based on several basic concepts which helped to overcome some of the earlier faults in type classification. The evaluations were to be made in such a way that data could be statistically analyzed in much the same manner that production records for sire proving are handled. Thirteen traits were selected to be included in the scorecard: stature, chest and body (considering age and lactation stage), dairy character (independent of performance), foot shape (angle), rear legs (side view), pelvic angle, rump width, fore udder attachment, rear udder width (at attachment), rear udder height (at attachment), teat placement (rear view), suspensory ligament (cleft), and udder depth (relative to point of hock). The scorecard also included areas for remarks and defects.

The Linear System certainly offers an opportunity to speed up genetic progress for improving functional type traits in all breeds of dairy cattle. This is an important economic consideration if such improvement helps to lower culling rates because cattle have better lasting qualities. Another important aspect is the increased value of surplus animals because of improved type.

GROWTH AND DEVELOPMENT

DAIRY ANIMALS have a definite growth period which results in an adult size that is characteristic for each breed. For instance, as Table 1 shows, the Jersey weighs about 1,000 pounds at maturity while the Holstein, a larger breed gains at a faster rate and weighs about 1,500 pounds at maturity.

Growth of an animal starts as a fertilized egg inside the dam's body. This growth before birth is called *fetal life*, and a developing offspring, whether cow or man, is called a *fetus* (FEE-tus).

The fertilized egg (beginning development of the animal in its mother's body) is about the same size in all mammals (animals that nurse their young). Thus in the beginning stages of fetal life, the rat and the cow are about the same size. Growth of the fetus continues in an orderly fashion from the time the egg is fertilized until birth. *Gestation* (jess-TAY-shun), or the pregnancy period, lasts about 9 months in cattle.

Table 1—Average Growth Chart for Females of the Various Dairy Breeds

Age *Months*	Ayrshire *Lbs.*	Guernsey *Lbs.*	Holstein *Lbs.*	Jersey *Lbs.*
Birth	71	65	933	50
1	86	79	115	70
2	114	105	155	96
4	190	177	260	176
6	281	267	379	268
8	371	350	491	357
10	451	427	589	432
12	518	490	685	495
14	576	556	752	549
16	635	605	820	597
18	690	663	890	644
20	743	712	961	694
22	790	763	1038	742
24	845	818	1104	785
Mature (6–7 yrs.)	1200	1100	1500	1000

Proper nutrition of the dam during gestation is important to fetal development, for the mother provides the unborn animal with its only food supply.

Birth causes a temporary check in growth, but the newly born animal soon recovers, and then growth proceeds in an orderly way. Body weight increases at a fairly steady and fast rate until the animal reaches about two-thirds of its mature body weight. As Figure 2 shows, the most rapid gain in weight is made between 2 and 12 months of age.

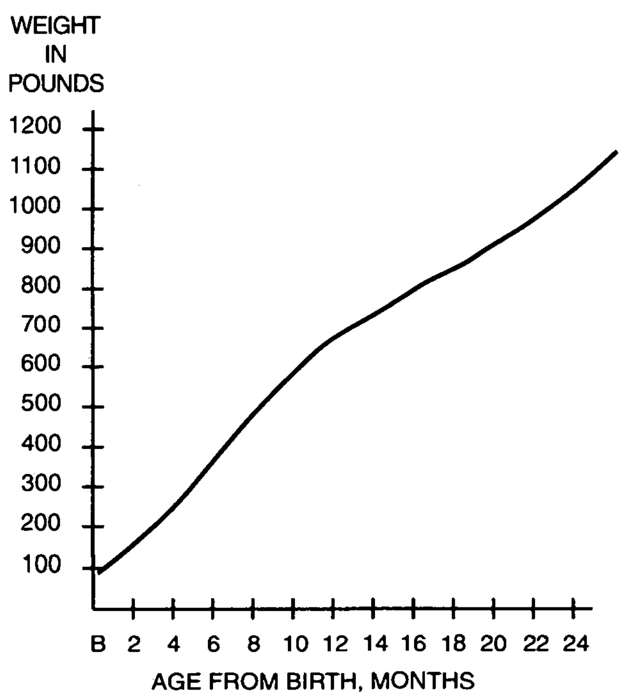


FIG. 2—Average growth curve of Holstein heifers.

Can you calculate the average daily gain of heifers from birth to 12 months of age by using values obtained from Figure 2? The answer is approximately 1.62 pounds per day. If you can determine how this answer was obtained, then you are a junior statistician (a person who deals with facts which can be stated in numbers).

The gain in weight during the second year of life is somewhat less, averaging only 1.15 pounds per day. After 2 years of age the gain continues at a much slower rate until mature weight is reached at 6 or 7 years of age. (Remember that these figures and the graph in Figure 2 are averages for Holstein heifers and are larger than comparable figures for the smaller breeds.)

The rate of growth in human beings differs markedly from the rate for dairy cattle. Humans have a much longer "growth period" in proportion to the average length of life. We reach our physical maturity or full growth after 18 to 20 years while the cow may reach full growth in 3 or 4 years. So you can see why the good dairyperson must know about feeds so he or she can give the cow all of the muscle and bone-building nutrients she needs during this short time.

Feed and Growth

Feeds that provide protein, energy, minerals, and vitamins for the growing animal are presented in the section on nutrition. During growth, the calf is forming new body tissues rapidly. This means there is a high requirement for feed nutrients, especially protein, for the calf just as for a growing child. Growing animals require more protein, energy, minerals, and vitamins to grow than mature animals need to maintain a constant weight.

Colostrum (co-LOSS-trum) milk is the crucial first meal for newborn calves. The calf, when born, has acquired little or no defense against disease and infection from its mother. The cow combats disease by building *antibodies,* which are found in the bloodstream. In order for the young calf to survive, nature has provided a "special milk" which contains more nutrients and less water than normal milk (Table 2). Colostrum milk also contains up to 70 times as many antibodies (immunoglobulins) as normal milk (Table 3). The very first milk following calving is the highest in antibody content and nutrients when compared to colostrum milk obtained at later milkings.

The benefits of colostrum milk are related to its high solids content which provides a quick source of easily digested energy and the immunoglobulins (antibodies) which provide disease protection. Based on caloric content, first milking colostrum has almost twice the caloric value of normal milk.

It is important to see that the newborn calf consumes at least 4 quarts of colostrum within the first 15 to 20 minutes of life. This is because the absorption of immunoglobulins is by a process known as pinocytosis. This process involves

Table 2—Composition of Cow's Colostrum and Whole Milk*

Constituent	Colostrum Milking First	Third	Fifth+	Whole Normal Milk
Total Solids %	23.9	14.1	13.6	12.9
Fat %	6.7	3.9	4.3	4.0
Protein %	14.0	5.1	4.1	3.1
Ash (mineral)%	1.11	0.87	0.81	0.74
Immunoglobulins, %	6.0	2.4	—	0.09
Vitamin A, ug/100 ml	295	113	74	34

* Adapted from Foley, J.A. and O.E. Otterby, 1978. Availability, storage, treatment, composition and feeding value of surplus Rostrum: A review. *J. Dairy Sci.* 61:1033.
+ Composite of fifth and sixth milking.

the creation of a fluid pocket for the transport of the immunoglobulins through the intestinal walls to the lymph. The rate of transport decreases rapidly as the calf gets older and stops completely by the time the calf is 24 hours old. Antibodies must be absorbed in the whole form since the digestive process will destroy their ability to give disease protection. Feeding the calf also tends to close down the absorption system so it is important that an adequate amount of colostrum milk be fed to the calf as soon after birth as possible. Don't rely on the calf voluntarily nursing her mother, because oftentimes the calf does not consume enough colostrum or is too weak to nurse.

Colostrum milk is a valuable nutrient resource and surpluses of the material can be fed to other calves. If there is too much colostrum milk produced to use immediately, it is possible to store the material by allowing it to ferment (sour) or by adding preservative type chemicals to it (acetic, propionic or formic acid). Calves prefer fresh or fermented colostrum to chemically preserved colostrum. Research studies have shown that calves fed fermented colostrum or chemically treated colostrum grow as well as calves fed whole milk.

When preserving colostrum be sure to store it at cool temperatures (70°F or lower) and in noncorrosive or lined containers. For further instructions on preserving and feeding stored colostrum milk, contact the Cooperative Extension office in your county.

Table 3—Average Composition (mg/ml) of the Major Antibodies (Immuno-globulins) in Colostrum Milk*

Lactation	Milking First	Second	Third
First	29.8	23.5	14.3
Second	30.5	22.4	11.4
Third	33.9	26.6	16.8
Fourth-Seventh (pooled)	41.6	36.3	24.9

*Adapted from Oyeniyi, O.O. and A.G. Hunter. 1978. Colostrum constituents including immunoglobulins in the first three milkings post-partum. *J. Dairy Sci.* 61:44.

Hormones and Growth

Besides being influenced by nutrition, growth is to a large extent also controlled by certain hormones. *Thyroxin* (thigh-ROCK-sun), a hormone from the thyroid gland located in the neck, is necessary for growth to occur at all. Growth hormone, which comes from the *pituitary* (pi-TEW-uhtary) gland located in the head near the brain, determines how much an animal grows. Most of you have seen giants or midgets, perhaps on television. These persons were probably affected by the growth-stimulating hormone. If there is an excess of the growth hormone given off from the pituitary during the growth period, then a small, undersized person will develop. You have no control over the hormones, but you can have a powerful effect over growth through feeding.

