Chapter 1

Man Must Measure

As a result of the fact I wanted to **measure** every aspect of the livestock with which I worked, I made numerous observations on my experimental animals. Weight, body measurements, body temperatures, rates of pulse and respiration, hair counts per square centimeter and tick counts were made.

From December 1937 onwards, body temperatures were taken and respiration and pulse rates were counted once a week on various heifers every two hours of the day from 6 a.m. to 6 p.m. and occasionally from 6 a.m. to 6 a.m the next day. The weight of each animal was determined at least once a month and 14 body measurements were taken every three months on each animal from birth throughout its productive life at the Research Station.

The hair diameters were determined with a lanameter and the entire hair coat of cattle of different types was shorn close to the body with a No. 0 clipper, its weight was determined and it was put through a felting machine at a hat factory in Johannesburg.

The Bonsmara is the only breed in the world where every mating was based on scientific data, where the concept **Man must measure** was always taken into consideration. Nothing was based on guesswork, or on worthless antiquated show standards.

The scientific data used in the breeding work were based on climatological data and adaptability measured by performance testing. The data included the 14 body measurements taken every three months; weight and average-daily-gain were determined each month.

The concept **Man must measure** included:

1. Measurement of adaptability based on all the available data on the foundation animals: the most composite measurement for adaptability, namely Average Daily Gain (weight for age),

as well as body temperature, rates of respiration and pulse, tick count, hide thickness, hair count per square centimeter, fertility, milk production, low mortality and ultimately longevity.

No heritable defects were tolerated, nor inferiority in function of any organ that resulted in lower resistance to stress or disease. No *locus minoris resistentia* was tolerated.

2. Measurement of growth by monthly weight determination.

3. Milk production was determined by measuring the calf's growth and weaning weight and also by measuring the actual milk intake of the calf by weighing it before and after suckling.

   That is how we established that an average 13.2 lbs. of milk production a day over a 205-day lactation period is the optimum for a ranch cow.

4. Fertility was measured by keeping a record sheet for every female kept in the herd and any cow that skipped two calves in eight years was slaughtered.

5. Body conformation is based on subjective evaluation by careful observation, but for our experimental animals 14 body measurements were taken on each animal from birth to maturity or until it was eliminated from the herd.

   The records and data taken from Concept 4 and the handling and measuring of thousands of animals under Concept 5 enabled me to formulate the concept of judging livestock for functional efficiency.

6. Temperament was measured by doing tractability tests on free-grazing animals. This was done by approaching animals in the grasslands and determining how near a man could walk to the grazing animal before the animal would walk away. The behaviour of the animals in the measuring pen where they were intimately handled gave a good indication of an animal's temperament.

7. Longevity was a measurement much neglected in the past. Most commercial cattle producers used to cull their brood cows at the age of eight or ten years. In our breed creation work, cows were kept in the herd as long as they could produce a good

calf annually and did not lose much condition (more than 20 percent of their weight at the time of calving). The young cows often lost less than 10 percent of their weight during the suckling period.

If an animal can satisfy our standards of longevity she cannot have a *locus minoris resistentia* and **must be functionally efficient.**

Towards 1946 I gradually developed the functional efficiency concept of livestock production. The result was that attention was given to factors which had essential bearing on economic and physiological traits. Selection of animals was based on principles of applied endocrinology and physiology and on performance and progeny testing.

The parameters on which selection was based:

1. **General appearance.** Well balanced and mobile with a thick, movable, smooth, red (preferably) hide with no hereditary defects. The head to display strong masculinity or femininity, with a strong muzzle with the lower jaw fitting properly onto the dental pad. All calves are to be dehorned within six weeks of birth.

   The Bonsmara was not established as a polled breed because polled bulls have a predisposition to prolapse of the prepuce.

2. **Conformation.** The correct proportion between fore and hind quarters, but emphasis was placed on the hind quarter where the most expensive cuts are situated.

   The area between the hip and pin-bones as well as that between pin-bones and thurls had to be large. Adult bulls were expected to weigh 1,800 to 1,980 pounds on pasture and the weight of cows had to be 1,200 to 1,390 pounds. I never wanted animals too large and heavy—nature does not tolerate extremes.

3. **Growth.** Calves were selected on the basis of normal weight, conformation and size at birth: that is approximately 7 to 7.5 percent of the dam's weight. They should be rapid-growing, bulls reaching 550 to 660 pounds and heifers reaching 495 to

550 pounds at weaning at eight months. From birth to maturity they should meet with required weight for age standards.

4. **Production.** Bulls were selected on the basis of fertility and the growth of their calves. Selection of breeding females was based on high fertility, milk production, and mothering ability to ensure a maximum number of rapidly growing calves. Bonsmara cows on an average give 15.2 pounds of milk daily over a six month lactation period with an average butterfat content of 4.8 percent. Heifers were required to conceive on reaching a weight of 700 to 790 pounds and subsequently to produce one calf each year over a lifetime. Females were culled if they failed to calve during two calving seasons. Weaning weight was regarded as the only practical measure of milk yield. The first culling of bull and heifer calves took place at weaning; thereafter, the animals were inspected every six months and only the best continued in the breeding herds.

Sir Lancelot Hogben's book, **Man Must Measure**, had a profound influence on my early research—I wanted to express everything in accurate data. Lord Kelvin said if you cannot express your research findings in accurate figures, your knowledge is superficial and mediocre. Hence, all the Bonsmara research work was based on accurate data.

Chapter 2

Livestock Ecology

Ecology has become a household word during the past decade or so, often used by environmentalists in an effort to compel legislators to introduce laws to prevent industry from polluting the environment.

Increased industrialization, especially in the Western Hemisphere, and the ever-increasing volume of travel have polluted the air which man, beasts and plants require for normal existence. Rivers and oceans are polluted by industrial waste products and by oil-carrying vessels.

Ecology is the branch of biology which deals with the mutual relations between organisms and their environment.

I have lectured on livestock ecology since 1940, in the light of the results obtained in the climatological research which was started in 1937 at the Messiná Research Station in the Northern Transvaal, South Africa.

As a result of the degree of instrumentation employed at the Messina Research Station during 1940, by which so many environmental factors could be measured, it was possible to correlate environmental data, which were accurately expressed in figures, with physiological data also expressed in accurate measurements.

At that time the lectures on livestock climatology, which were based mainly on the results obtained by correlating the influence of atmospheric temperatures with the physiological reactions of cattle, were changed to lectures on livestock ecology.

Since ecology contributes important facts and principles to the general evolution of animals in a particular environment, it became compulsory to correlate the different environmental influences on the hereditary variation found in the various animals tested. The influence of the measured environmental factors should be studied in detail concerning adaptability, growth, reproduction and resistance to disease.

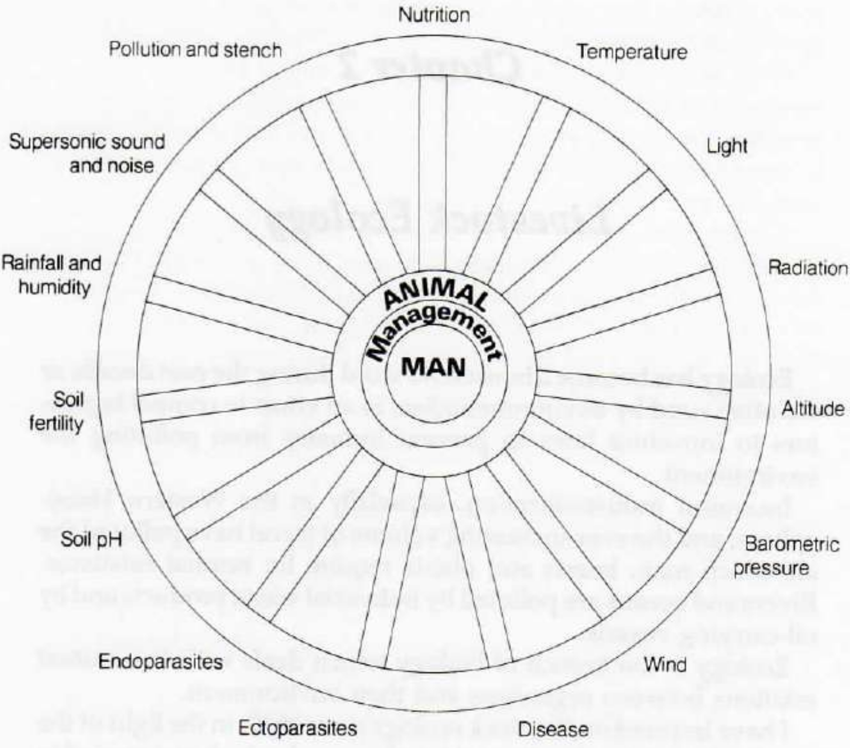


Figure 2.1 The livestock ecology wheel.

It was essential to work out the correlations between the environmental factors on the various reactions of animals, and to establish how directly these influence the morphology (animal form) of the animal, and vice versa. The problems in breeding for adaptability arise because many animal scientists are too often accustomed to attribute to a single cause that which is the effect of several environmental factors on the ultimate morphology and physiology of the animal.

For this reason I see the total livestock ecological concept as embracing the total interaction of the total environment on the total genetic make-up of the animal and on its total morphology (for the 15 environmental factors of the livestock ecology wheel, see Figure 2.1).

In an endeavor to comprehend clearly the influence of the total environment on the ultimate morphology and hence on the physiological reactions of animals, many animals that had their origin and evolution in an unfavorable environment were observed and studied in their natural habitat.

Many museums of natural history and zoos in foreign countries were visited, and the adaptability of animals such as the polar bear, penguin, camel and antelope species was discussed with curators of museums and zoos and with zoologists and physiologists the world over.

There can be no doubt that the adaptability phenomena exhibited by animals in unfavorable climates have an analogy in our domestic animals; hence, by applying our knowledge of adaptability phenomena, we can breed for adaptability in our domestic livestock without having to suffer the losses which a process of natural selection would have caused.

In livestock production it is essential to have a clear concept of how each environmental factor influences the animal and how we can breed animals to be better adapted to any environment. Livestock ecology is explained by the diagram of a wheel (Figure 2.1). The pivotal point of the wheel is man who is the most important single environmental factor in the interaction between heredity and environment. The animal is the hub and is in close symbiosis with man, who domesticated the animal. Of 3,000 vertebrate species of animals, only 30 have been domesticated.

Total environment is represented by the running surface of the wheel and each environmental factor which acts as leverage on the animal is a spoke. Each spoke has a direct influence on the animal. To evaluate the interaction between the animal and its total environment, the animal scientist must have a clear concept of what total environment embraces and it is necessary to indicate how the world is subdivided climatically.

Four Climatic Zones

The world is divided into four major climatic zones (Figure 2.2).

The first is **keen**, the regions where the atmospheric temperature never reaches a monthly average above 65°F and where relative humidity is usually lower than 65 percent. An area which is cold and dry is classified as keen. Cold and dry conditions are antagonistic to plant and animal life; hence, in keen climates we have very little vegetation to nourish animals. Highly productive animals cannot be maintained in a keen climate. In the slightly milder regions of the keen climate it is possible to keep animals such as reindeer which live on moss and lichen. In the keen climate we usually find certain fur-bearing animals which live on fish and other nutriments obtained from the ocean or from the sparse vegetation found in those areas.

The next large climatic zone is **scorching**. In the scorching zone we have an average monthly temperature varying from 65°F to well over 90°F with very low humidity. Scorching areas are semi-arid or arid because of the very low rainfall and extremely high temperatures. Plant growth is sparse and the plants, often thorny cacti species, are of low nutritive value.

The next zone is **raw**. In the raw climate the average monthly temperature seldom goes above 90°F and the humidity fluctuates between 65 and 90 percent. It is the zone best suited for crop and pasture production and an area where climatic stress on the animal is not great. All the improved breeds of livestock have been developed in countries with a raw climate, between latitudes 45° and 60° North. The stimulating and invigorating climatic conditions of those areas may have had a favorable influence on the efforts of the human inhabitants.

The next climatic zone is **muggy**. Regions which have high atmospheric temperatures of 90°F and higher and where the humidity is 65 percent and higher are called muggy.

To form a better understanding of the interaction between the animal and the environment, it is necessary to see various natural environments and to appreciate the climatic conditions which prevail there. Charles Darwin's writings are a constant source of inspiration and challenge to the biologist, as are his ideas on natural selection and evolution. Ernst Haeckel, who is considered the father of plant and animal ecology, stimulated my interest in the ecological relationship between plants and animals and its tremendous role in their economic success or failure.

A region with a typically keen climate is the Arctic Zone. There is little animal life except some fish in the fiords which are not iced over. Polar bears might get enough food in those areas. In the high Alps of Switzerland, above the timber line, the climate is also keen. It is cold and dry, unfavorable to animal and plant life; no animals can be kept at altitudes above the timber line.

The Alpine pastures in Switzerland are in a high altitude, raw environment. High altitude, raw environments are also found in South America, North America, and Europe at altitudes above 4,535 feet, where the rainfall is usually approximately two inches a month and the annual isotherm (the average temperature) does not exceed 60°F. In such areas the pasture growth is slow and the pastures succulent, low in crude fiber and high in protein. It is an

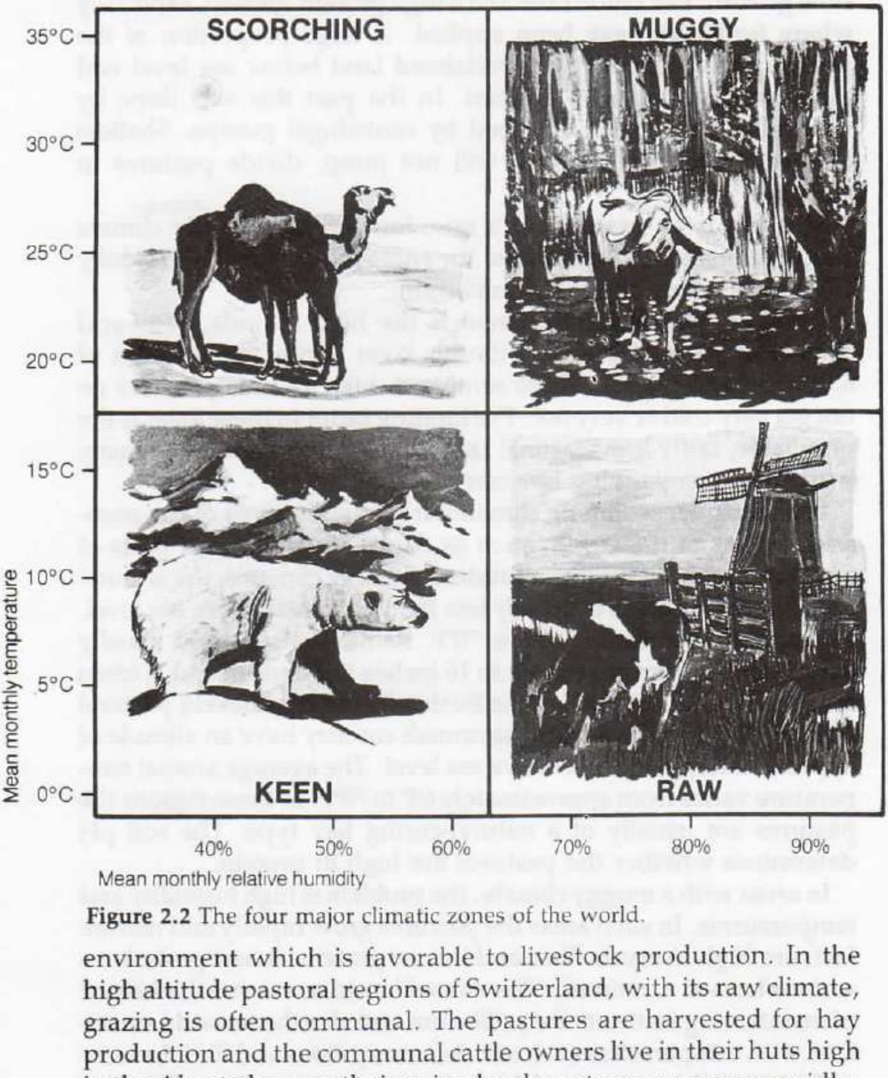


Figure 2.2 The four major climatic zones of the world.

environment which is favorable to livestock production. In the high altitude pastoral regions of Switzerland, with its raw climate, grazing is often communal. The pastures are harvested for hay production and the communal cattle owners live in their huts high in the Alps to be near their animals when storms come up rapidly. These storm are real hazards to the cattle; human endeavor is essential to prevent heavy losses of stock.

Holland has a low altitude, raw climate. Some of the pastoral areas of Holland are actually below sea level. The average temperature of Holland is below 65°F; it is cold during winter and has an average rainfall of at least 2 inches a month. The rainfall efficiency in Holland is exceedingly high. Pasture values are high because of slow growth, low crude fiber and a high protein content, especially where fertilizers have been applied. A large proportion of the pasturage in Holland is on reclaimed land below sea level and these areas have to be drained. In the past this was done by windmills, now being replaced by centrifugal pumps. Shallow ditches, which the animals will not jump, divide pastures in Holland.

Scotland is an example of a raw, low altitude, windy climate where animals need more feed for energy and must have woolly coats to maintain thermal equilibrium.

Another type of environment is the high altitude, semi-arid climate of parts of Namibia (South West Africa), at altitudes of 6,040 feet and higher. These semi-arid, high altitude pastures do not get very cold or very hot. The limiting factor in these areas is the unreliable, fairly low seasonal rainfall and low vegetation density with the accompanying low carrying capacity.

Low altitude, scorching climates are found in most of the semi-arid regions of the world, such as Africa, Australia and parts of South America. In the low altitude, scorching climates, the altitude of the ranching areas is usually less than 1,980 feet above sea level. The annual isotherm is above 70°F. Rainfall is sparse; it usually varies from approximately 12 to 16 inches per annum and is often seasonable and unreliable. The Bushveld and Middleveld pastoral regions of the South African savannah country have an altitude of approximately 3,465 feet above sea level. The average annual temperature varies from approximately 63° to 70°F. In these regions the pastures are usually of a natural-curing hay type. The soil pH determines whether the pastures are high in protein.

In areas with a muggy climate, the problem is high humidity and temperatures. In such areas the pastures grow rapidly and mature fast, are high in crude fiber and low in protein. Insect pests are a serious hazard to animals. The animal has to overcome the hazard of maintaining its thermal equilibrium and also the hazards associated with ectoparasites such as ticks, mosquitoes and flies. In areas with a high humidity and high temperatures such as Fiji, it is almost impossible to maintain Hereford, Shorthorn or Aberdeen Angus cattle or dairy breeds such as the Holstein and Jersey successfully unless appropriate shelter and nutritional conditions are provided. It is a problem for the animal to maintain a normal body temperature in those areas.

Areas of the southern United States, parts of Louisiana, Florida and Texas, have a muggy climate. High temperaure and humidity give the soil a low pH; the minerals in the pastures are leached out and in some of those areas the water table is near the surface. Such areas are deficient in both macro- and micro-elements. In a muggy climatic the problem of heat dissipation is always more severe than it is in a semi-arid climate.

Animals in the Four Climatic Zones

In an attempt to understand and appreciate the influence of the climatic regions of the world and their interaction on the animals, it is essential to study animals in the natural habitat. Animal behavior and physiological reactions must be carefully observed, described and interpreted. Adaptability phenomena in animals of particular areas must be assessed to use them in the breeding programs of domestic animals which have to overcome climatic hazards of corresponding environments.

The polar bear is an animal most beautifully adapted to a keen climate; its most obvious adaptability phenomenon is the white coat, made up of an inner heat-retaining coat and an outer protective hair which forms a formidable insulating layer. The inner heat-retaining coat is electrically positively charged, while the outer protective coat is negatively charged. When cold wind blows over the animal the static electricity between the two coats increases and the affinity of the two coats draws the outer coat tightly over the inner coat to improve the insulating powers of the coat. In this way radiation of energy from the body surface is reduced and maintaining body temperature is no problem. The polar bear also has a layer of fat approximately an inch thick over the body which also insulates it. The animal conforms to Bergman's and Allen's Laws that in a cold climate the animal is squarely built, has a small surface area per unit of weight, and relatively short and thick limbs. The polar bear's legs are exceedingly thick. If given a diet of fish, this animal will always select those fish that have the highest liver-oil content and provide the most readily available source of energy.

The American bison is adapted to the cold savannah areas of North America. The animal is beautifully adapted to overcome wind, snow and blizzards. All vital organs are protected by a dense outer protective coat and a furry inner heat-retaining coat. The bison also has an adaptability phenomenon in its reproductive organs: the testes are carried in a small scrotum and are drawn into the body cavity during the severe cold weather. Only during springtime, when warmer weather comes, will the animal drop its testes into the scrotum and become fertile.

The Bactrian camel is well adapted to the cold Siberian desert. It also has an outer protective coat and an inner heat-retaining coat. Because of the greatly varying climatic conditions between summer and winter in the Siberian desert, this animal has a thick winter coat it sheds rapidly during spring, so the camel becomes practically smooth-coated during the summer.

The Rocky Mountain goat has adaptability phenomena, especially for climbing steep ledges and mountains. Its color is also adapted to the environment.

The dromedary of the Asian deserts is adapted to scorching climate. This camel's nostrils close when dust storms come up. Its lips and tongue are poorly supplied with nerve fibers and it can consume fibrous and thorny desert plants without injuring the mucous membranes of lips, tongue and mouth. The animal has "false" eyelids which cover the eyes during dust storms. The areas of the body in close contact with the hot desert sand have callused pads. The camel can drink tremendous quantities of water at a time and, by an adaptability mechanism in the digestive system, can go for several days without drinking water. The feet are especially adapted to desert travel. During winter the animal has a protective outer coat and an inner heat-retaining coat which it sheds rapidly during the summer.

Animals adapted to the hot, tropical climates of the African Continent have adaptability phenomena which conform with Bergman's and Allen's Laws: the tropically adapted animal has a large surface area per unit of weight and the extremities—its limbs, tail and ears—are usually long, which increases the radiating surfaces of the body.

The kudu and impala are beautifully adapted to the subtropical environment of the semi-arid regions. Both these types of antelope have long limbs, flat bodies and a large surface area per unit of weight.

The zebra is well adapted to savannah country by way of mimicry: dark and light areas on the body. These animals are difficult to see in forested areas and this protects them from predators.

The lion may be "King of Beasts," but is completely under the control of man. By reward (feeding) and by punishment with a whip or "hot-shot" prodder, one can control a lion. Man has dominion over the wild as well as domesticated animals; he is the most important factor in the environment.

In muggy areas few breeds of livestock can be maintained. In the muggy climate of Trinidad it is impossible to maintain any improved breeds of domestic cattle. In this climate, it will be necessary for man to do a vast amount of selection and breeding work on the water buffalo which is extremely well adapted to a muggy climate.

Domestic animals exhibit certain adaptability phenomena due to natural selection and selective breeding. In the north of Scotland, the Scottish Highland breed of cattle is well adapted to an environment with drastic climatic conditions. It is cold and windy; the cattle are often exposed to moist winds from the North Sea. The soil has a low pH. The Scottish Highland breed has developed an outer protective coat of long medullated hair and an inner heat-retaining coat because it is continuously exposed to cold, moist winds. As a result of the low pH or low calcium content of the natural pasturage, these animals are small-framed. They are hardy and can stand the cold, moist wind. Animals of this breed taken to Norfolk in England, an area renowned for its fertile soil and good pastures, grew much larger than the animals in their natural habitat. Some purebred Scottish Highland cattle were taken to Norfolk over 200 years ago; they have been selected and bred pure in that environment and today the Scottish Highland cattle in Norfolk are much larger and heavier than those in Scotland. The difference in weight between bulls in the Highlands and in Norfolk is approximately 400 pounds in favor of those in Norfolk. The difference between the cows is approximately 200 pounds.

The Galloway breed, which also originated in Scotland, is also well adapted to a windy, cold climate. Animals exposed to cold, windy climates usually have a long outer protective coat and an inner heat-retaining coat and are square in body conformation.

The black-faced Scottish Mountain Sheep are well adapted to the tremendously hard climates found in northern Scotland. It is interesting that these sheep have a very short breeding season; lambs born outside the six-week lambing season die. The ewes come in heat for a short period and are anestrous the rest of the year.

The *Bos indicus* species of cattle, such as the Afrikaner of Southern Africa and the Brahman of the Americas and Asia, is well adapted to subtropic and semi-arid regions. The Afrikaner shows some interesting adaptability phenomena: it is sleek-coated, has a large surface area per unit of weight and a well developed dewlap and sheath or navel fold. They have well developed panniculus muscles and usually are thick of hide. Downward skin folds in the hide indicate a thick hide. Animals with a thick, pliable or movable hide have a high vascularity of hide; that is, the blood flow to the hide is profuse and such animals are well adapted to high temperatures and usually have tick- and fly-repellent hides.

The Importance of Nutrition

The most important spoke in the livestock ecology wheel is nutrition. Natural vegetation depends on rainfall, temperature and humidity. Types of animals maintained in any area depend on the total nutritional level of that environment.

In 1953 an advertisement by a company that produces animal feeds intrigued me. They indicated that, in 1910, 500 pounds of their pig rations were required to cause a 100 pound gain in weight, and the pigs reached 100 pounds in five months. By 1930, improved rations could cause the pig to gain 100 pounds on 360 pounds of feed. In 1953 the pigs could gain 100 pounds on 300 pounds of feed and could top 200 pounds in five months. They concluded the great improvement made in balancing their rations by adding antibiotics, minerals, and vitamins and by balancing the amino acids in the proper proportions could produce rations that could make pigs gain 100 pounds on 300 pounds of feed.

This advertisement is a half-truth. From 1910 to 1953 livestock breeders changed the body conformation and function of these animals and the improved rations were only partly responsible for the increased and more efficient gains in weight.

As a result of this advertisement, I bought unimproved native pigs in the Black territories of South Africa and brought them to the University of Pretoria where some native sows and Swedish Landrace sows were maintained. Young pigs of the unimproved native type and highly improved Swedish Landrace pigs were divided into two groups. One group was put on a 1913 unimproved ration composed of corn meal and a little tankage (blood-meal) and the other group was placed on a well-balanced 1957 commercial ration. The most amazing results were obtained.

The native pigs fed on the 1957 commercial balanced ration suffered badly. They grew slowly, scoured regularly and showed poor gains. The native pigs on the 1913 ration flourished and attained a weight of 134 pounds when those on the 1957 ration achieved only 85 pounds. This was a difference of 49 pounds in six months.

Improved Swedish Landrace pigs on the 1957 ration achieved over 200 pounds at six months, while those on the 1913 ration had a weight of only 180 pounds.

There is no doubt that the two types of pigs differed markedly in their ability to use various types of rations. Sows of the native and Swedish Landrace breeds were mated to native and Swedish Landrace boars. Both breeds of sows gave birth to purebred and crossbred litters. Hence the research workers succeeded in producing purebred and crossbred litters which had the same prenatal environment. The crossbred pigs on the good rations did well, while the native pigs on the good rations made poor growth. The native pigs on the 1913 rations produced a tremendous layer of fat which had a low iodine value, a firm fat, contrary to all expectations. The Swedish Landrace pigs on the 1913 ration produced an oily fat. The 1957 ration, which gave a firm fat in the Swedish Landrace pigs, gave an oily fat with high iodine value in the native pigs. The crossbred pigs produced by the native sow and the Swedish Landrace boar achieved a weight of 200 pounds on the 1957 ration, whereas their litter-mates which were pure native pigs achieved only 100 pounds.

At Robe Research Station in Australia the pastures are poor in copper and cobalt. Sheep suffer severely from cobalt deficiency. They get sway backs and steely wool and many sheep breeders went out of business because of the copper and cobalt deficiency. The classic work done by Hedley Marsden enabled those breeders to overcome the problem of the deficiencies of traces of copper and cobalt by adding small amounts of these minerals to the rations or by squirting a little copper sulphate solution in the mouths of the sheep. Black sheep that suffer a copper deficiency develop a white line in the black wool when they are on a copper deficient ration. When copper is added to the ration these animals grow black wool again.

It is essential in evaluating the nutritional and mineral deficiencies of an area that the cattleman should know the indigenous trees of an environment. Those areas in which *Tarconanthus camphoratus*, a shrub indigenous to South Africa, grows naturally are usually deficient in phosphorus. In all phosphorus deficient areas, cattle breeders suffer severe financial losses if they do not feed phosphate supplements. Phosphorus deficiency causes much lower fertility and a much slower growth rate. Steers which received 70 grams of bone meal daily under phosphorus deficient conditions had carcasses weighing approximately 750

Figure 2.3 The carcass of the control steer had a weight of 352 pounds, while that of the steer that had received 70 grams of bonemeal daily had a weight of 748 pounds.

pounds at the age of four years, whereas the control steers which did not receive the 70 grams of bone meal daily had carcasses weighing 350 pounds (Figure 2.3).

The rainfall and temperature of any particular region determine the protein value and the crude fiber content of pastures. In all regions of Britain where domestic breeds of livestock such as the Hereford, Shorthorn, Sussex and Aberdeen Angus have been evolved, the average monthly rainfall is approximately two inches a month and the atmospheric temperature varies from an average monthly temperature of approximately 40°F during the winter to approximately 60° to 65°F during the hottest summer month. In areas with a temperate climate and a steady rainfall, pasture growth is slow, crude fiber is low and crude protein is high. These areas have very succulent pastures.

New Zealand has an average rainfall of approximately 2.4 inches to 3 inches a month and an average monthly temperature seldom exceeding 65°F. Some of the lushest, mainly artificial, pastures in the world, with a high carrying capacity, are found in New Zealand.

In most semi-arid counties the rainfall is seasonal; dry seasons with no or practically no rain alternate with short seasons with heavy downpours. In South Africa the average annual rainfall in some of the semi-arid regions is approximately 16 inches, about half of which falls from the beginning of December to the latter part of February. The average monthly temperature varies from approximately 60° to 80°F, with an annual isotherm (average temperature) of 65° to 70°F. In these areas pastures grow rapidly and hence are high in lignin content, which means the crude fiber content is high and the protein value is low. In semi-arid regions livestock often suffer from nutritional deficiencies of energy and protein for a long period during the year.

The Importance of Temperature

Temperature is most important in determining which type of animal can be maintained in a particular region. In areas where the atmospheric temperature is high and where the annual isotherm (average temperature) is high, unadapted cattle will degenerate. Few British breeds of livestock can thrive in areas where the annual isotherm is above 65°F. If it exceeds 70°F all British breeds of livestock will suffer from tropical degeneration (Figure 2.4).

Tropical degeneration is characterized not only by stunted growth but also by a marked reduction in fertility. Animals not tropically adapted, which cannot withstand high temperatures, become hyperthermic and often show a rise in body temperature as high as 104° to 106°F. Young animals from birth to one year suffer appreciably more than older animals. The young animal's thermo-regulatory mechanism does not function properly at first; only when the animal is approximately one year old does the unadapted animal become able to maintain a body temperature a few degrees lower than in its first year. The tropically adapted animal will show little, if any, rise in body temperature at atmospheric temperatures of 85°F and higher. Animals that show signs of hyperthermia are tremendously retarded in growth. Shorthorn, Hereford and Aberdeen Angus cattle at the Messina Research Station often had a weight of as little as 700 pounds at three years of age, whereas the adapted animals that are heat-tolerant had a weight of 1,100 pounds or more.

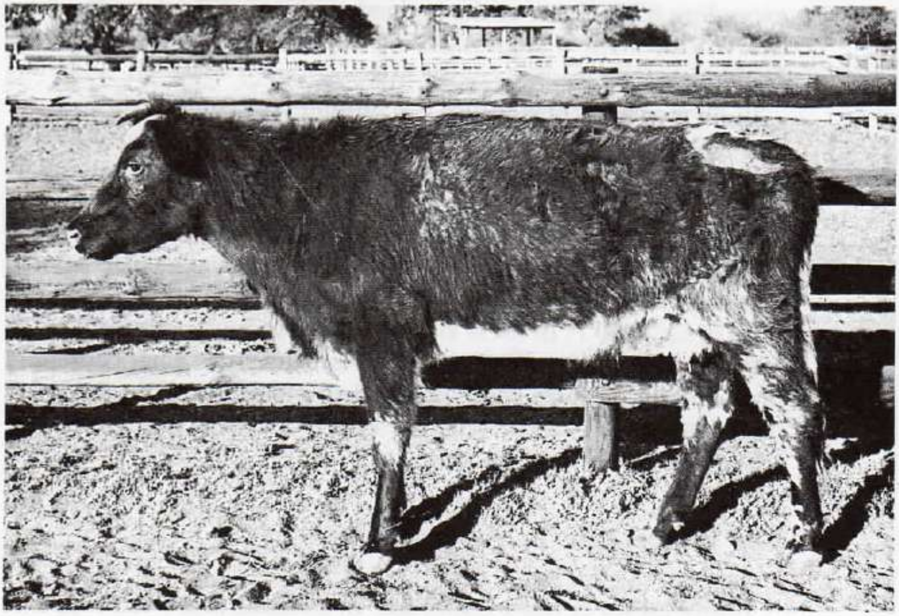


Figure 2.4 A tropical degenerate Shorthorn cow.

The tropically adapted animal is smooth-coated and has a thick, movable hide of high vascularity. Animals of the British breeds, although they are often beautiful at birth, soon develop an outer protective coat and an inner heat-retaining coat; animals not born with a sleek or smooth coat will suffer severely when young. A calf that is born beautiful may have a weight as little as 280 pounds when weaned at eight months. These animals have heavy coats and may suffer pituitary damage as a result of hyperthermia. Such animals are much retarded in shedding their hair; it is often delayed until the age of three to four years. These animals are usually sterile and have small pituitaries (1.4 to 2.5 grams). Post-mortem examination shows they have infantile ovaries in most instances (see Table 1).

Some of these tropical degenerates have the typical body conformation of the sterile animal. In one instance a typical tropically degenerated cow was removed from the Messina Research Station (annual isotherm 70°F) to the Experimental Farm of Pretoria University (annual isotherm 63°F). At the age of 11 years she had had no calves at the Messina Research Station but when removed to the Pretoria University Research Station this cow at the age of almost 12 years gave birth to her first calf. Although she was subfertile, the

Table 1: *Findings of clinical examinations of the genitalia of animals*

No. of animal	Date of birth	HTC at 1 year %	*Uterus size and condition	Size and condition of ovaries: Right	Size and condition of ovaries: Left	Pituitary weight g	Remarks
024 Pure-bred Shorthorn	26. 12. 39	82	Infantile	Infantile	Infantile	—	Slaughtered at age of 7 years. Permanently sterile. Slaughtered 27. 3. 47.
035 Pure-bred Shorthorn	2. 1. 40	79	Infantile	Infantile, inactive	Small corpus luteum	1,8	Body conformation degenerate. Permanently sterile. Slaughtered 27. 3. 47.
037 Pure-bred Shorthorn	2. 1. 40	77	Uterus small, soft-walled	Infantile, inactive	Small remnant of corpus luteum	1,6	Body conformation degenerate. Sterile. Slaughtered 27. 3. 47.
036 Cross-bred Afrikaner × Shorthorn	2. 1. 40	§	Uterus distended with fluid	Normal, contains corpus luteum	Normal	2,7	Sterile. Hydrometra. Slaughtered 27. 3. 47. Body conformation normal. Cross-bred.
115 Pure-bred Shorthorn	15. 1. 41	73	Infantile	Infantile and static	Infantile and static	—	Permanently sterile. Body conformation degenerate.
117 Pure-bred Shorthorn	21. 1. 41	82	Uterus soft, large wall has doughy feel	Small soft point probably follicle	Infantile, inactive	—	Body conformation degenerate. Found to be 6 months pregnant when slaughtered 27. 3. 47.
130 Pure-bred Shorthorn	12. 5. 41	68	Infantile	Infantile, size of pea	Infantile, size of small bean	1,5	Body conformation very much degenerate in form. Sterile. Slaughtered 27. 3. 47.
135 Pure-bred Shorthorn	22. 5. 41	70	Infantile	Small, inactive	Small, contains corpus luteum	1,7	Body conformation degenerate. Sterile. Slaughtered 27. 3. 47.
138 Pure-bred Shorthorn	23. 5. 41	—	Normal	Corpus luteum	Small and static	2,3	Body conformation normal. Slaughtered 27. 3. 47 at age of 7 years. Never calved.

* Clinical examination on live animals 14. 3. 45 by Dr J. R. Quinlan. Examination of genitalia of sterile cows slaughtered 27. 3. 47 by Drs S. W. van Rensburg and M. de Lange.

§ No climatological observations were made on animals 036 and 138. HTC of animal 036 will be above 85%.

change to a temperate environment and a better nutritional level had caused her to ovulate and to get with calf.

The Importance of Hair and Hide

Hair and hide play a tremendous role in the adaptability of animals. A mutant woolly-coated purebred Afrikaner bull, whose sire was a show-winning bull and whose mother was an outstanding Afrikaner cow, was obtained for tropical research work. This woolly-coated bull was brought to the Messina Research Station and mated to sleek-coated Afrikaner cows. Approximately half of his progeny were woolly-coated and half sleek-coated. In every instance the sleek-coated cattle had a greater weight than the woolly-coated ones. The woolly-coated progeny became tropically degenerated. The woolly coats acted as an insulating layer which did not facilitate the radiation of energy from the body. The smooth-coated heifer calves by this bull had an average weight of 535 pounds at eight months and the woolly heifers a weight of 328 pounds. The woolly-coated Afrikaner bull was mated to Aberdeen Angus, Shorthorn and Hereford cows. One Aberdeen Angus cow produced two bull calves by the woolly Afrikaner bull. The first bull calf was woolly-coated and the second smooth-coated. At the age of seven years, the weight of the woolly-coated steer was 870 pounds and the sleek-coated steer 1,357 pounds. It is obvious that hybrid vigor had no significance whatsoever in the animal that was not adapted.

Several of the purebred female progeny of the woolly-coated Afrikaner bull were mated to sleek-coated Shorthorn bulls. The Afrikaner cows produced some smooth and some woolly-coated calves. When the Afrikaner cows which were heterozygous in coat cover were bred to smooth-coated Shorthorn bulls, they produced smooth and woolly-coated calves. The calves that were born sleek-coated could overcome the hazards of the subtropics; they did not show a rise in body temperature or hyperthermia even when they were young. Those born woolly-coated could not overcome the hazards of high temperatures. At the age of eight years the steers born sleek-coated had an average weight of 1,654 pounds, whereas those born woolly-coated averaged only 799 pounds. (see Figure 2.5).

The animal with a sleek, thick hide with high vascularity will bleed profusely if the hide is punctured and injuries will heal rapidly; such animals are well adapted to high atmospheric

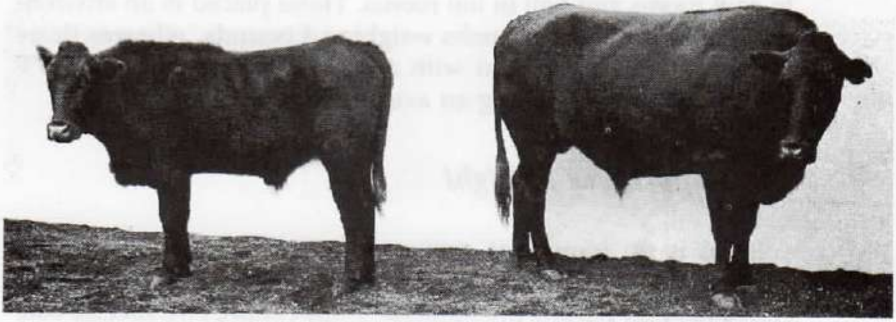


Figure 2.5 The woolly-coated steer had a weight of 799 pounds, while the smooth-coated one had a weight of 1,654 pounds.

temperatures. Wounds inflicted on the animal having a thick, movable, vascular hide heal within a week to ten days. Wounds on the animal with a woolly-coated, thin hide with low vascularity often take three weeks or longer to heal.

Miniature calves could be produced when cows with a low tolerance of heat were mated early in spring and were pregnant throughout summer. Calves as small as 20 to 40 pounds were produced by cows with a low heat tolerance that were pregnant during the summer. In every instance the bull calf had a weight smaller than that of the heifer calf. This is because the male fetus has a higher metabolic rate than the female fetus. The cow suffering from hyperthermia suffers appreciably more when pregnant with a male calf. In normal calves, the male is always heavier than the female. The miniature calves are often so small they can barely reach the udder of the cow and are often caused by the lack of adaptability of the mother. Heat-tolerant Afrikaner cows mated to Hereford bulls during spring produced heavy calves at birth, whereas Hereford cows with a low heat tolerance mated to Afrikaner bulls at the same time produced miniature calves. The difference in weight between the two reciprocal crosses was approximately 75 pounds as compared to 42 pounds when born during May and June (autumn).

In Australia, miniature lambs were seen in areas such as Queensland; no one knew what caused miniature lamb production. In 1949 when the results on the cattle were discussed in Australia, it was mentioned that the miniature lambs might be caused by ewes pregnant during midsummer. Perhaps some ewes were more heat tolerant than others; those ewes lacking heat tolerance would produce small lambs. Drs. George Moule and Neal Yeates mated several ewes and placed half the pregnant ewes in cold rooms and half in hot rooms. Those placed in an environment of 85°F produced lambs weighing 4 pounds, whereas those placed in an environment with an average temperature of 65°F produced lambs weighing an average of 8 pounds.

The Importance of Light

Light is an important environmental factor and greatly influences the metabolism and behavior of animals. Light is the most constant of the natural phenomena. Temperature on a specific date in different years might vary markedly, but the daylight length on one date of one year is the same as that of another year. Light has a marked influence on the metabolic process, on sexual activity, and on the hair-shedding of the animal.

Light-colored or white animals become photosensitive when they eat certain types of plants. If a cow eats goathead, *Tribulis terestes*, the white area on such an animal's body will slough off and become one festering sore.