Make a Growth Curve

Your animal should continue to grow rapidly, but do not overfeed so that she becomes fat. You can check Table 1 to see if your heifer is as large as she should be according to her age and breed. The average weights and growth charts for Brown Swiss and Milking Shorthorns are not listed, but the weights for these two breeds are close to those of Holsteins. You can use the figures (pounds and months) in Table 1 to make a growth curve for your breed just like the curve shown in Figure 2. Also you may wish to weigh your animal at various ages and mark the body weights on the chart to compare her growth curve with the average for the breed.

If you do not have a scale available to weigh your animal, you can estimate her weight by measuring her heart girth with a cloth tape or a steel carpenter's tape. Place the tape around her body just behind the front legs and shoulders and pull it tightly. Table 4 shows the estimated weights for various heart girth measurements. You can probably obtain a cattle weight tape from a farm supply store or your feed dealer. This handy tape has the animal weights printed on it, which corresponds to the heart girth measurements.

When to Breed

The age and size of your heifer largely determines the time you will want to breed her. Well-grown heifers should normally be bred when they are about 15 months old so they will calve at 24 months of age. Jerseys tend to mature somewhat earlier than the other dairy breeds so can be bred 1 to 2 months earlier if they are well-grown. If the heifer is smaller, breeding should be delayed. The minimum breeding weight for each breed follows:

Ayrshires	700 lbs.
Brown Swiss	750–800 lbs.
Guernseys	650 lbs.
Holsteins	750–800 lbs.
Jerseys	575 lbs.
Milking Shorthorns	750–800 lbs.

You will also want to consider the season of the year in which your heifer will calve when breeding her. Heifers that calve in the fall and early winter will usually produce more milk than those that freshen in the spring and summer.

Table 4—Estimated Weights for Different Heart Girth Measurements

Heart Girth *Inches*	Weight *Pounds*	Heart Girth *Inches*	Weight *Pounds*
26	80	55	501
27	84	56	526
28	89	57	552
29	95	58	579
30	101	59	607
31	108	60	637
32	118	61	668
33	128	62	700
34	138	63	732
35	148	64	766
36	158	65	800
37	168	66	835
38	180	67	871
39	192	68	908
40	208	69	947
41	224	70	987
42	240	71	1027
43	257	72	1069
44	275	73	1111
45	294	74	1153
46	314	75	1197
47	334	76	1241
48	354	77	1285
49	374	78	1331
50	394	79	1377
51	414	80	1423
52	434	81	1469
53	456	82	1515
54	478		

Choice of Sire

Choosing a sire to mate to your heifer is an important consideration. With artificial insemination widely available you will have many outstanding sires to choose from. As explained previously, milk production and type traits are influenced by the inheritance received from each of the parents. Milk production is further influenced by the way the cow is fed and cared for.

You will want to try to ensure that the offspring from your heifer will be endowed with the inheritance for high milk production as well as sound functional type traits. To accomplish this, choose a sire whose daughters have already demonstrated their ability to produce milk at a high level. Such a sire is more likely to transmit high production to his offspring than one whose offspring have no such production records. Although the sire does not produce milk, he is equally as important as the dam in determining the inheritance of the offspring.

To evaluate the sire you will use, study his pedigree, his offspring and their performance, and his ancestors. Be sure to select a sire proven for high production. Find out his latest Sire Summary proof to learn his PTA milk, PTA fat, PTA protein, and reliability. Also try to select a sire that has a plus PTA for Type.

If you believe your heifer has some type traits that need improvement, try to select a sire that has proven he can improve that particular trait. You may wish to talk to the artificial breeding technician or to others who know about the strong points of the sires available for your use. All artificial breeding organizations serving the Pacific Northwest publish mating guides to help dairypersons select sires to help improve the various type traits. In addition, all of the sire directories publish the linear trait data they have collected on the daughters of each bull in their organization. The breed associations also publish the official production and type proofs for the bulls within their breed. If you need advice or guidance on what to breed your heifer to, you should have no trouble seeking it out.

As we are talking about breeding heifers you should consider using a calving ease sire. The National Association of Artificial Breeders developed a system of evaluating sires for calving ease. Some bulls (particularly in the large breeds—Holsteins and Brown Swiss—sire very large calves and should not be used to breed first-calf heifers. Large calves cause difficult births. This condition is called dystocia (dis-tosh-ee-ah) and should be prevented. Every artificial breeding association publishes a calving ease summary for its sires.

If you carefully select a sire for breeding to your heifer, you are exercising the basic fundamentals in the science of dairy cattle improvement. Breeding decisions are challenging and can be most profitable if you utilize the knowledge at hand and have a bit of luck. We can predict production and type, but there is still some uncertainty as to the result of a mating. Although genetics is a "science" there is some "art" in the breeding of livestock.

THE WHY'S OF NUTRITION

WE LEARNED from the previous section on growth that the dairy calf needs many of the same nutrients as the growing boy or girl. The calf, however, develops a four-compartment stomach which allows it to obtain its nutrients in a much different form from the food that you might eat. The cow is a ruminant (animal that chews its cud) and has a much more complicated digestive tract than animals such as the horse or pig, which have a simple stomach containing only one compartment. Humans also have a simple stomach with a single compartment.

The cow's ability to make milk from forages (hay, silage, and pasture) and other feeds that are not suitable for humans to eat is the basic reason for the dairy farm. The dairy cow is extremely efficient in converting feeds which humans can't digest into a highly nutritious product for human consumption. The cow not only is a hay burner, but she converts low quality proteins from grains and other feeds into high quality proteins for human use.

Parts of the Stomach

The first compartment of the cow's stomach is the *rumen* (ROO-men) or paunch. It is by far the largest in the mature cow. The rumen serves as a reservoir for feeds and as a digestion vat. It contains numerous micro-organisms such as bacteria and protozoa that break down the forages into simple nutrients.

The second stomach compartment is the *reticulum* (ree-TICK-you-lum). People sometimes call this compartment the "honeycomb" because the wall of the reticulum is lined with folds of tissue that resemble a honeycomb. The function of the reticulum is quite similar to that of the rumen. Ruminant animals are grazers by nature and can be indiscriminant in their selection of feed. Because of this they often consume nails, pieces of wire, small stones and other foreign objects. These objects tend to accumulate in the reticulum and the presence of sharp objects can pose serious problems, especially if the reticulum is punctured. When foreign objects irritate or puncture the reticulum, the condition is called reticulitis (ree-TICK-youlight-us) or "hardware disease."

The third compartment is the *omasum* (o-MAY-sum). It is often called "manyplies" because of the many folds in its walls. These folds or "leaves" are powerful and are believed to remove the water from feed and grind or strain the feed into finer particles.

The fourth compartment, *abomasum* (ab-oMAY-sum), is more like the human stomach. Here digestive juices which help break down feed are secreted, and some digestion takes place.

The digestive tract of the young calf differs from that of the cow in its overall size and in the comparative sizes of the four stomach compartments. In Figure 3, you can see that in the young calf the abomasum and the omasum are much larger than the other stomach compartments. Under normal conditions, milk that is fed to a young calf goes directly into the abomasum where it can be digested readily. In calves that are fed hay and other roughages, the rumen develops rapidly so that at 1 year of age the sizes of the four compartments of the stomach have shifted to those of the mature animal. In the mature animal the rumen makes up about 80% of the entire stomach and is called the paunch or storehouse. It can hold about 35 gallons of feed and water.

Nutrients Needed

All animals require nutrients so they can grow, maintain their bodies, and move about. Cows must have additional nutrients to produce milk. The proteins, sugars, fats, miner-

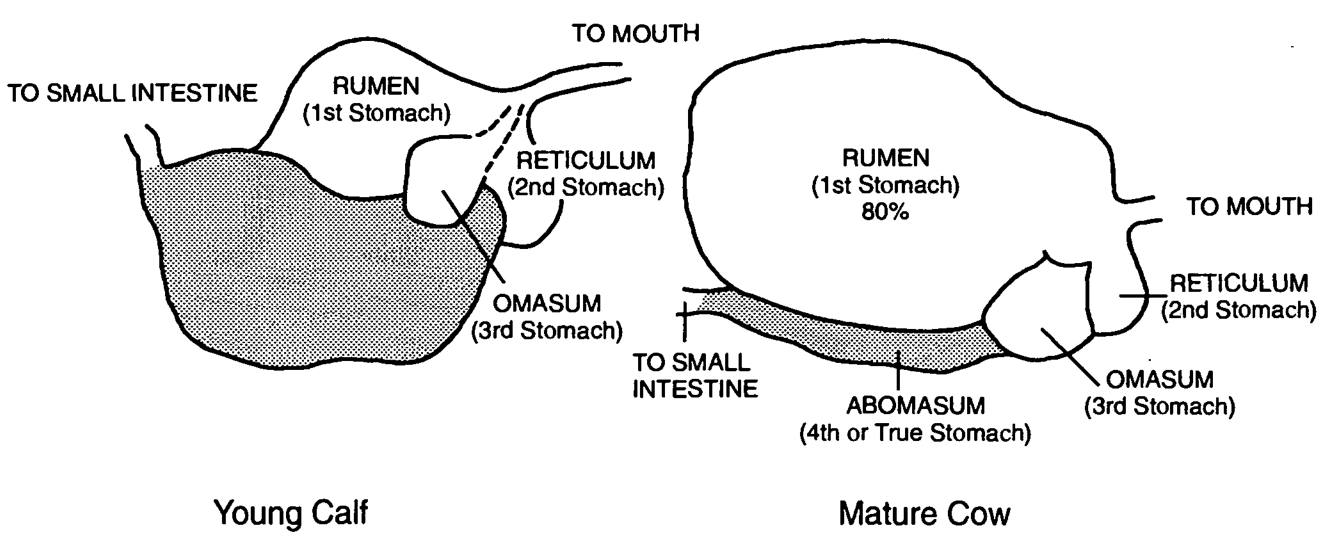


FIG. 3—Sizes of the various stomach compartments of the young calf and the mature cow.

als, and vitamins in the feeds cows eat supply these needs.