When other animals such as horses and mules eat plants that make them photosensitive, such as goathead, they will develop many photosensitivity symptoms. A white mule that consumed goathead had a hide that looked as if it were corrugated: the unpigmented areas were swollen whereas the pigmented areas were normal. Animals that consume plants like lantana suffer severe photosensitivity. If a cow or horse eats lantana it becomes photosensitive and will die if exposed to light. A Friesland cow that consumed lantana exhibited severe signs of photosensitivity: all the white areas of her body were badly inflamed, became one large sore and she lost all white hair. All mucous membranes were also severely inflamed. The animal was placed in a dark stable and recovered. Horses that consume plants that make them photosensitive develop vast sores on their bodies, called sandburn in Texas. As early as 1909 the veterinarians of the Department of Agriculture in the United States tried to solve this problem; as yet they have found no answer. It is advisable to put animals that suffer so severely from sandburn in a dark stable.

Radiation also has a marked influence on the animal. Animals which have no pigment in their eyes suffer severely. The most important rays that impinge on animals and cause damage are the ultra-violet rays. Daylight is composed of a spectrum of colored rays: red, orange, yellow, green, blue, indigo and violet. The rays just beyond the red spectrum are infra-red rays, which are heat rays. Beyond the violet spectrum are ulta-violet rays; these rays are chemical rays and when they impinge on an animal that has no color in the hide or has a dry hide from a lack of sebum secretion, these animals will suffer severely. The white animal will develop cancer or hyperkeratosis of the hide where the hide hardens and becomes sensitive. White-faced animals such as the Hereford will develop cancer on the eyelid from moisture forming on the eyelid owing to dust or other matter that irritates the eye.

Constant radiation of ultra-violet light may cause cancer on the eyelid or on the eye itself. The white-faced animal that lacks pigment in the sclera of the eye develops a cancer in the eye (Figure 2.7). Many ranchers have these cancers removed by surgical operation, but this is not very successful. We can, by selective breeding, breed Herefords with pigment around the eyes. The incidence of cancer in eyes of animals that have pigmented eyelids is negligible. By strict selection for pigment around the eye, the amount of pigmentation can be increased and such animals will never suffer from eye cancer. A survey on Hereford cattle in South Africa showed that in young animals the proportion of animals with pigment around the eye is relatively low (Table 2). In the older age group, six years and older, the proportion of animals with pigment around the eyes was much greater. Therefore, the mortality rate of the animals without pigment around the eye is appreciably higher up to the age of six years than it is in those with pigment around the eyes.

Animals can overcome the hazards of ultra-violet radiation if they have pigmented hides. A white color in the animal is a hazard, especially if the hide has no pigment in it. Animals tropically adapted like some of the Brahman breeds, white Afrikaner or white Nguni cattle, do have pigment in the hide. If the hair is shaved off, the hide will appear to be brown or black. These animals with dark hides can overcome the hazards of ultra-violet radiation and the hide usually has a profuse secretion of sebum which is spread over the hair and acts as an ultra-violet filter. Animals without pigment suffer severely and all breeds of livestock that lack pigment in the hide suffer from a condition called "white heifer disease."

In a group of Nguni cattle, those with pigment in the hide show a dark number when branded while those without pigment in the hide show a white number. Animals that are white suffer severely from ultra-violet impingement and are often sterile.

The influence of coat color and cover on the adaptability of

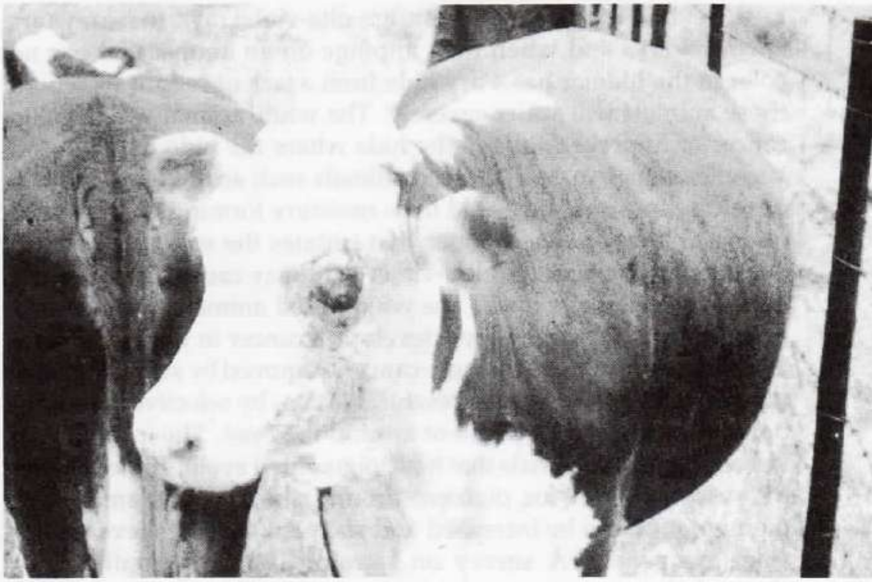


Figure 2.7 A cow with cancer of the eye.

Table 2: *Variation in pigmentation about the eyes of 560 Hereford cattle*

Herd	Classification according to amount of pigmentation			Incidence of ophthalmia, other affliction and cancer		
	+ +**	+	−	+ +	+	−
A	19	252	59	0	16	25 (1 cancer)
B	9	63	98	0	0	26 (2 cancer)
C	3	48	27	0	5	21
D	16	137	73	0	17	28
Total	47	500	257	0	38	100 (3 cancer)
Percentage of total (804)	5,8	62,2	32,0	0	4,7	12,4
Mara	55	159	102	0	17 (1 cancer)	22 (4 cancer)
Percentage of total (316)	17,4	50,3	32,3	0	5,4	7,0
Grand total (1 120 eyes)	102	659	359	0	55 (1 cancer)	122 (7 cancer)
Percentage of grand total	9,1	58,8	32,1	0	4,9	10,9
Proportion and percentage affected in each class	0/102	55/659	122/359	0	8,3 (0,2 cancer)	34,0 (1,9 cancer)

** + + = Pigment of 1,5 cm around the eye
\+ = A broken ring of pigment less than 1,5 cm around the eye
− = No pigment around the eye

Herds A, B, C and D are maintained in the temperate zone while the Mara herd is in a subtropical evironment.

animals is not well understood. It is essential in future research that more work be done on determining how color influences the adaptability of the animal to a higher incidence of infra-red radiation, ultra-violet radiation, and total solar radiation. It is essential to determine how these various colors react under the different nutritional conditions. At the Messina Research Station in the Northern Transvaal of South Africa, I bred cattle which were black, red, ash-grey or agouti, golden-yellow and white. It was intended to put these animals under artificial ultra-violet and infra-red radiation and to test them in the photo-period room and under natural conditions to determine their reactions.

Effects of High Altitude

High altitude is a problem for most animals. In high altitude areas, cattle must have a higher hemoglobin index than at low altitudes. In the early work done by Duerst, a Swiss animal scientist, it was proved that the high-altitude cattle of Switzerland, the Brown Swiss and the Simmental, had a higher hemoglobin index than any of the other breeds of cattle in Europe. We must evaluate the adaptability phenomena of animals adapted to high altitudes to understand the adaptability phenomena required by cattle at those altitudes. The llama, an animal well adapted to the high altitudes of the Andes, has a red-blood count of more than twice that of the human being. The llama on average has 14 million red blood cells per cubic millimeter; man has approximately 5 million. The affinity of llama blood to oxygen is also twice as high as that of man; hence, the llama is four times as efficient as man in utilizing the oxygen in the rarefied air at high altitudes.

At high altitudes various breeds of cattle are found which show certain adaptability phenomena, for example the Simmental and the Brown Swiss in Switzerland. From the point of view of color, the Brown Swiss with its dark-pigmented hide is appreciably better adapted to the high altitudes than the Simmental. The Simmental's white areas become hyperkeratinized and these animals often suffer. In high-altitude, semi-arid regions such as Namibia (South West Africa), the white areas of the Simmental are a real hazard.

Animals at high altitudes, such as those in parts of Switzerland and Namibia, must have pigmented hides. Because of high altitude, the ultra-violet impingement is intense and the oxygen content of the air is low. An animal such as the Brown Swiss is beautifully adapted to high-altitude environment. It has a dark hide containing brown pigment which assists the animal in absorbing infra-red radiation during cold weather. It can overcome the hazard of ultra-violet radiation; it is a slow grower and can overcome the hazard of irregular nutrition levels; and it has a high red-blood count. For these reasons Brown Swiss can easily be adapted to a subtropical environment. The subtropics also have a high ultra-violet radiation impingement and low oxygen tension from high temperatures. The only problem the Brown Swiss has to overcome in the tropics is to radiate heat and that can be brought about by selecting sleek-coated Brown Swiss.

Wind and pH

Wind is another environmental factor that requires certain adaptability phenomena. In the northern parts of Scotland and the eastern seaboard of New Zealand, cold and moist winds blow continuously. The most remarkable adaptability phenomenon in animals adapted to cold, moist winds is their two types of hair: the inner heat-retaining coat and outer protective coat. These coats are oppositely electrically charged. The inner heat-retaining coat is positively charged and the outer protective coat is negatively charged. When the wind blows over these animals, the charge becomes stronger, the hair packs closer and the animal becomes waterproof and "cold proof," which shows that the insulating coat functions efficiently.

Pigs constantly exposed to severe cold and wind develop long, woolly hair. In the forest of Yugoslavia, Mangalizza pigs which exist on nuts are constantly exposed; these pigs are woolly-coated, almost as woolly as sheep. In 1770 Captain Cook, on his exploratory travels in the Antarctic, dropped some pigs of the type kept in England at that time on the Campbell and Cook Islands in the Antarctic zone south of New Zealand. In 1943 research workers of the Ruakura Research Station in New Zealand encountered long-haired pigs with an inner heat-retaining coat and an outer protective coat (Figure 2.8). Only those pigs with the genetic potential to develop an outer protective coat and an inner heat-retaining coat had been able to survive. After almost 200 years, there were large numbers of pigs well adapted to the Arctic regions.

Soil pH is an environmental factor which has received little attention in the literature on ecology. The pH is a measure of the relative alkalinity and acidity on a scale from zero, highest acidity,

Figure 2.8 A woolly-coated pig, the progeny of pigs left by Captain Cook in 1770 on the Campbell and Cook Islands in the Antarctic.

to 14, highest alkalinity; a neutral solution is 7 pH. Where the soil pH is high, nitrification of bacteria in the roots of leguminous plants can take place, and if nitrogen becomes available the pastures are higher in protein value. Leguminous trees such as some of the Acacia species are indicative of a high soil pH. A soil pH of approximately 6.5 will produce pastures relatively high in protein. The calcium in such pastures is usually readily available to the cattle, so that they have good skeletal development.

The type of plant growth may be indicative of the pH of the soil and the skeletal development of animals. At the Mara Research Station, where the predominant tree is *Acacia tortulis* and pasture has a high pH, it was possible to rear large cattle. In a pasture not three miles away there was *Combretum apiculatum* grazing where the soil pH was low and animals kept in these pastures were appreciably smaller.

Steers indicative of the average of two groups kept in the *Acacia tortulis* pastures and steers in Combretum pastures differed 300 pounds in weight at three and a half years. The steers in the Acacia pastures averaged 1,245 pounds when those in the Combretum pastures had a weight of only 945 pounds. Many Texas cattlemen do not appreciate why cattle from East Texas grow bigger if moved to West Texas. Most pastures in East Texas grow in areas with a low soil pH; a lime fertilizer would add tremendously to the nutritional value of these pastures.

The Afrikaner breed, indigenous to the semi-arid subtropical areas of southern Africa, is extremely well adapted to the savannah country where Acacia trees predominate and mature cows approximate 1,197 pounds.

The Nguni cattle are best suited to the low pH pastures of the coastal regions and to the higher rainfall, lower pH areas of Swaziland. The mature cows approximate 750 pounds. Afrikaner cows maintained on pastures with a soil pH of approximately 6.2 averaged 300 pounds more than Afrikaner cows maintained on pastures with a soil pH of 5.4.

The problem of varying soil pH values had a marked influence on the skeletal development of cattle in Holland. This was known 100 years ago. It was known in Holland that cattle maintained in areas where forest and sandy soil with a low pH existed had small body conformation and were light boned. Animals kept where soil had a high pH were large framed and heavy.

Animals adapted to low soil pH and high humidity are most often shade lovers. The Nguni cattle in Swaziland (where the humidity is high and the soil pH low) are shade lovers because of the hazard to the animal of radiating energy in a humid climate when out in the sun—these animals are forest dwellers. Animals in coastal and humid areas are often light colored, ash-grey or almost white, and have pigmented hides.

Insects and Parasites

Insects such as ticks, mosquitoes and flies are a hazard to many animals in their natural environment. Tick-borne diseases are a serious hazard to most areas of Africa, and in research work done by Baque in Cuba many years ago it was found that ticks remove as much as 211 pounds of blood from one animal per annum. This hazard can be overcome by proper management and breeding: animals can be bred to be tick-repellent. Animals which have thick, movable hides, well-developed panniculus muscles and a sensitive pilomotor nervous system will move their hides rapidly at the slightest irritation and will be much more tick-repellent than animals with woolly hair and thin hides. The tick-repellent animal has well-developed panniculus muscles; those not tick-repellent have poor development of the panniculus muscles. The hide of the animal in areas where tick-borne diseases are a hazard is an efficient immunizing organ. Animals with thick hides become immune much more readily and succumb much less to tick-borne diseases than those with thin hides and woolly hair.

Conquering the screw-worm hazard in Texas and in the southern United States will completely change the approach to livestock production. Through the eradication of the screw-worm fly, the screw-worm problem has almost become a thing of the past. The increase in the deer population in many of the natural grazing areas has caused research workers to realize the livestock-carrying capacity of these pastures has changed. Since the screw-worm has been eradicated, cattlemen can probably produce calves in other seasons of the year than they did in the past. Now that this plague has been conquered, the livestock industry will have to do new research on cattle pasture management and carrying capacity and on the breeding seasons of cattle.

Animals vary in their ability to resist flies and other insects. Certain cows or horses are covered by flies and other biting and stinging insects, whereas others are free from them. It is possible to breed tick- and mosquito-repellent cattle. The animal with straight hair, a sensitive pilomotor nervous system, well-developed panniculus muscles and the animal which gives off sebum is much more insect-repellent than the animal with a dull, dry coat that does not have a sensitive pilomotor nervous control. The animal whose hair stands upright when it looks as if it is going to rain is a tick- and fly-repellent animal. The erector pili muscles make the hair stand up and this in all probability stimulates the secretion of sebum in the hair.

Internal parasites often become a hazard to animals. Where rainfall is periodic and heavy in the summer, animals often drink stagnant water in muddy tanks and suffer from internal parasites such as liverfluke and various types of worms. Animals on artificial pastures with a high stocking rate are often infested with internal parasites. Animals on artificially irrigated pastures are more parasite-infested on pastures irrigated by overhead spraying than on those flood irrigated. The problem of maintaining large numbers of cattle on intensive artificial pastures is largely one of combating internal parasites.

Animals susceptible to external parasites are also more susceptible to internal parasites. The less adapted animal with a lower nutritional status in a particular environment usually has a high incidence of external parasites and is often infested with internal parasites of one kind or another.

Susceptibility to Diseases

Disease plays a tremendous role in livestock production and lack of adaptability causes animals to be more susceptible to various diseases. Certain breeds of cattle are much more susceptible than others to diseases such as rickettsiosis (heartwater), a tick-borne disease which is location-specific to the subtropics and tropics. Animals with low heat tolerance usually succumb more readily to tick-borne diseases than do well-adapted, heat-tolerant cattle. Sheep that suffer from heartwater lose their fleece if they survive.

In some parts of the world, nutritional conditions cause certain endemic disease conditions. Subterranean clover in Australia, high in estrogenic hormones, causes bearing-down disease in sheep, which is prolapse of the uterus. Any disease that causes the animal to have a high temperature for a few days will result in permanent damage to the pituitary and such animals will never shed their hair or grow normally. They always are subfertile.

The Measure of Reproduction

The most sensitive index of adaptability in all animals is their ability to produce and reproduce regularly. Endocrine balance is the most sensitive barometer of the animal's ability to adapt to a particular climate. The scrotum of an animal is a thermo-regulatory mechanism: in some breeds of goats the testes are carried in two separate scrotums so that thermo-regulation is more efficient. The testes are in a scrotum with an appreciably larger surface area than would have been the case with one scrotum. The scrotum of adaptable cattle has a much thicker hide than that of cattle not adapted to the subtropics. Those breeds adapted to the tropics have scrotums that pucker on cold days. Furthermore, the spermatic vesicle in the subtropically and tropically adapted breeds is much more convoluted than in cattle from the temperate zones. When cattle are injected with radio-opaque substances such as chlor-bismuth, the volume of radio-opaque substance that can be injected into the spermatic vesicle of the *Bos indicus* breeds is much larger than that which can be injected into the spermatic vesicle of the *Bos taurus* breeds. The ability to maintain a testicular temperature a few degrees lower than the body temperature is most important for normal spermatogenesis to take place. Injury to the scrotum often causes a varicocele and the thermo-regulatory mechanism is disturbed. In bulls where a varicocele has developed the testes will hang lower and lower and become even more prone to injury than those of a normal bull.

Symbiosis Between Man and His Animals

In livestock ecology, man is the most important single factor in the environment and is necessary to breed livestock better adapted to certain climatic regions. The interaction between man and his cattle must be closely studied.

In a country like Switzerland, where the symbiosis between man and his cattle is close, labor is scarce. Every individual in the cattle-farming community has to contribute toward producing fodder for the cattle, and every individual in the family assists in hay making. The relationships among the animal, man and the environment is obvious in Switzerland. Every cow carries a bell around the neck because storms come up rapidly and are hazardous to the animal. Cattlemen who live in huts on the communal grazing must bring cattle to safety during storms and these animals can be reached rapidly by the people who know the sound of each bell. Those huge bells on the animals' necks are really part of the ecological relationship between man and his animals. The man has to know the bells that direct him to his cattle at times of emergency: he can bring them to safety if hazardous storms come up swiftly. In summer the animals are kept in stables because the hot, humid environment of midsummer is conducive to a high incidence of flies and other insects. Animals kept in stables are fed during the day and each animal's tail is tied to the roof to prevent it from hanging in the urine gutters.

There is probably no country in the world where the symbiosis between man and his animals is closer than in Holland. The stable and the homestead in Holland are often under one roof. In winter the animals are the warming mechanism of the Dutch homestead; the heat given off by the stabled animals keeps the house warm. The stable and the living-room are separated by a single door. Above the animals in the stable is the loft in which hay is stored. The animals are under continuous supervision by the owner and many of these cattlemen say their cattle have a soothing and calming effect on them. The tranquillity of the cows chewing their cud in a comfortably warm stable has a soothing effect on the husbandman; if he is worried the first thing he does is go into the stable with the tranquil cattle.

During winter the Friesland cattle are kept in an artificial climate created by the radiating energy in the stables. When these animals are out on the pastures in Holland, portable milking machines are taken to the cattle to milk them in the pastures.

In France where they have Charolais cattle, the main object with these animals is to produce beef with little fat. Hence they raise large cattle which can be achieved only on pastures with high nutritional value. The pastures in the regions of Nièvre and Vichy, France, where the largest herds of Charolais cattle are found, are lush and have many herbs. During summer the animals show a dark discoloration around the pinbones from scouring on lush pastures. The Charolais cattle are lethargic and will not move even if one goes up to them. They also have little resistance to tropical and subtropical diseases when taken from their natural habitat. The white color of these animals is in some instances a serious hazard.

In a country like New Zealand, where no concentrate feeding occurs and all the production of milk is off green pastures, cattlemen select those Jersey cattle with tremendous stomach capacity to enable them to produce enough milk. Only those animals that consume enough green pasture to produce enough energy and nutriment on the total digestible nutrient on a dry-matter basis are maintained in the herds. Ninety per cent of the dairy cattle in New Zealand are Jerseys with tremendous stomach capacity.

New Zealand has lush pastures and no concentrates are fed to cows there. Most cows calve in early spring and the incidence of twinning in New Zealand is appreciably higher than in other parts of the world. At the Ruakura Research Station in New Zealand (1949), 222 pairs of identical twins were born in experimental work.

The standard of livestock production in a country depends largely on the cultural and religious background of the people. In Africa, India and other parts of the world where most of the people are ignorant, superstitious and prejudiced, the cattle are poor. In Ovamboland the cattle are kept in corrals overnight and the women who milk the cows use wooden pails which are never washed.

Animals in a natural habitat will exhibit certain adaptability phenomena. In thickly forested areas, black cattle function better in an environment where the light is dull, where the incidence of infra-red radiation is low, and where the ultra-violet radiation is high. In areas of dense forest like parts of Mozambique, Swaziland or Angola, we find predominantly black cattle. Beyond the forested areas in the open savannah country, the color of the animals changes to a grey, light fawn or yellowish-white color.

In open savannah country where the infra-red radiation is intense and where the problem of high temperature is more pronounced than in areas with a more temperate climate, preference is given to red or light-colored cattle with pigmented hides.

Tropically Adapted Cattle

A thorough knowledge of livestock ecology is essential if we want to select and breed tropically adapted cattle. In cattle of the British beef breeds enough variation in the coat cover is observed to enable the breeder to select the variants which exhibit adaptability phenomena. If sleek-coated, thick-hided animals are selected, they will be much more heat-tolerant than those woolly-coated. The undesirable woolly-coated calves can be recognized at an early age (as early as three days old) by a felting test on their hair: a small sample of hair is taken from the animal's coat with a small pair of scissors, spat on and rubbed hard. If the hair felts into a tight mass, the animal will never become sleek-coated in a subtropical environment. A sample of hair of those animals with smooth, straight hair which is medullated (with a pith or core) will not felt when moistened and rubbed. The hair of the woolly-coated animal is of two types: an inner, heat-retaining coat, not medullated, and an outer protective coat that has medullated hair. There are primary and secondary hair follicles in the hide. The smooth-coated animal has medullated hair only. A hair grows from each primary hair follicle and in most instances there is a sebaceous gland attached to each hair follicle. Hence the secretion of sebum in the smooth-coated animal is appreciably higher than in the woolly-coated animal.

A complete coat cover of animals of the British breeds was closely clipped and put through a felting machine. The hair of the woolly-coated animals felted into a tight mass and required a force of 16 pounds to pull it apart. In the sleek-coated animals, a force of 7.5 pounds will separate any sample of semi-felted hair. Animals with hair lacking felting properties are tropically adapted.

In Herefords, further selection should take place to get them pigmented around the eyes. Although we can without great difficulty get the animals of the British breeds to be heat-tolerant, it is often much more difficult to get them immune to endemic diseases of the subtropics. In research carried out at South Africa's subtropical research stations, it was possible to change the mortality rate of the British breeds from approximately 30 percent to 10 percent by breeding them to be tropically adapted. One reason calves resulting from a cross of Brahman bulls and Hereford cows are not as good as the animals produced by the Hereford bulls and Brahman cows is that Brahman cows possess much greater natural immunity against the endemic diseases of the subtropics and tropics. The calves suckling on Brahman mothers in all probability obtain a greater spectrum of immune bodies through the colostrum of the highly immune cow. Where calves were switched from the Hereford mothers to Afrikaner, *Bos indicus*, mothers and vice versa, the mortality rate of those calves suckled on the Afrikaner cows was lower than ones suckled on the Hereford cows. It is a field of research which should be carried out on a large scale in the southern United States.

Out of a tropically degenerate Hereford herd, it was possible to breed by strict selection for adaptability a herd of Herefords well adapted to the subtropics. Selection was based on sleek coats, thick hides and pigmentation around the eyes. At the Mara Research Station in Northern Transvaal, a Hereford herd bred for tropical adaptation was established. In a period of approximately fifteen years it was possible to breed a completely adapted Hereford herd with all the phenomena required for tropical adaptation. The only problem that could not be overcome was the susceptibility of these animals to tick-borne diseases, although the mortality rate was reduced. The Hereford bulls selected in this program were all thick-hided, as indicated by downward skinfolds; they had pigment around the eyes, and the color of the hair on the neck, upper flanks, lower rib regions and lower thighs was appreciably darker than in the other regions or parts of the body.

In a survey made on Hereford cattle in three ecological regions of South Africa it was found that Hereford cattle with sleek hair in the subtropics were 200 pounds heavier at maturity than those woolly-coated. In the region of the Mara Research Station the average weight of mature woolly-coated Hereford cows was 988 pounds. Medium-coated animals achieved 1,089 pounds, and sleek-coated animals 1,184 pounds. In a temperate region the difference was 1,069 for woolly cattle, 1,043 for medium-coated cattle and 1,030 for sleek-coated ones, a difference of only 39 pounds between the sleek-coated and woolly-coated cattle in the temperate region. It became clear from this survey that adaptability phenomena such as a smooth hair coat is of much greater importance in a subtropical region than in a temperate region.

All animals can overcome cold if they are well fed. Tropical degeneration is the major livestock problem in all tropical and subtropical regions where the annual isotherm is above 65°F. When the adaptability work at the Mara and Messina Research Stations was started in 1937, those areas had thousands of cattle of the British breeds—Shorthorn, Hereford, Angus and Sussex—which were typical tropical degenerates. After careful research on the factors which bring about adaptability in the subtropics, it was possible by selection, breeding and crossbreeding to replace these animals by adaptable types.

By crossbreeding and inbreeding, a new breed of cattle has been evolved at Mara Research Station: the Bonsmara. The Bonsmara was bred along lines similar to those adopted in the breeding of the Santa Gertrudis in the United States, but a few different methods were adopted in the selection program. Animals were tested for climatic adaptation by taking the body temperature, respiration rate and pulse rate.

It was decided to breed cattle $\frac{5}{8}$ Afrikaner - $\frac{3}{16}$ Hereford and $\frac{3}{16}$ Shorthorn. After obtaining $\frac{5}{8}$ Afrikaner - $\frac{3}{8}$ Hereford cattle, and $\frac{5}{8}$ Afrikaner - $\frac{3}{8}$ Shorthorn cattle, these two types were interbred to get the $\frac{5}{8}$ Afrikaner - $\frac{3}{16}$ Hereford and $\frac{3}{16}$ Shorthorn. It was found that animals with more than half the blood of the British breed could not withstand the subtropical conditions. Herefords were brought in because they are better grazers than the Shorthorn, are more heat-tolerant and have a more even fat distribution than the Shorthorn. The Shorthorns were brought in because they mature faster than Herefords, have better milk production and are a uniform red color. By crossing the $\frac{5}{8}$ Afrikaner - $\frac{3}{8}$ Shorthorn with the $\frac{5}{8}$ Afrikaner - $\frac{3}{8}$ Hereford it was possible to develop a red animal with no white on it.

I am opposed to white on any animal; it is considered a hazard to any animal in the tropics and subtropics. (See Chapter 5 on crossbreeding, breed creation and the genesis of the Bonsmara.)

Some of these Bonsmara cows were selected for longevity, fertility and functional efficiency; in some instances cows that were 17 years old had 15 calves. The heavier calves weighed over 598 pounds at eight months and the lightest weighed 449 pounds at eight months. Any animal that showed hereditary weakness or a point of lower resistance was culled. The bulls used in the selection and breeding work at the Mara Research Station to establish the Bonsmara breed had to be functionally efficient. They had to be able to serve 50 or more cows in a breeding season of two and a half months. They were sexually active and highly fertile.

In the subtropical, semi-arid regions of the Transvaal Bushveld, those animals which degenerated were replaced by tropically adapted Afrikaner types and Bonsmara types. The livestock production policy in South Africa is based on the regionalization of breeds and types; that is, the climate is carefully mapped and the breeds of livestock that should be used or bred in a particular area are determined by the climatic conditions of a particular environment and the corresponding environment where the breed originated.

It is certain that in breeding programs the altitude, soil pH, temperature, radiation, light, humidity, the interaction of those factors on the natural vegetation, and how the cattle will react to the total environment must be considered. Only animals that can survive and breed regularly in those areas in which they are placed will be of economic importance.

Chapter 3

Selecting Livestock for Functional Efficiency

In Psalms 8:5-8, King James version of the Bible, David sings to the Lord:

> For thou hast made him a little lower than the angels, and hast crowned him with glory and honour. Thou madest him to have dominion over the works of thy hands; thou hast put all things under his feet: All sheep and oxen, yea, and the beasts of the field; The fowl of the air, and the fish of the sea, and whatsoever passeth through the paths of the seas.

This places a tremendous responsibility on man; he is the axis upon which all livestock and agricultural production centers.

Of 3,000 species of vertebrate animals, only 30 species have been domesticated. These live in close symbiosis with man. "The accident of the night," as Robert Ardrey calls human procreation, need not happen with animals. Man's responsibility compels him to control his animals, to measure them and to select them, and to manipulate their genetic make-up.

Genetic boundaries

At the moment of conception the complete genetic potential of the animal is laid down. This determines irrevocably the potential boundaries within which the individual can function, perform or produce during its entire lifetime. The boundaries are, however, rarely attained. The environment, including the intra-uterine en-

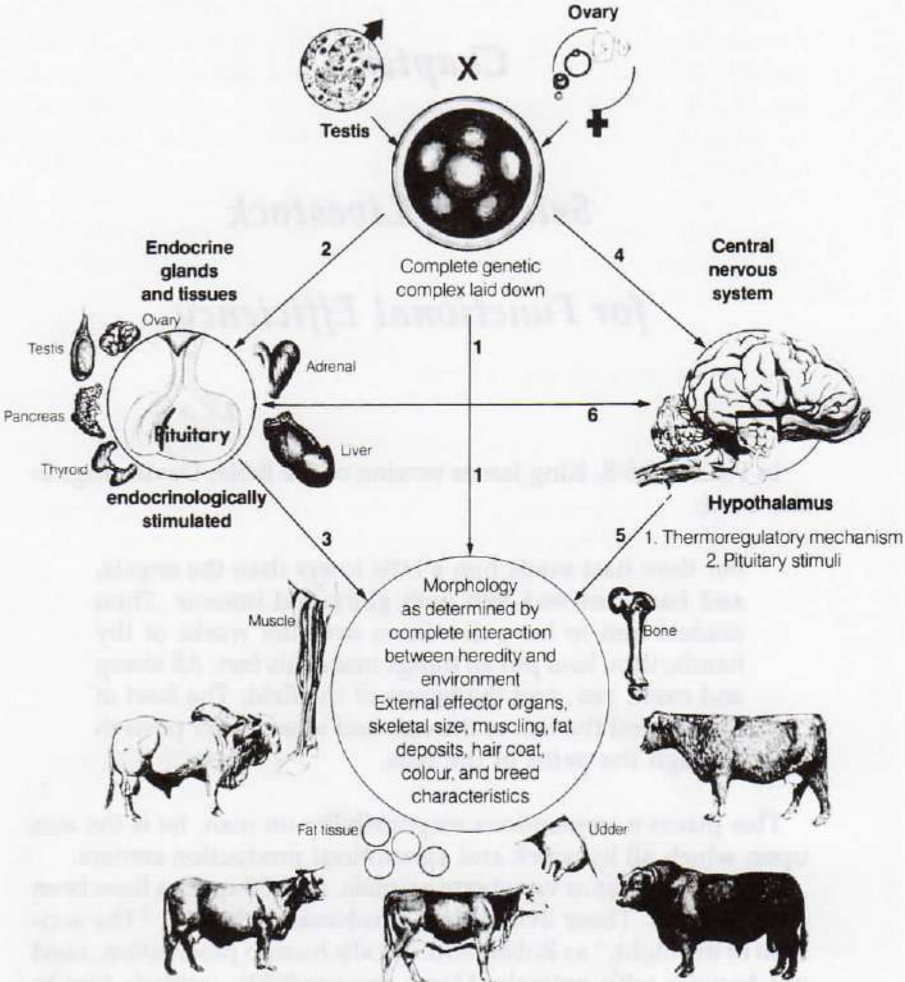


Figure 3.1 The interaction between genes and the phenotype. At the moment of conception the complete genetic potential of the animal is laid down. This determines irrevocably the potential boundaries within which the individual can function, perform or produce during its entire lifetime.

vironment, constitutes a severe limiting factor when it is unfavorable. It limits the full manifestation of the genetic potential of the animal; it retards skeletal development and ultimate size; it affects muscular development, coat length and appearance; it changes the body profile and various related anatomical features which reflect the normality of the animal.

Likewise, genetic or hereditary defects or limitations are reflected not only in function but also in the appearance of the animal. These morphological (animal form) alterations are the basis for the selection or judging of animals for functional efficiency. Of all the domestic animals, the bovine lends itself ideally to judgment for functional efficiency. Its conformation features are distinct and can be judged in terms of measurable production.

But conformation and efficiency of performance are meaningful only against a background of some important endocrine interactions of the body.

The hormones of the bovine

Figure 3.2 shows, in a diagram of the body of a cow, the position of the various endocrine glands, and indicates some of the most important pathways along which the endocrine system is activated. Figure 3.3 is another representation of these facts.

Hormonal balance—that is, excesses and deficiencies—is controlled through delicate feed-back mechanisms as indicated above,

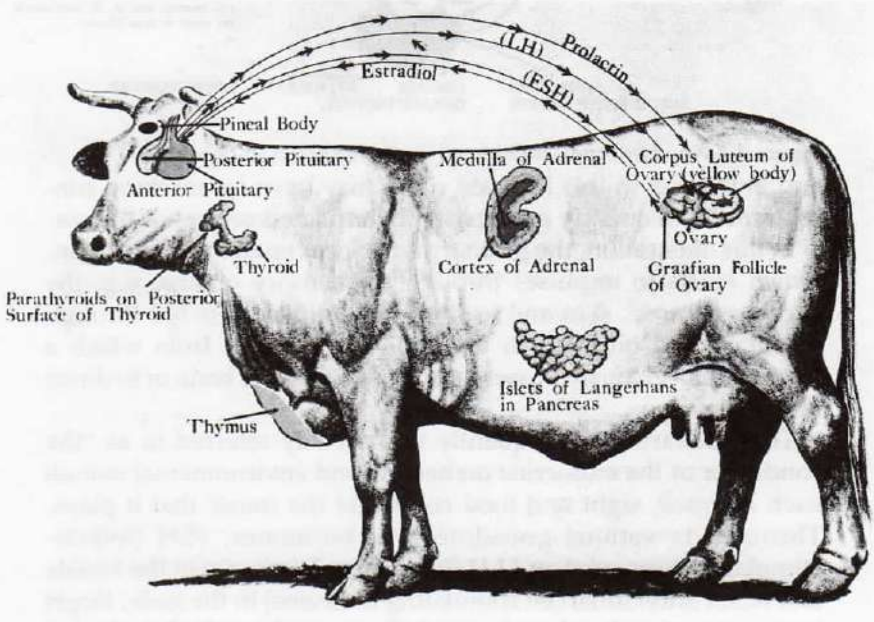


Figure 3.2 The location of the various endocrine glands in the body of the cow and the most important pathways through which they function are indicated.

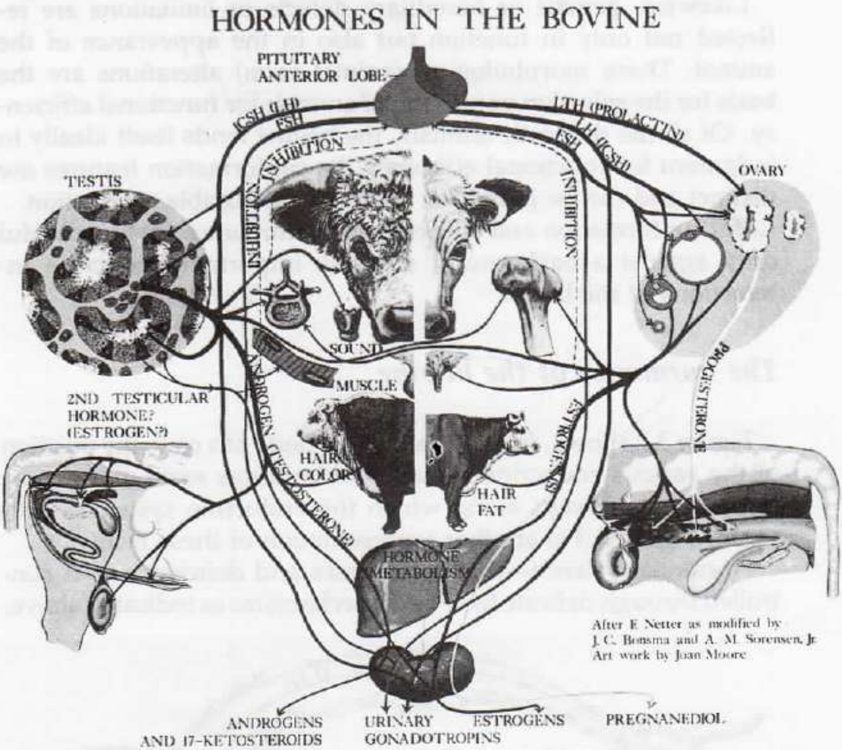


Figure 3.3 Another representation of the facts shown in figure 3.2.

and any break in this intricate chain may have far-reaching consequences, frequently on apparently unrelated organs or tissues.

In this illustration, the pituitary is in close contact with the brain, which reacts to impulses through the sensory organs, e.g. the eyes, ears, nose, skin and feeling. The impulses are fed through the brain and pituitary to the endocrine glands, from which a feed-back mechanism passes impulses back to the brain or to direct target organs.

The pituitary is consequently traditionally referred to as "the conductor of the endocrine orchestra" and environmental stimuli such as smell, sight and food constitute the music that it plays. Through its various gonadotrophic hormones, FSH (follicle-stimulating hormone) and LH (luteinizing hormone) in the female and ICSH (interstitial cell stimulating hormone) in the male, target organs are stimulated in the genitalia to produce the female and male sex hormones, respectively. In the female, ovarian follicles develop that produce estrogens and after ovulation a corpus luteum under stimulation of LH. The corpus luteum produces progesterone, which maintains pregnancy after fertilization and prevents further ovulation. In unfertile cycles the corpus luteum regresses through luteolytic processes and a further cycle is initiated through feed-back mechanisms.

This intricate process of cyclic reproductive activity in the female is frequently disturbed, either through spontaneous imbalance of the hormonal interactions concerned, or through environmental stress, for example nutrition, temperature and seasonal differences in daylight intensity. These hormonal fluctuations do not only disturb reproductive function; they also affect growth and body composition through involvement of metabolic hormones and through the effect of reproductive hormones on the metabolic process. Similar interactions operate in the male. ICSH is responsible for the production of testosterone by the interstitial cells in the testes. This is a potent androgen responsible for secondary male characteristics in terms of conformation and behavior.

In addition to the production of estrogens and androgens by the female and male genitalia, the pituitary also stimulates adrenal activity and the production of an additional source of estrogens and androgens and their precursors through ACTH secretion (adrenocorticotrophic hormone). These hormones function through a delicate balance of production and interactions through feed-back mechanisms illustrated in Figure 3.3. Again, adrenal sex hormones influence metabolic function while the adrenal excretes metabolic hormones directly into the system.

This information is presented to explain how imbalance, from whatever cause, can indeed disturb hormonal functions and consequently the reproductive and metabolic processes. In addition,

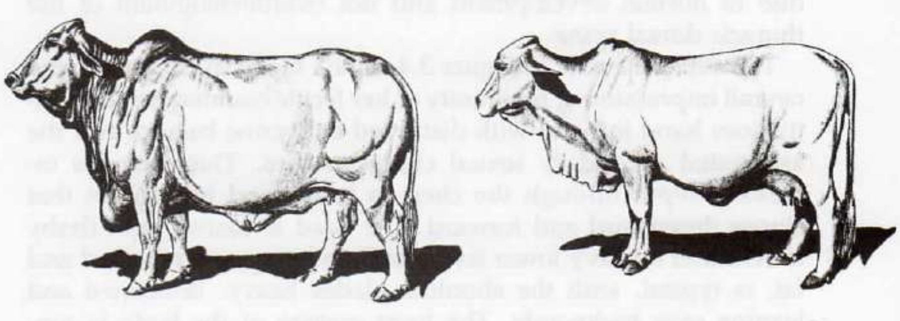


Figure 3.4 Brahman cows: the body profile of the sterile or subfertile cow (left) and the highly fertile cow (right).

metabolism and growth are influenced not only by the metabolic effects of the reproductive hormones. The thyroid gland is intricately involved in the growth process under stimulation of the pituitary gland through TSH (thyroid stimulating hormone).

Against this background it will now be shown how the reproductive and growth processes in the body of the animal are reflected in conformation features. Expertise in the hormonal, physiological and anatomical interactions is applied to judge the functional efficiency of the animals concerned.

Body profile and general build of cows and heifers

Femininity in the female is a direct function of the interaction of sex and growth hormones. The body of the highly fertile female is in beautiful proportion; she looks feminine or broody. Seen from behind, the largest diameter of the body is in the mid-rib region. She has a huge stomach capacity and is big from the hip to the pin and from the hip bone region to the stifle joint and the patella. Her brisket is not full and a fold of skin takes the dewlap all along the brisket backwards; the entire body profile shows the forequarters to be sleek and light and the hindquarters to have capacity and "depth." Figure 3.4 illustrates these points.

The highly fertile cow (Figure 3.4, right) is of slender build compared to her subfertile counterpart (Figure 3.4, left). Her neck and front portion are slim and her coat is sleek. She carries not fat or coarse muscling; her shoulder blades are lean and loose. The cartilaginous ends of the shoulder blades can be seen to move freely above the highest points of the thoracic vertebrae. This is due to normal development and not overdevelopment of the thoracic dorsal spine.

The subfertile cow in Figure 3.4 stands in sharp contrast to the overall impression of femininity of her fertile counterpart. Infertility goes hand in hand with disturbed endocrine balance and the associated secondary sexual characteristics. This includes increased depth through the chest, a heavy and full brisket that slopes downward and forward. The head is coarse, with fleshy cheeks and a heavy lower jaw; a buffalo hump, over-fleshed and fat, is typical, with the shoulder blades heavy, ill-defined and leaning over backwards. The front portion of the body is consequently heavy and masculine in appearance, with overall excessive muscular definition.

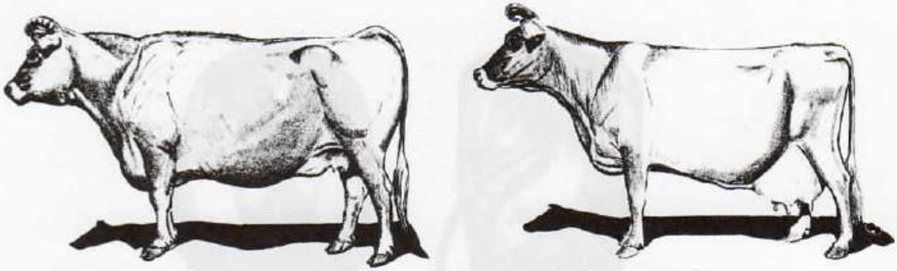


Figure 3.5 Jersey cows: low fertility (left) and high fertility (right).

These differences are well illustrated in the two Jersey cows in Figure 3.5.

The subfertile cow (left) is 8½ years old and has had no calves. The fertile cow (right) had seven calves and required only seven inseminations. The disproportionate body development, due to infertility and hormonal imbalance, is clearly seen in the subfertile cow, as compared to the sleekness and proportionate body of the fertile individual. Fertility and normal sex drive in the bull go hand in hand with strong muscular features. This means good muscular definition, freedom from excessive fat and the profile of a bull that has a well-developed front quarter and a masculine head and neck. Androgens, the male sex hormones, are sensitively reflected in the withers, which constitute the shoulder blades, spine and related tissues. Heaviness or coarseness of the withers with muscular definition and coarse hair growth, which is dark over those areas and the lower portions of the body, are good masculine features which are reduced by castration or subfertility.

Figures 3.6 and 3.7 illustrate these points in a highly fertile and in a subfertile bull. The fore-quarter and hind-quarter balance is particularly evident and it is clear that fertility is reflected in the masculinity of the head and fore quarters.

Figure 3.6 Bulls: low fertility (left) and high fertility (right).

Figure 3.7 Rear view of bulls with low fertility (left) and high fertility (right).

In the female a high level of fertility goes with a wedge-shaped body outline. The deepest point lies in front of the udder and the body narrows towards the first rib. The fertile cow has an unobtrusive brisket and a large abdomen. When ossification is delayed, as happens with reduced fertility, growth of the sternum and chine continue for longer than it does in animals that reach sexual maturity and normal hormonal balance at an early stage.

This is well illustrated in Figure 3.8. Castration prolonged the growth process in the steer that was castrated at six months. He has a rising chine and his long bones are longer and thinner than those of the steer castrated at two years or those of the intact bull. In the castrate, the front ribs, chine, brisket and head are late-maturing while, according to Sir John Hammond and other investigators, the rump and loin are the late-maturing parts of the body. This, however, applies to fertile animals only.

Figure 3.8 The influence of sex hormones on hair, muscular development and skeletal growth is shown on three animals, all 12 years old. From left to right: steer castrated at six months, steer castrated at two years, intact bull.

Figure 3.9 illustrates the principles involved, showing the scapulae and metacarpi of fertile and subfertile cows. These bones were taken from two twelve-year-old cows, of which one had had eight calves and the other none. In this latter case, the shoulder blades are heavy and bigger than in the fertile cow, and the cannon bone has grown longer and heavier. Together with increased growth of the brisket and chine, this accounts for the heavier front quarters of the subfertile cow or the steer castrated early.

There are other conformational signs of physiological or anatomical aberrations in the bovine body.

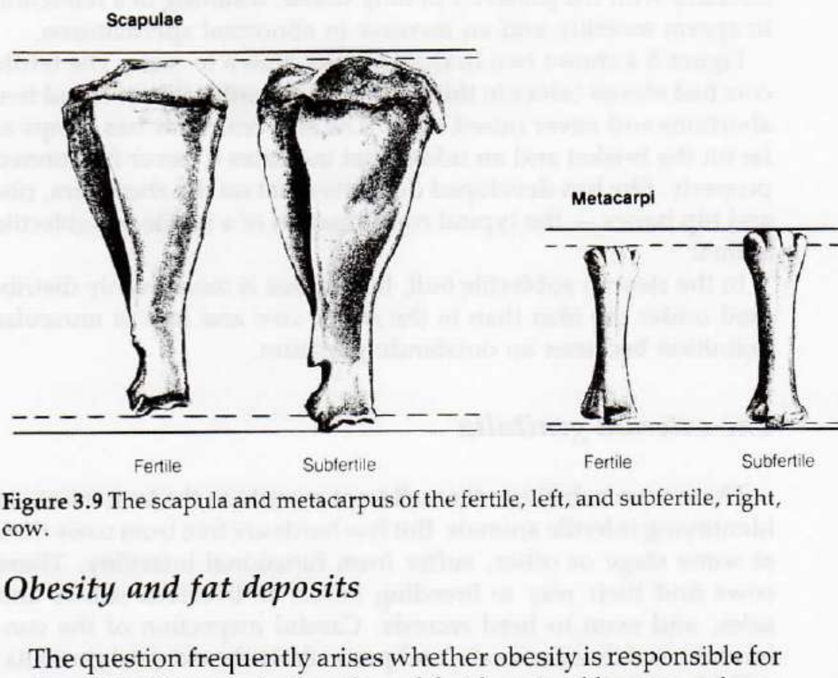


Figure 3.9 The scapula and metacarpus of the fertile, left, and subfertile, right, cow.

Obesity and fat deposits

The question frequently arises whether obesity is responsible for reduced fertility or whether the subfertile animal becomes obese. The answer is that obesity reciprocates low fertility, and vice versa. Naturally the cow that does not reproduce, for whatever reason, requires no energy for the intra-uterine growth of the fetus or for milk production and consequently increases in weight with ease. Overfeeding again decreases the fertile life-span. Biological and hormonal processes are accelerated. Follicular activity increases in the female and more inseminations are required for conception.

Cows maintained in a high condition are less profitable and require more veterinary attention. Their fertile lifespan is reduced; they succumb to various diseases such as laminitis, arthritis and uterine infections. The milk production of over-fat heifers is permanently reduced.

Feeding economy and longevity in the cow require freedom from obesity. Over-fatness has for too long been looked upon as good stockmanship. Disregarded as a handicap in animals, it has frequently and incorrectly been prized in show rings and at sales.

Bulls likewise require a high degree of physical fitness, which is never attained with obesity. It has been shown conclusively that fat accumulation in the neck of the scrotum insulates the testes. The heat-exchange system in the spermatic cord becomes ineffective with the presence of fatty tissue, resulting in a reduction in sperm mobility and an increase in abnormal spermatozoa.

Figure 3.4 shows two Brahman cows drawn to scale. The fertile cow had eleven calves in thirteen years; the subfertile cow had two abortions and never raised a calf. The subfertile cow has lumps of fat on the brisket and an udder that indicates it never functioned properly. She has developed deposits of fat on the shoulders, ribs and hip bones — the typical conformation of a sterile or subfertile animal.

In the steer or subfertile bull, fatty tissue is more evenly distributed under the skin than in the sterile cow and lack of muscular definition becomes an outstanding feature.

The external genitalia

There is no substitute for well-kept records as the best means of identifying infertile animals. But few herds are free from cows that, at some stage or other, suffer from functional infertility. These cows find their way to breeding herds, to livestock shows and sales, and even to herd records. Careful inspection of the conformation of these animals, and particularly the external genitalia, will identify them.

Infantilism or under-development of the external genitalia, particularly with over-prominence of the clitoris and coarse hair growth on the lower commissure and even a small and shrunken external genital opening embedded in perineal fat (Figure 3.10a), rarely depicts good fertility.

Figure 3.10b shows the external genital opening of a cow. It is underdeveloped with an enlargement of the clitoris and with excessive hair growth.

When these symptoms are noted, further scrutiny is required to check on the fertility status of the animal concerned. She is likely to

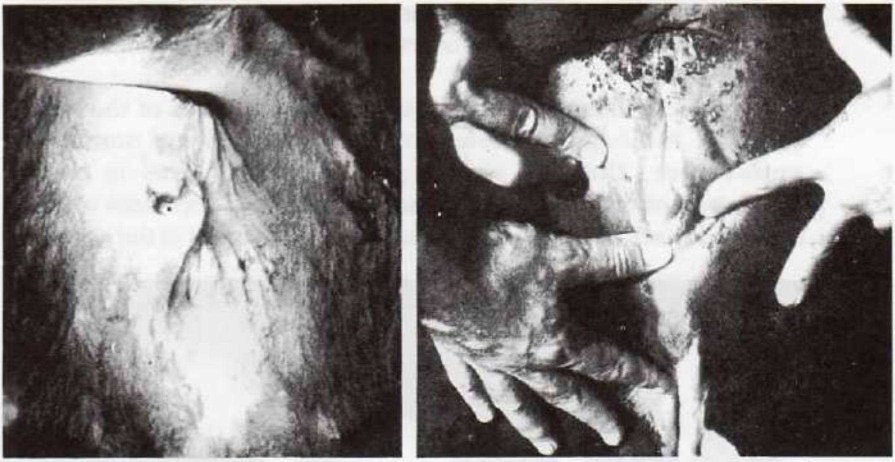


Figure 3.10 Infantilism or underdevelopment of external genitalia in cows on the left. Note the enlarged clitoris in the right photo.

show imbalance in body outline for high fertility, to have a heavy shoulder and brisket with masculine head and neck.

In the bull, a fine and pendulous sac with sparse hair covering, a lean scrotal neck and well developed and perfectly identical testes are prerequisites for high fertility and go hand in hand with desirable secondary male characteristics.

Figure 3.11 illustrates several undesirable features in the male genitalia. The testes are unidentical in shape. One is hard and the other flabby. Here the signs are pronounced, but even slight hypoplasia (underdevelopment or incompleteness) leads to sterility on the side concerned and this constitutes a serious heritable defect which should be eliminated through fearless culling. Figure 3.12 shows normal testes with proper tonus of the sphincter.

The scrotum forms a delicate thermo-regulatory mechanism which regulates testicular temperature and helps to keep it below body temperature. It can pucker up during cold weather, drawing the testes closer to the body. In work done with Dr. Harrison of Liverpool University, radio opaque treatment of the spermatic vesicles indicated that on X-ray examination, bulls adapted to tropical environments have more tortuous vesicles than bulls from temperate regions.

Excessive pendulousness of the scrotum in bulls, particularly at advanced age, predisposes to injury and impairs thermo-regulatory ability. Positive secondary sex characteristics in the bull, which indicate high levels of androgen activity, are proper and frequent cremaster-muscle activity, movement of the sheath, squirts of urination and long coarse hair around the sheath and on the tail switch.

Figure 3.13 illustrates further undesirable features of the male genitalia. Although the testes are well developed and normal in appearance, the bull shows gynaecomastia; this is over-development of the teat and a sure indication of hormonal imbalance and a lack of libido. The excessive development of the sheath,

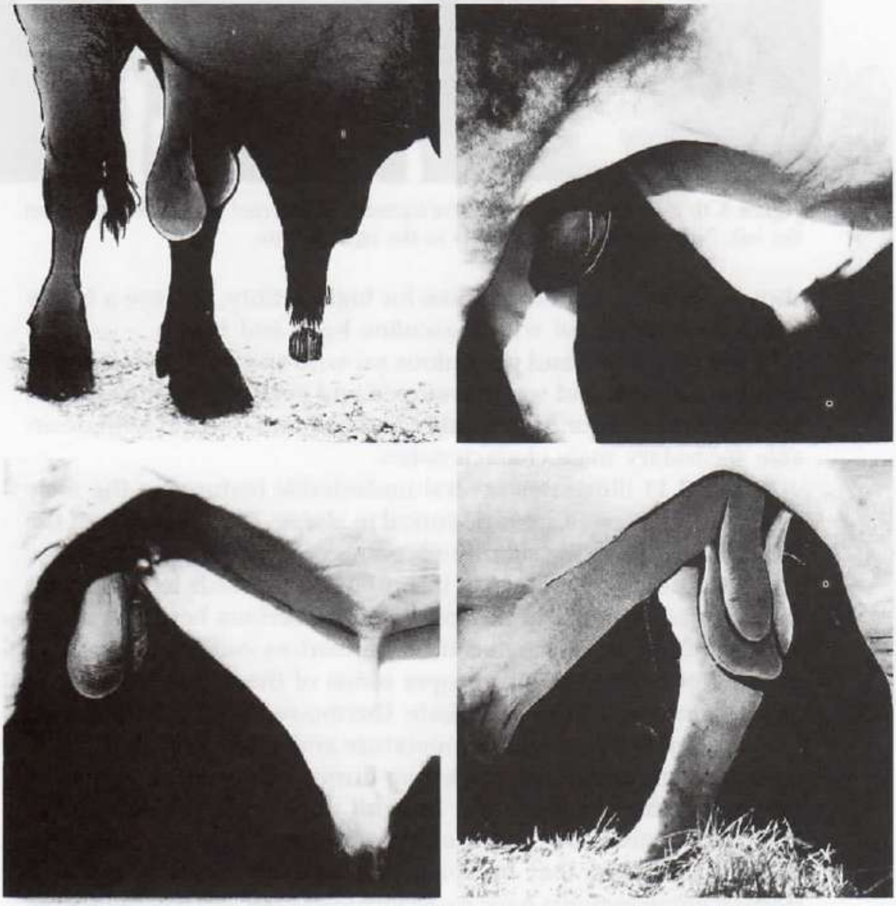


Figure 3.11 Undesirable male sex organs upper left photo: hypoplasia of a testis, a very large sheath and a protruding prepuce. **Figure 3.12** Upper right photo: a bull with normal testes and with proper tonus of the sphincter muscles which close the sheath opening. **Figure 3.13** Lower left photo: bull with gynaecomastia and a sheath opening which is too small. **Figure 3.14** Lower right photo: a case of serious hypoplasia of the left testicle.

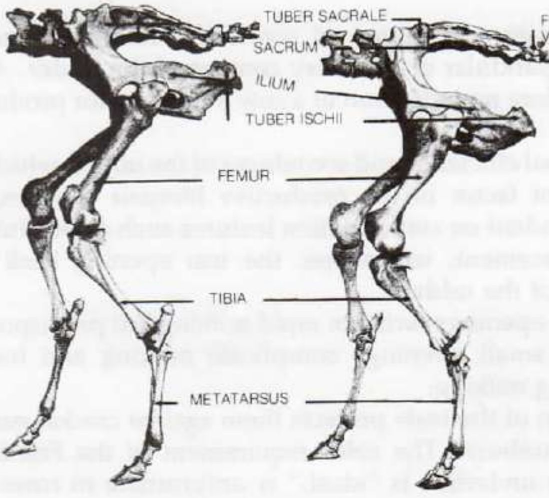


Figure 3.15 The skeletons of the hind limbs of a straight-hocked cow on the left, a difficult-calving (dystocia-prone) cow, and a normal cow on the right.

as in this illustration, frequently shows enlargement of its opening. This predisposes to a protrusion of the prepuce, a serious heritable defect that has been allowed to develop unhindered in certain breeds to an extent where the eradication of the condition becomes increasingly difficult.

In Figure 3.14, hind-quarter development in a hypoplastic bull (with the conformation of a steer) is illustrated. Superior muscle development in the normal bull and well-developed testes that are perfectly equal in size are well correlated with high fertility.

In the hypoplastic bull the testes are small, muscular development is inferior, and in the rump the pelvic girdle and hips are over-developed owing to prolonged growth.

Straight hocks are most undesirable and influence the hind-quarter conformation and functional efficiency. The thurls are pushed upwards and this results in a square rump, which is an unfortunate feature of the Friesland and many European beef breeds. It causes difficulty at calving and holds no advantages in regard to the amount of muscle or flesh on the hind quarter. (See Figure 3.15.)

Conformation of the udder and teats

Visual evaluation of the udder of the dairy cow is of little value in determining milk production. Fleshiness, which means fat infiltration and excessive deposition of connective tissue, frequently obscures the glandular or secretory content of the udder. A big udder is therefore no indication of a cow's capacity for producing milk.

The functional efficiency and soundness of the udder, which is a most important factor in the productive lifespan of cows, are critically dependent on conformation features such as pendulousness, size, placement, teat shape, the teat opening itself and pigmentation of the udder.

Everted teat openings facilitate rapid milking but predispose to mastitis. Too small openings complicate milking and induce bruising during milking.

Pigmentation of the teats protects them against cracks, painful milking and sunburn. The color requirement of the Friesland, where a white underline is "ideal," is unfortunate in cows and bulls. Pigmentation of the scrotum makes it resistant to warts, sunburn, ringworms and infection.

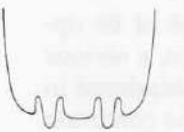


Figure 3.16

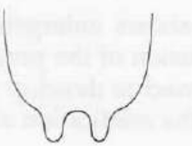


Figure 3.17

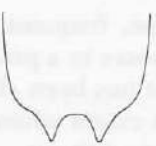


Figure 3.18

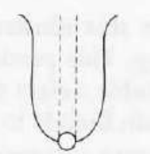


Figure 3.19

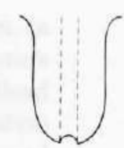


Figure 3.20

Figures 3.16 to 3.20 illustrate undesirable teat types and hormonal effects on the shape of the teats and udder.

The size and the shape of the teats accurately reflect the hormonal balance in cows and heifers. Cyclic and ovulatory inefficiency increases the size of the base of the teat, and udder development in the non-pregnant heifer is a sign of cystic ovaries.

Udder shape and size and teat shape convey much in the heifer and young cow. There is very little udder development in the heifer that has not come into heat yet. The teats are very small and pushed back into the skin of the udder (Figure 3.16). When a young heifer comes into heat regularly, the udder develops and the teats enlarge slightly; after several estrus periods the teats hang down perpendicularly from a fairly well-developed, firm little udder — it is what I call a beautifully developed maiden heifer udder (Figure 3.17).

When the heifer becomes pregnant, there is appreciable udder development, and if heifers are regularly observed it is usually not difficult to see all the endocrinological changes taking place as a result of pregnancy, such as specific hair shedding patterns and udder and teat development.

The heifer or young cow that has aborted no longer has a maiden heifer udder. The udder is very much larger, the teats are well developed and are typical of teats that have not been suckled; that is, they are broad at the base but taper to a fairly sharp point (Figure 3.18).

The older cow that has aborted after having suckled one or more calves usually has wrinkled teats with a firmly closed teat duct with a yellowish-creamy plug in the teat (Figure 3.19).

The cow that suckles a calf has well-formed teats, which are very smooth as butterfat is massaged onto the teat when the last milk is drawn during the process of suckling. The teat duct is open and recedes slightly upwards, so that is opens into a dimple at the end of the teat (Figure 3.20).

Udder attachment is of the utmost importance in selecting cows for functional efficiency. A cow with a poorly attached or an over-pendulous udder will not have a long productive life.

Hide and hair in selecting for functional efficiency

The hair and hide are an index of adaptability. For 23 years, from early 1937, I measured all the experimental animals at the Mara and Messina Research Stations. All the experimental animals were measured every three months, from birth until maturity or until such animals left the stations or died. Fourteen body measurements, including two hide-thickness measurements, were taken for each animal. This very close contact with these animals from their birth onwards enabled me to appreciate the differences in the textures of hair and hide. When the hair and hide condition was correlated with the climatological data taken on numerous animals of different types, it became obvious that the condition of the hair and hide is a wonderful index of an animal's adaptability.

The hide thickness was measured with a caliper that slips at constant pressure, so that all hide-thickness measurements were taken as objectively as possible.

From the climatological data taken on many animals of different types, it became very obvious that animals with thick, smooth-coated hides and with short hair of uniform thickness could stand high temperatures much better than cattle with woolly coats and thin hides.

When the hide of the short-coated, well-adapted animal is stroked, a deposit of a brown greasy substance sticks to the fingers. The hide of the unadapted animal is dry and only dust is stirred up when the coat is stroked.

In all the early climatological work done on cattle it was found that the well-adapted young bulls and heifers were early hair-shedders; that is, they started shedding their hair early in spring according to a fixed pattern. The first hair to be shed is the hair on the top of the neck and the crest, all along the spine to the tailsetting. This narrow line widens from the top downwards toward the mid-rib region. The shedding of hair on the lower belly region proceeds upwards. The last hair to be shed is on the medial line of the mid-rib region.

It also became very obvious that the early hair-shedding heifers reached sexual maturity long before the slow hair-shedding heifers.

Early hair-shedding in heifers is a very positive selection criterion for breeding for adaptability and fertility.

As I became well aware of the fact that early hair-shedding was correlated with ovarian activity, eight heifers were ovariectomized; four were treated with estrogen and four were kept as controls.

The four treated heifers started shedding their hair within three weeks after treatment and were completely smooth-coated within six weeks. Those of the control group were very tardy in shedding their hair; some of their hair in the mid-rib region was never shed.

It must be stressed that early hair-shedding is a very positive selection criterion for adaptability and fertility. No heifer that is not in a good nutritional state and that does not have normal ovarian activity will shed its hair early in spring.

The role of hair and hide in making an animal tick- and insect-repellent will be discussed in detail in a later chapter on the hair and hide of the bovine.

It must again be stressed that the animal with a thick, movable hide, with high vascularity and with sleek hair is far more repellent with regard to ticks and stinging insects than the animal that is thin-hided and dull-coated; the former is also appreciably more disease-resistant and much more fertile than the latter.

In the case of bulls the sexually active bull with tremendous libido secretes much more sebum than the low-fertile bull. A bull with a light-colored hide shows a dark-yellow pigmentation in the neck folds in a highly fertile bull; the whole hide has a creamy-

Figure 2.6 A miniature calf and two normal calves.

Figure 3.21 An intact two-year-old Afrikaner bull. Note his masculinity and aggressiveness. He has a thick, masculine hide.

Opposite, top: **Figure 3.22** The steer—half brother to the bull of figure 3.21—note his evenness of coat color. He is lethargic; no hair growing on the sheath opening. *Bottom:* **Figure 3.23** Steer treated with female sex hormones—note his feminine head, the relaxed ligaments of the rump, the fine hair and fine feminine hair on the sheath opening.

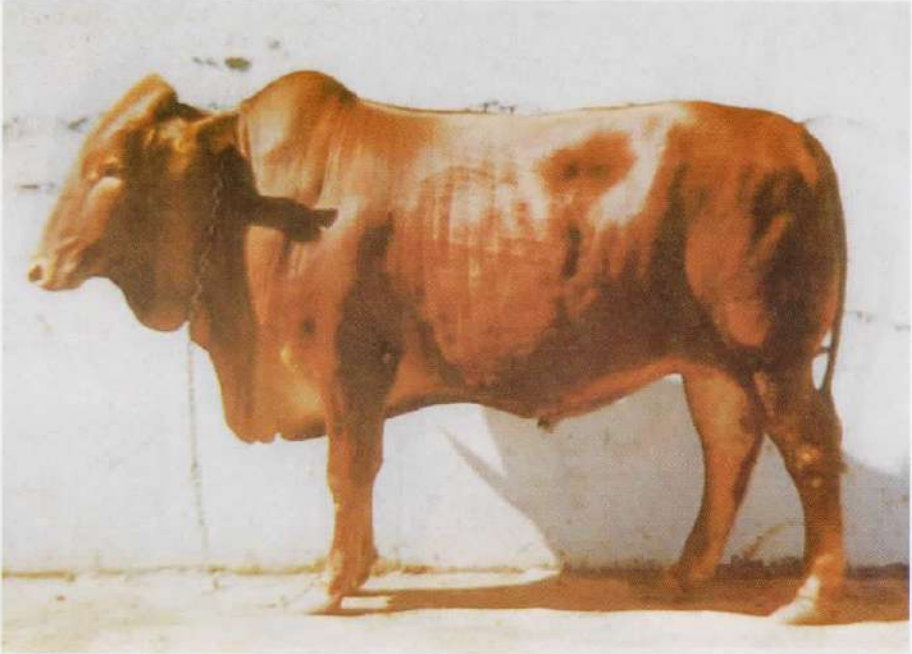


Figure 3.24 Steer treated with male sex hormones—note his masculinity, his thick hide and masculine hair, especially on the sheath opening.

Figure 3.25 Intact 18-month-old Hereford × Afrikaner heifer—note her femininity and smooth coat.

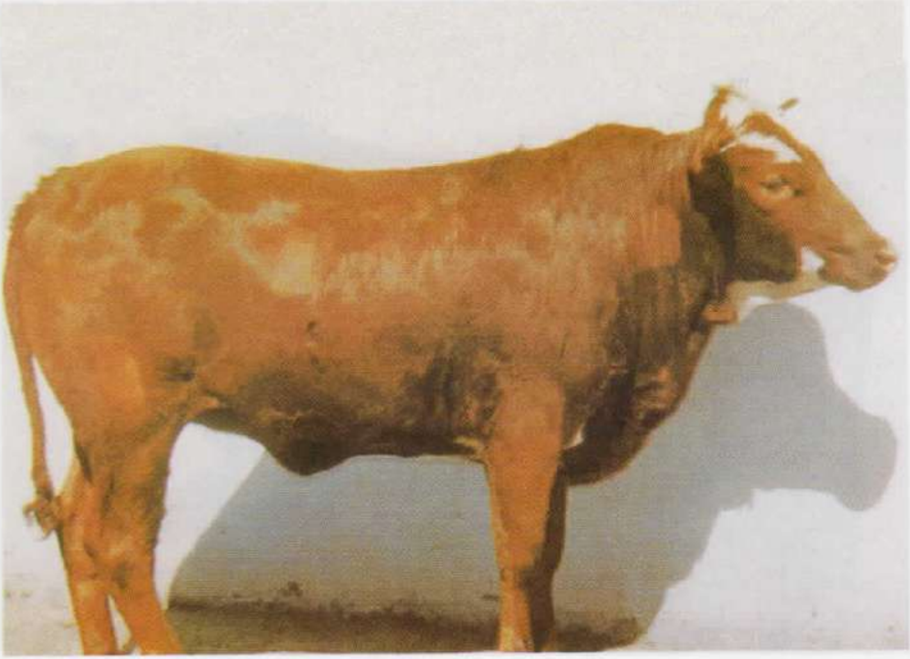
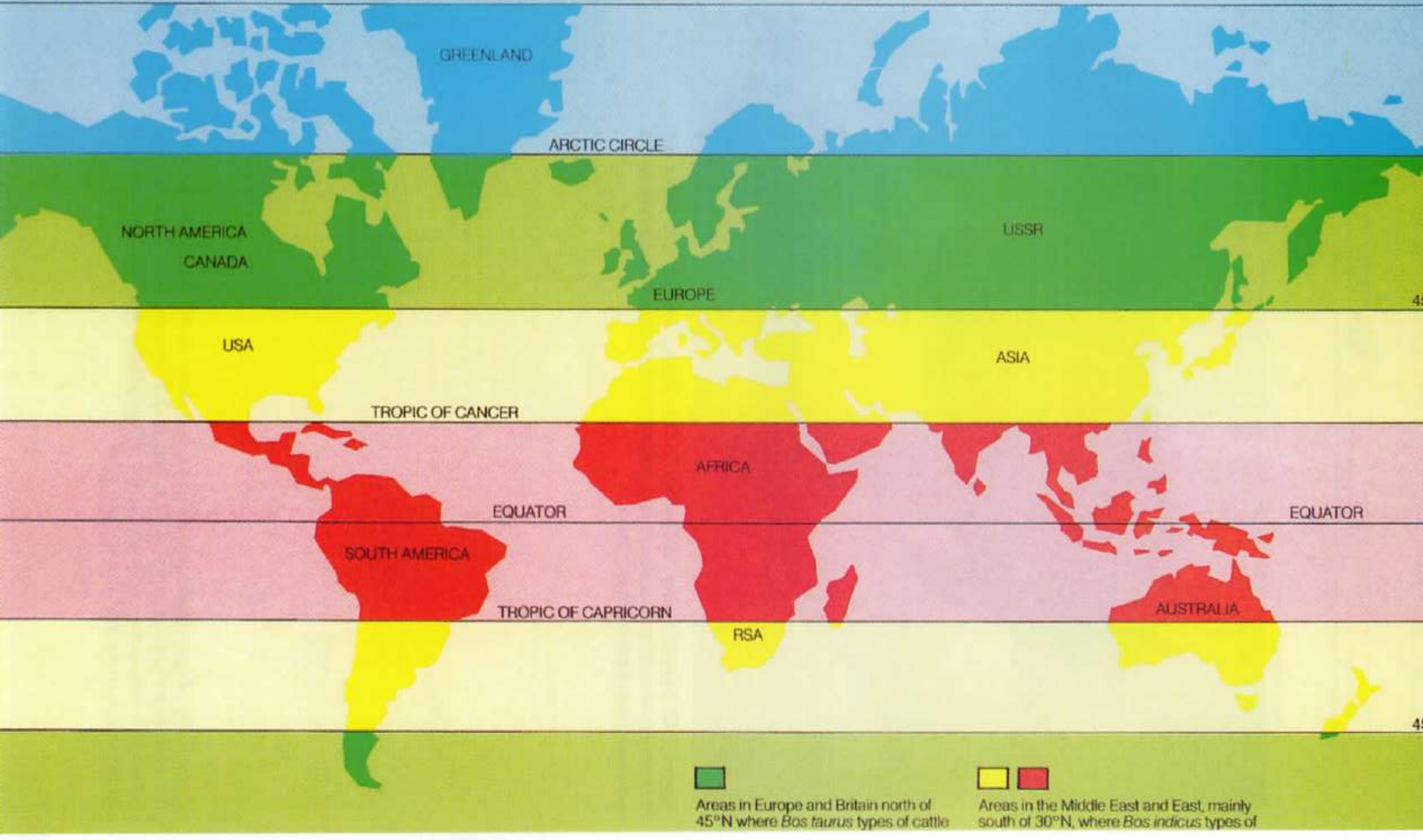


Figure 3.28 Spayed heifer, half-sister to the others, treated with male sex hormones—note the masculine head, coarse hair on the crest, male hair on the navel and large protruding clitoris.

Opposite, top: **Figure 3.26** Spayed heifer, half-sister to the intact heifer—note her coarse hair and lethargy. *Bottom:* **Figure 3.27** Spayed heifer treated with female sex hormones—note the udder development, the relaxation of ligaments of the rump and the smooth coat.

Figure 9.1 Where breeds of livestock had their origin and evolution.



white appearance. The hair of the bull with a low sexual drive is a dull white. When stroked with the hand, the hide of any bull with strong libido will leave a thick deposit of greasy material on the fingers.

The hair of the bull is completely different from that of the female. A bull of any breed has coarse, masculine hair on the head, neck, upper front limbs and on the thighs. The hair on the tail switch is coarse, masculine and very often curly.

In both male and female a full, thick tail switch is a certain indication of physical well-being. The hair of the tail switch of an unadapted animal is dry, straight and sparse. The highly fertile bull or cow usually has a luxuriant tail switch.

The hair on the opening of the sheath of the bull is coarse and also fairly luxuriant. In the case of a bull lacking libido, the hair is fine and sparse, and in the case of the steer there is practically no hair growth on the sheath.

The hair on the external genitalia of the fertile cow is fine and silky; subfertile and sterile cows have much coarser hair on the external genitalia. The udder of the highly fertile cow is covered by short, silky hair. The cow that is an irregular calver or that is sterile usually has long, fairly coarse, dense hair on the udder. Around the teats are long hairs extending beyond the opening of the teat.

Animal behavior and functional efficiency

In herd behavior there is a vast difference between the functionally efficient, highly fertile animal and the subfertile or sterile animal. The sterile or sexually abnormal animal is often an outcast and does not move within a group of animals. It is either well in front of a group of moving animals or well to the side of a group of grazing animals; it is never taken up as an integral part of the group.

This concept was beautifully illustrated several years ago when a cattle farmer presented two hermaphrodites to the Department of Animal Science at the University of Pretoria. These animals were outcasts: the cows did not associate with them, nor did the bulls. The bulls and cows at the university farm were not aggressive towards these two animals; they completely ignored them. The two hermaphrodites were asocial and did not form part of the normal cattle community.

In an effort to obtain clearer insight into how hormonal balance within the male and female influences the animal's behavior, eight bull calves and eight heifer calves, all half brothers and sisters, were treated in the following way:

Six of the bull calves were castrated and two were kept intact. Two of the castrates were kept as controls, two were treated with testosterone, and two were treated with estrogen. The two intact bulls showed all the secondary sexual characteristics of a bull: the hair, hide, muscling and general appearance were masculine and the behavior was challenging and aggressive. (See Figure 3.21, color section.) When heifers were brought into the same pen as one of these bulls, he would smell her and lick her but would not mount her if she was not in heat. The intact bull's behavior was at all times gentlemanly. When the heifer left the pen, he bellowed a farewell call after her.

The control steer in a similar situation was extremely lethargic. He took no notice of any animal coming into the pen and did not even prick up his ears. (See Figure 3.22, color section.) The steer that was treated with estrogen looked like a heifer. The hair on the opening of the sheath was fine and silky, the head was feminine, the ligaments of the rump were relaxed, and the animal resembled the nymphomaniac. (See Figure 3.23, color section.)

The steers treated with estrogen were very aggressive towards any heifer entering their pen — they regarded these heifers as intruders.

The steer treated with male sex hormone resembled a bull and he had a thick masculine hide. The hair on the opening of the sheath was masculine and the muscling and hump development were masculine. (See Figure 3.24, color section.) When a heifer was brought into the pen of this steer, he reacted like a sexual pervert, a real rapist. Whereas the bull acted towards heifers in a gentlemanly way, this testosterone-treated steer mounted the heifer without any preliminary rituals of lovemaking in the bovine world, such as smelling, drawing up the nostrils and licking the female.

Six of the eight heifers mentioned previously were spayed. Two were left as a control, the next two were treated with estrogen, and the last two were treated with testosterone.

The intact pair of heifers reacted normally: the hair-shedding was typical of the female, they exhibited normal estrus and calved normally in due course. (See Figure 3.25, color section.)

The control pair of heifers reacted exactly like the control steers, except that they had much coarser hair and hair-shedding was never completed. Rough hair remained on the mid-rib region. (See Figure 3.26, color section.)

The spayed heifers treated with estrogen developed very large udders; their whole hindquarter resembled that of the nymphomaniac cow. The relaxation of the ligaments of the rump was much more pronounced than that of the steers treated with estrogen. (See Figure 3.27 color section).

The spayed heifers treated with male sex hormones resembled bulls. The hair was coarse and had the typical male pattern and the clitoris extended beyond the lips of the vulva. (See Figure 3.28, color section). These animals reacted like pervert males, mounting intact heifers without the lovemaking ritual.

These eight groups of animals beautifully illustrated the influence of sex hormones on the body conformation of animals and on their behavior.

In breeding livestock, it also became very clear that males and females gave preference to their own kind. In work done with pigs to demonstrate the interaction between heredity and the environment, white Swedish Landrace sows were mated to black unimproved native boars and to Swedish Landrace boars in an effort to get crossbred and purebred pigs out of a sow.

We succeeded in getting purebred and crossbred pigs out of our small black unimproved native pigs as well as out of our Swedish Landrace sows.

The experiment worked, but in every instance the boar of the opposite breed to the sow should mate with the sow first since she will not stand to the other boar if the boar of her own breed mates with her first.

The same principle holds good in cattle and sheep. The cow or ewe gives preference to a bull or ram of the same breed.

In a cross-breeding program, cows of the same breed as the bull should not be placed in the group of cows to be crossed. The bulls in two groups of cows, for example Brahman and Angus, will first settle the cows of their own breed before proceeding to settle the cows of the opposite breed.

Performance and progeny testing

The breeding of livestock for functional efficiency should in the first place be based upon performance and progeny testing. This is the reason that no seedstock breeder of Bonsmara cattle can become a member of that breed society unless he is a member of the

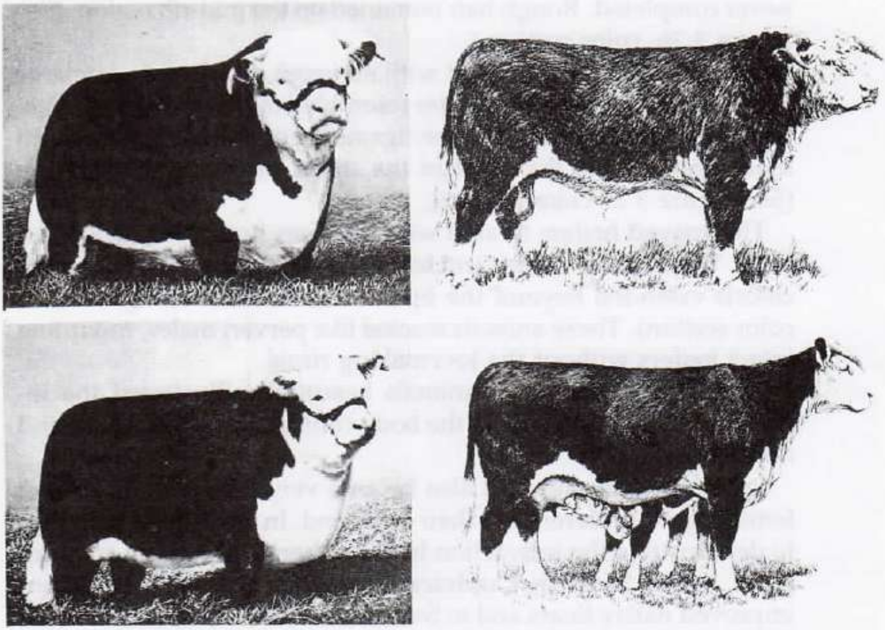


Figure 3.29 This is how Bonsma's concept of selecting cattle for functional efficiency changed the show standards in the United States. *Top:* Hereford bull, 1966 (left) and Hereford bull, 1967 (right). *Bottom:* Hereford cow, 1966 (left) and Hereford cow, 1967 (right).

Government Performance and Progeny Scheme. Performance and progeny testing is compulsory for every Bonsmara cattle breeder. Judging for functional efficiency is an integral part of performance testing; no animal that does not fulfill our standards of physical evaluation is put through a performance test. Every animal that has completed a performance test is again evaluated and if any hereditary weakness is observed, such an animal is culled immediately.

The subfertile animal has tremendous growth potential, hence the best performers have to be especially scrutinized. Bulls are scrutinized for hypoplastic (underdeveloped or incomplete) testicles and heifers are scrutinized for hypoplastic infantile external genitalia.

Selecting animals for functional efficiency before and after performance testing is the only way to eliminate heritable defects in a breed of cattle. This selection for functional efficiency requires a thorough knowledge of applied physiology and endocrinology. (See Figure 3.29).

My great objection to the judging of livestock at livestock shows is that so very few of the judges have a thorough knowledge of endocrinology and physiology. The judging is based on antiquated concepts that are often called "breed standards." I have often observed animals with serious heritable defects being awarded first and even championship prizes.

Shows are an integral part of the livestock breeder's profession. Here cattle of the various breeds are exhibited to give the prospective cattle breeder or buyer an indication what the cattle of a particular breed look like.

Livestock shows have come to stay, but they should be modified to include a better educational program where the placing of cattle is explained to the interested breeders in terms of functional efficiency.

Chapter 4

Breeding Livestock for Functional Efficiency

Producing as much good red meat per unit area as possible

> While the art of breeding requires intense application to detail, endless study, observation and application of a keen artistic sense, the rewards are great and I know of no task of such consuming and lasting interest.

This was written by the late Robert J. Kleberg Jr., of whose lifework the Santa Gertrudis breed is a product; it appeared in the **Santa Gertrudis Breeders International Recorded Herds** (Volume 1, 1953).

A great Friesland cattle breeder, the late Jan Wassenaar, once said:

> To create gives great satisfaction and by carefully selecting and mating your cattle you create better animals and this gives you a feeling of everlasting satisfaction—you are a "creator."

The endless study, keen observation and application of **animal science** to animal breeding enable the livestock breeder to produce better cattle. By "breeding for functional efficiency" is meant producing as much good red meat per unit area as possible without deterioration of the natural pastures.

The late Richard J. Kleberg wrote to Dr. John R. Mohr, then chief of the Bureau of Animal Industry, USDA, an article on the problems of the animal industry. Its main statement, summarized, amounts to this: Breed descriptions or standards on which breed improvements are mainly based **are not primarily founded on biological values; they are partly artificial devices lacking scientific basis**. As a result, improvement is delayed or checked. If pedigrees contain little beyond the names and identification numbers of ancestors, or if items entered in the pedigree records for each ancestor are only those of a more favorable character, they are a "meaningless genealogical jumble" and merely produce a false sense of security. If two or more breeds are developed for the same purpose they are simply arbitrary divisions.

These ideas are shaking modern animal breeding to its foundations, but they are only the logical consequence of this natural but nevertheless neglected question: **What is the purpose pursued by man in breeding domestic animals?** The only reply is: His purpose is to produce animals which at the lowest possible cost and expenditure of labor give the highest possible and longest lasting returns.

The main purpose of animal breeding, thus defined, has often been obscured. It is in fact only through quite recent developments that breeding for performance has found its way into animal industry, i.e. the wish to realize an increase and improvement in production performance of stock by selecting high-yielding animals for breeding purposes.

Fertility is a must

In order to produce the maximum amount of beef per unit area, it is absolutely essential to have highly fertile cattle, the females producing enough milk to wean heavy calves. High fertility in female stock means regular estrus, normal ovulation, ready conception on mating or artificial breeding, a normal gestation period, normal parturition, giving birth to a normal calf and ultimately weaning a good calf.

If cows can breed regularly for a number of years, high calving percentages bring about efficient production and the possibilities for selecting for functional efficiency are greatly enhanced. Functional efficiency will be considered in its broadest aspects including the combined effects of all factors through gametogenesis, libido, ability to copulate, estrus, ovulation, fertilization, embryo survival, gestation, parturition and mothering ability of the cow.

The low fertility of cows is the most important single factor that culls young cows for slaughter. In some regions of Poland, 20 percent of the female cattle are culled because of low fertility. Berge (1949) reported that in Norway 37 percent of the female stock were slaughtered because of low fertility. Hoekstra (Netherlands) reported that 22 percent of the dairy cows are annually butchered because of low fertility. No mention was made of the causes of the infertility of the cows. It is certain, however, that disease played a very minor role because in those countries contagious abortion has been controlled for many years and *Vibrio fetus* and *Trichomonas fetus* have rarely occurred since 1945.