The most important nutrient needs of a dairy animal are:

1. Carbohydrates (sugars) and fats for energy and milk production.
2. Proteins for body growth, body maintainance, and milk production.
3. Fiber for normal rumen function maintainance of normal milk fat tests.

Carbohydrates and fats (energy)—Grains or "concentrates" provide the most concentrated source of energy. Hay, silage, and grass provide energy, too, however, in a less concentrated form. Your animal would have to consume 6 or 7 pounds of pasture to obtain the same amount of energy found in a pound of grain.

Proteins—Proteins are important for growth, milk production, and repair of body tissues. Common sources of protein are legume hays, immature grasses, and oil meals such as soybean oil meal and cottonseed oil meal.

Minerals—Cattle require some of the mineral elements. Even if a mineral is considered to be essential, it can adversely affect an animal if it is included in the diet at excessive levels.

Calcium and phosphorus are necessary for good bone growth and considerable quantities of calcium are required for milk production. Legume hays grown on soils high in calcium content furnish much of the calcium for dairy cattle here in the Pacific Northwest.

Sodium chloride (salt) has been found to be essential for all animals. The two elements, sodium and chlorine, function in the body to control body fluid balances, heart action and have an influence on the nervous system.

Iodine is an essential element for animals and man. Although nearly every cell in the body contains iodine, the main iodine reserve is found in the thyroid gland. The thyroid hormones, which contain iodine, have a role in temperature regulation, metabolism, reproduction, growth, and development. A deficiency of iodine causes goiter ["big neck"] in cattle and humans. Iodine is considered to be deficient in many areas of the Pacific Northwest.

Selenium has been identified as being an essential mineral. It plays a role with Vitamin E in preventing "white muscle disease" in calves and also has been shown to help prevent retained placenta in cows at parturition (calving). Selenium is deficient in much of the Pacific Northwest so must be supplemented in the grain mix for cows. Too high levels of selenium can be toxic to animals.

Many dairypersons provide a simple mineral mixture of iodized trace mineralized salt and either dicalcium phosphate or steamed bone meal on a free choice basis to help balance the mineral needs for their herd. It was once thought that if such a mix were provided, the animals would eat all they need. Currently most animal nutritionists feel that cows will consume minerals offered free choice in excess of their need, but not at a level that would be toxic.

Several other mineral elements are essential for dairy cattle, but they are useually present in sufficient quantities in normal rations. Other essential elements include cobalt, magnesium, iron, copper, zinc, manganese, potassium, and sulfur. Some of these minerals are present in trace mineralized iodized salt which should be provided either loose or in a salt block. This is cheap insurance against trace mineral deficiencies.

There are a few minerals that are considered toxic to cattle that you should know about. Among these are lead and fluorine.

Lead—Acute lead toxicosis represents the greatest incidence of accidental poisoning in domestic animals. The most common source of lead associated with death in cattle is leaded paints.

Fluorine—Fluorine toxicity in animals may be encountered either through the water or feed. It is a concern to livestock producers living near industrial plants that heat earthy materials to high temperatures (copper smelters, aluminum plants, etc.).

Severe fluorosis causes stiffness in the joints, emaciation, loss of appetite, and mottling of teeth.

Vitamins—Vitamins are necessary for life and are usually referred to as "accessory growth factors." Very small amounts of vitamins are needed for normal growth and maintainance of animal life. Table 5 lists the vitamins that are considered to play an essential role in dairy cattle nutrition.

Water. Water is one of the most essential of all the nutrients. Animals can survive longer with no feed than they can without water. Water is one of the largest single constituents of the animal body. It comprises 70% in a newborn calf, and well over 50% in the mature dairy cow. Water is necessary to the shape and life of every cell and is a constituent of every body fluid. It serves to transport various substances and is a medium to carry nutrients to the cells and as a carrier of waste products. It is vital in the temperature regulation of the animal body and is necessary for many important chemical reactions of digestion and metabolism. In addition, water plays an important role in several other body functions in all species.

Water quality for cattle is important. Provide animals with an adequate supply of fresh water free of contamination from pollutants, be they bacterial or chemical.

The National Research Council (NRC) periodically publishes feeding standards tables giving the nutrient requirements and allowances for all classes of domestic animals. The NRC tables are widely used to calculate and balance rations. The NRC tables are under constant review by animal nutritionists and as new knowledge is accumulated the tables are revised.

Rumen Function and Digestion

Before feed can be used for energy by the body, it must

Table 5—Vitamins for Dairy Cattle

Name of Vitamin	Functions	Some Deficiency Symptoms	Sources	Comments
FAT SOLUBLE VITAMINS				
Vitamin A	For bone growth, night vision, maintenance of epithelial tissue—respiratory, urogenial and digestive tracts and the skin.	Stunted growth, loss of weight, night blindness, nervous incoordination, steriity in males and females or young are born dead or weak.	Vitamin A can be provided as the synthetic vitamin or as its precursor carotene. Rich carotene sources—green leafy hays (not over 1 year old), grass silages, lush green pastures, carrots, whole milk, dehydrated alfalfa meal.	Vitamin A found only in animals. Plants contain the precursor carotene—Animals able to store considerable Vitamin A. Both vitamin A and carotene readily destroyed by oxidation.
Vitamin D	Aids in assimilation of calcium and phosphorus. Necessary in normal bone development including the bones of the fetus.	Rickets in young, osteomalacia in adults.	Vitamin $D_2$1 irradiated ergosterol—the plant form. Vitamin D_3, the animal form—sunlight. Sun-cured hays, irradiated yeast.	Most mammals can use D_2 or D_3, however birds require D_3. Tissue storage of D very limited.
Vitamin E	An antioxidant muscle structure. Reproduction.	White muscle disease in calves. Reprodutive failure.	Germ or germ oil of plant seeds. Green plants. Green hays.	Vitamin E widely distributed in all natural feeds. Utilization of vitamin E is dependent on adequate selenium.
Vitamin K	Essential for prothrombin formation and blood clotting.	Prolonged blood clotting time, generalized hemorrhages, death in severecases.	Menadione (K_3). Green pastures, well-cured hays, fish meal. In general vitamin K widely distributed in normal animal rations. Also all classes of farm animals synthesize it.	Vitamin K has definite value in humans. Well known antagonists of vitamin K are dicoumarol and warfarin.
WATER SOLUBLE VITAMINS (B COMPLEX) This group includes thiamine, niacin, biotin, riboflavin, choline, folic acid, pantothenic acid, para-amino benzoic acid, pyridoxine and vitamin B12. The group of vitamins is essential; however, the bovine is able to utilize the B-complex vitamins that are produced by rumen micro-organisms. Also many normal feedstuffs are good sources of the vitamins in this group.				
Vitamin C (ascorbic acid)	Collagen formation. Formation of the intercellular substances of the teeth bones, and soft tissues. Increases resistance to infection.	Scurvy; swollen, bleeding, and ulcerated gums; loosening of teeth and weak bones.	Asorbic acid, citrus fruits, green pastures, well-cured hays.	In farm animals, odinary farm rations and body synthesis provide adequate vitamin C.

undergo drastic changes known as *digestion*. Thus, the term digestion includes all the changes the feed must go through within the digestive tract to prepare it for absorption into the bloodstream and use in the body. The feeds are broken down into the various nutrients—carbohydrates, fats, proteins, minerals, and so forth. These nutrients are further broken down into their component parts by the process of digestion.

When a cow is eating dry forage (hay), she chews her feed only enough to moisten it with saliva and enable her to swallow it. Saliva comes from glands located in the mouth. A cow eating dry feed may secrete as much as 125 pounds of saliva in 24 hours. The sensation of taste in humans depends upon saliva as it dissolves small amounts of the food we eat, enabling us to taste it with taste buds on the tongue.

After the feed is swallowed, it passes into the front of the cow's rumen where it is stored. When the cow has satisfied her appetite, she seeks a quiet place and proceeds to

Table 6—What's In Feed

Nutrient	Use	Where It Comes From
Protein	Growth, repairing body tissues, milk production	Oil meals, legume hays, immature grasses, skim milk, by-product feeds, whole cottonseed
Carbohydrates	Energy for: body maintenance, growth, milk production	Grains, hay, silage, pasture
Fats	Energy source	Grains
Minerals	Skeleton, essential parts of enzymes and hormones	Tracce mineralized salt, di-calcium phosphate, steamed bone meal, alcium in legume hays, phosphorus in grains and oil meals
Vitamins	Growth, reproduction, general health	A—green leafy forages, yellow orn B—produced by bacteria in rumen C—produced in digestive tract D—sunlight, fish oils, irradiated yeasts E—grains

ruminate or "chew her cud." Most cows will actually spend more time each day chewing their cud than eating. The feed in the rumen becomes moist. Then in the process of rumination, a mass of solid food (bolus) or "cud" is forced up the throat to the mouth. This process is called *regurgitation* (ree-gerji-TAY-shun). The cud is thoroughly chewed and swallowed again. Then the finely chewed feed passes into the other compartments of the stomach. And, the cow does all of this with no upper teeth in front!