It is generally accepted among population geneticists that the heritability of reproductive efficiency in beef cows is low (Warwick, 1958) and any progress made by selection for improved fertility will be slow. The low heritability estimates of cow fertility are partly artifacts since this trait is physiologically very complex and genetic differences in individual fertility are obscured by many factors such as disease, the libido of the bulls to which the cows are mated, and the fertilizing capacity of the bull's spermatozoa. Also confusing the issue is that selection has all too often favored those animals morphologically of a subfertile type for future breeding. We have only to look at pictures of famous cattle a hundred years ago to realize that the show-winning, subfertile types of cattle were the ones selected for breeding.

Reported estimates of heritable reproductive traits in beef cattle are few in number, most of the studies being carried out in dairy herds in Europe. Lindley and his co-workers (1958) studied the reproductive performance of a purebred Hereford herd and found the heritability for such traits as services per conception, calving interval and interval from calving to first breeding to be close to nil.

However, improved techniques of estimation have been devised and Shannon (1965) obtained a heritability estimate of 55 percent for conception rate in dairy cows in New Zealand. Additional new evidence that fertility has a higher heritability than previously thought comes from a study by Deese and Koger (1965) in a privately owned Brahman and crossbred herd in Florida. Heritabilities of 31 percent and 63 percent were obtained for first calving cows in Brahman and crossbred herds respectively. The heritability for the second calving record was 21 percent for Brahmans and

56 percent for crossbreds. These results are most significant and suggest that in unfavorable environments, where the mean reproduction rate is sub-optimal, heritability for conception rate is high enough so that significant genetic progress can be made through selection.

In view of the role artificial insemination plays in bovine reproduction and the emphasis placed on milk production in selecting sires for artificial insemination to the exclusion of constitutional defects and/or inadequacies, heritable lethal and sub-lethal defects warrant more than just passing attention. The Central Control Council for Artificial Insemination in the Netherlands (1953) obtained all the available information on hereditary defects in cattle and published a report which lists no fewer than nine lethal and 36 sub-lethal hereditary defects in cattle. Of the 36 sub-lethal hereditary defects no fewer than 14 affect reproduction.

It must be stressed that reduced fertility is far more common than complete sterility; both may be permanent or temporary, congenital or acquired at any stage of life because of some constitutional weakness.

Inherited defects of the reproductive organs

Hypoplasia in the bull. Hypoplasia (incomplete or underdevelopment) of the testes of the bull can cause serious breeding problems in the future.

Gonadal hypoplasia (underdeveloped sex organs) in both males and females of the Swedish Mountain cattle is a case in point. Lagerlof (1950) described this defect in bulls of the Swedish Highland breed. In these bulls, about 100 cases were studied and the degree of hypoplasia noted. In 81.9 percent of the cases only the left testicle was involved; in 3.6 percent the right testicle and in 14.6 percent both testicles. Eriksson (1950) proved that the hypoplasia of Swedish Highland cattle is cause by a recessive autosomal gene. The incidence of hypoplasia was reduced by strict selection from 16 percent in 1937 to 7.9 percent in 1942.

Blom and Christensen (1956) reported observations in 5,382 slaughtered bull calves; they found that abnormalities of the genital organs had almost doubled in comparison with results obtained ten years earlier. In examining the pedigrees of calves with aplastic Wolffian ducts, it was found that one bull had sired seven such calves, another bull had sired four and a third bull two. These research workers stated the aplasia was undoubtedly a hereditary defect.

In work done with Ayrshire cattle in Britain, it was found that all the Ayrshire bulls with hypoplasia of the testes were descended from one bull reported to have been hypoplastic. The defect in bulls is carried over to their female progeny. As a result the fertility of the Swedish Mountain cattle became disparagingly low.

According to observations made in South Africa, a certain correlation exists between the normal development of the gonads and the color of the coat. More strongly pigmented animals have better developed genital organs, whereas the highest incidence of hypoplasia was found in sires predominantly white. In red-brown cattle the cows should have an even color, but bulls should show a darkening of the hair on the head, neck, crest and the lower part of the body.

In the Swedish Mountain cattle a similar observation was made. Sires classified as white had 69 percent of the hypoplasia cases with only 5.2 percent among more pigmented ones. In Charolais bulls it was observed that those with a dull white color were more inclined to have hypoplastic testicles and lacked libido in comparison to those with a greasy feel of and yellowish hue in the hair.

Hypoplasia in the cow. Detailed studies were made over a period of twenty years on the sexual organs of 8,145 slaughtered cows. Lagerlof (1950) found that 13.1 percent, or 1,070 cows, had abnormalities of the reproductive organs. Of the animals affected, 87.1 percent had hypoplasia of the left ovary, 4.3 percent of the right ovary and 8.6 percent of both ovaries. Fincher (1946) observed that three daughters of one cow, each sired by a different bull, had a virtual absence of ovaries, together with an infantile genital tract and an absence of estrus activity.

It is obvious that hypoplasia of the gonads in both male and female is inherited and the only way to overcome this problem is by strict selection against it. The problem of the lowered fertility in the Swedish Mountain breed of cattle had its origin with two show-winning bulls, both with hypoplasia of the testicles.

From 125 matings of hypoplasts to hypoplasts, half the offspring were hypoplasts, a fourth were doubtful and a fourth normal.

Prolapse of the prepuce. The genetic aspects involved in the various factors that predispose to prolapse of the sheath have been clearly described by Venter and Maree in their paper, "Factors affecting prolapse of the prepuce in bulls."

The condition is found in various breeds but its detrimental consequences occur with greater frequency in certain breeds, especially in the Santa Gertrudis breed of cattle and in bulls of some of the polled breeds.

Venter's work shows that up to 30 percent of four-year-old Santa Gertrudis bulls were eliminated through prolapse of the sheath and subsequent phimosis (tightness of the foreskin so that it cannot be drawn back from over the glans) and paraphimosis.

Out of 244 bulls from 13 different breeds, Long (1969) recorded prolapse of the prepuce in 85 percent of polled breeds and only 1.4 percent of horned breeds. A high incidence of prolapse of the prepuce is reported in *Bos indicus* type bulls such as the Brahman. Donaldson and Aubrey (1960) reported on twenty cases of pathological prolapse of the prepuce of which 19 cases were from the Santa Gertrudis breed.

Among the anatomical features that might predispose to prolapse of the prepuce in bulls is pendulousness of the sheath as well as the sheath opening. That these abnormalities are highly heritable cannot be doubted. In **Santa Gertrudis Breeders International Recorded Herds**, Volume I, 1953, appear illustrations of Monkey, the foundation sire of the breed; Santa Gertrudis I, best producing son of Monkey; Tipo, best son of Santa Gertrudis I; and Coton, best son of Tipo and great-grandson of Monkey.

All four of these bulls exhibit to a greater or lesser degree of seriousness the two facets involved in prolapse of the prepuce; namely, a too pendulous sheath and a too large sheath opening.

There can be no doubt that gravity on the sheath and the anterior and downward position of the penis in the sheath as well as the tonus of the retractor penis muscle play a role in the predisposition to prolapse of the prepuce.

Surgical intervention affords relief in pathological cases of prolapse of the prepuce but the only way to eliminate this serious problem is through selection. Too many seedstock breeders shy from culling breeding stock with glaring heritable defects such as prolapse of the prepuce and hypoplastic testicles.

White heifer disease. In Great Britain at the end of the 19th century white heifer disease was noted among white Shorthorn heifers. It is estimated that approximately 10 percent of the white Shorthorns in England are affected with this disease, which is not a disease but a defect in the reproductive organs. The ovaries, Fallopian tubes and vulva are usually normally developed; the hypoplasia is confined mainly to the uterus, cervix and anterior vagina.

Rendel (1952) studied this condition in British Shorthorn bulls. One bull sired nine affected white heifers out of 23, four affected roans out of 115 and one affected red among 94. Apparently, homozygosity for white greatly enhances the manifestation of this phenomenon. This condition is also found among the Nguni (*Bos indicus*) breed of cattle in South Africa. At the International Congress of Animal Reproduction at Cambridge, Nordlund (1956) described twelve cases of this defect, all were the daughters of the same bull used in artificial insemination. The bull was not related to the dams, nor were the dams related to one another.

Impotentia coeundi. Another problem encountered among bulls is *impotentia coeundi,* when the bulls fail to complete the sexual act. This defect has nothing, or very little to do, with lack of libido. A relatively high frequency of *impotentia coeundi* existed in the Swedish bulls and it was thought to have been brought about by the selection of good-natured sires of a feminine type at the expense of sexual vigor. In a study of the sexual activity of five pairs of identical twin bulls of the Swedish Red and White breed, Bane found that *impotentia coeundi* occurred concurrently in three twin pairs, while two pairs had normal potency. The level of nutrition of the animals had no significant influence on the mating behavior of the bulls.

Several countries report that lack of ability to mate is a common reason for culling among bulls. Lagerlof, studying the records of some 13,000 insured bulls of the Swedish dairy breeds, found that compensation had been paid out on approximately 20 percent of the bulls; the most common cause was reproductive failures, especially among young bulls from one to two years of age. Table 3 indicates that the indemnities were distributed among the three groups of sexual disturbances which were mentioned in the case histories of the bulls.

Table 3: *Reproductive problem of bulls of three Swedish dairy breeds*

Breed	Inability to copulate	Inability to fertilize	Combination of both causes
Swedish red and white cattle	37,2%	21,5%	6,4%
Swedish Friesians	37,4%	15,1%	9,6%
Polled Swedish cattle (Highland)	68,0%	4,8%	4,3%

In polled cattle, Eriksson (1950) made a study of copulatory inability among sons of bulls that had exhibited the same defect and found that the figure was 45.8 percent as compared with 28.0 percent for sons of normal sires. *Impotentia coeundi* is often caused by certain ligaments that prevent the sigmoid curvature from straightening completely; hence, the penis cannot protrude from the sheath far enough to give the final thrust in serving the cows. This defect is now all too common in Afrikaner bulls of certain families and I have had occasion to give evidence in a court case in this connection. This defect in bulls can be remedied by surgery, but the Netherlands Herd Book Association has prohibited the use of such bulls at artificial insemination centers. As a result of the genetic origin of these defects, it is essential that a bull failing to inseminate a cow naturally is not used for breeding purposes.

In some breeds of cattle too large a sheath is encountered and prolapse of the prepuce becomes a serious impairment to natural breeding. Although circumcision can overcome this problem, it is a matter of serious consideration whether breeders should not discriminate seriously against bulls that have sheaths so large that the condition has to be remedied surgically in order to breed.

Nymphomania. Garm found a high frequency of nymphomania among dams of cows with nymphomania and he assumed that the predisposition for the disturbance was hereditary. At a field day at the Mara Research Station in 1958 I selected four nymphomaniac cows for a demonstration and found that all four had been sired by the same bull.

Inherited physiological defects of reproduction

Hormones. After having read Julius Bauer's book on constitution and disease, I understood that many reproductive disturbances are due to endocrine imbalance and run in families and therefore may be hereditary in their origin. Eriksson (1950) comes to the conclusion that sires with low copulatory efficiency had more ancestors being bulls with copulatory disturbances. He concludes that hereditary factors contribute to these disturbances and those of a physio-hormonal nature.

Twin experiments done in Sweden and in New Zealand indicate that mating behavior is a highly heritable characteristic.

Berthold (1849) proved that the effect of castration on male secondary sexual characteristics was due to the removal from the body of some substance secreted by the testes into the blood. In 1904, more than 50 years after Berthold's observation, Bayliss reported the present concept of hormonal action and thus opened up the subject of endocrinology.

Endocrine imbalance must have a marked influence on the reproductive ability of cows. It is realized that endocrine imbalance may be caused by various environmental factors such as overfeeding. It is also obvious that certain environmental factors that upset some cows endocrinologically have no influence on others. It is my opinion that some females have a hereditary predisposition to suffer from an endocrine imbalance at slight environmental stress.

Johansson in **Genetic Aspects of Dairy Cattle Breeding** discusses the work of Garm (1949). Garm made a comprehensive study of the syndrome *cystic ovaries* on material from Swedish Red and White and Swedish Friesian cattle. He distinguishes between nymphomania and adrenal virilism, depending on whether the erotomania is manifested in the female or male direction. In the female case, an increased secretion of the follicle-stimulating hormone (FSH) and a low production of the luteinizing hormone (LH) are supposed to cause persistent and enlarged follicles which results in prolonged production of estrogens. In connection with adrenal virilism the adrenal cortex was found to be hypertrophied and it is assumed that increased amounts of androgenic substances were produced, sometimes causing bullish behavior. In heifers it is typified by a buffalo body shape and erect brush-like hair extending from the crown of the head along the top of the neck and across the withers as far as the middle of the back.

Casida and Chapman (1951) studied the incidence of cystic ovaries in a herd of Holstein cattle and concluded that 31 percent of the daughters of cystic cows were cystic in the different service periods and 9.4 percent of the daughters of noncystic cows were cystic. Twice the difference between these two values, 43.2 percent, is the estimated heritability of the occurrence of cystic ovaries in this particular herd when the dams and daughters had the same number of service periods.

Kock and Berger (1954) found one Simmental bull had sired 28 daughters with cystic ovaries, after the first or second calving, out of 47 daughters. Sonnenbradt and Ranninger reported on a herd where approximately 10 percent of the cows were culled annually because of nymphomania and the defect was concentrated in certain families. These workers conclude that frequency of nymphomania can be decreased only by selective breeding.

Erb (1959) reported on studies carried out over a period of 30 years on a Holstein herd. Over 2,000 dam-daughter pairs were involved. The results seem to indicate that the tendency to twinning, cystic ovaries, retained placenta and estrus after conception are genetically interrelated. The frequency of these traits among daughters of dams which showed the same trait was compared with the frequency among daughters of dams not showing the traits. The results in Table 4 were obtained when the analysis was restricted to cows with at least two calvings. It is considered that all the traits mentioned in Table 4 are influenced by inherited common endocrine weakness. Silent ovulation or inconspicuous heat is a characteristic found among some animals in a herd.

Table 4: *Frequency of traits associated with reproduction among Holstein dam-daughter pairs*

Traits	Frequency among daughters		
	'Positive dams'	'Negative dams'	Difference
Twin births	17,4%	12,0%	5,4%
Retained placenta	33,2%	25,0%	8,2%
Ovarian cysts	16,5%	13,9%	2,6%
Cystic tendency	53,6%	45,8%	7,8%
Twinning and retained placenta and cystic tendency	68,4%	48,4%	20,0%

In Swedish artificial insemination associations, the inseminators classified almost a quarter of a million cows according to the intensity of the heat symptoms; they classified three groups—distinct, indistinct, and very indistinct. The percentages of diagnosed pregnancies in the three groups were approximately 57 percent, 45 percent and 26 percent respectively. Especially in cows with very indistinct estrus symptoms, timing of the insemination to ovulation has apparently been poor.

A publication by two South African research workers, van Rensburg and de Vos (1962), throws some interesting light on ovulatory failure in Afrikaner and Friesland cows. Using 161 Afrikaner and 118 Friesland cows, they found that of the 536 estrus periods observed in the investigation, normal ovulation occurred in 396 cases and failure to ovulate occurred in 140 instances, or failure in 26.1 percent of the periods. They report ovulatory failures were of two types, either delayed ovulation or anovulation. The former occurred in 66 percent of the failures, the latter in 34 percent. The possibility of ovulation terminating in follicular regression and atresia or cystic degeneration is also mentioned.

It also appears from their data that anovulation frequently recurs in the same animal and is more important in producing problem cows than is delayed ovulation. In four of the eight cow families studied, 87.8 percent of the estrus periods studied were followed by normal ovulation. In the other four families which exhibited poor reproductive ability, judged by the number of descendants, only nine of the 21 estrus periods, 43 percent, were followed by normal ovulation. Although the conclusion that hereditary predisposition is an important factor in ovulatory failure could be criticized by the statisticians on the basis of insufficient numbers, the trend nevertheless is very definite. Therefore, it would appear that ovulatory failure is an extremely important physiological aberration associated with low reproductive efficiency.

Another problem of the livestock breeder is the "repeat breeder." It is often possible to distinguish the repeat breeder in a herd on the basis of morphological deviations, but to the inseminator or physiologist she is without symptoms. The repeat breeder has been defined by Casida (1951) as a cow which manifests no clinical signs of infectious genital disease and in which rectal examination shows no signs of anatomical abnormalities of hyper-ovarian or hypo-ovarian activity. The animal does exhibit reduced fertility, and although it is customary to choose repeat breeders for experimental purposes on a basis of four or more unsuccessful services, Casida maintains that if insemination conditions are optimal, a single return from service is sufficient for a cow to qualify as a repeat breeder. Casida (1961) has reviewed the theoretical causes of repeat breeding and says that both fertilization failure and embryonic loss are major causes of repeat breeding. Poorly developed corpora lutea have been associated with high embryonic loss, but apparently progesterone therapy on repeat breeding is not convincing.

Van Rensburg and de Vos (1961) differ from Casida (1961) in their interpretation of a repeat breeder. Much depends on the significance which Casida attaches to the terms hyper-ovarian and hypo-ovarian activity. It must be mentioned that van Rensburg and de Vos consider ovulatory failure the most common cause of the repeat breeder or "problem" cow.

Evidence from the study of herd records

Inheritance from dams. There is no lack of studies concerning the heritability of female fertility in dairy cows, see Table 5.

Table 5: *Estimates of heritability of different measures of female fertility*

Measure of fertility	Cows	h^2	Reference
Calving interval	731	8,9	Rennie (1954)
Services per conception	12 512	2,8	Maijala (1965)
Regulating of heat cycles	834	5,0	Pou et al (1953)
Days calving to first oestrus	210	17,2	Olds & Seath (1953)
Frequency of ovarian cysts	8 938	15,0	Henricson (1957)
Frequency of ovarian cysts	341	43,2	Casida & Chapman (1951)

The estimates provided in the table are only a few. (The average h^2 estimate of most of the available data is a little over 2 percent.)

Estimates obtained from individual herds and from selected herds with careful recording indicate that higher heritabilities than the 2 to 4 percent reported in most cases are possible (Maijala, 1965).

Differences in the fertility of cattle families have frequently been reported. One of the earliest recordings is by Kab (1937) who found that for several generations 35 families of Yellow Franconian cattle exhibited high fertility and eleven families low fertility.

Inheritance from sires. The sire has been considered by several observers an important influence. Variation in the fertility of different strains led Taussig (1946) to suggest that bulls should be selected on the basis of the fertility of their families. Comparison of the fertility of bulls in herd-book data leads to the conclusion that some bulls do enhance the fertility of the breed while others have a harmful effect.

In the Allgau breed, Henle (1949) found that of 28 bulls, eight (28.6 percent) had an unfavorable influence on the fertility of their daughters. Further evidence was provided by Trimberger and Davis (1945), who found that when their records were analyzed on a sire basis considerable differences in fertility existed. Eleven daughters sired by one Guernsey bull had an average fertility of 2.25 services per conception, which differed significantly from the average of 1.71 services per conception for daughters of all sires.

Van Velzen (1963) analyzed data obtained from artificial insemination stations in the Netherlands and by comparing the conception rate of at least 200 daughters of each of eight bulls he found that the average number of inseminations required to settle these cows differed markedly.

Table 6 shows the daughters of the two bulls, L.T.8 and A, are much easier to settle than those of J.H.R. and T.H. It was not possible to settle 10.8 percent of J.H.R.'s daughters; whereas with

L.T.8 and JETZE only 6.1 percent and 5.4 percent, respectively, of their daughters did not settle.

The workers concluded that heredity played an important role in the fertility of the female progeny of the bulls compared. An important question not answered in this research work was: What is the correlation between the fertility of the bulls and their daughters? If I had to guess, I would say it is high.

Table 6: *Differences in the percentage pregnant and the average number of inseminations required to settle the cow*

Name of bull, abbreviated	Number of daughters	Per cent pregnant total	Per cent pregnant after insemination	Average number of insemination per successful pregnancy
A	389	93,6	75,8	1,47
L.T. 8	784	93,9	67,9	1,54
JETZE	318	94,3	67,9	1,58
W.A. 1	1 415	92,4	62,9	1,70
K	239	92,5	62,8	1,71
J.J. 2	338	92,6	61,8	1,75
T.H.	903	90,5	58,2	1,89
J.H.R.	538	89,2	57,8	1,92

Not only the conception rate but also the number of calves born alive is important. There are indications that some stillbirths are genetically controlled.

Research work done by van Dieten in the Netherlands established very significant differences in the frequency of stillbirths between paternal halfsister groups (influence of sire of the dams), shown in Table 7. He concluded this phenomenon was influenced by heredity. There can be no doubt that the sire has a marked influence on the number of calves born dead and on the number of instances where dystocia (difficult calving) occurs.

Table 7: *Stillbirths of calves of different sires, red and white (Rhein-Maas-Ysel) breed (abbreviated)*

Sire number	First calf heifers				Dam with more than one calf			
	Male calves		Female calves		Male calves		Female calves	
	Number	Per cent stillborn	Number	Per cent stillborn	Number	Per cent stillborn	Number	Per cent stillborn
04	1 266	22,7	1 243	14,0	2 096	5,4	2 110	4,0
11	410	18,8	439	5,5	1 010	2,8	982	3,9
28	691	18,6	581	9,5	2 551	4,4	1 446	3,9
33	780	10,9	756	4,8	1 559	3,3	1 347	2,4
45	468	6,2	481	3,3	897	3,0	882	2,5
Bulls average		16,0		8,9		4,6		3,3

Both bulls and cows may be responsible for causing dystocia. In the crossbreeding work done by the Milk Marketing Board in Great Britain, the Charolais bulls are shown to be more often responsible for dystocia than any other breed of bulls used. But it is also amazing that the percentage incidence of dystocia is much higher among Friesian cows than among Jersey cows, where Charolais bulls were used in both instances.

In the Netherlands it is well known that the progeny of certain bulls give calving difficulty; then, it is thought that the sire to which the female progeny of such bulls are bred has very little influence on the incidence of dystocia. In one closely controlled instance it was found that 50 percent of the daughters of one particular bull were regarded as being difficult calvers. In half of the cows having calving difficulty the calves had to be pulled and in the other half embryotomy was performed to save the cows.

Several sons of a bull, #O4, gave calving difficulty to their female progeny. It is considered a serious hereditary defect. The Dutch research workers consider the cause to be the inheritance of an infantile type pelvis.

Friesland cattle in England, Holland and South Africa are very susceptible to dystocia. Sir John Hammond thought it was caused by some hormonal imbalance in the cows of this breed. I think it is due to anatomical changes brought about by selecting for very square rumps and thurls which are too high. It is felt that straight hocks should be guarded against in both bulls and cows.

To summarize, the Dutch workers came to the following conclusions:

1. Heredity is largely responsible for stillbirths in calves. Avoiding the use of semen of bulls siring many stillborn calves for heifer insemination can lower the frequency of this symptom considerably.
2. Although bulls have an important influence on the average conception rate of their daughters and although selection for this trait is possible, the possibilities in practice are limited.

A fairly comprehensive review has been given here of various endocrine and other abnormalities which cause lowered fertility in cattle. Many of these abnormalities and endocrine imbalances have a genetic origin. To breed functionally better livestock, it is essential to select for breeding animals with no morphological abnormalities and no clinical symptoms of endocrinological imbalance.

It is not doubted that livestock breeders can successfully breed for functional efficiency. By strict culling and selection, it is possible to produce large ranch herds of 3,000 or more cows with a calving percentage of around 90 percent and average weaning weights of the calves at 200 days of 450 pounds and over.

Chapter 5

Crossbreeding

Breed creation and the genesis of the Bonsmara

The reason cattle producers resort to a system of crossbreeding and afterwards, as a sort of afterthought, to breed creation is that the two main types of domestic livestock, namely *Bos taurus* (the British and European breeds of livestock) and *Bos indicus* (Indian and indigenous African types) do not perform satisfactorily in all respects under the unfavorable environmental conditions in which we want to maintain cattle.

The *Bos indicus* type—the Brahman type of India and Pakistan—was never selected for economic functions or, as we call it today, functional efficiency. In South Africa and Africa as a whole, the *Bos indicus* types were not improved to produce more milk and meat. The South African pioneers traded Afrikaner-type cattle from the Hottentots and used these animals mainly for draft purposes: later, at the turn of the century, selection began for increased beef production. Unfortunately, the early breed standards put too much emphasis on non-significant esthetic factors such as a rising chine, long twisted horns, and a Roman-nosed, relatively narrow forehead.

The British and European breeds of livestock, on the other hand, were evolved and improved in the Northern Hemisphere where all metabolic functions can be more efficiently performed for reasons not often thought about by the livestock breeder.

The Northern Hemisphere is four-fifths land and one-fifth water; the Southern Hemisphere is four-fifths water and one-fifth land. Furthermore, the more important *Bos taurus* types evolved between 45° and 60° North Latitude. While only a small part of Argentina and Chile, which is almost uninhabited, falls between 45° and 60° South Latitude.

The metabolic functions of the bovine are greatly influenced by nutrition, temperature, light, and radiation, and these conditions vary markedly in the two hemispheres.

Natural pastures in the Northern Hemisphere are higher in protein value but are lower in crude fiber; hence, they have a lower heat-increment value than the pastures of the Southern Hemisphere, a factor which has a very marked influence on the animal's ability to dissipate heat and to stay in a condition of thermal equilibrium.

Owing to the low latent heat value of the large land masses, the winters in the Northern Hemisphere are very much colder than in the Southern Hemisphere. The winter range is snow-covered; hence, provision has to be made for wintering livestock. In the Southern Hemisphere the range is open; the natural pasturage is low in protein and phosphate content and the animals often have to survive on pasture of sub-maintenance value. The summer and winter temperature fluctuations are much greater in the Northern than in the Southern Hemisphere. The same is true of the photoperiod (daylight hours). It is of the order of 16 to 20 hours during the Northern Hemisphere summer, whereas it seldom exceeds 14 hours anywhere in the Southern Hemisphere. There may be as few as 2 to 6 daylight hours in winter in the Northern Hemisphere, whereas this period is seldom shorter than 10 hours in most of the inhabited parts of the Southern Hemisphere. It is also a fact that the solar radiation and ultra-violet impingement are much more intense in summer in the Southern than in the Northern Hemisphere.

All these environmental factors result in a vast difference between the metabolic functions of animals in the Northern Hemisphere and those in the Southern Hemisphere, or those that have evolved far south in the Northern Hemisphere in places such as India and northern Africa. Differences in climatic and environmental factors have a marked influence on the body conformation, the hair-shedding process, coat cover and color of cattle.

In an effort to breed for adaptability and functional efficiency in any environment, it is essential to know how any environmental factors will influence the adaptability phenomena of animals.

Owing to the evolvement of the *Bos taurus* in cold-temperate (raw) climate and the *Bos indicus* in a hot, dry (scorching) or hot, humid (muggy) climate, these two types of cattle differ from one another in body conformation, hair and hide, and metabolic function.

The indigenous types of cattle in South Africa, especially the improved *Bos indicus*, the Afrikaner, did not perform satisfactorily by economic traits such as the efficiency of food utilization, fertility, milkability, growth, and carcass grading. The British types of cattle lacked adaptability in our subtropical, semi-arid ranching areas. The result was that the authorities, especially Professor A. M. Bosman, then head of the Division of Animal Husbandry, Agricultural Education and Extension of the Department of Agriculture, and his principal animal-husbandry officer, Dr. D. J. Schutte, decided to launch a project to create a new breed which would fit the bill. During 1934 and 1935 both these scientists visited the King Ranch in Texas. They were so impressed by the potential of the Santa Gertrudis breed that they returned home determined to evolve a new breed along similar lines for the ranching areas of South Africa.

To carry out this project, a large cattle ranch of about 30,000 acres was acquired in 1935. This was to become the Mara Research Station (23°9′ South, 29°34′ East; altitude 2,970 feet; average annual temperature 66°F). In 1937 an extensive crossbreeding program was initiated at Mara. I had visited the King Ranch the previous year and was entrusted with the task of developing a new breed of beef cattle at Mara. Professor A. M. Bosman instructed me to evolve a breed similar to the Santa Gertrudis, namely ⅝ Shorthorn and ⅜ Brahman with the British of *Bos taurus* blood predominating.

Before 1940 it was considered that tropical degeneration of the British beef breeds was caused by malnutrition. The protein content of the natural pastures in the Southern Hemisphere is low. During late summer and early winter it drops to a critically low level.

Because poor nutritional conditions were considered to be the cause of tropical degeneration, a large-scale nutritional experiment was launched at the Messina Livestock Research Station in 1937.

Eighty-four head of beef cattle of the British beef breeds were divided in three groups of 28 heifers each. Each group consisted of 16 Herefords, 8 Shorthorns and 4 Aberdeen Angus heifers. The first group (H) received a protein supplement of 24 percent digestible protein and the second group (L) received a 12 percent digestible protein supplement. Both supplements had exactly the same energy value. The third group (K) received no supplement at all.

At the end of the first supplementary feeding period, which lasted from July 1 until December 1, 1937, there was no significant difference in weight between the three groups.

At that time I became aware that tropical degeneration of the British breeds of cattle was not due to a nutritional deficiency. In each group of heifers were individuals that thrived appreciably better than others. With the work of Albert Rhoad of the Jeanerette Research Station, Louisiana, in mind, I decided to do climatological tests on the 84 British-breed heifers. Twelve Afrikaner heifers were included in this project.

Careful observation proved that the heifers that showed the least climatic stress thrived best. Those animals that showed signs of stress on hot days had a high respiration rate, they panted, their tongues hung out and they dribbled profusely.

From December 1937 onwards, body temperatures were taken and respiration and pulse rates were counted once a week on various heifers every two hours of the day from 6 a.m. to 6 p.m. and occasionally from 6 a.m. to 6 a.m. the next day. The weight of each animal in the experiments at Mara and Messina Research Stations was determined at least once a month and 14 body measurements were taken quarterly on each animal from birth throughout its productive life at the research station.

Because I wanted to **measure** every aspect of the livestock with which I worked, I made numerous observations on my experimental animals. Weight, body measurements, body temperatures, rates of pulse and respiration, hair counts per square centimeter and tick counts were made. The hair diameters were determined with a lanameter. The entire hair coat of cattle of different types was shorn close to the body with a No. 0 clipper, its weight was determined and it was put through a felting machine at a hat factory in Johannesburg.

These elaborate tests on the hides and hair of cattle proved beyond a doubt that the hide and coat play a tremendous role the process of heat dissipation.

The ease of heat dissipation is of the utmost importance to enable the animal to maintain its thermal equilibrium in the hot environment of the tropics and subtropics.

At the time of the climatological research work at Messina Research Station, the breed creation work at Mara Research Station was also in progress.

As I indicated, Professor Bosman instructed me in 1937, then I was in charge of research work on both the experimental stations, to create a breed similar to the Santa Gertrudis breed of cattle at King Ranch, namely ⅝ British beef breed and ⅜ Afrikaner.

Four hundred specially selected Afrikaner cows at the Mara Research Station were divided into five groups of 80 cows each, which were then sub-divided into two groups of 40 cows each. The ten groups of 40 cows were mated to five types of British beef-breed bulls, namely:

a) Red Aberdeen Angus imported from Scotland
b) Hereford
c) Red Poll
d) Shorthorn
e) Sussex

All the cow herds were placed with the different breeds of bulls and each group was rotated annually so that all five breeds of bulls were mated to the respective herds of Afrikaner cows.

As a result of having cattle in all stages of upgrading from Afrikaner and Sanga (native cattle) to Aberdeen Angus, Hereford, Shorthorn and Sussex, all these cattle were incorporated in the climatological tests carried out at the Messina Research Station. With the tests on these animals with varying percentages of *Bos indicus* and *Bos taurus* blood, it became obvious that tropical degeneration was nothing else but chronic malnutrition caused by hyperthermia in those animals that could not readily dissipate excessive metabolic heat.

Animals suffering from hyperthermia have increased rates of respiration and pulse with concomitant metabolic, physiological, and endocrine disturbances.

In an effort to maintain a normal body temperature, the animal resorts to standing in the shade, standing up to the belly in water, and reducing its appetite. The result is the animal is chronically malnourished. This condition suppresses normal growth and reproductive functions.

The climatological research work carried out at the Messina Research Station proved beyond any doubt that the hair and hide of the bovine play a tremendous role in the animal's ability to dissipate excess body heat readily. Animals with a respiratory type of body conformation, with a wide forehead and convex profile, are much better adapted to the tropics and subtropics than animals with a digestive type of body conformation, a dished forehead and concave profile.

Comparative physiologists have shown that desert-adapted ruminants, such as the gemsbok, cease to sweat when deprived of water but pant rhythmically for many hours. This panting results in evaporative cooling of the mucous membranes which line the nasal sinuses and, consequently, cooling of the venous blood which drains from these areas. The cooled venous blood, in turn, cools the warmer arterial blood from the core of the body when they flow past each other in a network of blood vessels, the carotid rete, just beneath the brain. The net result of this intricate arrangement is that the warmer arterial blood is cooled by venous blood before the arterial blood enters the brain. The temperature of the brain remains well below its critical maximum.

If we accept this explanation—and it has been convincingly shown in several critical experiments—then it is only logical that the larger the surface area of the nasal sinuses, the greater the surface area available for evaporative cooling during panting. It would seem reasonable, therefore, to assume that cattle with broad heads and a convex profile (Roman nose) would be able to cool their brain tissue more effectively than those with narrow heads and a concave profile.

Because Afrikaner cattle, which are extremely well adapted to hot and arid conditions, also possess relatively large, broad heads with a convex Roman profile, appears to be of great importance in their physiological adaptation, not merely a fancy point dreamed up by cattle breeders. Similarly, among wild ruminants one finds that the wildebeest, which never sweats and relies on panting to keep its brain temperature below critical limits, has an extremely large head with greatly enlarged nasal sinuses and a convex profile.

In assessing the importance of the above phenomenon it should be kept in mind that brain tissue is particularly sensitive to high temperatures and only a slight rise in temperature above the critical maximum results in impaired function. Moreover, the importance of the brain coordinating so many functions, including reproduction, appetite, metabolism, growth and milk production, cannot be overemphasized.

Only after the climatological data on the various types of cattle were submitted to Prof. A. M. Bosman could I convince him that the proportion of blood in the new breed to be established should be just the opposite of the Santa Gertrudis, namely ⅝ Afrikaner (*Bos indicus* - A) and ⅜ British beef breed (*Bos taurus* British exotic - E).

At this early stage of the breed creation project it was not possible to decide which of the British beef breeds gave the best results when crossbred to Afrikaner cows.

Fortunately, at the time I launched the crossbreeding and breed-creation project at Mara, I had large numbers of cattle of various grades and types from pure British and Afrikaner and Sanga blood at the Messina Research Station.

The cattle at Messina Experimental Farm were used in what probably developed into the most comprehensive climatological and ecological experiment in the world. These experiments laid the foundations for the principles on which the various crossbreeds were to be selected for future breeding purposes. The comparisons of the five types of crossbreeds, namely Red Aberdeen Angus x Afrikaner, Herford x Afrikaner, Red Poll x Afrikaner, Shorthorn x Afrikaner, and Sussex x Afrikaner, were completed by 1943. Three of the five crosses were eliminated and only the Hereford x Afrikaner and Shorthorn x Afrikaner crosses were retained for further breeding.

The Messina climatological and ecological research work proved, without doubt, that adaptability declined when the percentage of blood of the British (*Bos taurus*) type exceeded one half. I decided, therefore, that the percentage of Afrikaner blood should predominate.

The work of breed creation at Mara Research Station

The research in breed creation work at Mara commenced in 1937, before I was really aware of which factors were involved in making an animal adapted to the tropics and subtropics. Fortunately it was decided before 1940 that the "new" breed should be ⅝ Afrikaner - ⅜ British. This decision was not based on imaginary qualities or hypotheses, but on accurate climatological data taken on numerous animals.

The first two Shorthorn bulls selected were Imvani Ferule and Imvani Footprint, both of which were roomy animals of tremendous length with smooth hair coats and thick, vascular hides. The Hereford bulls used in the original crossbreeding—Bromfield Gower, Vaalbosch Renown and the sons of Freetown Virginian, bought from the late Mr. Hamilton at Val, Transvaal—were also smooth-coated, roomy bulls with long bodies of a more modern type than some present-day American and British Hereford bulls. (See Figure 5.1.)

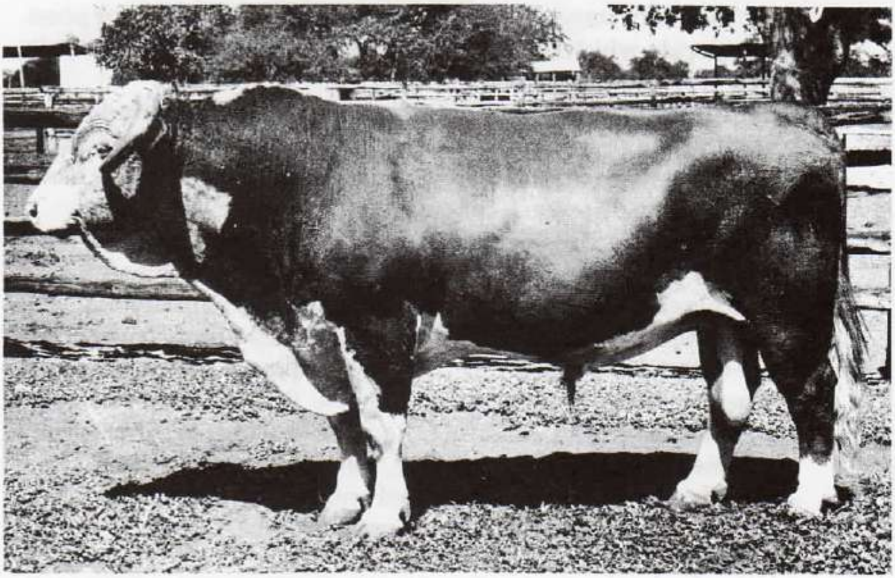


Figure 5.1 Hereford bull used in the original crossbreeding.

During 1938 I developed a method of scale photography for experimental animals that was far more accurate than scale photography used by British and American research workers. My scale photography was based on actual linear body measurements of cattle, while the British and American research workers placed the animals against a grid.

All the foundation animals used in the breed-creation work were photographed to scale at regular intervals and this enabled me to illustrate the complete genealogy of the "breed." (See Figure 5.2.)

Figure 5.2 illustrates the breed creation genealogy for seven generations, with every foundation animal on the original illustration photographed to a scale 1:12.5.

Matings 1 and 2 (Figure 5.2) indicate the first cross between Shorthorn bulls and Afrikaner cows and Hereford bulls and Afrikaner cows. The Shorthorn bull was Imvani Footprint and the Hereford bull, illustrated, was Vaalbosch Renown.

Note the body length of the British beef-breed bulls and how sleek-coated they were. Every bull used in the original crossbreeding was selected on the record of the dam's fertility, milk production and docility and was performance tested.

It was indeed fortunate that the research team selected the original Hereford and Shorthorn foundation sires they did. These bulls had all the characteristics of hair and hide that enable animals to overcome the problems of subtropical climatological conditions. These characteristics were later found to be of great importance in selecting animals for subtropical and tropical adaptability and for tick-repellency.

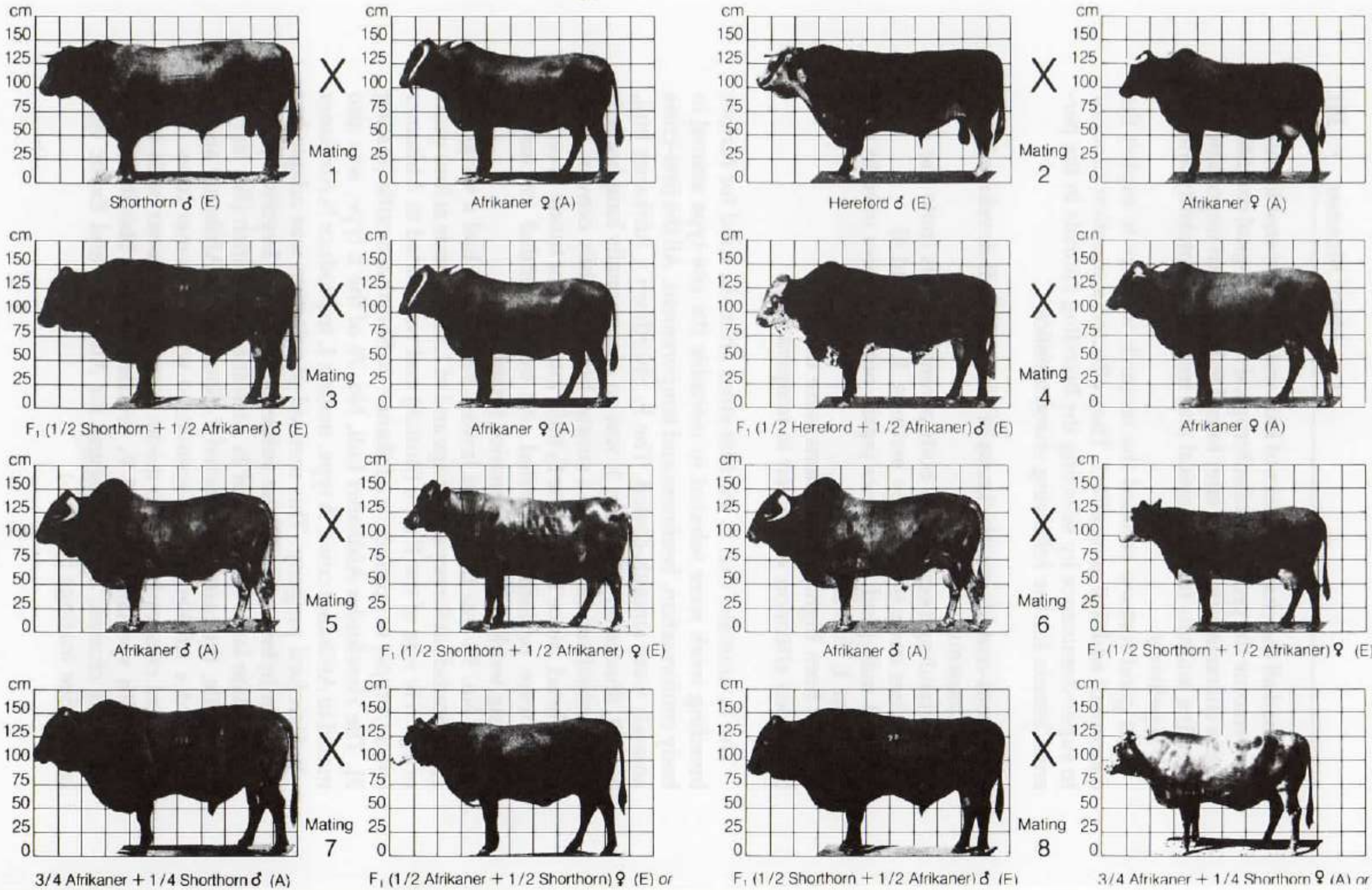
This good fortune enabled the research workers to exploit the concept of additive gene effect. They effected a situation superior to super-dominance by selecting the breeding animals in the parental breeds for the following characteristics:

1. Smooth-coatedness, thickness of hide and well-developed subcutaneous muscling.
2. Outstanding beefiness in both parental breeds (note the Afrikaner cows used in the matings: 1, 2, 3 and 4).
3. Good milk-producing cows (again note the cows used in matings 1, 2, 3 and 4).
4. Bulls from highly fertile dams were used.
5. Serious attention was given to temperament.

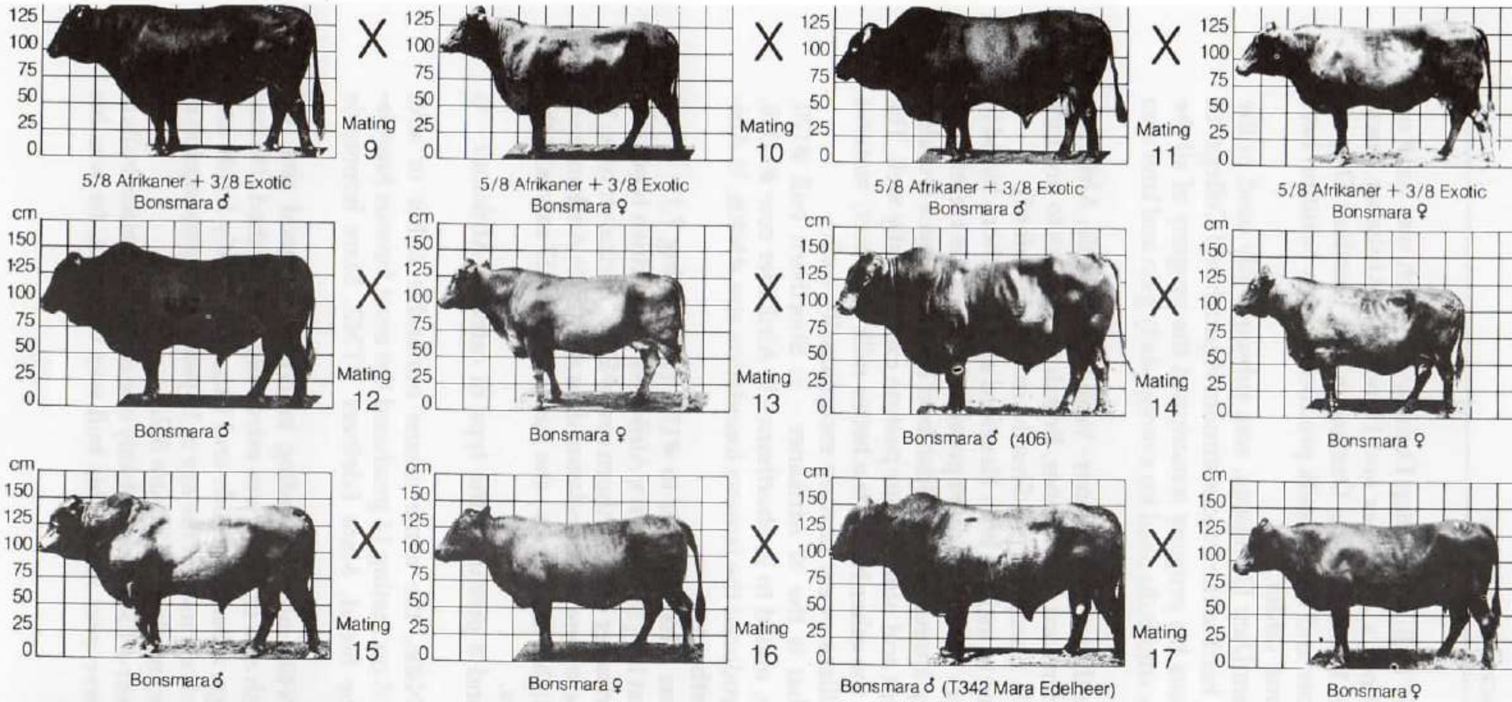
The F_1 animals, that is the first-cross animals, used for further breeding work were selected to resemble the sire-type animal in body conformation, beefiness and temperament. All the first-cross animals were smooth-coated. The F_1 Shorthorn x Afrikaner bull, No. 98, illustrated in mating 3, was an exceptionally long-bodied, well-fleshed animal; he had a strong, broad, slightly convex, masculine head. Since 1940 all the F_1 bulls intended for future breeding work were performance tested. All bulls intended for further breeding work were performance tested.

Bull No. 98 was the son of Imvani Ferule and had a weight of 1,782 pounds at three years of age and of 1,969 pounds at four years of age. He was of the E type (British) and was mated to Afrikaner cows (A type) to produce ¾ Afrikaner - ¼ Shorthorn cattle (mating 3). The Hereford x Afrikaner bull, No. 76 of the E type, was also mated to Afrikaner cows, A type, mating 4, to produce ¾ Afrikaner - ¼ Hereford progeny. This method of selection was adapted to maintain hybrid vigor in the subsequent crosses beyond F_1.

To obtain large numbers of ¾ Afrikaner - ¼ British (*Bos taurus*) type cattle, the carefully selected F_1 Shorthorn x Afrikaner and F_1 Hereford x Afrikaner bulls were used with Afrikaner cows. The reciprocal crosses were also made: namely, Afrikaner bulls were used with specially selected F_1 females of both Shorthorn and Hereford crosses, again selecting for Afrikaner and Exotic type cattle. (See matings 5 and 6.)



Shorthorn ♂ (E)
X
Mating 1
Afrikaner ♀ (A)
Hereford ♂ (E)
X
Mating 2
Afrikaner ♀ (A)
F₁ (1/2 Shorthorn + 1/2 Afrikaner) ♂ (E)
X
Mating 3
Afrikaner ♀ (A)
F₁ (1/2 Hereford + 1/2 Afrikaner) ♂ (E)
X
Mating 4
Afrikaner ♀ (A)
Afrikaner ♂ (A)
X
Mating 5
F₁ (1/2 Shorthorn + 1/2 Afrikaner) ♀ (E)
Afrikaner ♂ (A)
X
Mating 6
F₁ (1/2 Shorthorn + 1/2 Afrikaner) ♀ (E)
3/4 Afrikaner + 1/4 Shorthorn ♂ (A)
X
Mating 7
F₁ (1/2 Afrikaner + 1/2 Shorthorn) ♀ (E) or
F₁ (1/2 Shorthorn + 1/2 Afrikaner) ♂ (E)
X
Mating 8
3/4 Afrikaner + 1/4 Shorthorn ♀ (A) or
cm
150
125
100
75
50
25
0


125 100 75 50 25 0
Mating 9
5/8 Afrikaner + 3/8 Exotic Bonsmara ♂
125 100 75 50 25 0
Mating 10
5/8 Afrikaner + 3/8 Exotic Bonsmara ♀
125 100 75 50 25 0
Mating 11
5/8 Afrikaner + 3/8 Exotic Bonsmara ♂
125 100 75 50 25 0
5/8 Afrikaner + 3/8 Exotic Bonsmara ♀
cm 150 125 100 75 50 25 0
Mating 12
Bonsmara ♂
cm 150 125 100 75 50 25 0
Mating 13
Bonsmara ♀
cm 150 125 100 75 50 25 0
Mating 14
Bonsmara ♂ (406)
cm 150 125 100 75 50 25 0
Bonsmara ♀
cm 150 125 100 75 50 25 0
Mating 15
Bonsmara ♂
cm 150 125 100 75 50 25 0
Mating 16
Bonsmara ♀
cm 150 125 100 75 50 25 0
Mating 17
Bonsmara ♂ (T342 Mara Edelheer)
cm 150 125 100 75 50 25 0
Bonsmara ♀

The Afrikaner bull, Mara Diep Damascus, which was used on many F_1 Shorthorn x Afrikaner and Hereford x Afrikaner cows, was the son of Marshall Vale Damascus and Leeubult Diep, a highly fertile cow and a good milk producer with a beautiful beef conformation and udder.

The bull, Mara Diep Damascus, was subsequently used in the Afrikaner stud herd of the Potchefstroom Agricultural College. In performance tests his progeny outstripped the progeny of all the other Afrikaner stud bulls used for average daily gain and later also for fertility.

Mating 7 was that of ¾ Afrikaner - ¼ Shorthorn bulls, Afrikaner type, with F_1 Hereford X Afrikaner, British type, cows to produce ⅝ Afrikaner - ⅜ European (3/16 Shorthorn - 3/16 Hereford).

It was decided to include both Hereford and Shorthorn blood in the ⅝ Afrikaner - ⅜ British where possible because the Hereford is the best grazing animal of the British beef breeds; it has a wonderful temperament and utilizes sour pasture exceptionally well. The Shorthorn, on the other hand, is a better milk producer, matures earlier, and utilizes sweet pasture exceptionally well.

Mating 7, that is the ¾ Afrikaner - ¼ Shorthorn bull #170, Afrikaner type, mated to ½ Shorthorn - ½ Afrikaner cow #H318, British type, produced the famous foundation sire #N406, ⅝ Afrikaner - ⅜ Shorthorn.

Bull #170 was a half-brother to #171. (See mating 7.)

Mating 8, that is F_1 Shorthorn x Afrikaner #98, British type, was mated to ¾ Afrikaner - ¼ Shorthorn cow #E306, Afrikaner type, to produce the most famous foundation dam #L305, ⅝ Afrikaner - ⅜ Shorthorn: a highly fertile cow, she had produced 17 calves at the age of 19 years.

Matings 7 and 8 produced the type of cattle ⅝ Afrikaner - ⅜ British.

Edelvaar #N406, the name means honorable father or sire, mated to #L305 on mating 14 produced the most famous foundation sire of the breed, Mara Edelheer #T342, Mara honorable gentlemen.

The sire #N406, an outstanding individual of good size, exceptional length and capacity was extremely well-fleshed. He had four sound legs, a beautiful hide and hair, was highly fertile and was still extensively used at the age of 14 years. (See photograph of Mara Edelheer, mating 17, Figure 5.2.)

Mara Edelheer #T342 was probably one of the best-made bulls of any breed I have ever seen. This bull was vigorous, he was his dam's fifth calf and had reached 506 pounds at weaning. He had tremendous libido; when he was four years old he settled 85 cows during a service season of two and a half months.

From Matings 9, 10, and 11 onwards we no longer speak of the resultant progeny as ⅝ Afrikaner - ⅜ British; they are Bonsmara, a breed in its own right.

Man must measure

The Bonsmara is the only breed in the world that can boast a pictorial genealogy from the start of the breeding work until the Bonsmara breed was established.

It is also the only breed in the world where every mating was based on scientific data, where the concept **Man must measure** was always taken into consideration. Nothing was based on guesswork or on worthless antiquated show standards.

The scientific data used in the breeding work was based on climatological data and adaptability measured by performance testing. The data included 14 body measurements taken quarterly; monthly weight and average daily gain were also determined.

The steps set out in the illustrated breed creation genealogy (Figure 5.2) are as follows:

STEP 1 (Matings 1 and 2)

1. Shorthorn bulls × Afrikaner cows
2. Hereford bulls × Afrikaner cows

Result:

F_1 Crossbred cattle
½ British *Bos taurus* - ½ Afrikaner *Bos indicus*

STEP 2 (Matings 3, 4, 5, and 6)

3. F_1 (½ Shorthorn - ½ Afrikaner) bulls, British
crossed on Afrikaner cows
4. F_1 (½ Hereford - ½ Afrikaner) bulls, British
crossed on Afrikaner cows
5. Afrikaner bulls crossed on F_1 cows,
(½ Shorthorn - ½ Afrikaner) cows, British
6. Afrikaner bulls crossed on F_1 cows,
(½ Hereford -½ Afrikaner) cows, British

Result:

¾ Afrikaner - ¼ British (Shorthorn or Hereford)

STEP 3 (Matings 7 and 8)

7. ¾ Afrikaner - ¼ Shorthorn bulls, Afrikaner
   crossed on F_1 cows, either
   ½ Afrikaner - ½ Shorthorn cows, British
   ½ Afrikaner - ½ Hereford cows, British
8. F_1 (½ Shorthorn - ½ Afrikaner) bulls, British
   crossed on cows, either
   ¾ Afrikaner - ¼ Shorthorn cows, Afrikaner
   ¾ Afrikaner - ¼ Hereford cows, Afrikaner

Result:

⅝ Afrikaner - ⅜ British, the Bonsmara

STEP 4 (Matings 9, 10, and 11)

⅝ Afrikaner - ⅜ British crossed on
⅝ Afrikaner - ⅜ British

Result:

Bonsmara

STEP 5 (Matings 12, 13, 14, 15, 16, and 17)

Bonsmara × Bonsmara (final step with rigid selection)

Result:

Bonsmara

From 1943 the numbers of Bonsmara cattle were steadily increased by judicious and stringent selection. The factors selected were adaptability, fertility, milk production, growthiness, body conformation, temperament, and longevity.

The name Bonsmara, as a perpetual tribute to Bonsma and the Mara Research Station where the breed was established, was suggested by E. A. Galpin, one of the first cattle breeders in the co-operative breeding scheme and a keen and faithful supporter of the breed.

Bonsmara herdbook

I realized by the mid-1940's that if I were to succeed in establishing the breed in my lifetime I had to establish the breed on farms outside the departmental research stations. This was also important for increasing the gene pool on which selection for the eventual herdbook would be based. The following points are of con-

Table 8: *Standard of excellence of Bonsmara cattle*

Item	Desirable	Permissible	Undesirable
Functional efficiency fertility	*Cow:* Feminine, regular calving, calving with ease. *Bull:* Masculine and virile, high libido. Must settle at least 40 cows in a breeding season of 60 days.	Bulls must be able to settle more than 30 but less than 40 cows in a breeding season of 60 days.	*Cows:* that calve for the first time after 3 years of age; nervous. *Bulls:* aggressive; mean during service season.
Disposition (temperament)	Calm, tractable.		Nervous, wild.
Size	Large for age, fast gaining, good feed converters.	Medium-sized.	Too large and flat, or too small.
Hair	Short, straight, smooth; early hair shedding in spring. Bulls darker in colour than cows.	Slightly roughcoated. Very even-coloured bulls.	*Cows:* with coarse hair on head and neck. *Bulls:* with very fine, even-coloured hair.
Hide	Thick, pliable, high vascularity and movable, sensitive pilomotor activity, well pigmented; neat navel flap or sheath.	Thin, dry; lack of movement; dusty and dirty in appearance.	Tight skin, woolly-coated, frosty-coated; over-large navel flap or sheath.
Legs and hooves	Well set, strong, sound legs and feet; darkly pigmented hooves; joints not large and arthritic in appearance.	A little heavy-jointed; pasterns a bit straight.	Very short legs, very long legs, too fine-boned, weak pasterns; straight or sickle-hocked, small hooves, overgrowing coronets.
Udder and teats	Well-attached medium-sized milky udder, teats not too large or too small, and should be well pigmented.	Slightly too large and pendulous, too small, white teats; imbalanced quarters.	Teats too large or too small for newborn calf to suckle; meaty udder; hairy udder; poorly attached; goaty udder.
Sheath	Normal, neatly attached, well-closed sheath opening with good sphincter control.	Slightly open sheath opening.	Excessive sheath development, pendulous sheath. Any form of prolapse of prepuce.
Testicles	Good size, well down in scrotum, clearly defined neck to scrotum.	Slightly small or slightly too large scrotum, slightly twisted.	Every deviation from normal should be a disqualification.
Body conformation	Symmetrically balanced bulls; clearly defined muscles.	Flat and deep.	Flat, too deep; uneven distribution of fat, prominent brisket.
General form or type	*Cows:* Smooth-muscled, good length of body, well-sprung ribs, good bone, strong legs with free movement. *Bulls:* Deep in front but well-muscled in hind quarters; cows lean in neck and shoulders, well-developed hind quarters, slightly drooping rump.		*Bulls:* with broad feminine hips; *cows* with deep chests and light hind quarters.
Head	*Bull:* Masculine. Alert, broad and slightly convex.	Straight or slightly concave.	Head too long or too short. Short, dished face should be disqualified; drowsy appearance indicative of lack of libido.

Item	Desirable	Permissible	Undesirable
Ears	Medium size, cocked forward.	Large or too small, droopy.	
Horns	Bulls and cows should be dehorned.	Natural polledness.	
Neck	Well-developed crest and clearly defined muscles in bull. Lean, flat, and free from dark-coloured hair on cow.	Fat; not muscular enough in bull. Roundish, inclined to be heavy in cow.	Flat ewe neck in both bulls and cows.
Shoulders	*Bull:* Neat attachment, free-moving, well-muscled. *Cows:* Neat, free-moving, lean not heavily muscled.	Too fine, loose.	Rising chine in cows.
Brisket	Broad with skinfold clearly defined over brisket.	Slightly forward, downward sloping.	Prominent heavily fleshed, fat-infiltrated, forward and downward sloping.
Heart girth (circumference of body behind shoulder blades)	*Bull:* Deep, broad, fairly full; virile appearance. *Cow:* Not deep, broad but relatively lean with feminine fore quarters.	*Bull:* Cut in behind shoulder blades, lack of uniform depth. *Cow:* Heavily fleshed over shoulders; wide and fat between shoulder blades.	All degrees of deviation from the previous descriptions which are more pronounced.
Back	Broad, straight. *Bull:* Muscles over loin pronounced. *Cow:* Level and broad muscling; smooth and flat.	Too long and not quite level.	Sway or hollow-backed, too short.
Loin	*Bull:* Prominent, giving the impression of strength. *Cow:* Prominent but smooth, not pronounced.	Slight slackness of loin in both the cow and bull.	Any indication of weakness in the loin.
Ribs	Well sprung, not quite perpendicularly placed from spine. Placed with a slight angle posteriorly. Rib broad, flat. Deep through chest region in bulls.	Flat-ribbed, lack of good spring of ribs.	Flat-ribbed and shallow in bulls.
Hipbones	*Bull:* Broad but not feminine. *Cow:* Broad but free from hard lumps of fat.	Bulls should not be 'hippy'; fat on hips undesirable.	Too broad, inclined to be fat in bulls. Narrow.
Rump	Broad, somewhat rounded on top, fairly long and with a moderate slope, front to rear.	Too straight and level rump especially in cows.	Drooping rump and roofy.
Hind quarter and thighs	Broad, long, flat when viewed from the rear. Muscles clearly defined in bulls. Smooth in the case of cows.	Rounded when viewed from the side.	Lack of depth of thigh muscles or very prominently rounded.
Tail and tailsetting	Smooth insertion well to the rear, the tail must hang down perpendicularly and must have a well-developed switch.	Placed too far forward. Cut in on inner thighs.	Placed too far forward with rounded buttocks cut in at inner thighs.

Item	Desirable	Permissible	Undesirable
Colour coat	Solid red; bulls a shade or two darker than cows.	Slightly mottled white spots on head, white on underline, white teats in cow.	Patches of white on head and outside underline.
Skin	Pigmented, dark brown.		

Disqualification:
Animals shall be disqualified for any extreme manifestation of undesirable characters or for hereditary defects that occur in bovines, such as hernia, cryptorchidism, wry nose, wry tail, double muscling, malformed genitalia, too large teats in cows, undershot and overshot jaw, straight hind legs, frosty coats, congenital thyroid disturbance, fused teats, infantilism of external genitalia in bulls or cows, any signs and symptoms of subfertility and lack of functional efficiency. All cattle to be entered in herd-books must be performance and progeny tested. A cow that failed to calve during two consecutive calving seasons must be eliminated. No heifer that does not calve before she is three and a half year old is eligible for registration.

siderable interest in the further development of the Bonsmara breed.

In 1949 I co-opted several prominent farmers from the Bushveld in the Transvaal; they began testing Bonsmara bulls on their herds.

In 1952 the Department of Animal Husbandry agreed officially to lend Bonsmara bulls to selected farmers. In 1953 a further six farmers received bulls; five more farmers received bulls in 1954; five more in 1955; and six in 1956.

In 1956 the department had out on loan 60 bulls under their Co-operative Loan Scheme. These bulls were being tested by farmers in the Northern Transvaal, North-Western Cape, the Eastern Cape, Natal Highveld, Transvaal Highveld, and the Springbok Flats. The department itself was testing the breed on several research stations.

In 1960 it became compulsory for co-operators to join the Performance Testing Scheme of the Division of Animal Husbandry and Dairying. At this stage many co-operators objected to keeping the required records necessary for the Performance Testing Scheme and made no attempt to comply with the agreement made between them and the department.

In 1963 the Division of Animal Husbandry and Dairying was finding it increasingly difficult to provide all the facilities envisaged under both schemes and, therefore, to enforce the stipulated conditions of performance testing. It was becoming apparent that unless a firm policy was adopted and practiced, the breed would not make the envisioned progress.

In 1964 co-operators in the Loan Scheme approached the Division of Animal Husbandry with the request that co-operators be allowed to form an association to assist in the development of the Bonsmara breed.

The Bonsmara Development Program

The following announcement appeared in **The Meat Industry**, official journal of the South African Livestock and Meat Industries Control Board:

The Bonsmara Development Program will be carried out as follows:

1. The breeding and development of the Bonsmara will be under the control of the Animal Husbandry and Dairying Institute with Dr. G. O. Harwin as the officer-in-charge, in co-operation with Professor J. C. Bonsma and members of the Bonsmara Cattle Breeders Association.

2. The Program will consist of two phases:
   A) The breeding of Bonsmara cattle at state institutions.
      a) Three state herds will be kept
         (i) A central or elite herd at Mara Research Station
         The elite herd of 140 outstanding breeding cows has subsequently been transferred to Roodeplaat and the breeding program is under the supervision of Mr. D. J. Bosman, senior animal scientist at the Institute of Animal Husbandry and Dairying at Irene.
         (ii) Additional herds of 80 breeding cows each at Roodeplaat (north of Pretoria) and Armoedsvlakte Research Station (near Vryburg).
      b) Surplus breeding animals will be sold to officially approved Bonsmara breeders. Surplus selected bulls will be sold annually at a fixed price of R200 each. The bulls at present on loan to co-operators of the old Bonsmara scheme will be re-inspected and those considered suitable for further breeding may be purchased by the co-operator concerned at a fixed price of R200, provided the co-operator is accepted in the new development program as an officially approved Bonsmara breeder.
   B) The breeding of Bonsmara cattle by officially approved breeders:
      a) Officially approved breeders will be selected strictly and approved by the Animal Husbandry and Dairying Research Institution in co-operation with the Bonsmara Cattle Breeders Association.

b) All approved Bonsmara herds must participate in the Beef Performance Testing Scheme of the Department of Agricultural Technical Services Breeders will have to comply with the requirements of the scheme. Accurate records must be kept of all cattle in Bonsmara herds A register must be kept of all herds.

c) The Bonsmara Cattle Breeders Association will be recognized as the official association of Bonsmara breeders and will function under the guidance of the department.

d) Officially approved Bonsmara breeders will preferably be chosen from the Transvaal Bushveld and North-Western Cape.

e) The number of Bonsmara breeders will be restricted according to the availability of selected Bonsmara bulls. Only selected performance-tested bulls will be allowed for use in approved Bonsmara herds. In addition to approved bulls from state institutions, bulls of approved breeders will also be considered for selection and use in Bonsmara herds.

In addition to the above-mentioned persons, other officers of the Department of Agricultural Technical Services may assist in the program.

The Bonsmara Cattle Breeders Association

The first annual general meeting of the society was held December 1964. The constitution, which had previously been approved by the Division of Animal Husbandry and Dairying, was unanimously adopted. The Council also elected a selection panel to co-operate with members of the Division of Animal Husbandry in selection of animals for the central register. The second annual meeting was held in March 1968 and since then a meeting has been held in March each year. In 1964 there were 25 members. Since then the membership has increased steadily: in 1970 there were 53, in 1974 there were 165, and in 1977 it stood at 319, with 1,297 approved bulls and 36,006 cows on the register. In 1980 it stood at 341 members with over 2,000 approved bulls and 43,000 cows on register.

Progress and research with the breed

The most outstanding Bonsmara bull used in the early development of the breed was No. 406, a bull with a straight backline that was apparent in all his progeny. This bull was used for twelve years in the Mara herds and sired outstanding bulls such as Edelheer (T342) and Bok (Y 135). Bok was sold to H. Nel and was still in use at 17 years of age. Numerous outstanding heifers were mated to these sires in the establishment of the breed.

Furthermore, the breed was fortunate in that constant research was carried out and comparisons made with the excellent Afrikaner and Hereford herds bred at Mara since 1943. Much of this work has been published. The research was often carried out over long periods of time, frequently by the workers completing the project rather than those who initiated it. This research has meant that an accurate assessment of the potential of the breed has been available from the outset in addition to the standard production records.

The calving percentage of Bonsmara cows has been consistently over 80 percent when worked out over lifetime production, and research continues to improve this parameter (Skinner, 1962, unpublished).

While gestation length and weight at birth of Bonsmara calves were intermediate between the "parent" breeds (Joubert and Bonsma, 1959; Skinner and Joubert, 1963), milk production of Bonsmara cows was significantly greater than that of either the Hereford or Afrikaner (Reyneke and Bonsma, 1964). Bonsmara calves, therefore, had a higher average daily gain (Bonsma and Skinner, 1969), weaning weight, and weight at 1, 2 and 3 years (Joubert, 1957). Moreover, since the advent of heartwater immunization, Bonsmara calf mortality has been at the same level or lower than the Afrikaner calf mortality and considerably less than the Hereford (Joubert, 1957). Bonsmara oxen grew significantly faster to 38 months off the veld (Eloff, Reyneke and Skinner, 1965) and produced heavier carcasses. Joubert (1957) gives the carcass weights of Bonsmara, Afrikaner and Hereford steers off the veld at three years as 665, 594, 528 pounds, respectively. The Bonsmara also excelled in the feedlot: four young Bonsmara steers of 20 months of age averaged 1,140 pounds with an average carcass weight of 704 pounds at the 1952 Witwatersrand Spring Show. Two years later (1954) four young steers of 19½ months averaged a live weight of 1,215 pounds and a carcass weight of 720 pounds (Joubert, 1957).

There is little doubt that the breed is continuing to improve. In

Table 9: *Percentage breeders and cows of the more important beef breeds of South Africa involved in the official Beef Performance Testing Scheme 1979*

	% Breeders	% Animals
Afrikaner	21,5	27,9
Bonsmara	100,0	100,0
Brahman	10,7	25,3
Brown Swiss	15,9	68,0
Charolais	7,9	22,1
Hereford	22,5	49,0
Pinzgauer	22,4	58,6
Santa Gertrudis	23,8	32,6
Shorthorn	26,3	46,3
Sussex	19,9	29,7
Averages	24,2	50,5

1964 the Bonsmara summer calves at the Mara Research Station averaged 475 pounds, the highest average for summer calves of any breed up to that date. Bosman (1969, unpublished) has also found that the average weaning weight from breeder herds has been consistently improving. For example, in the North-Western Cape they increased from 435 to 460 pounds and from 402 to 418 pounds for bulls and heifers, respectively, from 1966 to 1968. Greater increases were recorded in the Northern Transvaal, from 411 to 477 pounds and 374 to 433 pounds for bulls and heifers over the same period. It seems certain that the pattern will continue while the departmental research and guidance are matched by the enthusiasm of progressive breeders, although future advances may not be quite so spectacular.

As indicated, no Bonsmara breeder can become a member of the Bonsmara Cattle Breeders Association unless he participates in the Beef Performance Testing Scheme of the Department of Agricultural Technical Services. Breeders have to comply with the requirements of the scheme.

Performance testing

Included in the Department of Agriculture's Performance Testing Scheme for 1976 were 9,712 heifers. This included the heifers performance tested in 19 beef breeds. Of these 4,776 or 49.2 percent of all the registered beef heifers were Bonsmara heifers with an average weaning weight at 205 days of 398 pounds. The average for all the other breeds, including the large breeds, was 396 pounds.

Of all the bulls performance tested during 1976 by the Department of Agricultural Technical Services, 48.6 percent were

Bonsmara bulls. A total of 9,056 beef bulls of 17 beef breeds were tested; of these, 4,401 bulls were Bonsmaras. The average 205-day weight of all the bulls in the test was 429 pounds, whereas the 4,401 Bonsmara bulls averaged 438 pounds.

In the phase D tests carried out on the seedstock breeders' farms, 1737 bulls of 12 breeds were tested under government supervision; of these bulls 837 or 48.2 percent were Bonsmara bulls.

The inter-calving period of 13,144 Bonsmara cows in the official Department of Agricultural Technical Services performance testing scheme for the years 1974 and 1975 was 418 days, giving the breed an accurate calving percentage of 87.3.

The average inter-calving period for all the 32636 cows of 19 breeds performance tested was 444 days, giving an average calving percentage of 82.2. The total number of cows of 15 breeds in performance tests in 1979 were 81,071 and of these 32,394—or 39.9 percent—were Bonsmara cows.

It is now just over four decades ago that my co-workers, co-operative Bonsmara breeders and so many of my past students embarked on this breed-creation work. No fewer than thirty Bachelor of Science, Agriculture; Master of Science, Agriculture; and Doctor of Science, Agriculture, theses have been put out by past students.

In addition, quite a number of scientific publications have appeared in which the experimental material was Bonsmaras. All these studies analyzed the factors influencing the productivity and functional efficiency of Bonsmara cattle and continually monitored the comparative productivity as a whole under a wide range of environmental conditions. The various aspects of breed creation were investigated especially in relation to breeding for increased adaptability and functional efficiency. These studies have also added to our present knowledge of genetic parameters. Presently much attention is being paid to the potential role of Bonsmara cattle in crossbreeding programs. From preliminary experimentation it can be concluded that Bonsmara cattle can contribute a great deal to economic beef production through crossbreeding with selected breeds.

Chapter 6

Hide and Hair

The animal hide—the skin and hair covering—is the largest organ of the body. It comprises approximately seven to eight percent of the live weight of the animal. Forming the barrier between the external environment and the animal, the hide is of paramount importance in determining the adaptability of the animal to prevailing environmental conditions. The hair coat accurately reflects the well-being of the animal, its hormonal balance, and its nutritional status.

As a result of industrial development and the urbanization of regions, accompanied by increased density of the human population, commercial beef production has been forced out of the more favorable environments. Over the last century cattle raisers have encountered many problems of heat tolerance and other associated environmental consequences. In the past, these were ignored or grossly misinterpreted until I indicated in 1940 the existence of biological differences between adapted and unadapted types of livestock. Since then many workers, mostly in Australia, have investigated the problem in the hope of finding the physiological basis of heat tolerance and clarifying various other aspects of the adaptability of cattle to tropical and subtropical conditions.

This chapter aims to compile the information available at present on the role played by the bovine skin and hair in the individual animal's adaptability and functional efficiency under varying conditions of the environment. It attempts to correlate the nature and structure of skin and hair with body function and reaction. This presentation of the limited knowledge on the subject will, one hopes, stimulate further investigation to reveal facts of the utmost importance to breeders in the less favorable livestock regions of the world.

The histology of the skin and hair

It is necessary to know the basic structure and function of the animal skin and hair to understand its role in the adaptability of animals to various environments. The following details should be of assistance.

The skin

The skin covers the surface of the body and consists of two main layers: a superficial covering of stratified squamous epithelium which is the surface epithelium or epidermis; and a deeper layer of dense, irregular connective tissue, called the corium or dermis. Beneath the latter is a looser connective layer, the superficial fascia or hypodermis.

The cellular layers of the skin

Epidermis. The epidermis is stratified squamous epithelium that in most areas can be divided into a deep growing layer called the stratum germinativum and a superficial hornlike layer called the stratum corneum. These are subdivided into secondary layers of which the superficial layer has three divisions and the deep layer two divisions.

The following layers are distinguished in the epithelium:

1. The stratum cylindricum or basale consists of a layer of columnar cells that produce most of the epidermis.
2. The stratum spinosum is composed or stratified prickled cells that fill in all the depressions between the dermal papillae.
3. The stratum granulosum consists of serrated cells that show the first sign of cornification.
4. The stratum lucidum is formed of several layers of flattened, closely packed cells and occurs only in certain skin areas.
5. The thick stratum corneum consists of many layers of flat, elongated, cornified cells.
6. Melanocytes are responsible for skin pigmentation and occur in close association with the cells of the stratum cylindricum.

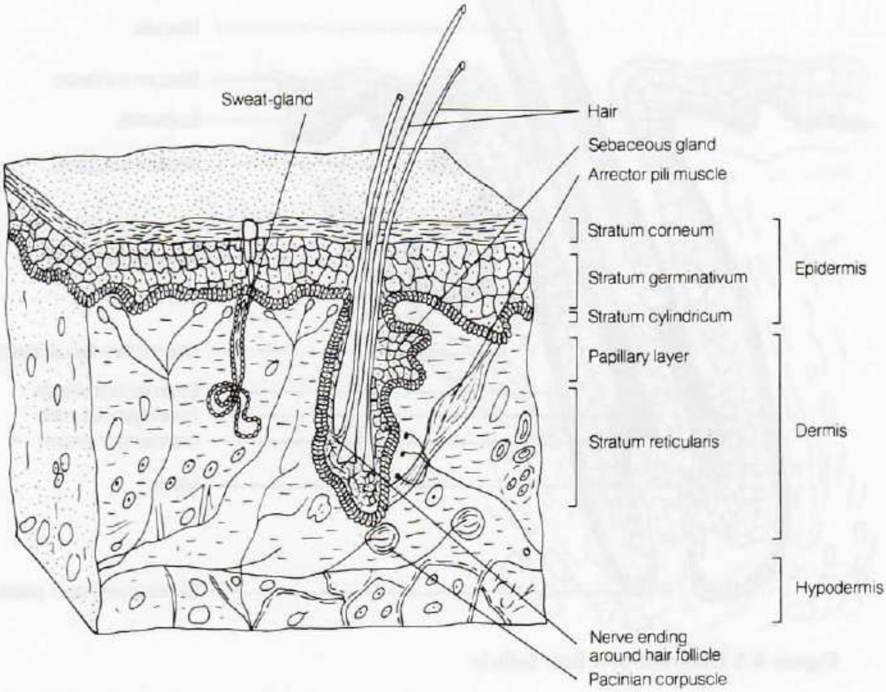


Figure 6.1 Vertical section through the skin.

The rate of cell division in the deeper layers of the epidermis increases under the influence of increased blood supply and irritation or pressure.

Dermis (or corium). The dermis can be subdivided into a papillary layer immediately beneath or below the epidermis and a deeper reticular layer that makes up the major part of the dermis.

Arteries, veins, capillaries, and lymphatics of the skin are concentrated in the dermis. Sympathetic nerves from the rami communicantes of the spinal nerves, supplying sweat-glands, sebaceous glands, and arrector pili muscles in the dermis.

Hypodermis. This subcutaneous layer consists of loose connective tissue which allows movement of the skin and which, in many places, forms an important depot for the storage of fat.

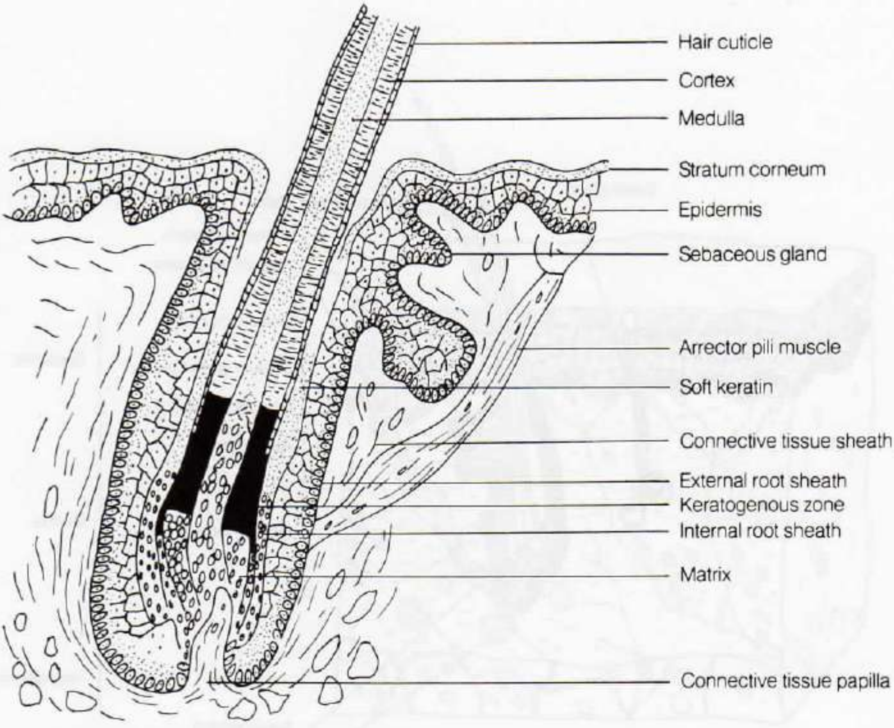


Figure 6.2 Diagram of a hair follicle.

Glands of the skin

Sebaceous glands. The sebaceous glands are immediately under the surface of the skin. They make up the superficial layer of glands and occur in the middle depths of the corium. They usually open into the neck of a hair follicle and they are simple holocrine glands.

Sebum, which is the sebaceous secretion of these glands, results from the partial destruction of glandular cells and consists of cellular debris and a lipoid (fatty) mixture high in cholesterol. The greasiness of the secretion of the sebaceous glands protects the skin surface, particularly against excessive drying out.

Sweat-glands (Tubular skin glands). Two types of tubular skin glands are recognized: merocrine and apocrine.

1. In merocrine tubular glands, the secretory portion consists of a narrow tube generally coiled into a ball. The excretory duct

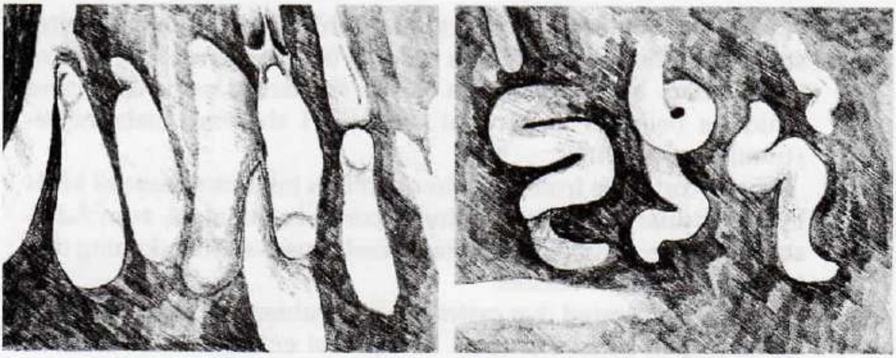


Figure 6.3 *Left:* Sweat gland of *Bos indicus*. These glands are sac-like, densely packed and have wide luminae forming almost a complete layer of water in the skin. *Right:* Sweat gland of *Bos taurus*. These glands are narrower, coiled, and fewer in number than in *Bos indicus*.

passes between dermal papillae to the surface, not into a hair follicle. These glands exude a moist secretion (sweat).

2. Apocrine tubular glands usually have much wider secretory tubules than the preceding. They are serpentine or coiled into a ball and each is associated with a hair follicle. Their secretory portion is ventral to the sebaceous gland. In domestic animals, the apocrine glands make up most of the tubular skin glands. These glands produce watery sweat in response to heat stimulation.

Color of the skin

The color of the hide is determined by the presence of pigments within the cells of the epidermis and by the optical effect of light scattering.

Skin color is attributed to three components. Oxyhaemoglobin in the circulating blood imparts a reddish hue to unpigmented skin as well as a yellowish inherent tissue color, partly due to carotene. The predominant shade of the skin varies from black to brown and is contributed by varying amounts of melanin, which is produced in the skin by specialized cells with elaborate branching processes called melanocytes. These cells are located below the Malphigian layer of the epidermis, to which melanin—produced by the melanocytes—is transferred.

Differences in skin color between animals are attributed not to differences in the numbers of melanocytes in the skin but to differences of pigment that these cells produce.

The activity of melanocytes is controlled by melanocyte-stimulating hormone, MSH, a product of the intermediate lobe of the pituitary body, which has certain similarites with ACTH and which is believed to account for ACTH showing melanocyte-stimulating activity.

Hydrocortisone from the adrenal cortex inhibits release of MSH by the pituitary. Where the adrenal cortex is damaged, as in Addison's disease, inhibition decreases and causes skin darkening due to excessive MSH release.

In 1957 I indicated that castration and subfertility produced skin lightening in bulls. I suspect that pineal enlargement, which is associated with hypogonadism, might be involved. Although synthetic melatonin has as yet not been found to affect human melanocytes, further investigation to establish the role of the pineal gland in male fertility and skin color is suggested.

The muscles, vessels and nerves of the skin

Smooth muscle occurs in sheets and as muscles of the hair follicle (arrectores pilorum). A network of thick nerve bundles is located in the subcutaneous stratum. Each hair is served by a nerve-ending.

The arteries that supply the skin are located in the subcutaneous layer. A dense network of capillaries exists outside the basement membrane of the sebaceous and sweat glands. Each hair-sac has its own blood vessels.

Vascularization of the hide is of the utmost importance in heat dissipation by animals in hot environments.