How Feed Is Broken Down

Vigorous movements and actions in the other three compartments of the stomach help break down the food materials into nutrients. Chemical substances called *enzymes* (EN-zimes) are present in the digestive tract. They break down these nutrients into simpler materials. Enzymes are produced in various parts of the digestive tract and act as keys in starting certain chemical reactions in digestion. Enzymes are sometimes called *catalysts* (CAT-uh-lists) because they start certain reactions but do not enter into them and are not used up in the process. Carbohydrates are broken down by enzymes into simple sugars such as *glucose*. Thus, when a person eats ice cream or a cow consumes corn, the carbohydrates in the food must be changed to glucose before they can be used in the body.

The way in which carbohydrates and proteins are digested in the cow is drastically different from that in a simple-stomached animal. This difference allows a cow to consume and use coarse feeds such as forages. Digestive juices, such as those in the human stomach, are not able to digest very coarse feeds such as *cellulose* (CELL-you-lohs). This material forms the cell wall of plants and makes up a large portion of forages. Cellulose and other coarse materials are broken down by bacteria in the rumen. This is why a ruminant can consume and digest forages that simple-stomached animals cannot.

The Role of Bacteria

"Bacteria break cellulose down into short chain fatty acids (acetic, propionic, and butyric acids), which serve as food for the ruminant animal just the same as simple sugars." Acetic acid is the same as common table vinegar, and butyric acid is one that is found in butterfat.

These fatty acids are called volatile fatty acids because they are changeable and will readily become a vapor when heated. Gases (such as carbon dioxide, which has the chemical formula CO_2) and heat are produced in the rumen as byproducts of bacterial action. The heat is used by the cow to help keep warm during cold weather.

In man and simple-stomached animals, the proteins in feed are broken down by enzymes into *amino acids*. Amino acids are the "building blocks" of all body cells, enzymes, blood proteins, and antibodies used by the body in fighting infections, so a daily intake of protein is necessary for growth and life. There are 23 known amino acids of which 10 are considered "essential," which means that they must be supplied in the daily rations for simple-stomached animals.

Protein digestion in the ruminant is entirely different from that in simple-stomached animals. Bacteria in the rumen are able to break down complex proteins into simpler forms such as ammonia (NH_3). The bacteria in turn take the simple forms that contain nitrogen (N) and hook them together with fatty acids, such as acetic acid ($C_2H_40_2$), to form amino acids. Thus, bacteria in the rumen are able to *synthesize* (SIN-the-size), or manufacture, the essential amino acids required by simple-stomached animals.

Recent dairy cattle nutrition research has indicated that some proteins a cow consumes are not degraded or broken down in the rumen by rumen microbes, but are passed through to the abomasum where they are digested. These proteins are called "by-pass" proteins. They are of interest because they may be useful in feeding high producing cows (which have a high protein requirement), as it isn't necessary to increase protein levels above normal levels in a ration. Protein is the most expensive nutrient in a ration and ways to save feed costs are always of interest to dairy farmers.

Bacteria Are Also Consumed

Rumen bacteria are able to use limited amounts of nonprotein substances that contain nitrogen and build them into amino acids. One of these nonprotein nitrogen (NPN) sources is urea. The amino acid balance of the proteins fed to ruminants is not a matter of great importance because all of the essential amino acids are manufactured or synthesized right in the rumen by microbial action. As the bacteria pass through the digestive tract they are broken down or digested. The protein nutrients inside them are released in the form of amino acids for use by the animal's body. This is the way the B-complex vitamins made by bacteria become available to the animal.

The feed material passes out of the stomach into the small intestine where most of the nutrients are absorbed into the bloodstream. The small intestine, which may be up to 130 feet long in mature cattle, is lined on the inside with little finger-like projections called *villi* (VILL-eye). These villi are richly supplied with blood vessels, and the digested nutrients (glucose, amino acids, etc.), which are soluble, are readily absorbed through them into the bloodstream. Some absorption of simple nutrients may take place directly through the rumen wall into the bloodstream.

The Process Is Completed

Minerals and perhaps the vitamins are dissolved by digestive juices in the stomach and made ready to be absorbed into the small intestine. Fats are broken down by enzymes in the small intestine and absorbed. Water requires no digestion and can be absorbed directly into the blood. The nutrients are carried throughout the body in the blood to nourish all parts of the body.

As pointed out earlier, the absorbed nutrients are used for maintaining the body, repairing tissues, making milk, and for reproduction. The waste material from the feed passes on through the small intestine into the large intestine and is excreted.

The process of digestion in the rumen of the dairy cow is one of the most remarkable biological processes found in nature. The cow provides a home in her rumen for bacteria, and she consumes feed so that the bacteria can live on the celluloses and proteins in the feed. The bacteria in turn are digested and release nutrients that go into the bloodstream to feed the cow.

THE STORY OF INHERITANCE

THE WORD "INHERIT" means to receive something from relatives or friends. Frequently, we think of this in terms of money or property, but of greater importance is the *genetic* inheritance we receive from our parents. This largely determines our physical characteristics such as color, size, and shape.

One of the most interesting characteristics of living things is their ability to reproduce themselves with reasonable accuracy. You have no difficulty in telling the difference between a calf and a lamb. And if you are an expert, you have no difficulty in identifying the breed of the calf, that is, whether it is a Jersey or Guernsey calf. All the known inherited characteristics behave according to definite scientific laws. Genetics is the science which deals with these laws and inheritance in general.

How Life Begins

A calf, like humans and other mammals, grows entirely from one cell, a fertilized egg. This cell is formed from the union (joining) of two minute cells—one called the sperm from the sire and one called the *ovum* (OH-vum), or egg, from the dam. The joining of the sperm and the egg to form a single small cell is called *fertilization* (fur-till-uh-ZAY-shun) and results in the beginning of a new individual and a new life. The single cell from which the new individual grows is so small that it can barely be seen without a microscope. If one could see it with the naked eye, the cell would be about the size of a tiny speck of dust glistening in the sunlight. This tiny bit of living material is the only bridge between the offspring and its parents. All inherited characteristics must be contained in the fertilized egg.

In the center, or *nucleus* (NEW-klee-us), of each of these cells are rod-shaped structures called *chromosomes* (CROW-muh-somes). Each chromosome contains units of inheritance known as *genes* (jeans). The chromosomes are similar to a string of beads with the genes located on the chromosomes as shown in Figure 4. The gene is the basic unit of inheritance. Each inherited character—such as hair color, eye color, or milk production—is controlled by one or more genes.

The chromosomes always appear in pairs, except in the sperm and the egg where only one member of each pair is found. In cattle, there are 30 pairs of chromosomes in each body cell. In the egg of the cow, then, there are 30 individual chromosomes, all slightly different from each other. For each individual chromosome in the egg there is another chromosome corresponding to it in the sperm of the bull. Thus, when the sperm and egg join to form the new animal, the chromosomes become paired to make up the 30 pairs of chromosomes (see Figure 5).

This joining of the chromosomes enables the genes to become paired also, and one gene pair may determine whether or not the animal has horns, another pair may determine the color of the coat, and other pairs will influence milk production. Only one sperm can fertilize an egg, so one chromosome from each pair is contributed by the sire and one by the dam. Thus, each parent contributes equally to the inheritance of the offspring.

In the dairy cow only one egg is usually formed at a time, but millions of sperm are produced in the bull. When the primary egg cell divides in the cow, one-half of the chromosomes go to each of the resulting cells. However, most of the other cell material goes to the egg which leaves a small cell called a *polar body*. The egg cell is the important one, and the polar body is cast off with no apparent function. At the time of breeding, the sperm are deposited in the reproductive tract of the cow, and one sperm will fertilize the egg.

Sex Determination

The sex of the new individual is determined by the chromosomes. Of the 30 pairs of chromosomes, there is one special pair called the sex chromosomes. These two chromosomes are diagrammed in Figure 6, which shows the male and female sex cells, the sperm and the egg (sex chromonosomes are tabled X and Y). In the male, one chromosome of the sex-determining pair is labeled X, and the other chromosome is shorter and is labeled Y. In the female cell, both chromosomes of the pair are labeled X. When the cells divide, the male cell forms one sperm which carries an X chromosome and another which carries the Y chromosome. The female cell forms an egg with an X chromosome only. If the X chromosome from the male joins with the X chromosome from the female, the offspring will be a female. If the Y chromosome from the male joins with the X chromosome from the female, then the offspring will be a male. Chance alone determines what will happen.

Since only X chromosomes are produced by the female, the sperm from the male is what determines the sex of the offspring. Of course this is determined by whether or not a sperm containing an X-bearing chromosome or one containing a Y-bearing chromosome fertilizes the egg. The contribution from the male does decide the sex of the new individual, but the male has no control over which sperm will fertilize the egg. All males produce an equal number of sperm containing X and Y chromosomes, so the sex of the new individual is determined entirely by chance.

Milk Inheritance

The inheritance for milk production is somewhat more complicated. For this example let us say that three gene pairs are involved, although many hundreds of pairs may be involved. The capital letters in Figure 7 stand for 4,000 pounds of milk production and the small letters for 2,000 pounds of milk. If the large A, small b, and large C (AbC) chromosomes from the male join with AbC chromosomes from the female, the new offspring will be AAbbCC and have the potential to produce 20,000 pounds of milk. However, if the other two chromosomes aBc unite, the individual will have the potential to produce only 16,000 pounds of milk. Again it is possible for any combination of the chromosomes to unite at the time of fertilization. Can you join the chromosomes from the male and the female in such a way that the offspring would have the potential to produce 18,000 pounds of milk?

Basically, this is the way inheritance works. However, inheritance is much more complicated and these are only simplified examples. Usually, there are several gene pairs involved for each inherited characteristic. This is especially true for determining milk production where hundreds of gene pairs may be involved. Some pairs are more desirable than others. Therefore, we find a wide range of differences among cows in their milk-producing ability. This helps us see why the pedigree and selection of a good sire are important in providing the best chance for desirable genes.

Inheritance and Environment

Environment means "surroundings" and includes all factors other than inheritance. For dairy cattle, environment could be defined as the sum of all conditions and influences which may affect the development and performance of an animal. This would include such things as weather, housing, feed, and management. Therefore, good inheritance alone is not enough. The amount of milk and fat a cow produces is dependent upon two groups of factors:

1. *Her inherited capacity for production.*
2. *The environmental factors such as feed and care.*

An animal with inheritance for superior milk production cannot produce at a high level without good feed and care. Likewise, a champion swimmer could hardly demonstrate his or her ability on a dry desert. Animals cannot choose their environment. They are dependent upon humans to care for them. Usually the response of animals is closely associated with the care they get. As a rule, there is a greater difference in environment between herds than there is in the inherited ability of the animals in the herds.

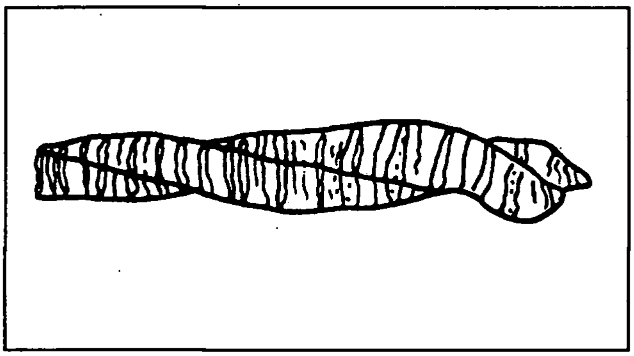


FIG. 4—A chromosome with genes.

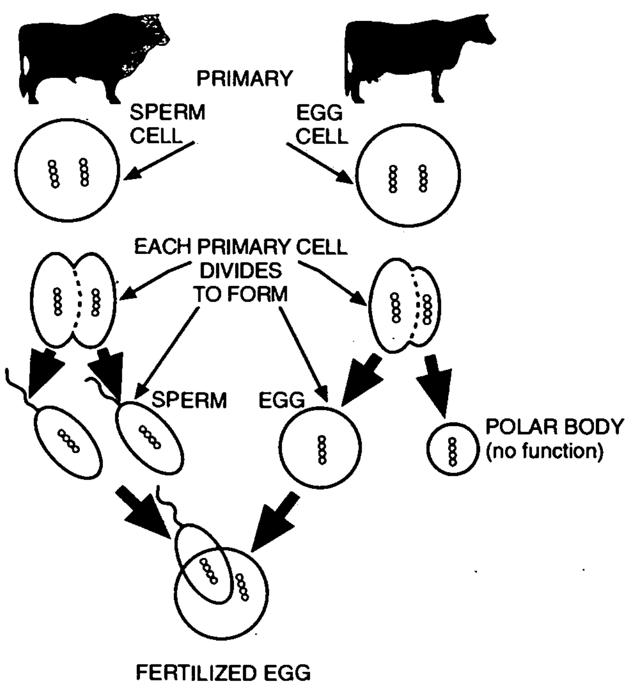


FIG. 5—Formation of sex cells and the start of a new individual. Only one pair of chromosomes is shown.

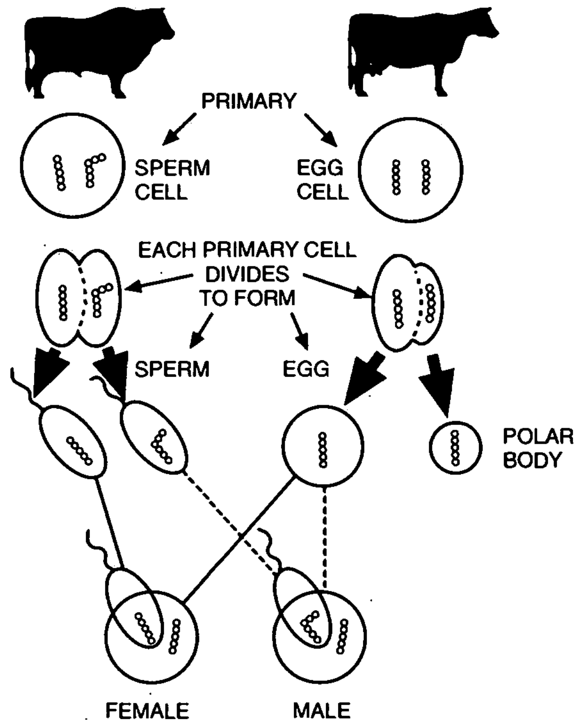


FIG. 6—Sperm and eggs may unite in these ways to give a 50:50 sex ratio of the offspring.

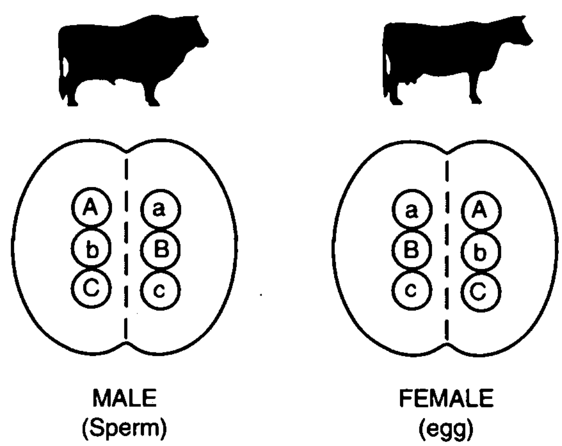


FIG. 7—Each of these genes makes some contribution to milk production.

How To Make Improvement

We cannot see genes and chromosomes. Therefore, the only way we have to determine the genetic make-up of an animal is by the animal's own performance. If the animal is young and has no production records, then we must rely on the performance of its parents as an indicator of the animal's expected performance. A basic understanding of inheritance through chromosomes and genes helps us to see the importance of studying the pedigree before selecting an animal. All of this points to the necessity of production testing in order to have the information available for evaluating the performance of animals.

Research has given cattle breeders an opportunity to make faster genetic gains than at any time in the past. By superovulating an outstanding cow, fertilizing the resulting eggs with semen from one of the best sires of a breed, and transferring the fertilized embryos to recipient animals, it is possible to greatly multiply the genetics of the best animals in a breed. Other advances have made it possible to freeze embryos in much the same manner as semen. Another advance has made it possible to split embryos so identical offspring can be produced. Scientific research will continue to make genetic advances possible.

REPRODUCTION IN THE FEMALE

THE COW not only contributes the female sex cell (egg) necessary for starting a new individual, but she also provides the environment in which the egg is fertilized and the new individual is nourished during its fetal days of life. These functions are carried out by the primary and secondary organs, as shown in Figure 8.

Parts of the Tract

The *vulva* is the only part of the reproductive tract than can be seen in the live cow, since the other parts are located

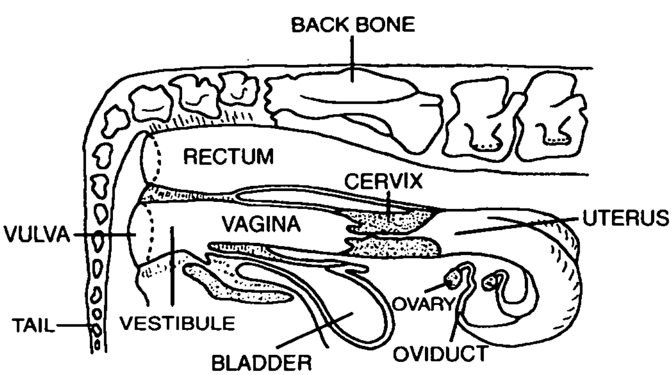


FIG. 8—Reproductive organs of the cow.

inside the body. The *vestibule* (VESS-tuh-bewl) extends inward about 4 inches from the vulva to the *urethra* (you-REE-thruh), which is the opening of the bladder. The *vagina* (vuh-JIE-nuh), which is about 12 inches long, extends from the urethra to the *cervix* (SIR-vicks). These tubes receive the male sex cells (sperm) and also serve as a birth canal for the calf at the time of calving.

The cervix is a tough muscular organ with a small opening in the center leading into the *uterus* (YOU-tur-us). In natural mating, the sperm are deposited in front of the cervix in the vagina, but in artificial insemination a small tube (catheter) is passed through the cervix and the sperm are placed in the uterus.

During pregnancy the cervix secretes a thick waxy substance which forms a "plug" to prevent the entrance of foreign materials into the uterus where the young calf is developing. The uterus, located just in front of the cervix, is a cavity which holds and nourishes the developing new life. It consists of a short body and two horns which look like ram's horns. The uterus serves as an incubator for the developing calf during pregnancy. The oviducts extend from the horns of the uterus to the ovaries. These tubes or ducts serve as a passageway for the egg and sperm. Fertilization usually takes place in one of the oviducts, and then the fertilized egg passes to the uterus where development proceeds.

How the Egg Is Formed

The two ovaries are the primary organs of reproduction in the cow. They produce ova (eggs) and *hormones* known as female *hormones*. Hormones are chemical regulators that control the functions of many different organs in the body. They are produced by a gland in one part of the body but have their effect on other parts of the body. The hormones involved in reproduction travel through the bloodstream from the glands where they are produced to the target organs where they have their effect. The ovaries are regulated by hormones from the *pituitary* gland (the master gland). The pituitary is located at the base of the brain.