The hair

Hair covers almost the entire body of most domestic animals, but many variations in hair texture exist between species and even in different body areas.

A hair follicle develops first as a thickening and then as an ingrowth of epidermis into the corium of the skin. The follicle consists of a connective tissue sheath. The internal epithelial sheath intimately covers the root of the hair, is continuous with the epidermis, and gives rise to the sebaceous glands which are associated with hair follicles. The epithelial cells covering the papillae actually form the hair itself.

When a hair is ready to be shed, the epithelial cells over the papillae stop multiplying and become cornified. The papilla atrophies and the hair falls out or is pushed out by a new hair developed from epithelial sheet cells in a similar manner to the hair formation just described.

A typical hair consists of an inner medulla (core), an outer cortex, and a thin covering called the cuticle.

Color of the hair

The quantity and type of melanin in the cortical cells determine whether the hair will be black, brown or red. Epidermal melanocytes located over the tip of the dermal papillae, where the hair has its origin, are responsible for melanin pigmentation of the hair shaft. The medulla may contain pigment that has little effect on hair color. Air between medullary cells is believed to result in white or silver color when the cortex lacks pigment.

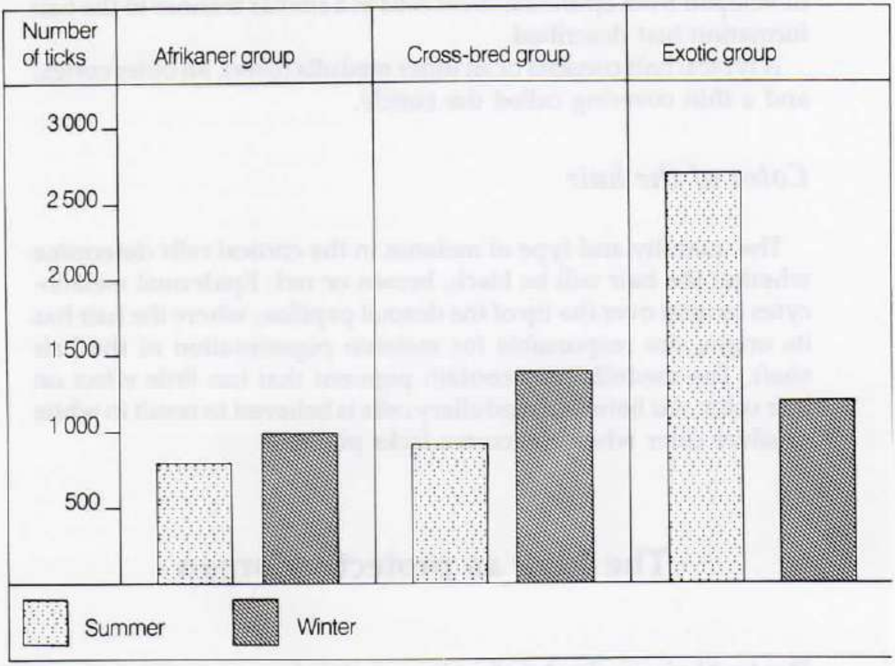
The hide as protective organ

Protection against infection and injury

The skin and hair of animals serve as the first line of defense against infection and therefore play a vital role in the protection of animals. The efficiency with which this takes place is increased by the antibacterial properties of the skin and the skin surface. The vital importance of the skin in this respect is illustrated by the increase in rate of infection in skin damaged by injury. When the skin is injured through tearing, burns, or wounds, or infected by micro-organisms, a series of reactions follow in the area of injury. These reactions strive to restore the damaged skin and to destroy the impairing agents causing an inflammatory reaction. Inflammation is characterized by redness due to a higher blood supply to the area, resulting in a higher concentration of leucocytes and other wandering cells in the infected or injured area. The higher blood concentration also transports waste products from the injury and promotes new cell-formation in the damaged area.

The factors which cause infection and are responsible for injury and disease can be classified as follows:

Graph 7: *Relation of the total number of ticks on various groups of animals during summer and winter.*



1. Living agents such as external parasites, or micro-organisms such as bacteria, either of which are able to produce toxins extremely injurious to living tissue.
2. Non-living agents such as extreme environmental temperatures, ultra-violet radiation, and mechanical injury.
3. Irritating chemical agents.

Protection against external parasites

Wilkinson (1955) made observations on undipped cattle infected with *Boophilus microplus* ticks in Central Queensland and found that Zebu crosses were infected to a significantly lesser degree. He ascribes this feature to Zebu cattle's thicker skins.

In 1944 I stated that ticks prefer to infest cattle on body areas where the skin is significantly thinner and where they are protected from direct solar radiation. I observed that Afrikaner cattle were only 30 percent infested in comparison to 70 percent in the

British breeds. I consider that this phenomenon may be due to one or more of the following causes:

Mechanical repulsion of skin parasites by animals is of true significance in tropical and subtropical regions. Skin sensitivity and a well-developed subcutaneous muscle for mobility and twitching, together with a long mobile tail, ear movements, licking and rubbing, are so instinctive that these activities proceed even without parasites (Bonsma, 1949). In summer Afrikaner cattle carried only 8 percent of the tick population of British breeds and in winter 40 percent. Australian results recorded that Droughtmaster cattle, without being sprayed, carried ten times fewer ticks than did British breeds which had to be sprayed four to five times a year. Engorged ticks on resistant cattle breeds are smaller, take longer to mature and lay fewer eggs than ticks on more susceptible European breeds.

In tick-resistant animals, too, a swelling develops at the site of the tick bite with the formation of fine drops of serous exudate on the skin surface, which on drying form sticky granular scales in which large numbers of larvae are trapped and killed.

Afrikaner cattle have significantly thicker hides and are less hide-bound than other breeds. The nature of the hair and hide plays an important role in tick-repellence and susceptibility to tick-infestation. Ticks prefer a long and woolly hair coat; cattle with long woolly coats always have a higher tick-infestation in subtropical areas. These types are not adapted to such environments. They are subjected to a lower feed intake owing to hyperthermia and they are prone to tick-borne diseases. Consequently, they often appear miserable and emaciated. Thin cattle always have a higher tick-infestation than cattle in good condition, because the "good doer" has a thick movable hide and sleek hair, where sebum secretion acts as a tick-repellent.

Certain cattle diseases such as heartwater (rickettsiosis) are tick-born and it can be expected that cattle lacking tick resistance will be more susceptible to such diseases (see Table 18).

Other protective mechanisms

An additional function of the skin is its role in immunizing animals against certain pathological conditions. When the antigens enter the body and meet the immunoproteins, defensive cells increase in numbers and antibodies are produced for protection. It is essential that the antigen be applied gradually to avoid an acute infection and it is in this respect that the skin plays a vital role.

The secretion of the sebaceous glands keeps the skin and hair pliable and protects them against drying and the penetration of moisture.

Another protective feature of the hair and hide is the role they play in regulating body temperature. Animals with thick, sleek hides have high vascularization of the hide, which enables the animal to dissipate heat readily.

A glossy, smooth coat reflects solar radiation more effectively than a woolly coat. White or brown hair and a pigmented hide reflect a large proportion of the infra-red rays impinging on the animal. The pigmented hide, plus the sebum secretion in the hair, screens ultra-violet rays. Black hair and hide do not reflect as much infra-red radiation as white or red hair, but they are more efficient in screening ultra-violet radiation.

It has been observed when selecting cattle for functional efficiency that there is no single factor that gives such positive result as the selection for early hair-shedding in spring. Early hair-shedders are well adapted to environmental conditions, they reproduce regularly and have high production records. Animals shed their hair early in spring only if they are well adapted and in good nutritional status with proper hormonal balance. Animals in poor nutritional condition and with functional disturbances in their reproductive ability will not shed their hair early in spring. A high estrogenic status and regular cyclic activity are prerequisites to early hair-shedding followed by a clean and glossy coat in early summer.

All research on hair and hide in relation to adaptability, wound healing, growth and reproductive status, indicate the existence of a close correlation between all these economically important functions and coat score.

Recommendations to cattle breeders in cold and cold-temperate regions, therefore, should be to select early spring hair-shedders in cattle that grow heavy coats in autumn.

It is important to select bulls with masculine coats and females with feminine coats.

For the improvement of livestock, breeders are advised to employ a knowledge of the effect of the reproductive system on the seasonal change in the hair and hide of cattle in the selection of functionally efficient individuals.

Hormonal control of the hair coat

Successful reproduction is largely dependent on an intricate hormonal balance. We have now shown conclusively that this delicate balance is reflected accurately in the secondary sexual characteristics, many of which are revealed in the appearance of the hair and hide.

In the female, estrogenic hormones inhibit hair growth to a considerable extent, causing hair to be finer. Counts have shown that, under the influence of estrogen, there are fewer hairs per unit area. Estrogen causes the skin to be thinner and softer, mainly as a result of a thinner epidermis and reduced size of the sebum glands. A high level of estrogen may even cause overactivity of the sebum glands.

In cattle, hair growth takes place in cycles of approximately three months duration. Under the influence of estrogen, hair-follicle activity is prolonged and consequently there is a close link between sexual activity and hair-shedding.

The male hormone testosterone has, in most cases, an effect opposite to that of estrogen on hair growth. It causes hair to be thicker, coarser and darker in color. Testosterone causes the skin to be thicker, especially in the region of the neck and shoulders; the hair is particularly dark and coarse in this region. Androgens from the adrenal cortex have the same influence and an over-production of androgens in females causes masculinity. Characteristic masculine hair growth will not develop with deficiency of testosterone.

Thyroxin has a obvious effect on the appearance of the hair and hide. With the absence or deficiency of thyroxin, hair growth is delayed, hair is dull and sparse and the skin is thick and has a keratinized appearance. The greatest effect of thyroxin is on the early stages of hair growth. The hormones of the adrenal cortex delay the initiation of hair growth. An excess of these hormones, again, has the same effect as testosterone on the secondary sex characteristics. Continuous administration of adrenalin inhibits hair growth, possibly due to disturbance of the carbohydrate metabolism of the body. Under the influence of adrenalin, the absorption of glucose by various tissues is reduced. Estrogen again stimulates the pituitary to secrete ACTH so the activity of the hormones of the adrenal gland and estrogen are linked.

Somatotropin is essential for the growth of a mature hair coat. In a hypophysectomized animal no mature coat develops; the hair remains fine and soft. The influence of STH is most noticeable in the diameter and length of hair.

The sebaceous glands are also under hormonal control; they enlarge with puberty but undergo atrophy with hypophysectomy. The gonadotrophic hormones, especially, stimulate the secretion of these glands. The gloss of an animal's coat, which is mainly due to the secretion of sebum, is consequently dependent on correct hormonal balance.

Pregnant and lactating cows are inclined to become smooth-coated. This is attributed to the inhibiting effect of estrogen, progesterone and LTH on hair growth (Bonsma, 1943). It has been shown, for example, that PMS will cause molting in hens irrespective of the season.

Hair-shedding can be controlled artificially by varying the length of daylight. While the exact stimulus varies between species, it is generally accepted that the influence of light is implemented by hormones.

Impulses are conveyed along the optic nerve to the thalamus, which regulates secretion of the trophic hormones by the pituitary body. This increase in hormonal secretion, as influenced by the length of daylight, has been confirmed by various investigators.

In the more temperate latitudes, the variation in the length of daylight between seasons is great, but the variation gradually decreases as one approaches the tropics. This diurnal light/dark stimulus in the tropics is often not pronounced enough to affect the shedding of winter coats by European breeds of cattle, which in turn is associated with decreased fertility due to hormonal deficiencies or imbalances. This is aggravated by hyperthermia, which develops as a result of the long hairy coat.

The hide as a thermo-regulatory organ

The ability of the body to maintain a fairly constant temperature despite marked environmental changes is a decided advantage when one considers its physiological functions. It allows biochemical reactions, on which all productive processes depend, to continue with minimal seasonal interference. Cattle are warm-blooded animals and the efficiency with which various mechanisms come into action to offset the stress caused by excess heat or cold is a measure of their adaptability.

It is realized that the normal body temperature varies, variations being influenced by age, sex, season, time of day, environmental temperature, exercise, eating, digestion, and drinking of water.

Heat is constantly produced in the body as a result of the continuous physiological processes. Therefore, to prevent the consistent rise in body temperature, heat must be lost continually.

Heat is lost from the animal body in the following ways:

1. Radiation, conduction and convection
2. Vaporization of water from the skin and respiratory passages
3. Excretion of feces and urine

In comparison with the first two methods, the last-mentioned is of minor importance and will not be discussed.

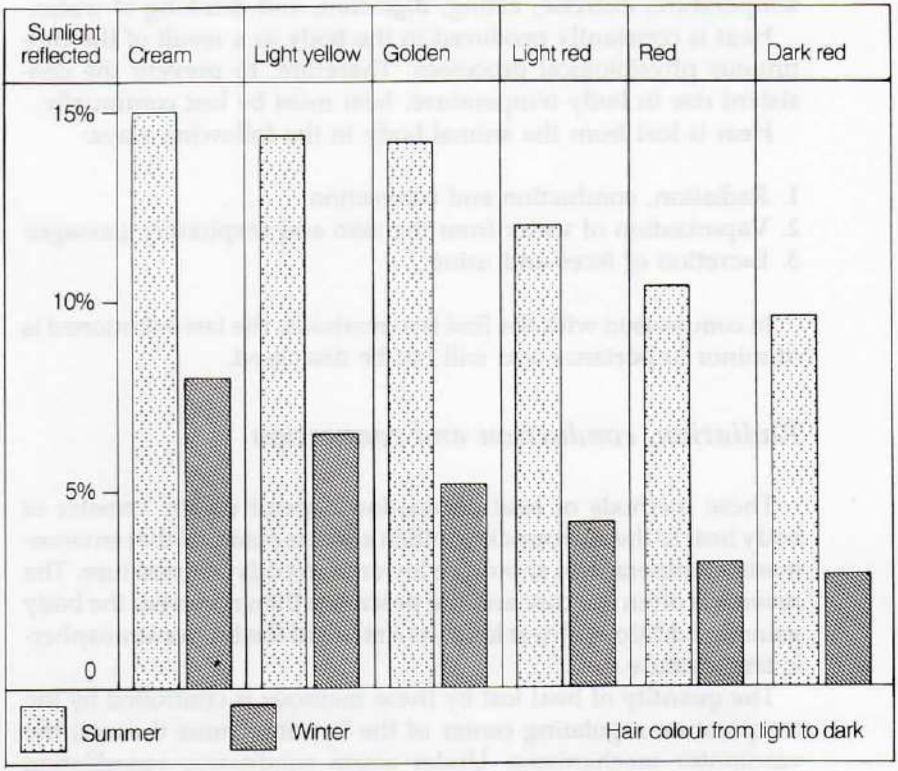
Radiation, conduction and convection

These methods of heat dissipation depend on the transfer of body heat to the surrounding milieu and it is essential that environmental temperatures should be lower than body temperature. The reverse is often the case and the process is then reversed; the body gains an additional "heat load" as a result of the higher atmospheric temperature.

The quantity of heat lost by these methods is controlled by the temperature-regulating center of the hypothalamus through the vasomotor mechanisms. Under warm conditions, vasodilation takes place causing a greater flow of blood to the skin surface. This will cause an increased heat loss due to convection and conduction if the atmospheric temperature is lower than the body temperature. Should this not be the case, other means of heat loss, such as water vaporization, are necessary for the animal to maintain thermic equilibrium. At low temperatures, vasoconstriction takes place enabling the animal to conserve its heat.

Radiation is subject to the normal physical laws of heat transfer and this is where coat color and type play an important role. Radiation takes place with greater efficiency between dull, dark objects; especially when compared with bright, light-colored objects. In 1943 I showed that this principle was applicable in cattle. Thus, in hot, open areas, like the savannah regions of Africa and Australia, where animals are exposed to severe infra-red radiation, a light, glossy coat would be of advantage; whereas in hot regions where there is dense shade, a dark coat would be of value for heat

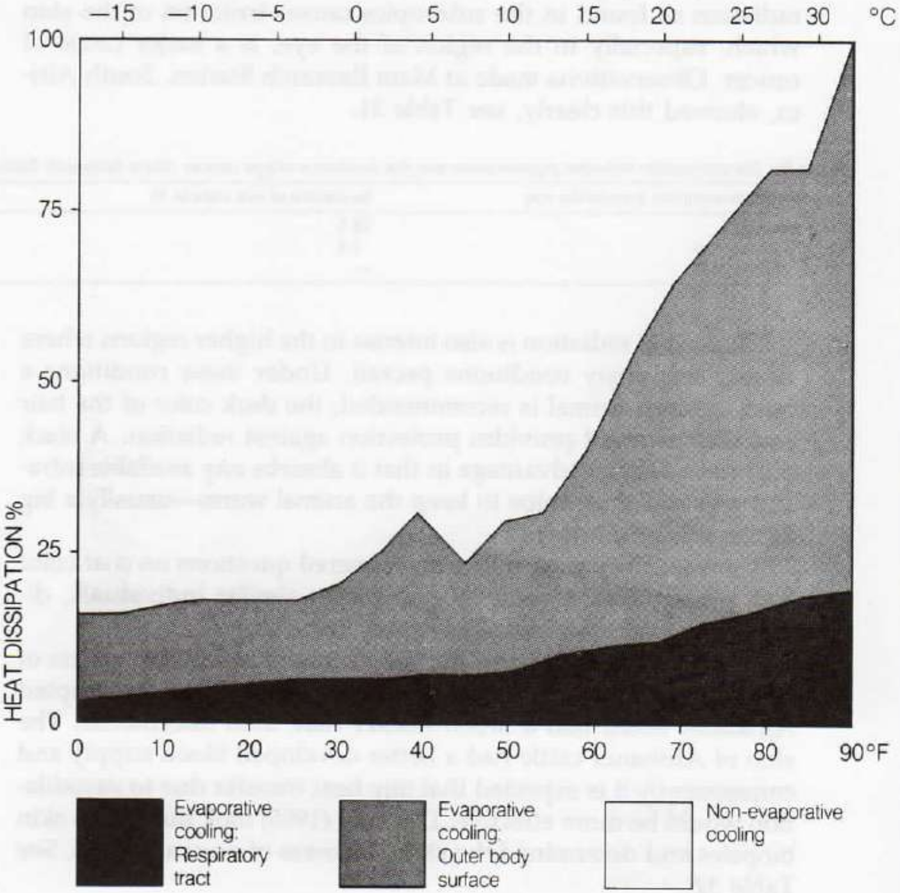
Graph 8: *The influence of coat colour of Afrikaner cattle on percentage of sunlight reflected (Bonsma, 1943).*



dissipation. The thick bush of Angola is an example of a tropical area where dark cattle do best. Graph 8 demonstrates the above principle regarding to coat color and reflection.

This apparently simple phenomenon was investigated by Schleger (1963), who found that the heat absorption of dark-red and light-red coats differed by some five percent, which, under the given conditions of solar radiation, was equal to 30 percent of the endogenous heat load. However, he could find no tendency in the darker animals to have higher rectal temperatures and growth studies showed that they performed better. It appears that differences in effective solar heat load between light and dark red are insignificant or are counter-balanced, possibly by thrift factors correlated with darker coat color. While this may apply to colors within one major color group it does not necessarily apply to other coat color groups.

Graph 9: *The percentage heat loss through various mechanisms as influenced by environmental temperature (Kibler and Brody from Dukes, 1955).*



As can be seen by the differences between winter and summer coats (see Graph 9), the physical state of the hair also plays an important role. The seasonal differences may be attributed largely to the lack of gloss of the winter coat as well as the increased length of hair. The latter point is further illustrated by a comparison of the reflecting ability of a red Afrikaner and a red Shorthorn. The Afrikaner, a short-haired breed, reflected 12 percent of sunlight/heat as compared with the longer-haired Shorthorn, which reflected only 4 percent. Coat length also plays a role in evaporation from the skin; this aspect will be discussed later.

Ultra-violet radiation is an important factor when one considers adaptation in the subtropics. For protection against the short ultra-violet rays, a pigmented skin is vital. Without pigment, intense radiation as found in the subtropics causes irritation of the skin which, especially in the region of the eye, is a major cause of cancer. Observations made at Mara Research Station, South Africa, showed this clearly, see Table 31.

Table 31: *The correlation between pigmentation and the incidence of eye cancer (Mara Research Station)*

Degree of pigmentation around the eye	Incidence of eye cancer %
Unpigmented	38,5
Slightly pigmented	7,6
Totally pigmented	—

Ultra-violet radiation is also intense in the higher regions where cloudy and misty conditions prevail. Under these conditions a black-colored animal is recommended; the dark color of the hair and skin pigment provides protection against radiation. A black coat has a further advantage in that it absorbs any available infra-red rays and thus helps to keep the animal warm—usually a big factor at high altitudes.

There are, however, many unanswered questions on coat color and a comparative study of genetically similar individuals, differing in hair color, would be most revealing.

A study of vascularity of the skin is important as the success of vasodilation is dependent on this factor. I found that the adapted Afrikaner breed had a much thicker hide than Shorthorns. The skin of Afrikaner cattle had a better developed blood supply and consequently it is expected that any heat transfer due to vasodilation would be more effective. Dowling (1955) took numerous skin biopsies and determined the skin thickness of several breeds. See Table 32.

Table 32: *The average skin thickness of various breeds of cattle (Dowling, 1955)*

Breed	Skin thickness (mm)	Breed	Skin thickness (mm)
Devon	8,15	Zebu	5,77
Hereford	6,77	Shorthorn	5,69
Friesian	6,08	Aberdeen Angus	5,75

The Zebu was shown to have only an average skin thickness, which suggests that a thick skin is not a common factor with all adapted breeds. Skin thickness is used as an index of skin vascularity; no doubt a more accurate measure would show great breed differences. In my work on the hide thickness of livestock, where skinfold thicknesses on thousands of animals were taken over a period of 23 years with a caliper which slips at constant pressure, I found that Afrikaner cattle (*Bos indicus*) had appreciably thicker hides than the British breeds of beef cattle.

Skin area to unit volume or unit weight is a relationship which has received much attention in adaptation studies. On the strength of this, cattle have been divided into two types, the metabolic type such as the British beef breeds, and the respiratory type, such as the dairy breeds and all indigenous cattle of the tropics.

The Zebu has a skin surface area some 12 percent greater than the skin surface area of animals of the British beef breeds of equal weight. However, McDowell (1965) could not detect any change in the heat tolerance of a Zebu after he had surgically removed the dewlap, hump and part of the ears. Therefore, although it is true that the ratio of surface area to live weight is important in heat tolerance, the difference caused by the various appendages in negligible.

The hide area per kilogram of weight in cattle of the British beef breeds is approximately one square decimeter.

Evaporative cooling

Because sweating in bovines is not easily visible, the ability to sweat through the skin has been doubted or its importance underestimated. However, it is the only method of heat loss generally available to animals in temperatures above their normal body level. As this is normally the position in the tropics for the greater part of the year, the importance of sweating cannot be overstressed.

Panting causes increased vaporization from the lungs and bronchial tubes but does not play an important role in heat dissipation; in fact, excessive panting increases the metabolic heat produced by the body.

The importance of respiratory cooling diminishes rapidly with age as the calf's sweating mechanisms become more efficient.

In both *Bos taurus* and *Bos indicus*, each hair follicle is accompanied by an arrector pili muscle, a sebaceous gland and an apocrine gland. Hayman and Nay (1956) found the glands of *Bos taurus* to be extensively convoluted and tube-like in appearance. The sweat-glands in the Zebu were only slightly convoluted and more sac-like. Tables 33 and 34 contain summary of their findings.

Table 33: *A comparison of the sweat glands of Zebu and European cattle (Nay and Hayman, 1956)*

Breed	Volume	Mean length	Mean diameter
Zebu	$23.1 \times 10^6 \mu^3$	936μ	153μ
European	$10.1 \times 10^6 \mu^3$	724μ	129μ

Table 34: *A comparison of number and depths of sweat glands of various breeds (Nay and Hayman, 1956)*

Breed	Number of sweat glands per cm^2 of skin	Average depth of sweat glands in μ on midside ± SD (Standard deviation)
Zebu	1 507	724 ± 70
Jersey	1 005	940 ± 138
Friesland	996	896 ± 58
Red Poll	981	1 112 ± 116

Thus it can be seen that Zebu cattle have one and a half time as many sweat-glands per unit area as do the European breeds. When one considers that the Zebu are of the respiratory body type, with a large surface area per unit weight, one comes to the conclusion that, per unit weight, Zebu cattle have a far greater number of sweat-glands in comparison with the *Bos taurus* breeds. Not only have the Zebu more sweat-glands, but each gland is some two and a half time larger than those of the European breeds.

Dowling (1955) found that the highly functional papillary layer of the Zebu is significantly thinner, the follicles are more numerous, and the apocrine and sebaceous glands are better developed than in the European breeds. The glands themselves are much nearer to the surface and are closely packed together forming a continuous "lake" of fluid approximately one millimeter (0.04 inches) thick. Yeates (1965) states that this condition could probably have some other value besides being a reservoir for sweating: for instance, it could also permit absorption of radiant heat.

The significance of skin evaporation for heat regulation is clearly illustrated in the graph of Dukes (1955) See Graph 9.

Coat type can also play an important role in the efficiency of evaporative cooling. This was dramatically shown by Yeates, Hines and Lee (1955) when they produced by artificial light opposite types of hair (winter and summer coats) in two groups of Shorthorn calves. These two groups were exposed to a temperature of 105°F for three hours and the heat tolerance coefficient was calculated using the formula of Rhoad: HTC = 100-10 (rectal temperature °F - 101°F). Six months later, when the coat types were reversed, they were again tested. Shortly after the test both groups were clipped and the HTC calculated. The results are shown on Table 35.

These figures show how essential it is for long-haired cattle to shed their winter coats in spring if they are to survive hot summers.

A long hair coat appears to form an insulating layer around the body. Air is trapped around the body and, being a poor conductor of heat, its presence greatly reduces the possible heat dissipation by reducing the efficiency of sweating, convection and radiation.

Table 35: *The influence of coat state on the heat-tolerance coefficient (Rhoad) of calves (Yeates, Hines and Lee, 1955)*

Group	Coat state	HTC	Coat state	HTC	Coat state	HTC
1	Long	42	Short	51	Clipped	52
2	Short	54	Long	39	Clipped	54

Chapter 7

Soil pH and Soil Fertility

The effect of the soil

on animal growth and size

If we are to accept the Bonsma livestock philosophy, which says nutrition is the most important single factor in the environment, it can be concluded that the role of soil fertility and pH as supplementary factors in determining the level of nutrition are also of great importance. It now remains to describe in what ways these factors can modify, or influence, the conformation and physiology of our farm animals.

It is indeed strange that Wright, in his comprehensive review, should give such scant attention to this factor in the environmental complex. There is no doubt that this factor exerts a strong influence on the growth and development of our farm animals.

Soils may be acid, neutral or alkaline in reaction. Each degree of soil reaction, or set of chemical conditions in soils, affects plant growth in a certain way, owing either to a depressed solubility of some elements or to increased solubility of others. The chemical conditions which accompany the different degrees of soil reaction, therefore, may be favorable to the growth of some crops and unfavorable to others. In other cases they may affect growth very little. The object of this chapter is to discuss the effect of soil reaction and fertility on the development of, first, grass as a plant and, second, the animal feeding on the grass cover. This chapter is therefore confined to those elements affected by soil reaction and considered to be limiting factors in South Africa by du Toit, Malan, Louw, Holzappel and Roets (1932, 1935, 1940), and deals mainly with South African conditions.

Definition of soil fertility and pH

Soil fertility is determined by the availability of the different inorganic elements to the plants growing in that soil. This is mainly a result of the composition of the parent rock material which determines the minerals to be found and the pH and to a large extent determines the availability of those elements (Table 21).

Table 21: *Soil fertility in relation to the availability of different inorganic elements*

Grades of soil fertility	Nitrogen	P_2O_5 Phospho-oxide %	K_20 Potash %
Poor	<0,05	>0,05	>0,075
Average	0,05-0,1	0,05-0,1	0,075-0,15
Fairly fertile	0,1-0,2	0,1-0,2	0,15-0,3
Fertile	>0,2	<0,2	<0,3

The pH of the soil defines the acidity or alkalinity of the soil which in an aqueous solution is the negative logarithm of the hydrogen ion concentration in the solution: pH 7 is neutral, pH 14 is maximum alkalinity and pH 1 is the maximum acidity.

Soil acidity is primarily a function of colloidal fraction of soils. Much of the colloidal material of soil reacts as a complex acid radical of low solubility around which are clustered positive ions at varying distances from the nucleus. These cations are hydrolyzed to some extent and their places are taken by hydrogen ions from the water. The hydroxide ions so formed produce an alkaline reaction in the soil solution. When the numbers of hydrogen and hydroxide ions in the solution are equal a neutral reaction exists. (Miller and Turk, 1954.) (See Figure 7.1.)

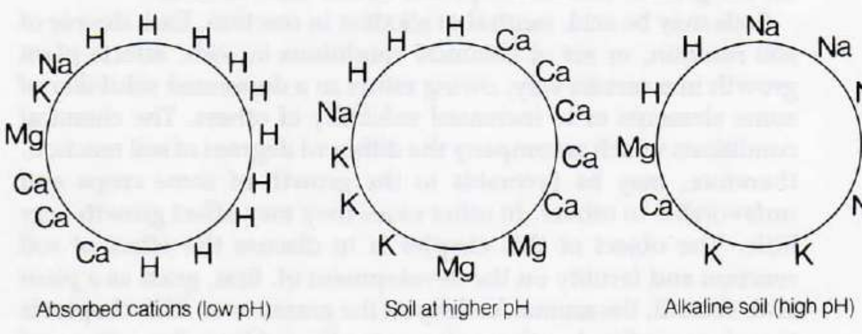


Figure 7.1 Collodial particles of soil type.

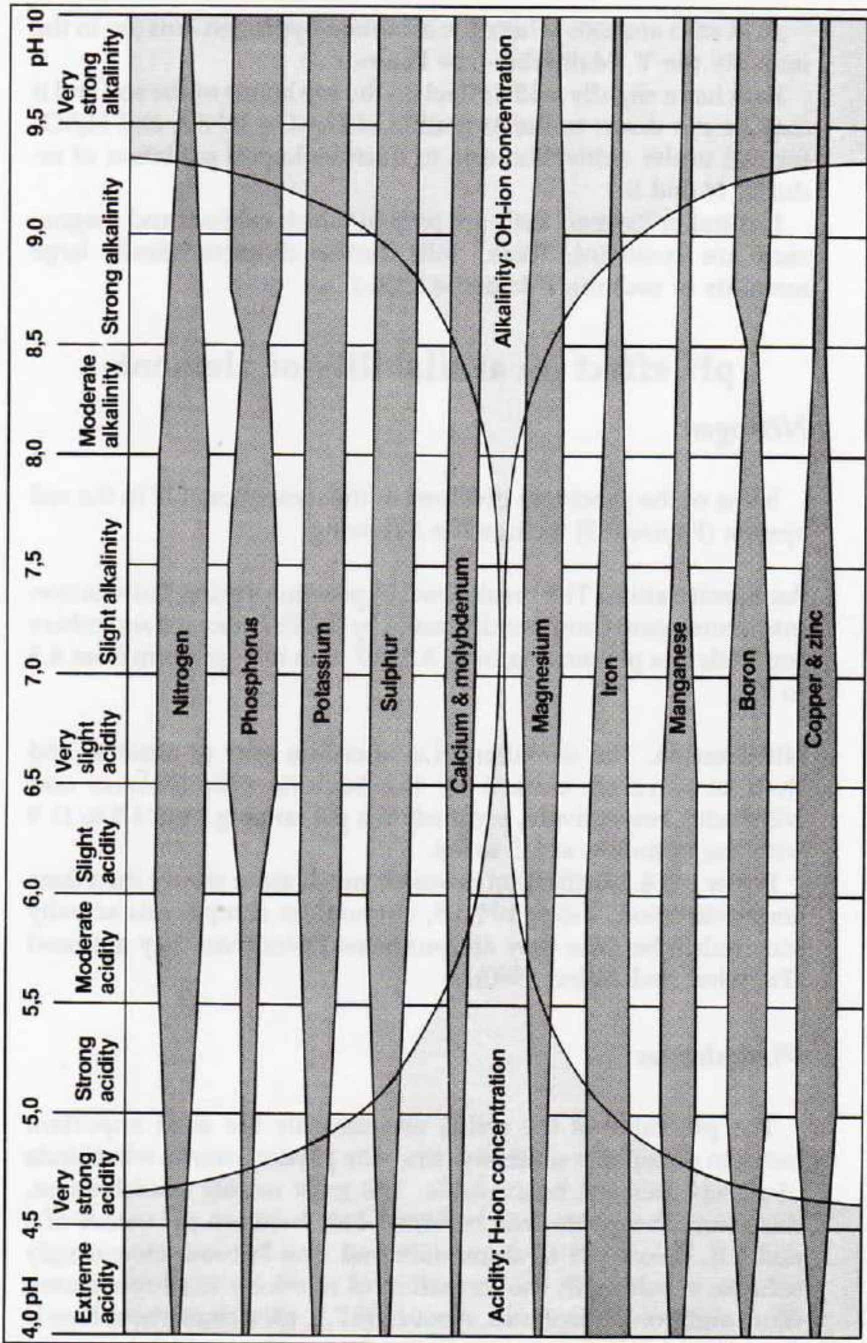


Figure 7.2 The influence of pH on availability of nutrient elements.

Acid soils are soils where the absorbed hydrogen ions are in the majority (de V. Malherbe - see Figure 7.2).

Rain has a slightly acidic effect on the top layers of the soil and it may be put down to the formation of H_2CO_3, HNO_3 and H_2SO_4 formed under cultivation due to microbiological oxidation of reduced N and S.

Neutral or "sweet" soils are soils in which calcium and magnesium are dominant. "Brak" soils contain characteristically large amounts of sodium. (Malherbe 1938.)

pH effect on availability of elements

Nitrogen

Some of the processes involved in the dynamics of N in the soil system (Figure 7.3) include the following:

Ammonification. The breakdown of proteins during putrefaction into ammonium compounds caused by *Bacillus mycoides* and others proceeds at a pH ranging from 3.5 to 7 with the optimum from 4.5 to 5.5.

Nitrification. The oxidation of ammonium salts to nitrates, and then to nitrates, caused by the bacteria *Nitrosomonas* and *Nitrobacter*, respectively, proceeds at a pH ranging from 4.5 to 11.9 with the optimum at 6.5 to 7.6.

Below pH 6, nitrification proceeds much more slowly then does ammonification. Below pH 5.5, ammonium compounds actually accumulate because they are produced faster than they are used (Teuscher and Adler, 1960).

Phosphorus

The pH value of the soil is undoubtedly the most important factor in phosphate solubility, since the pH determines what kinds of phosphates will be available. The most readily available one, dicalcium phosphate, will be found only between pH values of 6 and 7.8. Below pH 6, aluminium and iron become increasingly soluble, resulting in the formation of relatively insoluble aluminium and iron phosphates. Above pH 7.5, tricalcium phosphate is formed which is also practically insoluble. Above pH 8, however,

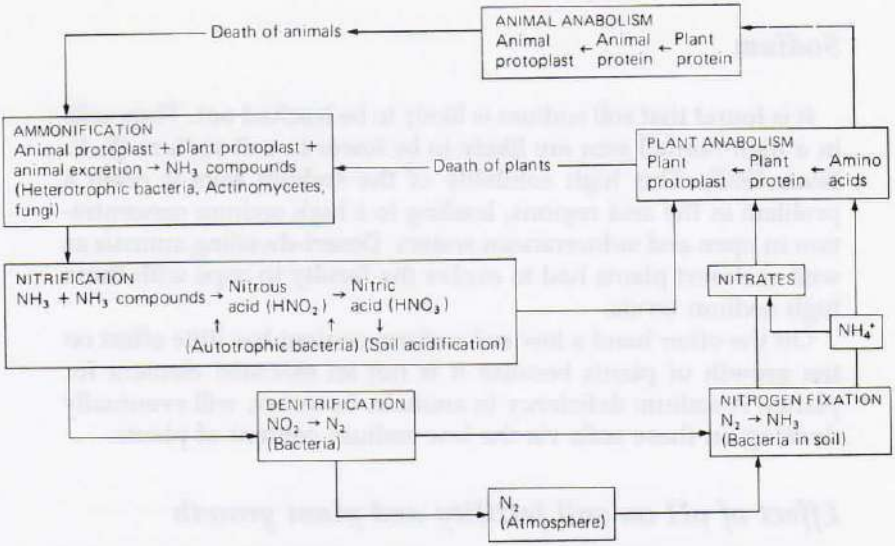


Figure 7.3 Processes involved in the dynamics of nitrogen in the soil system.

Table 22: *Phosphate solubility*

pH range	Phosphate bound with	Solubility
3-4	Iron and aluminium	Relatively insoluble
5-6	Iron	Almost insoluble
6-7,8	Calcium (as dicalcium phosphate)	Reasonably soluble
above 7,8	Calcium (as tricalcium phosphate)	Almost insoluble
	Sodium (as disodium phosphate)	Soluble

soluble sodium phosphate is almost certain to be present (Teuscher and Adler, 1960).

Calcium

There is a great deal of truth in the statement that the improvement of yields resulting from lime application to acid soils is frequently due not so much to the raising of the pH value as to the added supply of readily available calcium. This is because the average healthy plant requires relatively large amounts of calcium and highly acid soils commonly have a low calcium content (Teuscher and Adler, 1960).

Sodium

It is found that soil sodium is likely to be leached out. Thus soils in a high-rainfall area are likely to be lower in soil sodium (F. E. Bear, 1953). This high solubility of the sodium salts is often a problem in the arid regions, leading to a high sodium concentration in open and subterranean waters. Desert-dwelling animals as well as desert plants had to evolve the faculty to cope with these high sodium levels.

On the other hand a low soil sodium content has little effect on the growth of plants because it is not an essential element for plants. A sodium deficiency in animals, however, will eventually develop on these soils via the low sodium content of plants.

Effect of pH on soil fertility and plant growth

1. In general, the lower the pH the less available are the macro elements N, P, S and Mg, whereas the micro or trace elements become more available except molybdenum.

   A most important concept regarding the effect of pH on the availability of elements is the precipitation or fixation of the phosphate ions. Most of the arable soils in South Africa are acid, with highly available iron and aluminium salts. With application of phosphatic fertilizers to these soils the Fe and Al salts precipitate the PO_4 ions in insoluble form.
2. Nitrifiers, i.e. bacteria which transform NH_4 to nitrites and nitrates, become increasingly less active as the pH drops. As their activity is also associated with vegetation it cannot be ascribed entirely to pH.
3. NH_4 and NO_3, the sources of N to the plant, are not affected to a great degree by soil pH as they are highly soluble in water.
4. Low pH will inhibit the activity of earthworms and insects which are normally responsible for the mechanical mixing of dead herbage with the surface layer of the soil. In their absence, dead herbage accumulates and forms a mat that inhibits germination.
5. The effect of pH on pastures is more marked than in cultivated crops, as in a pasture there are many species of plant life competing with each other and those best able to withstand low pH will tend to overcome their neighbors and dominate the flora.

6. The palatability of the pasture is affected by the pH; this has been shown to be true by Atkins and Funten, who demonstrated that sheep will always give preference to areas of ±pH 6.5 and will shun areas of pH 5.
7. Optimum pH for plant growth is considered to be between 5.5 and 6.5. Most plants can exist from pH 4 to pH 9, but above and below these levels root injury occurs.
8. Soil fertility is a difficult term to define but if we accept that a soil with high fertility contains all the essential elements in sufficiently large proportions to allow maximum growth of the crop or herbage it supports, then we may conclude that the effects of soil fertility on the plant cover will be either to decrease or increase the volume of production and its percentage of elements present in that herbage. It is interesting to note in this respect that the luxuriance of plant growth is not a measure of the amount of certain trace elements occurring therein, as the plants may not be dependent on these elements for growth. Therefore the ecologist who would determine trace element deficiency in the pasture of his animals will not always be assisted by visible leaf symptoms.

Function of nutritional elements

The minerals present in an animal's body may be divided into roughly three groups, depending on their essentiality for animal life:

1. Essential elements: Calcium, magnesium, sodium, potassium, phosphorus, chloride, sulphur, iron, copper, iodine, zinc, manganese, cobalt, molybdenum and selenium.
2. Probably essential elements: Fluoride, bromide, barium, strontium and chrome.
3. Non-essential elements: Silicon, rubidium, boron, aluminium, titanium, arsenic, nickel, cadmium, vanadium, silver, lead, bismuth, tin, gallium.

A brief discussion of some of these elements may illustrate the importance of different elements for animal life.

Nitrogen (protein)

It has long been known that all animals must have in their feed at least a certain minimal amount of protein or convertible source of nitrogen. The proteins are absorbed from the intestines as amino-acids.

These protein and nitrogen derivatives then pass into the blood and are carried to various parts of the body where they are synthesized into tissue proteins and other nitrogen-containing tissue constituents. They may be utilized by the body to replace tissues used up in the "wear and tear" of body processes. Included here are enzymes, hormones and other (Maynard and Loosli, 1962).

Phosphorus and calcium

The skeleton of the mature animal contains about 26 percent inorganic matter, 20 percent protein, 4 percent fats, and 50 percent water (Morrison, 1959). Similar figures are given by Maynard and Loosli (1962). About 85 percent of the mineral matter is calcium phosphate, 14 percent calcium carbonate and 1 percent magnesium phosphate (Morrison, 1959).

The growth of bone in length takes place at the junction of the epiphysis and diaphysis. The cartilage between is a temporary formation that grows by the multiplication of its own cells to be replaced at both surfaces by calcified bone (Maynard and Loosli, 1962).

Approximately 80 percent of the phosphorus of the body occurs in the bones and teeth. The large amounts of phosphorus found elsewhere than in the bones are present mostly in organic combinations such as phosphoprotein, nucleoprotein, phospholipids, phosphocreatine, hexo-phosphate and others (Maynard and Loosli, 1962).