The reproduction activity of the female occurs in cycles approximately every 21 days. During one of these cycles a little blister (called a *follicle*) forms on one ovary, and inside this follicle the egg is formed. Also, a hormone called *estrogen* (ESS-tro-jen) is formed inside the follicle as it grows and matures. The secretion of estrogen reaches a peak when the follicle is almost ready to rupture and the egg is ripe. When the egg is ready to be fertilized, this hormone causes the cow to show *estrus* (ESS-trus), or physical signs usually known as "in heat." This is the time the cow should be bred.

When the follicle ruptures releasing the egg, the cavity where the follicle ruptured is replaced by a yellow body known as the *corpus luteum* (kor-pus-LOO-tee-um). The corpus luteum produces a hormone called *progesterone* (pro-JESS-tur-own) or, the hormone of pregnancy. If the egg is fertilized, the corpus luteum produces progesterone throughout the pregnancy period. If the egg is not fertilized, the corpus luteum regresses and fades away. Then a new follicle is formed on the ovary and the same cycle is repeated. The estrus cycle of cows is about 21 days; however, the range can be between 18 and 25 days.

Fertilization

The sperm fertilizes the egg in the oviduct. The fertilized egg begins its development and passes down the oviduct to the uterus. Here it attaches itself to the uterus and forms a water sac around it called the *placenta* (plaa-SEN-tuh). The young calf develops its own blood supply. There is no mixing of the blood of the young calf and its mother. If you use your imagination to place the 34-day-old or the 70-day-old fetus shown in Figure 9 over in the uterus shown in Figure 8, you will have a picture of how the calf develops inside the cow. The uterus stretches in order to hold the developing calf and gradually returns to its normal shape after the calf is born.

All the body parts of the developing calf are formed by the 45th day of pregnancy; there is a gradual increase in the size of the developing calf. The normal birth rates of calves will range from 45 pounds for the smaller breeds of dairy cattle to 100 pounds or more for the larger breeds. The length of gestation (pregnancy) for the various dairy breeds follows.

BREEDS	DAYS
Ayrshire	279
Brown Swiss	290
Guernsey	283
Holstein	279
Jersey	279
Milking Shorthorn	282

Parturition or Calving

At the end of the gestation period the calf is fully developed and ready to be born. The process of giving birth to the young in all mammals is called *parturition* (par-tew-RISH-un). This is what causes mammals to start producing milk so they can feed the newborn animal.

Parturition or calving is brought about by the action of hormones. Certain hormones cause the reproductive organs of the birth canal, which is the passageway from the uterus through the cervix, vagina, vestibule, and vulva, to become relaxed and stretched so the calf can pass through. A hormone called *oxytocin* (ocks-i-Toe-sin) from the pituitary gland causes strong contractions, or squeezing, of the uterus which forces the calf out through the cervix and on through the birth canal. The calf is dropped free from its surrounding water sac. The calf begins to breathe and starts life in its new environment outside its mother.

After calving, the cow requires at least 45 to 50 days before her reproductive tract returns to a normal, healthy condition. This much time is necessary for the uterus to recover from the previous pregnancy and return to the normal size. If the delivery was difficult or if the placenta was retained, a longer period of time may be necessary before the reproduction tract is in condition for another pregnancy. A cow should not be bred back until 55 to 90 days after calving.

HOW MILK IS PRODUCED

MANY YOUNG PEOPLE who do not live on farms believe that "milk comes from a bottle or carton." The dairy cow is actually the milk making machine and she spends a considerable portion of her lifetime providing a nutritious food for human consumption. In addition to the milk she produces, she may leave several heifers to replace her, as well as bull calves that might be used for breeding purposes or for veal or beef. After a long productive life, she may end as beef herself.

FERTILIZED EGG (2-CELL STAGE) 1 DAY — 34 DAYS — DEVELOPING CALF 70 DAYS

FIG. 9—A fertilized egg and how it develops in the uterus during the first 70 days.

Inside the Udder

The process of "making milk" is considered to be one of the most wonderful processes in nature. Before domestication, the cow probably only produced enough milk to feed her calf. Through selection, the application of genetic principles, and by using improved feeding and management methods we have now developed many cows that can produce milk in excess of 10 to 15 times their body weight during each lactation.

The mammary gland or udder of the cow is comprised of four separate quarters with each quarter being drained by a teat (Fig. 10). The entire udder is located outside the cow's body (Fig.11). The blood supply and nerve fibers enter the udder through the inguinal canal (an opening at the top center of the udder). The udder is attached to the body by a combination of ligaments, connective tissues, tendons, and the skin surrounding it. Of these, the medial suspensory ligament which attaches to the body wall and extends down between the two halves of the udder to divide it lengthwise is considered to be the main weight-bearing attachment of the udder. Research workers at the Agricultural Research Service, Beltsville, MD, reported that the average empty weight of 50 udders removed from lactating cows to be 52 pounds. The udders of Holstein cows during the early part of lactation averaged 73 pounds. To this must be added the weight of the milk and blood in the udder. It has been estimated that udders of high-producing cows together with their contents will weigh between 100 and 250 pounds. Such a load must be well suspended if it is to remain in a proper position.

If the medial suspensory ligament breaks or stretches too much, the floor of the udder lowers and causes the teats to strut out or, if severe, the teats relocate along the sides of the udder. This condition is sometimes referred to as a "broken udder floor," "weak suspensory ligament," or as having the "pan out of the udder."

Milk is secreted or formed by a tiny cellular structure called an *alveolus* (al-VEE-O-lus). The alveolus looks much like a balloon and is lined inside with a single cell layer (Figure 12). The outside of each alveolus is covered with a rich supply of blood vessels. The cells lining the inside wall of the alveolus utilize the nutrients circulating in the blood stream to make milk. These nutrients pass through the cell walls to be made into milk and there is no mixing of blood and milk inside the udder. Alveoli (plural for alveolus) are elastic and can expand to store the milk that is secreted. Surrounding each alveolus are smooth muscle fibers that react upon stimulus to literally squeeze the milk from each alveolus and into the extensive duct system that drains the udder downward to each teat.

There are literally millions of alveoli in the udder. Figure 13 shows the structure of the interior of the udder. Alveoli are grouped together in clusters called *lobules* (LOB-ewls) with each lobule resembling a small bunch of grapes with each alveolus representing a grape. The lobules are arranged into groups called *lobes*. The lobes are drained by the extensive duct network in each quarter to the *gland cistern* which in turn drains into the *teat cistern.*

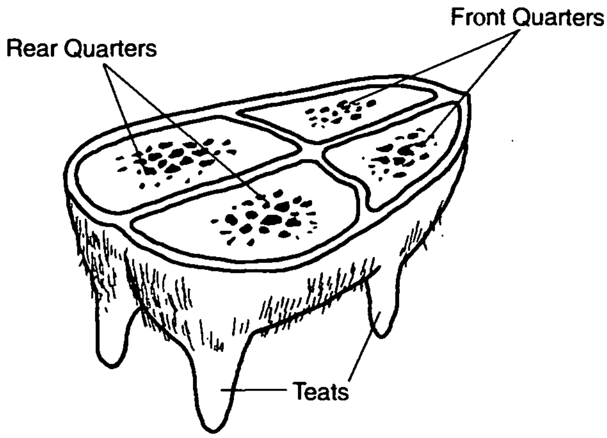


FIG. 10—Milk is secreted through four distinct quarters.

For the cow to make milk she must pump tremendous amounts of blood through the udder. It has been estimated that 400 pounds of blood must be pumped through the udder in order to produce a single pound of milk. This means that a cow producing 100 pounds of milk a day must pump 20 tons of blood through her udder daily.

Daily Harvesting

When you milk a cow, you do not take the milk. A physiological mechanism is triggered that allows the cow to be milked. This phenomenon is known as "milk let-down." When the cow is stimulated to let down her milk the nerve endings in the teats and the udder floor send a nerve impulse to the brain which, in turn, signals the *pituitary gland* to secrete the milk let-down hormone. This hormone is called *oxytocin* which is released into the blood stream and is carried to the udder where it reacts to cause the smooth muscle fibers around the alveoli to contract to cause milk let-down.

For best results the stimulus for let-down (usually washing the udder and teats) should be administered about 1 minute prior to attaching the milking machine teat cups or beginning to hand milk. Cows are creatures of habit and one should not change routines when it comes to milking. They should be milked at regular time intervals and should be handled in such a way as to make milking a pleasant experience for them.

If cows are frightened or stressed at milking time they may not let down their milk. The *adrenal glands* secrete a hormone called *adrenaline* that can block the action of oxytocin. This explains why cows should be milked on a regular schedule and be handled as quietly and gently as possible.

ANIMAL SANITATION AND PUBLIC HEALTH

HAVE YOU HEARD of Louis Pasteur? His work led to the *pasteurization* of milk. His accomplishments opened the way for a great period of progress in improving the health of man and animals. Infectious diseases have always been a menace to humans and animals. But, science has contributed to the control of many diseases, and research continues to further control and combat disease.

Prevention of Disease

Prevention is the most effective and economical way to treat diseases. Sanitation is a major factor in disease control. Many cattle ailments result from infections caused by bacteria or viruses. These organisms may enter the body through any opening such as the mouth, lungs, reproductive tract, skin cuts, or navel cord (in newborn calf). Disease organisms get into the bloodstream and multiply. Animals that are poorly fed or kept in dirty, damp quarters may catch diseases more frequently. Nothing can protect the animal—or the public that consumes the animal's products—like good care and management of the animal by its caretaker.