Whale blood contains from 35 to 45 mg of phosphorus per 100 ml, most of which is in the cells. The element occurs primarily as organic combinations. With inorganic nutrition, our main interest lies in phosphorus which occurs in the plasma. In health its level generally lies between 4 and 9 mg per 100 ml, depending on age and species (Maynard and Loosli, 1962).

Blood cells are almost without calcium but the serum in health contains 9 to 12 mg per 100 ml in most species. Two types of serum calcium are distinguished: diffusible and non-diffusible. Most of the non-diffusible calcium is bound to protein. The diffusible fraction which makes up 60 percent or more of the total is present largely as compounds of phosphate and bicarbonate and is the part that has been of principal significance in calcium and phosphorus nutrition. It is important to note that various physiological factors tend to maintain a constant level despite high intakes on the one hand or marked body losses on the other (Maynard and Loosli, 1962).

Sodium

By far the largest proportion of the body sodium is found in the extra-cellular fluids, where it undergoes an active metabolism. The element makes up 93 per cent of the basis of the blood serum and is thus the predominant basic element concerned with neutrality regulation. A lack of the element lowers the utilization of digested protein and energy and prevents reproduction. Requirements for growth range between 0.1 percent and 0.2 percent of the ration for rats, chicks, pigs and calves (Maynard and Loosli, 1962).

A interesting adaptation syndrome in the sodium metabolism of cattle and sheep was reported by Evans (1954, 1963), who found that animals with a superior heat tolerance invariably had a higher erythrocyte sodium content than animals suffering under conditions of high environmental temperatures.

Tables 24 and 25 are adapted from work by du Toit et al. (1932, 1934, 1935 and 1940). For this chapter, figures have been selected from the available data for nine sweet and sour veld areas. Because

Table 23: *Chemical composition on a dry-matter basis of pasture samples*

'Sour Veld'

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Phosphate in grass	0,137	0,142	0,104	0,112	0,092	0,077	0,061	0,068	0,130	0,138	0,148	0,145
Protein	8,1	7,03	6,82	5,92	5,37	4,48	4,40	4,62	8,30	8,70	10,32	9,95
Na in grass	0,075	0,055	0,025	0,027	0,018	0,012	0,025	0,036	0,038	0,043	0,080	0,025

'Sweet Veld'

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Phosphate in grass	0,158	0,152	0,134	0,139	0,140	0,166	0,123	0,119	0,134	0,145	0,160	0,213
Protein	8,54	7,84	6,42	7,12	6,53	7,86	6,86	6,55	8,25	7,75	8,43	9,77
Na in grass	0,35	0,28	0,30	0,20	0,21	0,41	0,14	0,29	0,21	0,17	0,27	0,31

Table 24: *'Sour Veld'*

	1930 May	31 May	31 Oct.	32 Jan.	32 Apr.	32 July	32 Oct.	33 Jan.
P_2O_5 grass	0,14	0,25	0,17	0,25	0,22	0,20	0,21	0,26
P-blood	4,8	4,5	4,0	5,1	5,0	4,7	4,1	4,26
Crude protein grass	3,5	4,0	3,3	4,6	4,3	3,7	4,8	4,9
Na_2O grass	0,26	0,20	—	0,087	0,08	0,08	0,09	0,03

Table 25: *'Sweet Veld'*

	1930 May	31 May	31 Oct.	32 Jan.	32 Apr.	32 July	32 Oct.	33 Jan.
P_2O_5 grass	0,41	0,42	0,38	0,31	0,33	0,26	0,55	0,33
P-blood	4,9	5,4	5,3	7,2	5,2	4,3	4,7	4,9
Crude protein grass	8,4	6,1	8,3	7,9	9,0	7,5	12,7	7,7
Na_2O grass	0,61	0,53	0,24	0,44	0,96	0,60	0,90	0,74

du Toit and co-workers did not take soil pH into account in their work, pH values for the different areas cannot be given, but the tables are given merely to illustrate differences in grass composition in the areas which may differ in soil pH and are from so-called sour and sweet veld areas. Table 24 has grass samples taken from Fort Beaufort, Adelaide, Bedford, and Queenstown areas to represent sweet veld and samples from Elliot and Maclear to represent sour veld. Table 25 has samples from Bedford and Albany districts to represent sour veld.

It will be noted that only elements that du Toit and co-workers considered to be limiting for animal nutrition have been selected.

Effect of nutrient shortages on the animal

Protein

Since protein is the principal constituent of the organs and soft structures of the body, a liberal and continuous supply is needed in the food throughout life for growth and repair. Transformation of food protein into body protein plays an important part in the nutritional process (Maynard and Loosli, 1962).

Morrison (1959) further states that it is obvious that far more protein is needed for growth, lactation and reproduction than for mere maintenance. The figures for the requirements of digestible protein for various classes of livestock are as follows:

Wintering beef calves	7.5 percent
Wintering year-olds	6.0 percent
Pregnant beef cows	5.0 percent
Milking beef cows	5.5 percent

Workers have found that for pigs to make satisfactory gains on corn, not only nutrients should be added but also more protein of the right kind, which will correct the deficiencies of the corn protein (Morrison, 1959).

Phosphorus and calcium

As these two elements are so closely associated with each other in metabolism it is felt that they should be discussed together even though it is considered that calcium is not a limiting nutrient. In the body they occur combined, for the most part, and an inadequate supply of either phosphorus or calcium in the diet limits the nutritive value of both. It has been shown that the development of the skeleton is dependent on the supply of calcium and phosphorus in the ration (Maynard and Loosli, 1962).

To quote Monnig and Veldman (1961), "The South African soils are notoriously deficient in phosphorus and consequently the grazing often also contains inadequate phosphorus." For healthy bone formation, farm animals in South Africa require relatively large quantities of phosphorus. On phosphorus-deficient grazing animals will naturally show signs of phosphorus deficiency. They grow and develop poorly and in severe cases they show signs of rickets.

Henry (1886) showed that the bone of pigs fed corn and minerals was twice as strong as those of pigs fed corn only. The former group made relatively good gains whereas the latter group was unduly fat and dwarfed. Maynard and Loosli (1962) stated that a low blood-phosphorus level was a characteristic finding of low phosphorus nutrition, especially in pigs. Further, a failure of bone nutrition during growth not only arrests the normal growth but also results in various structural abnormalities.

It has been pointed out that the soil of Jersey Island is more deficient in phosphorus and calcium than that of Guernsey, where cattle are larger. Further, breeders of the Island type Jerseys in the United States of America recognized that there was a tendency for the cattle to become somewhat larger and more rugged in bone where they were fed and kept mainly on soils rich in minerals (Morrison, 1959).

At Mara Research Station the grazing may be divided into two types: Haak-en-steekveld *Acacia tortilis*, which is a typical sweet veld type, and Rooibosveld *Combretum apiculatum*, which is a mixed veld type.

In a grazing experiment using Afrikaner oxen it was found that at three and a half years of age those on Rooibosveld had a weight of 935 pounds whereas those on the Haak-en-steekveld weighed 1,151 pounds, which is a difference of 216 pounds. This latter group had much more fat and therefore obtained far better grades at marketing.

Ashton attributed the large skeleton of the Brown Swiss to the soils of Switzerland, which are of volcanic origin and are high in calcium and phosphorus. The grass cover is found to have a high protein content and these animals live virtually on roughage alone. The cattle of Brittany, in an area where the soil is notoriously low in pH, are small, mature cows having an average height at withers of 3.3 feet and a weight of 598 pounds.

Sodium

Aries and Smith (1952) showed that salt deficiency in lactating dairy cows was due primarily to an inadequacy of sodium. Such cows developed depraved appetites, loss in milk production, loss of weight and occasionally signs of neuro-muscular abnormality such as shivering and irregular heart action while on a deficient diet.

Asdell and co-workers (1937) stated that on a deficient diet a train of symptoms and signs developed in rats which resulted in death. Retarded growth, eye lesions and disturbances of the reproductive functions were the primary manifestations.

Effect of area differences on animal growth

Tables 26, 27, 28, 29, 30 indicate the differences in growth rate as measured by weight and different linear body-measurements, which are influenced by the ecology of different areas.

Table 26: *Chemical composition of the soil*

District	Vicinity	Top Soil CaO	P_2O_5	N	pH	Lower soil CaO	P_2O_5	N	pH
1	Caledon	0,07	0,18	0,073	4,5-5,7 on hills	0,21	0,03	0,066	5,0-6,1 on hills
		—	—	—	5,8-6,7	—	—	—	6,5-8,5
2	Cathcart	0,2	0,03	0,5	6,2	0,03	0,03	0,6	6,1
	Butterworth	0,27	0,04	1,32	5,9	0,38	0,10	0,09	6,5
3	Bulver	0,40	0,19	0,29	4,8	0,33	0,17	0,06	5,1
	Edgecombe	0,25	0,05	0,08	5,2	0,29	0,06	0,05	7,3
4	Bethal	0,27	0,10	0,34	6,1	8,09	0,10	0,02	7,5
	Bethlehem	3,2	0,07	0,07	6,6	0,33	0,05	0,04	5,4

Table 27: *Climate of the four districts*

District	Vicinity	Monthly variation in Rel. Humidity %	Yearly Average %	Average Temp. °C	Average Rainfall mm
1	Cape Town	79 (max.)	—	17,5	992,0
2	Somerset East	49-60	52	17,6	942,0
3	Dundee	47-67	57	17,6	1 304-1 480
	Pietermaritzburg	57-63	65	17,6	1 304-1 480
4	Bethal	52-68	59	14,0	960-1 200
	Standerton	44-66	55	14,0	960-1 200

Table 28: *Average mass of Friesland cows in the four districts*

Age in years	District 1 no.	mass kg	District 2 no.	mass kg	District 3 no.	mass kg	District 4 no.	mass kg
1	21	330,5	37	390,4	12	282,9	25	291,0
2	20	525,0	12	418,0	22	416,2	25	342,4
3	18	542,6	14	505,0	16	425,7	33	448,3
4	22	593,0	14	536,6	19	456,7	24	536,0
5	16	634,0	24	590,7	13	504,6	23	541,0
6	27	641,0	21	604,0	21	521,3	57	568,5
7	17	664,2	8	629,0	20	546,4	46	574,8
8	17	687,2	11	642,7	23	548,4	27	589,8
9	15	605,0	4	538,0	15	593,2	17	591,0
10	6	708,3	10	629,1	8	517,7	7	612,7
11	3	707,1	—	—	7	568,3	12	568,9

Table 29: *Measurements taken on stud Hereford cattle*

	District	pH	Width of hipbones 18-30 months	over 30 months
Male Animals*	1	6,6	42,0 cm	47,2 cm
	2	5,3	43,7 cm	49,0 cm
	3	7,6	42,7 cm	48,6 cm
Female Animals	1	6,6	43,0 cm	44,4 cm
	2	5,3	41,0 cm	43,9 cm
	3	7,6	43,0 cm	45,1 cm

* The data on male animals are not of much value, since so many bulls are brought in from elsewhere.

Table 30: *Height of spinous processes of the dorsal vertebrae*

	District	pH	18-30 months	over 30 months
Male Animals	1	6,6	113,8 cm	125,1 cm
	2	5,3	114,1 cm	125,3 cm
	3	7,6	112,6 cm	125,4 cm
Female Animals	1	6,6	116,6 cm	122,1 cm
	2	5,3	114,0 cm	118,8 cm
	3	7,6	114,2 cm	120,2 cm

The first group of tables gives the condition of the soil, relative humidity, temperature, rainfall and weight of Friesland cattle of various ages for the different areas as studied by Gilliomee (1958).

Naude, in his work on Herefords bulls in 1959, showed that there was a difference in growth and development between climatic areas.

Discussion

As this chapter is primarily concerned with soil pH and its effect on animal growth, it was felt that soil reaction had to be defined first. The effect of this reaction on the availability of plant nutrients and the part played by these nutrients in animal metabolism have been dealt with.

It is not intended to dwell on these sections in the discussion but to deal with the relative nutritive value of the grasses, how these values would probably be affected by soil pH, and what result this variation due to soil pH would have on the development of the animal.

From the data it will be seen that with the advancing season and advanced growth-stage, the percentages of protein and phosphorus decrease in the grass, while it is common knowledge that the crude fiber increases.

Several factors can be put forward for these seasonal changes as growth advances. The formation of dry matter and the accumulation of carbohydrates proceed at a faster rate than the absorption of soil nutrients, thus leading to a decreased concentration of protein and nutrient elements in the plant. This is especially pronounced during the formation of stems, which are invariably lower in protein and nutrient elements. Roughages in the low pH areas of the tropics and subtropics have a high heat-increment value, which will cause hyperthermia in those cattle that do not dissipate excess metabolic heat readily. This is the reason cattle in the low pH regions of the tropics and subtropics are of a small, respiratory type. In the cold-temperate regions of the world where the pH is low, the livestock are of a small, digestive type body conformation, for example the Shetland ponies of Shetland and the small *Pie Noir* cattle of the province of Brittany in north-western France.

Second, actual losses of nitrogen and elements from the herbage take place after flowering, when these elements are translocated to the roots for storage for the next season's growth. Further losses are brought about by rain through leaching of the maturing dead herbage, which supports the belief by many that abundant rains do not appear to favor a high phosphorus content of the grasses.

Sour veld occurs mainly in areas of higher altitude and rainfall, whereas sweet veld is generally characteristic of the regions of lower rainfall and in valleys where alluvial soil high in soluble nutrients—especially calcium, phosphorus and sodium—has been deposited. Topography also plays a significant role in drainage and the leaching of soluble constituents. The type of rock material of the soil also plays an important role in the loss of soluble inorganic matter.

From the data provided it is seen that the decrease in protein and nutrient content during winter is less pronounced in sweet veld than in sour veld. It is believed by some this may be due to certain sweet-veld annual grasses, where probably little or relatively slow translocation of nutrients from the shoots to the roots takes place. Frosts in sweet-veld areas tend to be later and generally there is less rain to bring about leaching. Sweet-veld areas hold out longer because of the presence of bush and shrubs. This bush herbage tends to stay greener later into the season than does the grass.

Generally speaking, values for the blood phosphorus of about 4.5 mg per 100 ml blood are not in any way indicative of phosphorus deficiency, but as many classes of livestock were examined the above figures are by no means exact and should be used only to indicate possible sufficiencies or deficiencies.

It is interesting to note the lack of direct correlation between the phosphorus content of the pasture and that of the animal's blood. In many cases it is suggested, first, that the pasture collected may not have represented a true sample of that eaten by the stock and, second, that the percentage value of phosphorus in the pasture gives no indication of the amount of pasture available of that composition. The data could be confused even further by mobilization of phosphates from the bones. The phosphorus content of the blood is not a reliable index of phosphorus deficiency in the pasture.

Therefore, for comparative purposes, the figures should be taken over a period of time rather than in mere months. If this were done, a slight advantage would be shown in favor of sweet-veld pasture.

The figures do show that neither of the above selected areas can be said to indicate sufficiency throughout the year, although the figures suggest in both cases that during seasons of active growth the pastures probably contain enough phosphorus for the requirements of non-lactating stock.

The crude protein is low at times and can hardly be believed to satisfy the protein requirements of animals at all seasons of the year. Bearing in mind the requirements given in the text, however, for phosphorus, an appreciable increase in the protein content of the pasture occurs with new growth. Sodium (Na) values will also be seen to vary as well but are probably not as greatly affected by season as are protein and phosphorus. Nevertheless, this also indicates the marked superiority of sweet veld over sour veld.

From a purely qualitative point of view, taking chemical composition as the criterion, it therefore seems justified to conclude that sweet veld is better than sour veld under our climatic conditions. It must be born in mind, however, that the animal will probably be able to satisfy its daily need on a smaller area and in shorter time on sour veld than on sweet veld because of the generally denser vegetation.

It is obvious that young animals should require a larger proportion of protein and nutrient elements in their rations because of their extremely rapid growth. The proportion of these nutrients required decreases gradually as the animal becomes older.

It is general practice to calve during spring and to wean during the autumn. From this, and the data in the text, clearly the weaning calf enters into the most difficult period of its life. It is at the period of maximum growth acceleration and thus, for maximum production, nutrients are at their greatest demand. We find, however, that it is taken away from its mother's milk and is put on pastures of deteriorating quality.

It is therefore impossible to expect that the animal will realize its full growth potential; in other words, the calves would be stunted in bone and muscular growth during the winter. The figures for composition do, however, suggest that the calf would not suffer so severe a setback on sweet veld as it would on sour veld. The calf on sour veld would therefore not be expected to have the same bone and muscular growth as that on sweet veld.

It is true that an animal that has gone through a hard period shows tremendous recuperative powers when conditions improve, if it has not suffered too serious a setback. One would therefore expect animals on good sweet veld pasture to reach nearly full development for age during summer, but it is doubted whether the sour-veld calf would make up its more severe setback to the same extent. The animal can use nutrients from the reserves stored in the bones in time of sufficiency. This, however, can only lead to retarded growth of the bone and it is doubted, too, whether the animal can store sufficient nutrients to see it through the winter without suffering adverse effects under our South African sour-veld conditions. Further, it must be remembered that the body can store only little, if any, protein.

Another possibility is that the deficiencies during winter affect the pregnant cow in that she draws on body reserves to nourish the fetus. When conditions improve during spring and summer, she is unable to replace this loss because she will be lactating. The lactation itself might be adversely affected by the drain of pregnancy. Thus the outcome would be a small calf at birth, possibly a slow growth rate to weaning, and a cow which most likely would not come into season because of an upset or imbalance in the body metabolism. Animals born and bred on low pH soil would therefore be expected to have less bone growth and thus have a smaller weight than those grown on a higher pH, all other factors being equal. This is supported by the comparison of Jersey Island type of cows in the United States, Ashton's Research on the Brown Swiss, the Brittany cattle of France and the Zebu types in the Himalayas of India, and also by work conducted at the Mara Experimental Station.

When Europeans moved into Zimbabwe-Rhodesia about 80 years ago there were certain native breeds bred up under naturál selection for their own particular areas. The Matabele cattle were adapted to the sweet-veld areas, where the nutritive value of the grass was high. The grasses here were primarily annuals with relatively high protein value and it was found that the animals were larger than those of the Mashona, who ran theirs in a more sour area with grass of a high fiber and low protein content.

Another example of pH sensitivity is the well-known fact that fish are susceptible to pH changes in their water. The optimum pH is from 6.5 to 6.8; if it drops to 4.5 growth is seriously retarded.

Although the tables given in the text do show area differences, it is felt that little importance can be attached to them for animal growth in different areas. The data are on Frieslands, a dairy breed, and on Hereford bulls; it is thus felt that supplementary feeding, especially for bulls, plays too large a role for the differences to be considered seriously. As pH is not only an internal soil factor but is also affected by environment, it is felt that this difference in growth is due not only to pH, but can be greatly influenced by such ecological factors as temperature, radiation from the sun, altitude, humidity and precipitation.

The common belief among livestock-men that the fertility of the soil in any one country, district, farm, or even any one section of farm, has an effect on the size and ruggedness of the animals that originate there is substantiated.

A rhetorical question: Why, in days when land was cheaper, did farmers summer their stock on sour veld and winter them on sweet veld?

Chapter 8

Breeding Livestock in Unfavorable Environments

A detrimental influence on an animal will come from every environmental factor that differs in the extreme from the same environmental factor in the environment in which a domestic animal had its origin and evolution.

To breed cattle adaptable to an unfavorable environment the breeder must know how each of the fifteen environmental factors in the ecological livestock wheel influences the animal.

As a result of differences in hereditary characteristics the various breeds and even types within a breed react differently to environmental stimuli. The reaction of types of cattle within a breed to external stimuli is intimately associated with anatomical-physiological characteristics which have developed as a result of natural selection.

Knowledge of how an animal reacts to the different meteorological conditions is of value to the cattle breeder as a guide to the selection of cattle possessing those attributes which promote adaptability.

Nutrition as an ecological factor

In the cold and cold-temperate regions the rainfall efficiency is high. Natural pasturage has a dense sward and plant growth is relatively slow. Hence, the quality of the pastures is good; they have high protein value, are relatively low in crude fibre, and have a low heat-increment value. Closed winters (pasturage covered by snow) compel the harvesting of pastures; good-quality hay and silage are made. A uniform feed supply is guaranteed during summer as well as winter.

In the cold-temperate regions of the Southern Hemisphere the nutritional value of the pastures is low. In the semi-arid subtropics the natural pastures form a naturally curing hay of good quality, but the quantity is low. In the humid subtropics, the pasture grasses are high in crude fibre, low in protein, and have high heat-increment values.

In the U.S.A. and Europe the management aspect of livestock production is far superior to anywhere in the Southern Hemisphere. In fact, it is my considered opinion that poor management is an important limiting factor in livestock production in the Southern Hemisphere.

Nutrition adaptability: Body conformation and function

The nutritional status of animals in the Northern Hemisphere is on the average better than that of cattle in the Southern Hemisphere. Management, too, is on the average better than in the Southern Hemisphere.

As a result of ample feed supplies, animals have little trouble maintaining thermal equilibrium. Body conformation is specialized to be functionally efficient.

In the Northern Hemisphere beef cattle are of the digestive type with heavy winter coats. Dairy cattle are of the respiratory type, mostly smooth-coated. Cross-breeding in the cold-temperate regions of the Northern Hemisphere should be done with *Bos taurus* × *Bos taurus* types. In the Southern Hemisphere, because the winters are not "closed" (snow covered to require hay feeding), cattle suffer from a severe winter nutritional depression. In the semi-arid subtropics fairly large cattle can be maintained. In the humid subtropics, cattle will be small-framed. *Bos indicus* × *Bos taurus* cross cattle give best results in the hotter areas of both the Northern and Southern Hemispheres.

Atmospheric temperature as an ecological factor

As the Northern Hemisphere is four-fifths land and one-fifth water and the latent heat value of land mass is low, tremendous fluctuations between summer and winter temperatures occur. In many areas the fluctuation between the summer and winter isotherm is 122°F. In the Southern Hemisphere the fluctuation between the summer and winter isotherm is seldom over 68°F. The Southern Hemisphere is four-fifths ocean and one-fifth land, hence the lower fluctuation between summer and winter temperatures.

In the Northern Hemisphere much livestock production takes place between 45° and 60° North Latitude. In the Southern Hemisphere little production takes place south of 45° South Latitude.

Atmospheric temperature adaptability

Due to the tremendous fluctuation in temperature between seasons, the cattle which evolved in the far north, especially in windy areas, have heavy winter coats and relatively smooth summer coats. In the Northern Hemisphere it is essential that livestock have heavy winter coats to retain thermal equilibrium. In the areas north of 35° North Latitude, only *Bos taurus* × *Bos taurus* crossbred cattle are recommended. If the European dual purpose or beef cattle are used for crossbreeding purposes, only breeds that do not have too long gestation periods should be used to prevent dystocia (difficult calving) problems.

In the beef-producing areas closer to the equator, short-haired beef breeds should be crossed with the British and European beef breeds. Between the Tropics of Cancer and Capricorn, at altitudes below 3,300 feet, only tropical-adapted breeds of cattle should be used for crossbreeding with the European and British beef breeds. Up-grading to the *Bos taurus* types is not possible where annual isotherms are above 70°F.

Light (photoperiod) as an ecological factor

In the cattle-raising areas of the Northern Hemisphere the difference between summer and winter daylight (photoperiod), which is the most important stimulus to hair shedding, is about 12-16 hours. In the Southern Hemisphere, in areas where livestock are kept, the difference between the summer and winter photoperiods seldom exceeds 4-6 hours, except in southern South America. The difference in the summer and winter photoperiods is the strongest impulse involved in hair growth and hair shedding. Temperature fluctuations are also involved but to a minor degree.

Light (photoperiod) adaptability

In the Northern Hemisphere only cattle that can grow heavy winter coats should be crossed for increased beef production. Hair color and pigment in the hide are important. Lack of pigment in the hide could cause serious trouble as a result of snowburn in spring.

In the Southern Hemisphere smooth-coated breeds (especially *Bos indicus*) should be used in crossbreeding with the European and British breeds. Early hair-shedding *Bos taurus* types give greater hybrid vigor (additive gene effect) for adaptability than randomly selected *Bos taurus* cattle.

Radiation as an ecological factor

The ultra-violet and infra-red radiation in the Southern Hemisphere is more intense than in the Northern Hemisphere because the sun is appreciably closer to the earth (3.1 million miles) during the southern summer than during the northern summer.

At high altitudes the ultra-violet impingement is intense. At low altitudes, especially between the Tropics of Cancer and Capricorn, the infra-red radiation is intense. During winter and spring in the Northern Hemisphere, ultra-violet radiation is intense due to reflection of diffused light from the snow covered ground.

Radiation adaptability

In the Southern Hemisphere, especially in the area between the Equator and the Tropic of Capricorn, smooth-coated cattle with a high sweat-gland count (*Bos indicus*) should be crossed with smooth-coated *Bos taurus* types. In the Northern Hemisphere, south of the Tropic of Cancer, Brahman and Santa Gertrudis types should be crossed with *Bos taurus* types. In every instance, lack of pigment in the hide of the breeds used in crossbreeding is a hazard. Cattle, such as the Brown Swiss, that are adapted to a relatively cold high-altitude environment with intense ultra-violet radiation adapt readily to the tropics and are a good dual-purpose breed to cross with Brahman and Hereford in a triple cross.

Altitude as an ecological factor

At high altitudes—5,000 feet above sea level—ultra-violet impingment is intense. In most areas of high altitude where the geologic formation is of igneous origin, soil pH is low. In the regions where the geologic formation is of sedimentary origin, the soil pH is higher, pH 6.5 to 7.5.

Altitude adaptability

Where altitude is high the air is rarefied and ultra-violet impingement is intense. In such areas cattle should have a well-pigmented hide and hair color should preferably be full-color brown or black, e.g. Brown Swiss color. Large cattle can be bred in areas with high soil pH at high altitude. In the regions with low pH cattle will be small. At high altitudes it seems that crossbreeding should be based on using full-colored brown or black adapted types, e.g. Aberdeen Angus, Galloway, Brown Swiss and Simmental.

Barometric pressure as an ecological factor

It is not clear how changes in barometric pressure influence livestock, but they may have a direct influence on the water-electrolyte balance.

Barometric pressure adaptability

No suggestions are made with regard to cross-breeding in areas of different barometric pressure.

Wind as an ecological factor

Certain regions of the world are more windy than others. Wind has a direct bearing on the evaporative loss of energy from the hide. Wind stimulates hair growth, an adaptability phenomenon.

Wind adaptability

In the windy regions of the world *Bos taurus* types of cattle, especially the heavy-coated breeds, should be crossed, e.g. Galloway x Shorthorn. The short-haired breeds such as *Bos indicus* types should not be used. Smooth-coatedness is a dominant characteristic.

Disease as an ecological factor

Many endemic diseases have an ecological etiology, such as tick-born diseases, diseases carried by mosquitoes, and stinging flies. Cattle indigenous to such areas often have a natural immunity to these diseases. Most of these diseases are location-specific.

Disease adaptability

In those parts where there is a high incidence of disease-carrying insects, such as ticks, smooth-coated *Bos indicus* types of cattle (cattle that are tick-repellent) should be crossed with smooth-coated European and British beef breeds. Crossing of *Bos taurus* × *Bos taurus* types in the humid subtropics will produce little hybrid vigor and mortality will be high.

Ectoparasites as an ecological factor

The incidence of external parasites such as ticks, stinging flies and mosquitoes is controlled primarily by climatological conditions such as high atmospheric temperatures or humidity. There is a marked difference in the incidence of tick infestation among breeds and types of cattle. The *Bos indicus* types with short hair and high sweat-gland counts are much more tick- and fly-repellent than the *Bos taurus* types.

Ectoparasites adaptability

The *Bos indicus* types adapted to the humid subtropics and tropics are often tick-repellent. They have short, non-medullated hair, a high sweat-gland count per unit area, and high hide vascularity. Cows of these breeds can be crossed with bulls of the European and British beef breeds. It is essential that the mother cows be indigenous to the region in which crossbreeding takes place. In the tropics and subtropics the mortality rate of crossbred calves by European and British beef bulls on *Bos indicus* cows is much lower than in the reciprocal cross. *Bos taurus* × *Bos taurus* crossbreeds in such an unfavorable environment will not give hybrid vigor and the mortality rate is high.

Endoparasites as an ecological factor

In many regions of the world, especially in the Southern Hemisphere, the incidence of internal parasitism (worms, liverfluke, cysticercosis, etc.) is high. It is often a result of bad management at drinking troughs; it is also often a problem of intensification.

Endoparasites adaptability

In the developing countries several of the indigenous breeds have developed a certain degree of resistance and tolerance to the endemic internal parasites. All these are probably *Bos indicus* types. *Bos indicus* types should be crossed in these areas to obtain a certain degree of hybrid vigor and tolerance to parasites.

Soil pH as an ecological factor

Soil pH has a marked influence on the availability of nitrogen, calcium and phosphorus to plants; hence, indirectly to animals. Where the soil pH is between 6.5 and 7.5 the nitrogen in the soil is assimilated by the plants; pastures grown in such areas are relatively high in protein value. Lucerne (alfalfa), clovers and leguminous plants flourish in such areas. These plants are also relatively high in Ca and P_2O_5. In the semi-arid subtropical areas, where the soil pH is between 6.5 and 7.5, the pastures form a natural-curing hay during winter. Where the soil pH is low, below 6.0 or 5.5, the pastures are low in protein value and in available calcium and phosphorus. In areas of the humid subtropics and tropics, where the soil pH is less than 5.5, the natural pasturage is low in protein, calcium and phosphorus and high in crude fiber. Also, due to fast lignification it has a high heat-increment value.

Soil pH adaptability

The soil pH is decisive regarding the size and type of cattle that can be maintained in any region. In the high pH areas, such as the Nièvre district in France, large cattle can be produced. In all, the temperate areas of the world with a fairly good rainfall, 25 inches to 30 inches per annum, and a pH of 6.5 - 7.5 can produce large cattle, e.g. Charolais, Simmental, Brown Swiss and Hereford. These breeds can be crossed to produce hybrid vigor in the temperate zones. In the semi-arid subtropics, with a soil pH of 6.5 - 7.5, large

Bos indicus types, such as the Afrikaner or American Brahman, can be crossed with the British and European beef breeds to produce large crossbred cattle. In the humid subtropics with a low soil pH, only small cattle can be produced: only *Bos indicus* types should be crossed because, apart from lack of protein, calcium and phosphorus for muscle and bone formation, heat dissipation is also a real problem.

Soil fertility as an ecological factor

Soil fertility itself has no direct influence on the production of livestock, but indirectly it does have a marked influence on the quantity and quality of feed produced. In the cold temperate areas where soil fertility is high, an abundance of feed high in protein and available calcium and phosphorus is produced. In the humid subtropics and tropics where soil fertility is high, an abundance of roughage high in crude fiber is produced.

Soil fertility adaptability

In the cold temperate regions where soil fertility is high, large cattle that are efficient feed utilizers can be crossed, e.g. Charolais, Simmental, South Devon, and the larger British beef breeds. It is obvious that the largest cattle in the world are found in the most fertile areas and valleys of Europe. Crossbreeding of some of these large breeds with British beef breeds is not recommended. The long gestation periods of some breeds result in late calving, dystocia, and large calves at birth; often a breeding season is skipped every fourth year. In the humid subtropics only small *Bos indicus* types should be crossed.

Rainfall and humidity as ecological factors

Rainfall and humidity influence pasture production and directly influence the incidence of ticks and other insects and parasites. They also have a direct influence on available minerals in the soil and on the soil pH.

Rainfall and humidity adaptability

Only cattle which are adapted to the particular rainfall and humidity conditions should be crossed.

Pollution and stench as ecological factors

Pollution and stench are problems of intensive livestock production, large feedlots, and the accumulation of animal waste.

Pollution and stench adaptability

Stress causes foundering in cattle in feedlots and under intensive production. Cattle of docile temperament are needed to avoid this problem. Many of the *Bos indicus* crossbred types founder readily under intensive feedlot conditions. Only temperamentally docile *Bos indicus* types are recommended for cross-breeding.

A Summary

The crossbreeding policy advocated for any area is dictated by the limiting factors of the environment. Body conformation is correlated with adaptability; and body conformation and function are closely correlated. Breeding and crossbreeding for adaptability prevent the losses and hazards encountered in natural selection. It is clear, however, environment is the vital factor that determines the production potential of any region and again determines which types and breeds can be most profitably crossed to produce maximum functional efficiency.

The four factors—environment, adaptability, body conformation and function—are closely linked and inseparable.

The whole concept of breeding livestock adaptable to a specific environment is based on ecological and genetic principles.

The probability of survival and functional efficiency of livestock increases with the degree to which they adjust themselves harmoniously to their total environment.

This principle is basic to the concept of the balance of nature and forms the basis of all agricultural production in the optimum utilization of natural resources.

Chapter 9

Livestock Philosophy

> Philosophy is the art and law of life and it teaches us what to do in all cases and like good marksmen to hit the white at any distance.
>
> Seneca

> True philosophy is that which makes us to ourselves and to all about us better; and at the same time, more content, patient, calm, and more ready for all decent and pure enjoyment.
>
> Lavater

The *Shorter Oxford English Dictionary* defines philosophy (in the original and widest sense) as the love, study, or pursuit of wisdom, or of knowledge of things and their causes, whether theoretical or practical.

On two previous occasions I wrote on Livestock Philosophy: first as a reprint in the University of Pretoria New Series of Publications No. 5, 1958, and again as a chapter in the book *Wortham Lectures in Animal Science*, published by the Texas Agricultural Experiment Station, Texas A. & M. University, College Station, Texas (1965).

Since that time I have travelled widely and seen livestock production in developed and developing countries in both the Northern and Southern Hemispheres. As a result of my early research work on livestock climatology and ecology, I have come to the conclusion that total environment plays a determining role in the total expression of the genetic make-up of man and beast.

During the earlier of these writings on livestock philosophy, more than two decades ago, the philosophy was based on Psalms 8:4-8 (King James Version):

> What is man, that thou art mindful of him? And the son of man, that thou visitest him? For thou hast made him a little lower than the angels, and hast crowned him with glory and honour. Thou madest him to have dominion over the works of thy hands; thou hast put all things under his feet: All sheep and oxen, yea, and the beasts of the field; the fowl of the air, and the fish of the sea, and whatsoever passeth through the paths of the seas.

On all who know these verses and practice livestock husbandry, these words place a tremendous responsibility, and the phrase "They are put under man's feet" implies that it is the duty of Christians to improve that which has been given them; if they fail to do so they are failing in their responsibilities. Since the writing of the 1958 and 1965 livestock philosophies, I have decided to widen and deepen my whole approach to livestock production. I found it necessary to take the biblical approach to livestock philosophy much further back in the history of the Bible; my present philosophy is based on Genesis 1:9-12 (King James Version) which refers to the third day of creation:

> And God said, Let the waters under the heaven be gathered together unto one place, and let the dry land appear: and it was so. And God called the dry land Earth; and the gathering together of the waters called He Seas: and God saw that it was good. And God said, Let the earth bring forth grass, the herb yielding seed, and the fruit tree yielding fruit after his kind, whose seed is in itself, upon the earth: and it was so. And the earth brought forth grass, and herb yielding seed after his kind, and the tree yielding fruit, whose seed was in itself, after his kind: and God saw that it was good.

On the third day of creation, four-fifths of the land mass of the earth was put in the Northern Hemisphere and only one-fifth in the Southern Hemisphere. As a result of the surface areas of the oceans being appreciably larger than those of the land and because the latent heat value of water is appreciably higher than that of the land, it is obvious that fluctuations in the temperature on land are much greater in the Northern Hemisphere than in the Southern Hemisphere. (See Figure 11.1, color section.)

It came about that on the third day of creation the major climatic

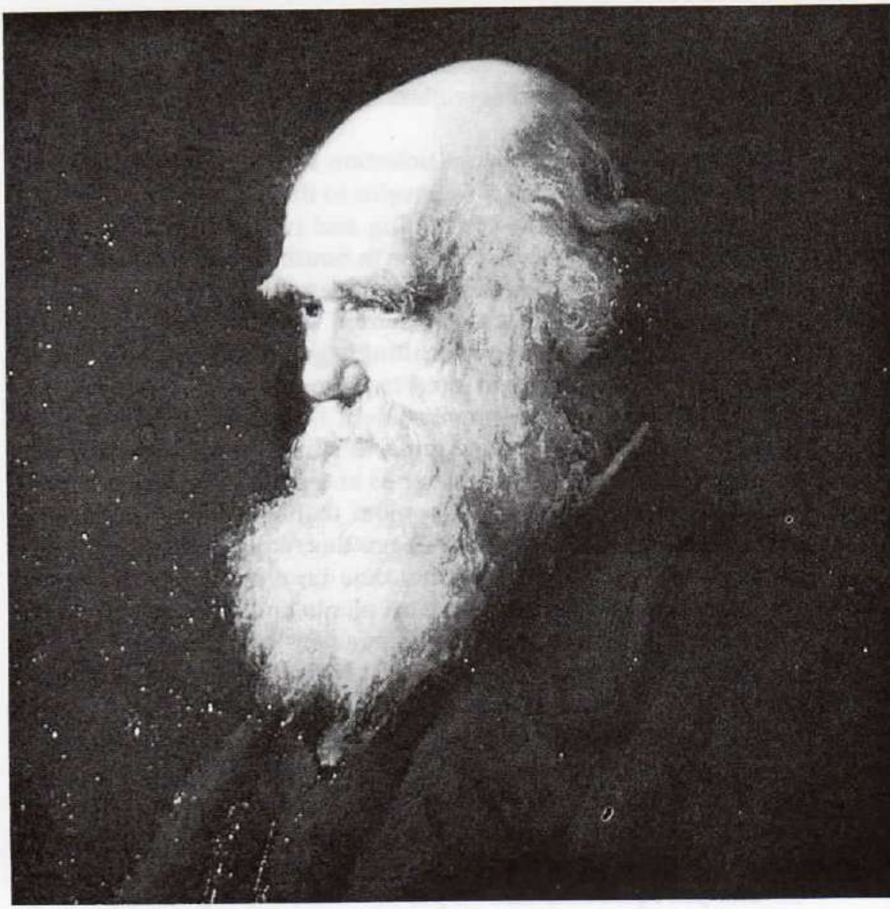


Figure 9.1 Charles Robert Darwin, 1809-1892.

zones of the earth were laid down; we know the four major zones as Scorching, Keen, Raw and Muggy. (See Figure 2.2.) The total climate of each zone determines which plants and animals are best adapted to that climatic zone.

As a young student and animal scientist, I was profoundly influenced by Darwin's writings, especially his books *Origin of Species, The Descent of Man,* and *Variation of Animals and Plants.* During the early 1950s I had the good fortune to visit Darwin's home in Cambridge, again a great inspiration.

Darwin's world came in through his eyes; he appreciated; he interpreted and retained what he saw; he philosophized on adaptation; and he shared his world with us who came after him. It is essential for every animal science research worker to try to equal Darwin's powers of observation. The stimuli to improve an animal scientist's powers of observation are knowledge, curiosity and enthusiasm in his work.

Darwin's concept of natural selection as a base for breeding for adaptability in animals is of little value to the livestock breeder. It is too expensive, it is time-consuming and ruthless, and costly.

At the Messina Research Station in South Africa I tried to breed a tropically adapted Shorthorn herd by natural selection; within 30 years this herd, which was started with 30 good Shorthorn females and to which an outstandingly good bull was introduced every two years, had been bred to extinction.

Darwin's idea that the environment had a direct influence on plant and animal life was adapted to suit the climatological and ecological research work in progress at the Messina Research Station. Since Darwin's days, now more than a hundred years ago, sophisticated instruments have been developed to enable the research worker to obtain accurate data on environmental factors that have a profound influence on plants and animals.

Sophisticated instruments and apparatus have been developed to measure the reactions of animals, physiologically, endocrinologically and in other aspects such as growth, to determine how weather and climate influence livestock.

During the war years (1939-1945) sophisticated meteorological instruments were installed at Messina Research Station, instruments which, apart from measuring maximum and minimum atmospheric temperatures, measured solar energy in gram-calories per square centimeter per minute; a cooling ball measured radiation from the nude body; an ultra-violet dosimeter; a wind recorder; a Campbell-Stokes sunshine recorder; a black-bulb thermometer; and a Macbeth light-intensity meter which measured tropical light in foot-candle units.

The importance of total environment on the vegetation, and hence on animals in a particular environment, made me realize how important the interaction between total environment and total genetic make-up was in giving expression to the total morphology and the physiological reactions of an organism.

A thorough knowledge of the climate and weather is essential if a research worker is engaged on climatological and ecological research work.

As a result of being engaged in climatological and ecological research work since the end of 1937, I became aware of the im-

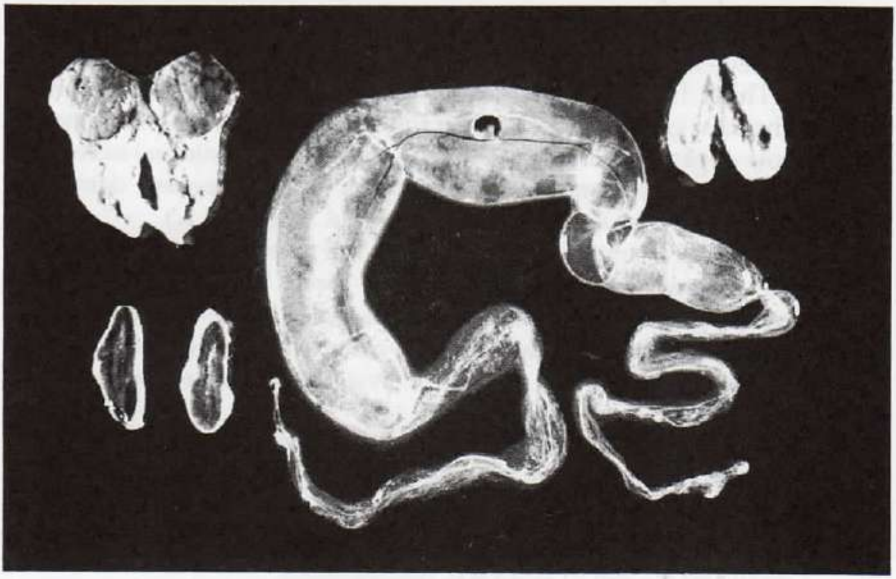


Figure 9.2 The developing fetus 32 days after conception.

portance of knowing how environmental factors cause certain reactions in the bovine.