The body tries to fight disease itself. The animal body has a remarkable series of cells called *phagocytes* (FAG-o-sites) that are of utmost importance in preventing disease. They are widely distributed in the body and are capable of destroying invading bacteria. There are other natural body defenses such as inflammation, which is a "walling off" of the invading organisms in an effort to localize an infection and protect the rest of the body. However, these natural body defenses can be overpowered, and the animal can become sick or die.

Certain things can be added to the natural defenses to help protect the body. When some foreign material called an *antigen* (ANN-tuh-jen) gets into the bloodstream, the body forms *antibodies* (ANN-tuh-bodies), which are specific protective substances. The antibodies react against the offending antigen to overcome its harmful effects. The antibodies formed are specific for the particular antigen (a specific antibody will work only against a specific antigen), and they will remain in the body to protect it against this specific invader. This is the way in which a vaccination protects you against a specific disease.

Vaccines Produce Antibodies

A vaccine is the commercially produced antigen of a particular disease. It actually gives the animal a slight case of the disease itself in order to force the body to manufacture protective defenses against the disease. It is strong enough to cause the body to make antibodies against it, that is, build up a "resistance," but not strong enough to overpower the body and cause the harmful effects of the disease.

Perhaps you have been vaccinated for polio, which is a disease caused by a "virus" organism. If so, you were injected with a polio antigen which caused antibodies to be built up in your body. These antibodies will remain in the bloodstream to attack and kill any polio virus that might enter the body at any time. Again, these antibodies are "specific" and would give you no protection against any other disease, such as smallpox.

Dairy Farmers Protect Public Health

Medical science has made tremendous progress in improving people's health. The dairy farmer plays a vital role in protecting the health of the milk-consuming public. Since milk is a commonly consumed beverage and one of our most important foods, it must be kept scrupulously clean and pure.

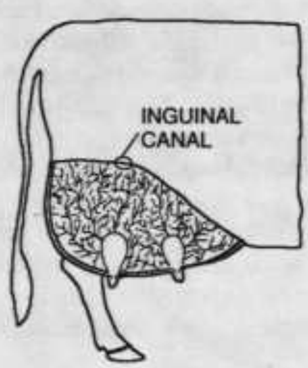


FIG. 11—The only connection between udder and body is through the inguinal canal.

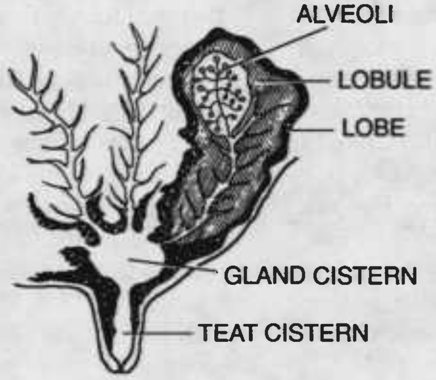


FIG. 12—Inside the udder.

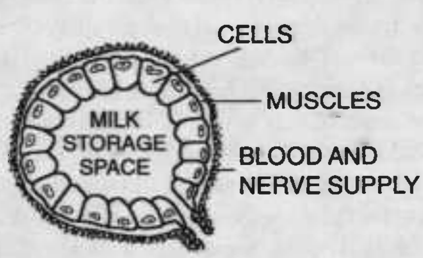


FIG. 13—An alveolus (the milk-secreting structure).

For consumer protection, there are health and sanitation regulations designed to ensure the purity and wholesomeness of milk. They include measures taken on the farm to ensure the purity of the raw product and more regulation designed to ensure its purity when it is ready to be consumed. Inspection of barns and farm milk-handling facilities is done on a routine basis. The cows are also checked to make sure there are no diseased animals. No other raw food product is regulated more closely than milk. The dairyperson provides facilities and produces a high-quality product that meets these strict requirements.

In addition to the regular inspection of dairy farm facilities, the raw milk is monitored closely for bacteria, somatic cell counts (SCC), sediment and adulteration with water and antibiotics. These constant checks help insure that healthful, high quality milk is delivered to the milk processor.

The second group of regulations involve the processing of dairy products and the bottling of milk. In addition to very stringent regulations to monitor the cleaning and sterilization of plant equipment, these regulations include standards for pasteurization. This process was named after Louis Pasteur, who discovered that heating milk to a high temperature (140°F) for 30 minutes would destroy all disease-causing bacteria. Pasteurization is an extra protective measure for making milk safer for consumption. Most milk is now pasteurized at higher temperatures for very short time periods (i.e. 180°F for 15 seconds). When the milk is pasteurized at these temperatures it is rapidly cooled to temperatures slightly above 32°F to help retain milk's keeping qualities and inhibit bacterial growth.

The American dairy industry has gained worldwide acclaim for producing safe, healthful products for human consumption. We can buy milk and dairy products from any dairy, store or restaurant with full assurance that they are safe, pure and wholesome.

MILK MARKETING

ALL MILK LEAVING DAIRY FARMS must meet certain quality standards. Milk has been historically graded A, B, or C, depending on sanitary standards and other quality measurements. Virtually all of the milk produced in the Pacific Northwest (Washington, Oregon, and Idaho) is produced as Grade A milk. This means the milk is of the highest quality and as such, may be used for fluid consumption. However, Grade A milk will be also be put to other uses. Where lower grades of milk are produced (B and C), they can only be used for the manufacture of powdered milk, butter, and hard cheeses. The lower grades of milk are usually referred to as "factory milk."

Modern milk marketing tends to price milk to the producer on the basis of usage. That is, milk sold for fluid consumption and certain other uses command a higher price than milk sold for evaporation or powder uses. The usage designations are referred to as CLASSES. Therefore milk pricing is based on Class I, Class II, and Class III usage.

In many areas dairy farmers produce milk under a Marketing Order which is administered by the United States Department of Agriculture or by a state milk marketing administration. The milk orders usually determine the usage of producer milk and administer the price the dairy farmer receives for his or her milk based on its usage in the market area. Some dairypersons therefore sell their milk based on two prices: that utilized for Class I uses and that for Class II and III uses. Currently many marketing order areas price milk on a blend basis whereas other areas still use a two-price system (base-surplus) for paying for milk.

Milk marketing is undergoing some rather sweeping changes. We are hearing more about *component pricing* (i.e. pricing milk based on its protein content, total solids and/or fat content) and in some areas milk is now marketed on a component pricing system. Until recently milk prices were historically based on milk fat content. Such a system fails to recognize the value of many milk components that are important nutritionally, such as protein and other non-fat milk solids. Component pricing is designed to recognize the value of all milk components rather than just the milk fat portion.

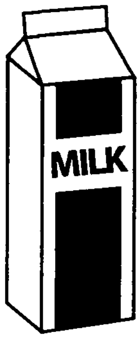
MILK A GOOD FOOD

MILK HAS PLAYED an essential role since the beginning of civilization. Prehistoric drawings from the Sahara, dating to 8000 B.C., feature picture stories of cattle. A mosaic frieze found at the ancient temple of UR (3500 B.C.) near Babylon depicts a dairy scene with milk containers and strainers. The word "milk" comes from the ancient Sanskrit word "Mrjati," which was used to describe the milking action.

Milk's role in the settlement of our country has indeed been important. The first cows arrived in this country in 1611 at Jamestown Colony and helped bring an end to a terrifying starvation. The Pilgrims who came on the Mayflower to found Plymouth Colony made the mistake of not bringing cattle with them. Due to the lack of suitable food, especially milk, nearly half of those who came to the New World on the Mayflower died the first winter, including every child under 2 years of age. Following that tragic experience, the governor of Plymouth Colony ordered that one cow and two goats be brought over for each six settlers.

In the Pacific Northwest, Dr. John McLoughlin of the Hudson Bay Company brought the first milk cows to Fort Vancouver in 1838. Many early day settlers trailed their cows with them to provide milk as their wagon trains traveled westward.

When we think of milk as a liquid containing about 87% water, we seldom realize the importance of the solids it contains. Actually milk contains more solids than "solid" foods like fruits and vegetables (see Figure 14).



WATER	86.75%
PROTEIN	3.50%
CARBOHYDRATE	5.00%
FAT	4.00%
MINERAL (Ash)	0.75%

FIG. 14—The contents of milk.

Milk's Nutrients

Milk makes an important contribution to the nutritional well-being of our country. No other food has gained such wide acceptance and due to its nutritional qualities, is often referred to as "nature's most nearly perfect food."

A quart of milk provides one-half the daily amount of protein, a third of the vitamin A, and all of the calcium needed by the average adult. In addition, it provides carbohydrates and fats that furnish fuel or energy for our bodies.

Proteins—Milk contains high-quality proteins due to the presence of all the amino acids found in proteins, including those regarded as essential. Casein (KAY-seen), a protein found only in milk, comprises 78% of the total proteins in milk. Because of its high quality, it is used as a standard for evaluating the protein of other food. Protein's main functions are to build and repair body tissues, form antibodies, hormones, and enzymes.

Minerals—Milk's minerals include among others, calcium, phosphorus, magnesium, and zinc. It is best known for biologically available calcium, which is more difficult to obtain in other foods. Phosphorus is required in the proper ratio to calcium to form bones and milk provides these two minerals in about the same ratio as is found in bone.

Lactose—or milk sugar, is a carbohydrate and furnishes a source of the fuel or energy value of milk.

Milk Fat—(also referred to as butterfat) is also a source of energy for the muscles. The fat soluble vitamins—A, D, E, and K are carried in the milk fat.

Vitamins—all of the known vitamins A, B. C, D, E, and K are found in milk in varying quantities. Vitamin A is present at high enough levels to provide a significant portion of our daily requirement. One quart of milk will furnish 30% of the vitamin A needed daily by the average adult.

Dairy products (excluding butter) supplied 75% of the calcium; 34.7% of the phosphorus; 39.8% of the riboflavin; 22% of the protein; 21.1% of the magnesium and 19.8% of the vitamin B12, while furnishing only 11.4% of the calories in the American diet in 1975[1].

Milk and milk products are one of the four basic food groups deemed essential to an adequate diet. Milk is enjoyed by people of all ages and is nearly indispensable in the diet of children. From infancy through the early growing years and on into adolescence, young people require the essential nutrients, minerals, and vitamins that milk and other dairy products provide.

Milk isn't "just for kids" though. A nutritionally adequate diet is just as important for adults. Although nutrients are no longer required for growth in adults, they are needed for body maintainance so adults require the same nutrients as children and adolescents, however in different proportions. The concept that calcium is no longer required after the skeletal structures are fully formed is incorrect. The 1980 Recommended Dietary Allowance (RDA) calls for 800 milligrams (mg) of calcium daily for adults. Two glasses (1 pint) of milk daily would provide almost 75% of this amount.

Recent research indicates that milk should be an important segment of the diet for the elderly. This is partially due to the increased prevalence of the disabling symptoms of osteoporosis. Osteoporosis involves the demineralization of the bones and since there is a loss of the bone matrix and minerals, a diet generous in protein, calcium, vitamin D, and fluorine has been recommended.

When you see the advertising slogan "Every Body Needs Milk," it is indeed quite an accurate statement. Unfortunately some people are unable to enjoy the good taste and nutritional qualities of milk because of allergic reactions or due to an inherited inability to digest milk sugar.

The dairy industry also makes a significant nutritional contribution by providing up to 35% of the beef consumed in this country.

MANAGEMENT AND DECISION MAKING

NOW YOU SHOULD BE READY to ask yourself, Why do I really want to learn these things?—The scientific principles of selection. How dairy animals grow and develop. The principles of nutrition, inheritance, and breeding."

What are your goals? In short, why do you have a dairy project? Knowing the scientific principles involved in dairying can be satisfying just in itself. In this age of great scientific progress, knowing and understanding many things is essential. But, back to our question—knowledge for what purpose? Is it knowledge just for the sake of knowing more about your dairy project? There's some of this, but there's much more. So let's begin by taking stock (inventory) of your present situation just as you would in any other business project.

[1]Dairy Information Guide-Milk, American Dairy Association.

What resources do you have for a dairy project? Resources refer to the facilities and means available for conducting a project. All resources can be classified under the heading of fixed assets, labor, capital, or management. Since resources represent possible sources of income, all of these except management can be measured in fairly concrete terms of dollars and cents. Management, in particular, has both a quantitative (dollars and cents) and a qualitative (quality of product) dimension. You will be the manager, one person, but how good are you now as a manager and how good can you be?

Setting Goals Leads To Success

Next, what about your goals? What do you want to achieve? And, how do you go about increasing your chances of achieving your goals, whatever they are? Working all of this out is called "decision making." It is a regular management process that dairy farmers engage in all the time. They have to in order to stay in business. So should you. The process of using resources to achieve goals—that is, the decision making process—might be illustrated as shown in Figure 15. Resources are also called *inputs* because they are the things you are putting into your project. The inputs in the decision making process of carrying on your dairy project are the fixed assets (your animal), labor, capital, and management. The *outputs*, if you are a good manager, will be profits or whatever goal or goals you have chosen. And, here is where the quality of the manager (you) is so important because you may start with good resources and then manage them poorly. How can you be sure that the quality of the management decisions is as high as possible?

Good Decisions Depend on Thorough Information

How good your decisions are is based directly on how much information you have and how you use it. And that's where knowledge regarding selection, breeding, and feeding of your dairy animal becomes important. Let's examine your resources again.

Fixed assets refer to your animal.

Labor is what work you will provide and what you might be able to get others to provide.

Capital, in this case, will be feed costs, breeding fees, veterinary costs, and others.

Management—you as manager.

We'll use the first resource, fixed assets, and the last, management, to illustrate the importance of scientific information in decision making, that is, decision making for the *purpose of achieving* goals.

First, take the fixed assets. You have the problem of selecting an animal for your project. Now look at goals. If your goal is to make as much profit from your project as possible, then you need to study the animal's pedigree carefully. This should tell you how well the animal may be expected to produce and how well she can pass this ability on to her offspring. Good type is also desirable but only if good type and high expected production can be found in the same animal. Remember, your goal is maximum profits, and you need a high milk producer to achieve it.

Now take a different goal. Suppose you were interested only in show ring performance and not concerned with expected milk production (or in foundation herd requirements, or profits from the sale of milk, or other possible goals).

Then your decision making processes might consider dif-

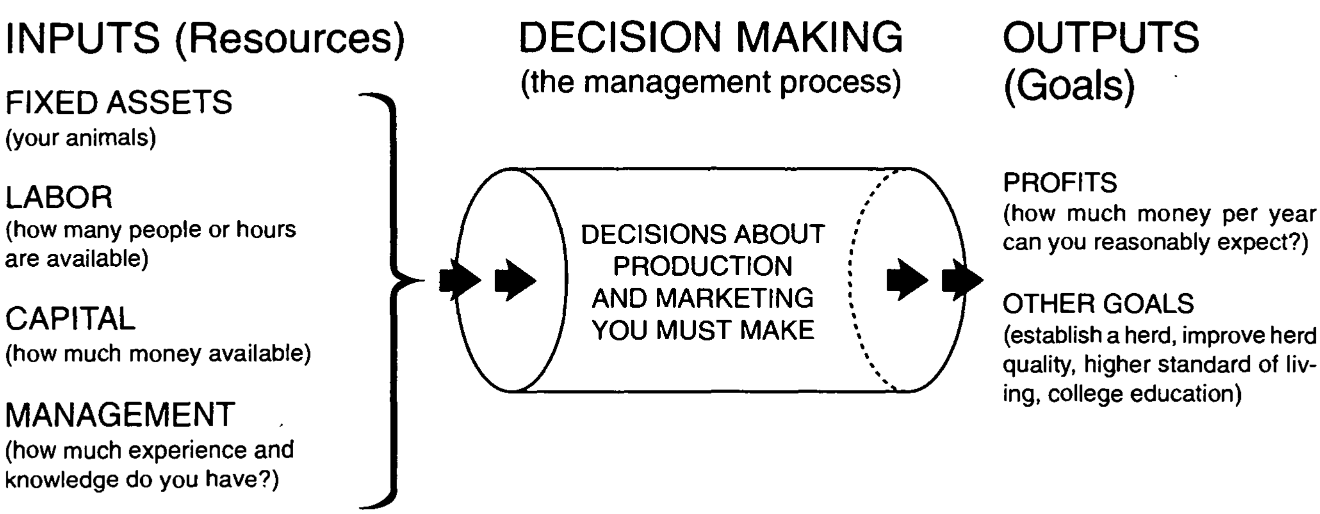


FIG. 15—Uses of resources and good decision making in achieving goals.

ferent factors. You would look at the pedigree for pointers on body conformation first, and perhaps milk production second. Also, you might spend a different amount on equipment and other facilities.

Once you think you have selected the right animal for your goal, you have the problem of being sure that she actually produces up to her ability. This is actually your job as manager. Proper feed given in the proper amounts is needed for good growth and development and for top production of milk. Again, you have come to the place where thorough information makes the difference. What goes into good feeds? How are the feed components (nutrients) used by a dairy animal? Just how does digestion take place? What are the nutrition requirements of your animal at different stages of growth and production? These are the "why's" of your decisions that must be answered if you want to reach your goals scientifically. Your decisions will be better if you know your animal's requirements, why she requires them, the composition of your feed, and the part played by each feed component. Now you are gaining knowledge that moves you into the realm of science. Scientific management greatly increases your chances of achieving your goals.

Now let's sum up what we've said. You have chosen a dairy project for some reason. Why? What are your goals? Once your goals are defined, how can you increase your chances of reaching them? There is a process for reaching your goals. It involves inputs (resources), decisions about production and marketing, and outputs toward your goals. It is called decision making or the management process. The kind of decisions made in this process depend on your knowledge of the "why" of what takes place. The knowledge needed for making good decisions about the use of your resources becomes a means to an end to reach a goal or goals. The more we know of the "why" of what takes place, the greater the chance that our goals will be reached.

Personal computers are being used more widely as an effective tool to help make decisions. The computer's ability to receive and store large amounts of data (information) and furnish it to the user quickly has made for sweeping change in the way we make management decisions. Dairy farmers have been quick to realize the amount of help computers can provide them in the decision making process for their very complex business.

Management is simply making decisions. The management process is the same whether you are raising one cow or a hundred. Also, it is the same whether you are raising sheep or cows or selling groceries instead of milk. Management is continuous because people, regardless of age or occupation, are constantly making decisions in their businesses and in their own lives. You can manage poorly or manage well in all cases, depending on the information you have on which to base your decisions.

THE DECISIONS ARE YOURS

THE DAIRY BUSINESS in the United States is large indeed. It consists of about 11 million dairy cows that make an important contribution to our human needs. Science has made and will continue to make an important contribution toward the high position attained by the dairy industry. The dairy industry requires alert and interested young people trained in the fields of animal science and food science. The challenges of the future are as great as those of the past. Your future and your success will be determined by the decisions you make.

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