During the early 1950s I formulated my first ecological livestock production wheel. Originally (1950-1965) there were 13 environmental spokes in the ecological livestock wheel, namely Nutrition, Atmospheric Temperature, Light, Radiation, Altitude, Barometric Pressure, Wind, Disease, Ectoparasites, Endoparasites, Soil pH, Soil Fertility, and Rainfall and Humidity. Later two more man-made environmental hazards to man and beast were added: Supersonic Sound-Noise, and Pollution-Stench. (See Figure 2.1.)

All these environmental factors can be measured with modern sophisticated instruments.

Once the animal scientist knows his environment, the next step in his livestock philosophy program is to correlate the influence of environmental factors with the animal's reactions.

And the next step then is to master the genetic principles of animal breeding. At the moment the sperm fuses with the ovum, the complete genetic make-up of the animal-to-be is laid down. At the moment of conception it is determined what breed of animal is to develop from the fertilized ovum. At that moment the complete make-up of the animal's endocrine and central nervous systems is laid down. (See Figure 3.1.)

Thirty-two hours after conception the fertilized ovum is in the eight-cell stage of embryonic development, containing the complete genetic make-up of the future animal.

Thirty-two days later this fertilized ovum is a developing fetus. The total genetic expression of this fetus in the pregnant animal is now dependent on the interaction among all the internal as well as external environmental factors acting on the pregnant dam and hence directly on the developing fetus. (Figure 9.2.)

When the fetus has developed to full term and is born, each of the 15 environmental factors has a direct influence on the developing new-born animals. Each of the 15 environmental factors has a target organ on which it has a direct influence; it may be the whole animal, or the endocrine system, or the central nervous system.

If, by research, the animal scientist can breed livestock that does not react drastically to adverse environmental factors he has succeeded in breeding for adaptability.

The adaptable animal is one that is in harmony with its environment, an animal in complete homeostasis.

Once the animal scientist or livestock breeder has succeeded in breeding adaptable livestock, he can bring about a situation of stability of soil, economic livestock production, low mortality and longevity. Then it is possible to select for high fertility. (Figure 9.3.)

If an animal is not adapted to a specific environment, it will suffer from chronic malnutrition, degeneration, lowered fertility and increased risk of mortality. If unimproved breeds of livestock are brought into an environment that can maintain better livestock, a situation is created that causes uneconomic feed utilization, cash-cropping becomes necessary and the ultimate result is soil erosion and total deterioration of the environment.

The keeping of livestock that are in harmony with the environment in which they are maintained brings about maximum utilization of the natural resources.

The next step in livestock philosophy is to select from the adaptable cattle those that are highly fertile. The principle of selecting livestock for functional efficiency is based on a sound knowledge of animal physiology and endocrinology. (See Figure 3.3.)

This concept of selecting livestock for functional efficiency has taken the antiquated, empirical ideas of livestock-judging out of the doldrums of black magic and witchcraft into an exact science. The judging of livestock for functional efficiency requires sharp observation and exact interpretation of the animal scientist's knowledge of physiology and endocrinology and how these prin-

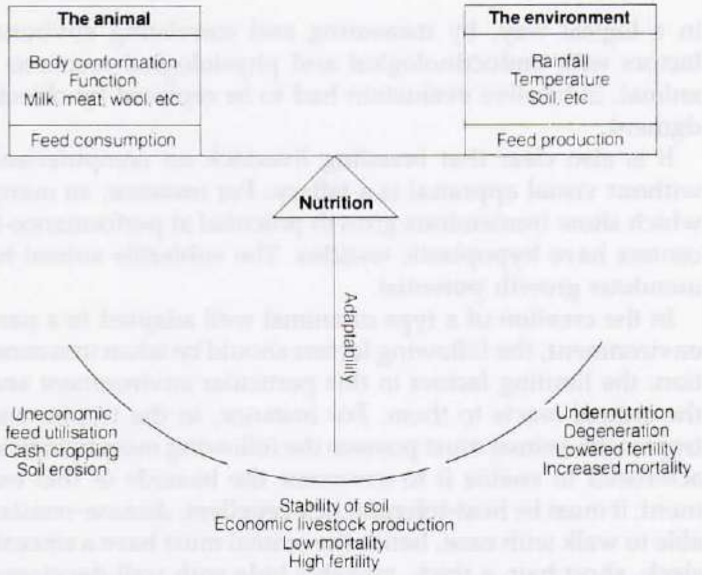


Figure 9.3 Balance between the animal and its environment. The pivot on which this balance rests is nutrition. Its sensitivity is a function of the adaptability of the animal to a particular environment. The success of animal production depends on the management of the interaction between animal breeding and feeding.

ciples influence skeletal growth, the hair and hide, muscular development, fat deposits on the body and animal behavior—in males, females and neuters.

The principles of selecting livestock for functional efficiency were adopted by the American Hereford Breeders Association. This breed society's standards of excellence have been completely changed from the overfatsubfertile types to the highly fertile types, in which over-fatness has made way for well-muscled livestock with a high cutability rate of carcass. (See Figure 3.29.)

Fortunately, several breeds of livestock in the U. S. A. are following the concept of selecting for functional efficiency.

All the factors so far involved in livestock philosophy—knowing the environment, knowing the principles of Darwin's natural selection and his keen observation, a sound knowledge of animal breeding and genetics, the selection for adaptability, and finally the selecting of livestock for functional efficiency—have been combined in an effort to breed an animal especially adapted to South African conditions.

All the principles of my livestock philosophy have been applied in a logical way, by measuring and correlating environmental factors with endocrinological and physiological reactions of the animal. Subjective evaluation had to be replaced by objective judgment.

It is also clear that breeding livestock on computerized data without visual appraisal is a fallacy. For instance, so many bulls which show tremendous growth potential at performance-testing centers have hypoplastic testicles. The subfertile animal has tremendous growth potential.

In the creation of a type of animal well adapted to a particular environment, the following factors should be taken into consideration: the limiting factors in this particular environment and how the animal reacts to them. For instance, in the tropics and subtropics the animal must possess the following morphological characteristics to enable it to overcome the hazards of that environment: it must be heat-tolerant, tick-repellent, disease-resistant and able to walk with ease, hence the animal must have a smooth coat, sleek, short hair, a thick, movable hide with well-developed subcutaneous muscling, high vascularity of the hide, and four sound legs with dark hooves.

These attributes of the adapted animal have been determined by measurement and correlation.

It is on these principles that the breed-creation work at Mara Research Station, which resulted in the creation of the Bonsmara breed of cattle, was based.

As a result of having no vested interest in cattle, it was possible to eradicate ruthlessly all heritable defects that cropped up in this work. (See Chapter 5)

Once the breed or type of cattle was established it was essential that all adaptability phenomena and economic traits be measured.

Many thousands of Bonsmara type cattle took the place of cattle that were not adapted to the tropics and subtropics.

During the late 1960's, I developed a diagram which was called the periodic chart of animal science. The whole object of this exercise was to measure not only adaptability and functional efficiency but also efficiency of feed utilization. (Figure 9.4.)

To enable the livestock breeder to do this, input measurements must be taken: Input, that is, feed-intake of protein, carbohydrates, fat, vitamins, minerals and water; the intake of a complete ration.

The total feed intake goes through the darkest chemistry laboratory in the world—the digestive tract—and then through the proc-

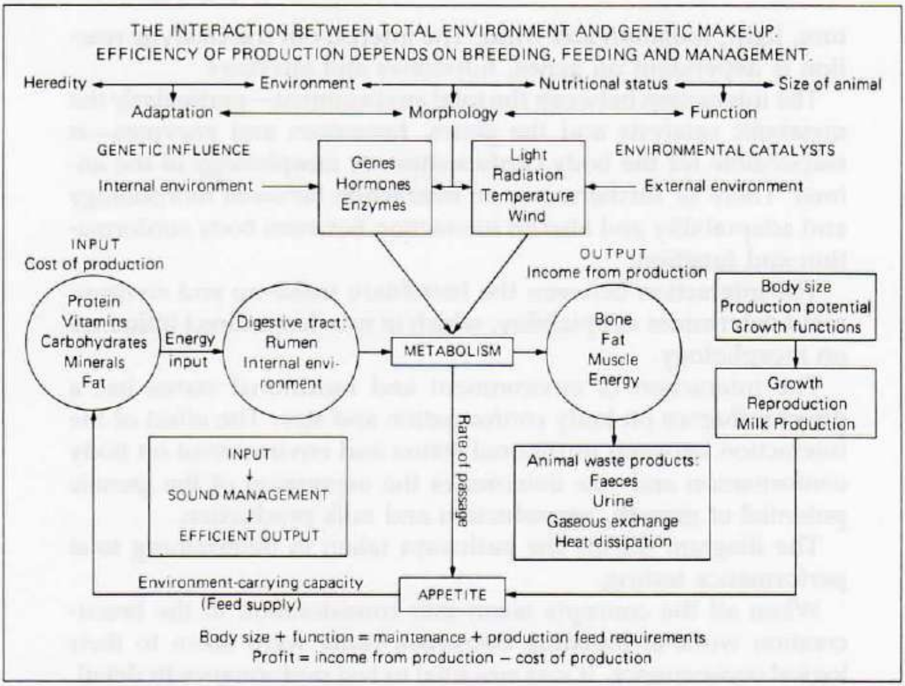


Figure 9.4 Factors affecting body size and production (function).

ess of metabolism to produce the animal end-products: bone, fat, muscle and energy; and the waste products: feces, urine, dissipated heat and gases.

The quantity of end-products of bone, muscle and fat determines the size of the animal. The production potential of the animal is a growth function and the amount produced is dependent on size. Size, however, is a function of time and feed intake.

Growth-weight increase *per se*, reproduction, and milk production are the economic factors important to man. These three growth factors determine the animal's appetite. Whether this appetite will be satisfied depends on the carrying capacity of the environment and the amount of feed available. Hence it is obvious that all production potentials of animals are dependent on the suitability of the environment to enable the animal to be in a state of homeostasis and have an abundant feed supply. (See Figure 2.4.)

The efficiency of feed conversion into end-products valuable to man is dependent on efficiency of the animal's metabolism. The catalysts that have a direct influence on this efficiency are temperature, light, radiation and wind. The intensity of the catalytic reaction is dependent on genes, hormones and enzymes.

The interaction between the total environment—particularly the metabolic catalysts and the genes, hormones and enzymes—is responsible for the body conformation or morphology of the animal. There is, furthermore, an interaction between morphology and adaptability and also an interaction between body conformation and function.

The interaction between the hereditary make-up and environment determines adaptability, which in turn has a direct influence on morphology.

The interaction of environment and nutritional status has a direct influence on body conformation and size. The effect of the interaction between nutritional status and environment on body conformation and size determines the expression of the genetic potential of growth, reproduction and milk production.

The diagram directs the pathways taken in determining total performance testing.

When all the concepts taken into consideration in the breed-creation work of breeding Bonsmara cattle were taken to their logical consequence, it was essential to test performance in detail. The cattle had to be bred to be adaptable, highly fertile, functionally efficient and to be efficient converters of feed into the end-products valuable to man. Every concept in this breed creation work was based on the principle **Man must measure**. (See Figure 5.2.)

This approach to livestock production is based on research. Research is the earnest, purposeful, persistent, intelligently directed effort to gain new knowledge of a selected subject; the spirit of research is devotion to truth and an insistent longing for better understanding.

I compare my research work to climbing a mountain. This concept is illustrated by a section of the Rocky Mountains beautifully reflected in a mirror-clear lake near Lake Waterton in Canada.

The mountaineer climbing the mountain has one ideal in mind: to reach the highest peak. So often he comes up against an obstacle, a ledge which he cannot conquer, then there is only one thing to do and that is to climb down, move away from the mountain, and use his field-glasses to observe the mountain from afar. This enables him to get an objective view of the mountain and gives him an idea how to approach the mountain. This is objectivity in climbing a mountain. Objectivity in research is essential to broaden one's view of the research problem; it enables the researcher to be open-minded.

When approaching the mountain from afar the mountaineer is again struck by the beautiful reflection of the mountain in the mirror-smooth lake. Reflection in research means meditation, contemplation, thinking, reading, deep consideration and discussion of research problems.

How does one get the mountain to reflect so beautifully in the mirror-surfaced lake without any blurred edges? By focusing, and this must be perfect. Focusing in photography means to have the object clearly defined in the viewer so that the image produced by the lens is clear and there are no blurred edges.

Focusing in research means converging all energy on a point where ignition is to take place. The research worker must put all his energy with enthusiasm and fire into his clearly defined research problem within the limits of the image on which he has focused his lens.

The mountaineer now—after having considered every problem of mastering the mountain, that is, by an objective approach, by reflection and by having the problem clearly defined—climbs the mountain and reaches the summit to plant his flag on top. If he is the first one to plant his flag on top, he senses a feeling of sheer exhilaration. Unfortunately, more often than not, another mountaineer has reached the top before him; that does not matter because he might have found a better way to the top, and in any case on having reached the summit he finds that his horizons have widened.

Research to the researcher is exactly the same as climbing the mountain is to the mountaineer. The three essentials are objectivity, reflection in its broadest sense and focusing, concentrating all energy on the research problem. Solving the research problems enables the researcher to reach the top, it widens his horizons and his knowledge becomes wisdom.

More than four decades of animal science endeavor has given me my global approach to livestock production. The object is, if possible, to improve livestock production from North to South and from East to West in an effort to produce more red meat for a hungry world (Figure 9.5).

It is my considered opinion that some breed societies have fixed ideas about what the ideal type of livestock of their particular breed is. They have made their breed standards so concrete that no modification can take place. They have reached a point where they

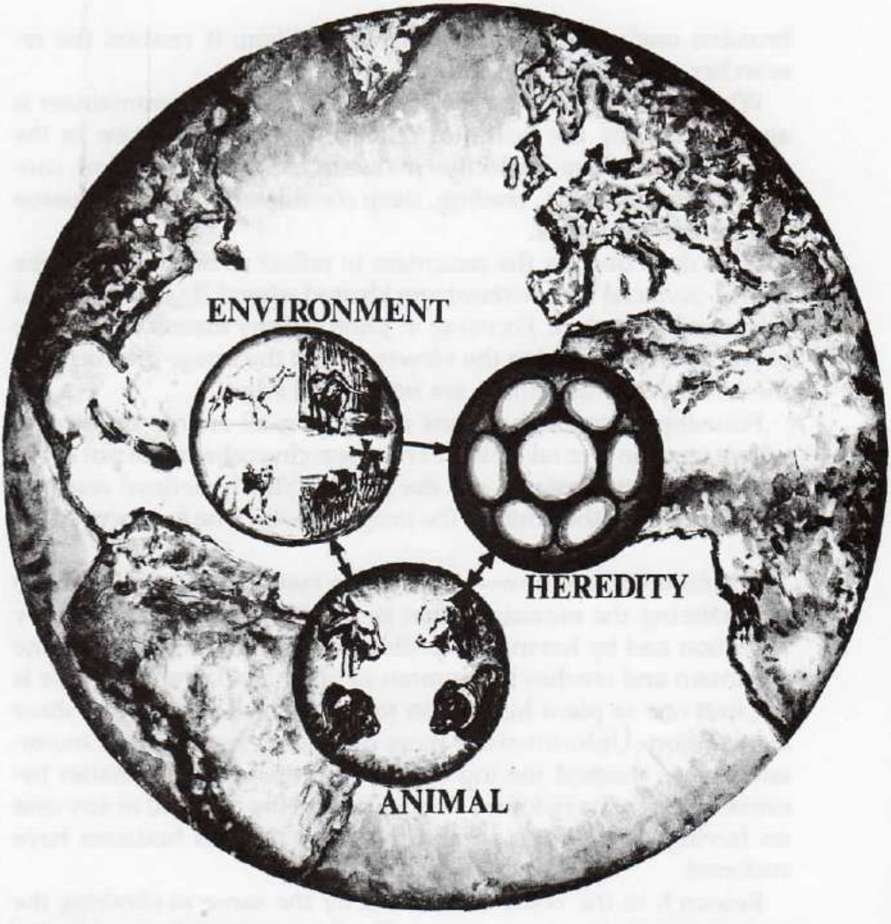


Figure 9.5 The interaction between total environment, total genetic make-up and the animal.

cannot select desirable variants; hence they cannot improve their cattle. These fixed idols of clay or brass are nothing but the prejudiced visions of men who really worship an image that has not been measured by performance testing nor by functional efficiency. Prejudice and conservatism are the main obstacles which in many instances prevent the improvement and progress of certain breeds.

Ignorance is another factor detrimental to the improvement and welfare of breeds and breed societies. If breed societies have an inspection system of their cattle by livestock inspectors, it is essential that these livestock inspectors be well acquainted with modern trends in animal research and have a thorough knowledge of livestock production physiology and of functional anatomy. They must be well read and must regularly associate with scientists in other fields of animal production to enable them to judge animals on a logical, objective and functional basis. The breed societies' inspectors should be men of the highest integrity and should not be peddlers of livestock for certain breeders on a commission basis. An ignorant livestock inspector or cattleman will not make the progress in livestock breeding that is essential to keep abreast of time.

Superstition also plays a role in hampering progress in livestock production and it is why so many of the less educated peoples cannot produce functionally efficient livestock.

Man is the most important factor in efficient livestock production. Man can, within limits, modify certain external environmental factors and by breeding, selection, feeding and **management** modify a particular environment to some extent to produce highly-productive and well-adapted cattle for a particular environment.

If man's approach changes due to certain economic factors and he loses the incentive to breed better livestock, the livestock improvement program will degenerate.

So many cattlemen have completely lost the incentive to produce better livestock because they need not show a profit on their livestock enterprises; they have made money in other fields of commerce and industry.

Because these men have gone into livestock production for a token of social and financial status, many production sales which started off as honest endeavors to distribute and disseminate superior germ plasm have degenerated into social events, galas where materialistic power is demonstrated and where status and friendship are traded.

The three essentials for the cattleman who honestly desires to buy good cattle at a production sale are the following: good health to have a healthy optimism; a thorough knowledge of production physiology and functional anatomy to enable him to assess efficiently the animals to be sold; and absolute sobriety.

The object of a production sale should be to sell at a fair price superior genetic material in an honest endeavor to improve the livestock industry of a country.

My livestock philosophy

To sum up, my livestock philosophy is based on:

1. **The world map**, the difference in the land masses of the Northern and Southern Hemispheres and how this influences world climate. The first essential for the animal scientist in any region is to know the climate and topography of his farm well.
2. **Darwin's approach** to natural selection and how this had to be modified to suit modern livestock selection criteria to breed for adaptability.
3. **The livestock ecology wheel** with its 15 measurable environmental factors which can be correlated with measurable physiological and endocrine reactions and how these correlations influence morphology.
4. **The genetic concept** that emphasizes the interaction of the total environment on the total genetic make-up of the animal.
5. **The interaction** between the environment and the genetic make-up of the animal leads, through competent selection, to the breeding of adaptable livestock.

   A thorough knowledge of environment, applied animal breeding and sound selection criteria enable the breeder to breed a "tailor-made" animal for any environment.
6. **Adapted animals** are in harmony with their environment and this brings about optimal utilization of natural resources.
7. Once adaptable animals are bred, **selection pressure** can be applied in breeding livestock that are highly fertile.

   In this context, a valuable aid to the livestock breeder is a good knowledge of production physiology, endocrinology and functional anatomy. Such knowledge enables the breeder to select animals on a basis of functional efficiency.
8. This process of selecting livestock for **functional efficiency** has changed the standards of excellence of several breeds.
9. Once animals are bred that are adaptable and functionally efficient these animals have to be **tested for performance and progeny**. To make performance testing meaningful a thorough knowledge of livestock nutrition is essential. This concept gave rise to the drawing of the diagram I called my "periodic chart of animal science."

10. These philosophical ideas enabled me to change the livestock produced in the subtropics and tropics from so many tropical degenerates into well-adapted, **functionally efficient livestock**.
11. Many of these livestock-production problems have been solved by **research.** There is an analogy between research and climbing a mountain.
12. All the research and philosophical concepts on livestock production and teaching ideals and wide travelling over a period of more than four decades have been fused together to give me a **global approach** to livestock production.

Chapter 10

Tropical and Subtropical Livestock Production

The developing countries of the world, situated mainly in the tropical and subtropical regions of the world, have 74 percent of the world's manpower. Of the world's arable land, 58 percent is situated in these areas. They also possess 70 percent of the world's cattle population, 63 percent of the world's sheep population and 60 percent of the world's pigs.

With these dominant natural resources at their disposal, these areas produce only 21 percent of the world's milk, 34 percent of the world's meat, 50 percent of the world's mutton and 30 percent of the world's pork.

In the developed countries—the countries with a temperate or cold-temperate climate—the milk production per 250 acres is 37,070 pounds, whereas it is only 5,379 pounds in the developing countries. Likewise, the meat production in the developed countries is 6,043 pounds per 250 acres against only 2,508 pounds per 250 acres in the developing countries. As a result of the population density in these tropical and subtropical regions and their relatively low production of animal products, it is no wonder that malnutrition and famine take on catastrophic proportions.

The *per capita* consumption of meat in the developed countries is 119 pounds, against only 24 pounds *per capita* in the developing countries. The milk consumption is 708 pounds against 51 pounds *per capita* for the developed and developing countries, respectively.

The object of this chapter is to try to indicate in a logical and rational way why animal production in the developing subtropical countries is so low.

Many years ago I developed my livestock ecology wheel (see Figure 2.1) which demonstrates that man is the axle on which everything in the animal production process centers. The lubricant that enables the wheel to rotate freely around the axle is management. The smoothness of rotation depends on the balance of the wheel, hence each spoke must be equidistant from the rim to the hub. In other words, to establish forward movement or progress in the process of livestock production the domestic animal must be in harmony with its total environment.

Let us determine by logic and reasoning why the production of milk and red meat in the tropics and subtropics is so low.

Let us start with the axle of the wheel.

A well-known, but not fully appreciated fact, is that livestock management in the subtropical and tropical countries is poor.

It is well known that the tropics have an enervating influence on man. As early as the year 1620, R. Burton made the following statement in his **Anatomy of Melancholy:**

> Whence proceed that variety of manners and a distinct character as it were to several nations? Some are wise, subtile, witty; others dull, heavy; some bigger, some little, some soft, some hardy, barbarous, civil, black, dun and white, is it from the aire, or from the soyle, or influence of starres or some other cause? Why doth Africa breed so many venomous beasts, Ireland none?

Huntington believes that man works efficiently and is in the best health at such times and in those areas where the mean temperature is between 37°F and 65°F with frequent fluctuations of moderate extent across this mean range.

High temperature and high humidity are enervating and finally depress man.

Semple, quoting W. Z. Ripley, makes the following statement:

> The tropics tends to relax the mental and moral fiber, induces indolence, self-indulgences and various excesses which lower the physical tone.

There can be no doubt that the poor management of stock in the tropics and subtropics is to a large extent due to the attitude of man towards his livestock and his grazing.

In the Northern Hemisphere the pastures are snow-covered during winter and provision must be made to feed cattle, hence efficient haying processes have been evolved. In the Southern Hemisphere, in the tropical and subtropical ranching areas, little provision is made for winter feeding because there are no closed (snow covered) winters.

European ranchers in the tropics and subtropics rely on cheap black labor, which is often unreliable. Management programs such as inoculation, the arrangement of breeding seasons, calf weaning and dipping, are so often not efficiently executed and the result is lowered calf crops and increased mortality rates.

The three biggest drawbacks to improved livestock production by the indigenous people in the tropics and subtropics are ignorance, prejudice and superstition. The only solution for this problem is education.

The biggest increase in red-meat production in the tropics and subtropics can be brought about by improved ranch and livestock management. (See Chapter 2.)

Several breeds of livestock maintained in the tropics had their origin and evolution in different climatic regions of the world, hence their management and nutritional requirements differ greatly. The quantity of feed that an animal can consume and convert into animal products depends on the animal's ability to maintain a state of thermal equilibrium in a specific environment.

The animal's ability to maintain thermal equilibrium in any area is largely dependent on the animal's adaptability which, in turn, is influenced by its origin and evolution. Thus, for the full physiological manifestation of the animal, it requires an environment that closely resembles its environment of origin and evolution.

The first spoke of the livestock ecology wheel (Figure 2.1) is nutrition, and this is the most important single factor that has a direct influence on the welfare of the animal.

The problem is that in the humid subtropical and tropical regions, the natural pasturage grows fast, lignification takes place rapidly and the plant material on which the animal feeds therefore has a high crude fiber and lignin content and a low protein content, and consequently a high heat-increment value.

High productivity involves a high rate of heat production which is compatible with the tolerance of both internal and external heat stress.

Cattle in the humid subtropics and tropics must be able to dissipate heat efficiently and so they are relatively small, smooth-coated and of a respiratory type, e.g. the Sanga cattle of East Africa and those of West Africa.

Another reason that the natural pasturage in the humid subtropics and tropics has a low feeding value and a high heat-increment value is the soil pH in such areas is low, hence the available calcium and phosphorus in the soil are also low and nitrification does not take place readily.

This is a further reason why cattle and other livestock in the humid subtropics and tropics are small. There is a positive correlation between the soil pH and the size of the cattle in a specific region. (See Table 10.)

Table 10: *The relationship between soil pH, available Ca and P_2O_5, and size of cattle*

Region	Transvaal Highveld	Transvaal Bushveld	Zululand
Average pH value	5,44	6,46	6,28
Percentage available Ca	0,076	0,094	0,144
Percentage available P_2O_5	0,0014	0,003	0,0026
Average height at withers	120 cm	130 cm	132 cm
Average mature mass	482 kg	536 kg	586 kg

(All data were taken on mature Afrikaner cows seven years of age and older.)

The problem of the semi-arid subtropical areas is although the quality of the feed in appreciably better than that of the humid subtropical and tropical areas, the available quantity is low and hence the lack of density in the vegetation causes cattle to walk many miles a day to get their fill. It is essential for cattle to move with ease in the semi-arid subtropical ranching areas of the world.

Also, cattle must move with ease in the semi-arid ranching areas because watering facilities are often far apart and cattle that graze far away from the drinking points often come to water only every second day. This has a depressing influence on feed consumption and results in a slower growth rate and a lowering in the calving percentage.

Table 11 clearly illustrates how different breeds and types of cattle differ in their effective walking ability on hot days.

At the time these walking tests were carried out on the cattle, water-deprivation tests were also carried out. From Table 12 note that cattle adapted to the subtropical ranching areas—those animals that move around with ease—can withstand water deprivation much better than cattle that are less adaptable and that in all probability skip a day in visiting a watering point.

Small wonder, therefore, that cattle which are not adapted to the semi-arid ranching areas of the Southern Hemisphere become tropic degenerated owing to chronic malnutrition.

The degeneration is caused by the inability of the animal to move with ease and to dissipate heat readily.

The selection of cattle, which can contribute to the improvement of meat and milk production in areas where high atmospheric

Table 11: *Walking tests on cattle of different breeds and types*

	Shorthorn, Woolly-coated	Shorthorn, Smooth-coated	Afrikaner, Very smooth-coated
Minimum no. animals/test	6	6	6
Total no. different animals tested	15	10	10
No. tests	6	6	6
Distance walked before showing signs of severe distress (km)	6,4-9,6	25,6	25,6
Average body temperature at end of tests (°C)	41,6°C	40,5°C	38,9°C
Maximum atm. temp. during days of test	34,4°C. In case of these cattle walking discontinued at 10 a.m., atm. temp. 30°C.	34,4°C	34,4°C
Remarks	Three out of 15 animals could not proceed beyond 6,4 km. All other animals were reluctant to move farther than 9,6 km.	All smooth-coated beef cattle could walk 25,6 km, showing signs of severe distress. Five animals had body temp. above 40,6°C.	All animals could walk 20 km with ease. In one test a group of Afrikaner cattle walked 64,0 km in 12 hours without showing signs of distress.

At the time these walking tests were carried out on the cattle, water-deprivation tests were also carried out. From Table 12 it is clear that cattle that are adapted to the subtropical ranching areas, that is, those animals that move around with ease, can withstand water deprivation much better than cattle that are less adaptable and that in all probability skip a day in visiting a watering point on days they have moved a long distance from it while grazing.

Table 12: *Water-deprivation tests*

	Breed	
	Afrikaner	Exotic
Number of animals	4	4
Number of tests	3	3
Percentage mass loss after withholding water 24 hours	1,5%; 6,8 kg	15%; 47,6 kg
Percentage reduction in feed consumption after 24 hours *	0	24
Percentage loss in mass after 48 hours	9	21
Percentage reduction in feed consumption after 48 hours *	56	62
Percentage mass recovery at end of two weeks	96,5	92,0

* Feed intake previously determined in two groups. Percentage reduction in feed intake calculated on intake control group receiving feed and water.

temperatures are a hazard to those animals that are not tropically adapted, is best achieved by direct measurement of production—by performance and progeny testing in their specific environment.

Fortunately there is a close correlation between an animal's physiological reactions (such as body temperatures, respiration rates and pulse rates) and productivity.

Hyperthermic animals lose their appetite; many of them in an effort to maintain a normal body temperature stand in the shade and eat less. The lowered heat production partly enables them to overcome heat stress. Obviously, therefore, there is a close correlation between body temperature and productivity.

The climatological work on livestock carried out by me during the period 1937-1960 at the Messina Research Station (ϕ = 22°16′S; Y = 27°54′E; H = 1,722ft and annual isotherm Tm = 71.6°F) has proved beyond doubt that animals of the *Bos taurus* breeds suffer severely during the summer months when the average temperature on many days goes beyond 95°F and frequently even 104°F. The European and British breeds of cattle that have been bred for greater efficiency in feed utilization, i.e. animals whose physiological functioning has been adapted to a high level of feeding, were the ones that suffered most in hot weather.

Cattle were kept under constant observation at the Messina Research Station. Body temperatures, respiratory counts and pulse rates were taken at regular intervals, on one day every week throughout the year. The observations started on new-born calves and continued until the animals reached the age of six to ten years or left the farm. All animals were under regular observation for infectious diseases that might have influenced the results.

When animals experienced difficulty in dissipating surplus heat, a marked increase in the respiration rate was recorded, followed soon afterwards by marked hyperthermia. These reactions are much more drastic in young calves under the age of one year than in mature cattle. There are also marked differences in reaction between cattle of different types within the *Bos taurus* breeds.

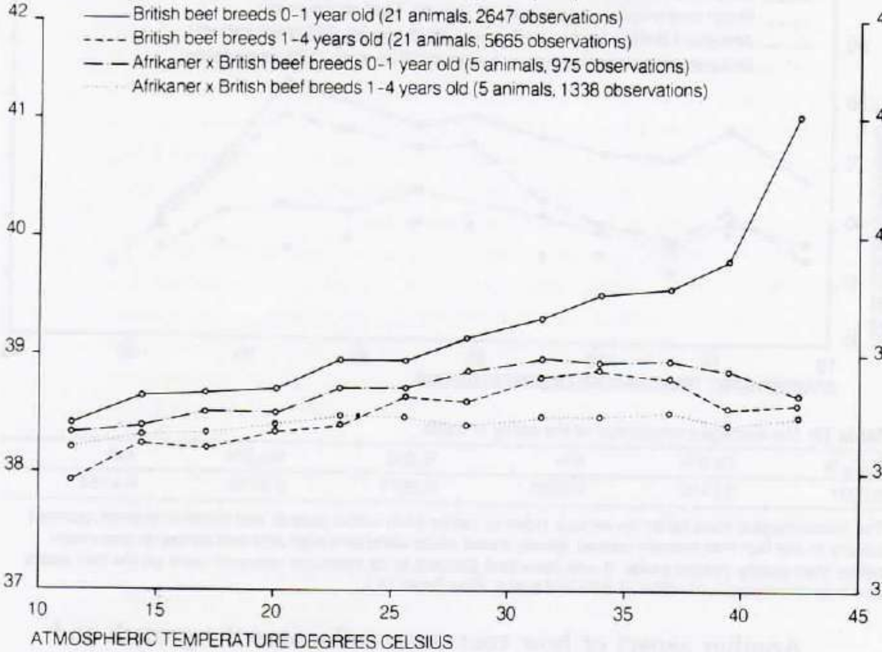
The normal respiration rate for cattle should be approximately 20 per minute and the average body temperature approximately 101.6°F. Three graphs, based on numerous observations, illustrate boldly how far *Bos taurus* cattle deviate from normal as compared to *Bos taurus* × *Bos indicus* crossbred cattle. Young cattle should consequently be provided with good shade in the tropics and subtropics. Graphs 1, 2 and 3 convey the facts.

Other observations made on cattle in the subtropical climate of Messina Research Station were to measure the amount of saliva cattle lost as a result of drivelling (dribbling).

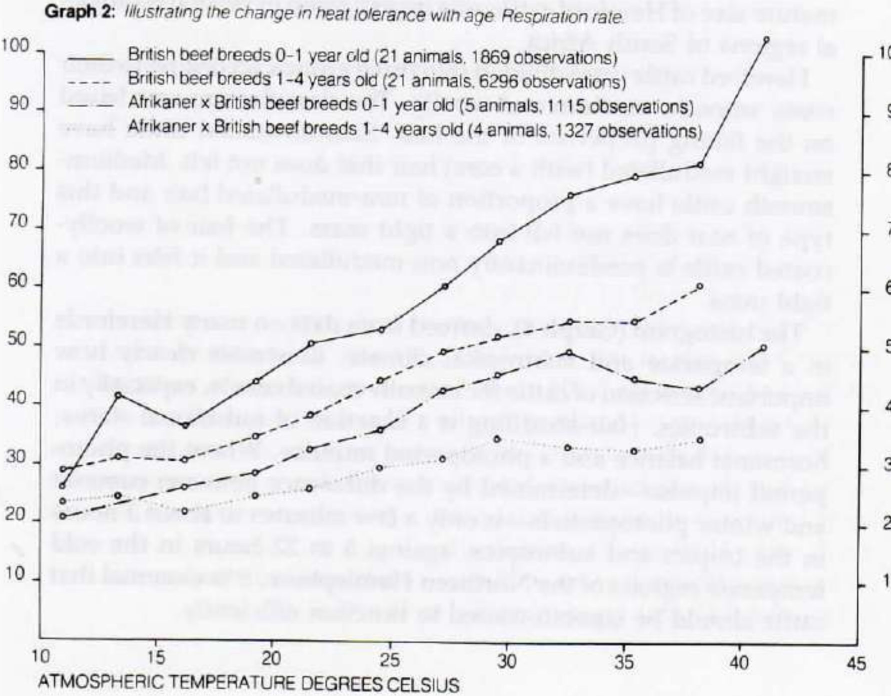
On a hot day, with maximum temperature of 93.2°F, Aberdeen Angus bulls lost as much as 7,967 g of saliva, Shorthorn bulls 4,633 g and Herefords 2,204 g, i.e. 8.48 quarts, 5.3 quarts and 2.44 quarts respectively. Afrikaner cattle did not drivel at all.

The climatological data taken on various types of cattle, both within breeds and between breeds, showed clearly that smooth-coated, glossy cattle could withstand high ambient temperatures much better than woolly-coated cattle. It was therefore decided to do intensive research work on the hair coats and hide thicknesses of cattle of different types. (See Table 14.)

Graph 1: *Illustrating the change in heat tolerance with age. Body temperature.*



Graph 2: *Illustrating the change in heat tolerance with age. Respiration rate.*



Graph 3: *Illustrating the change in heat tolerance with age. Pulse rate*

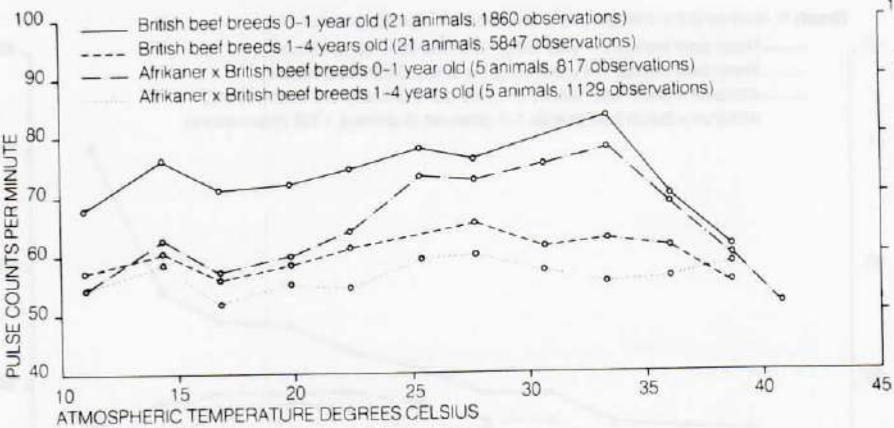


Table 13: *The average composition of the saliva in cattle*

P_2O_5%	Ca 0%	N%	K_20%	Na_20%	Ash
0,0031	0,0153	0,0260	0,0671	0,0710	0,4134

The climatological data taken on various types of cattle, both within breeds and between breeds, pointed clearly to the fact that smooth-coated, glossy cattle could withstand high ambient temperatures much better than woolly-coated cattle. It was therefore decided to do intensive research work on the hair coats and hide thicknesses of cattle of different types. (See Table 14.)

Another aspect of how coat cover influences the growth and mature size of Hereford cattle was investigated in several ecological regions of South Africa.

Hereford cattle were divided into three groups according to their coats: smooth, medium and woolly. The classification was based on the felting properties of the hair. Smooth-coated cattle have straight medullated (with a core) hair that does not felt. Medium-smooth cattle have a proportion of non-medullated hair and this type of coat does not felt into a tight mass. The hair of woolly-coated cattle is predominantly non-medullated and it felts into a tight mass.

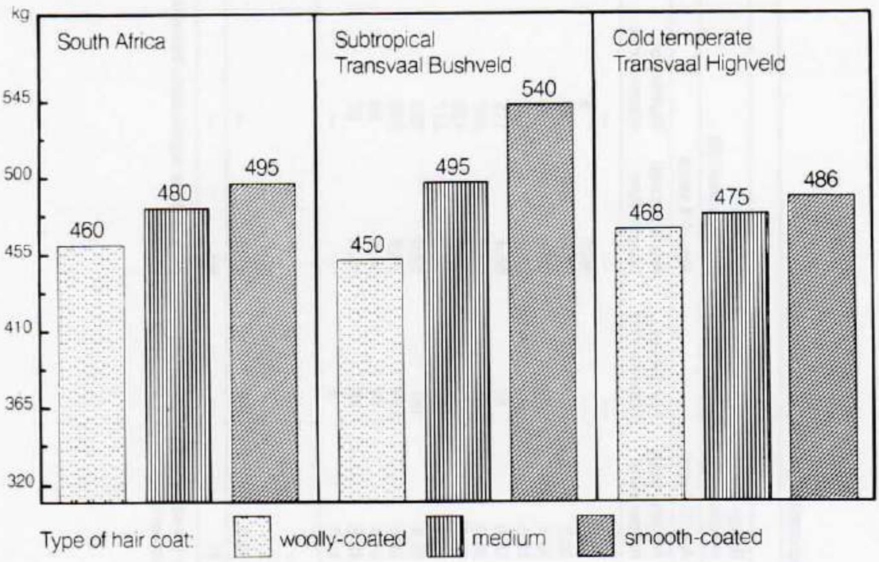
The histogram (Graph 4), derived from data on many Herefords in a temperate and subtropical climate, illustrates clearly how important selection of cattle for smooth-coatedness is, especially in the subtropics. Hair-shedding is a function of nutritional status, hormonal balance and a photoperiod impulse. Where the photoperiod impulse—determined by the difference between summer and winter photoperiods—is only a few minutes to about 3 hours in the tropics and subtropics, against 8 to 22 hours in the cold temperate regions of the Northern Hemisphere, it is essential that cattle should be smooth-coated to function efficiently.

Table 14: *The differences in the physiological reaction of smooth-coated and of woolly-coated cattle within the same breeds*

	Body temperatures: different types of cattle							
	British beef breeds (smooth-coated): Hereford (7), Aberdeen Angus (2), and Shorthorn (2)				British beef breeds (woolly-coated): Hereford (2), Aberdeen Angus (2), and Shorthorn (6)			
	Age: 0-1 year		Age: 1-4 years		Age: 0-1 year		Age: 1-4 years	
Atmospheric temperatures °C	Average body temperature	Number of observations	Average body temperature	Number of observations	Average body temperature	Number of observations	Average body temperature	Number of observations
4- 7	—	—	—	—	—	—	—	—
8-10	—	—	38,1	4	—	—	38,0	4
11-13	38,2	4	38,1	10	38,2	7	37,8	12
13-16	38,6	11	38,3	54	38,4	17	38,2	55
16-18	38,5	31	38,2	130	38,5	58	38,2	124
19-21	38,7	49	38,4	156	38,6	82	38,4	172
22-24	38,8	94	38,4	324	38,9	148	38,5	367
24-27	38,9	116	38,6	392	39,0	179	38,7	433
27-29	38,9	120	38,6	366	39,3	194	38,7	417
29-32	39,2	109	38,7	312	39,4	181	38,9	353
33-35	39,3	104	38,8	255	39,5	149	38,9	278
36-38	39,3	49	38,5	91	39,7	74	38,9	99
38-41	39,5	24	38,6	26	40,8	40	38,9	27
41-43	40,2	2	—	—	41,3	4	—	—
Average body temperature for atmosphere above 29.4 °C	39,2	—	38,7	—	39,5	—	39,0	—
HTC %	83	—	93	—	77	—	89	—

Note: Reactions 0-1 year significantly higher than for 1-4 years ($P<0,01$). Reactions between breeds and between types within breeds differ significantly between 0 and 1 year and also between 1 and 4 years ($P<0,01$) in the case of 2 and 4 against 1 and 3 other comparisons ($P<0,05$).

Graph 4: *Differences in mass in mature Hereford cows.*



The difference in weight between smooth-coated and woolly-coated mature Hereford cows in the subtropics is 198 pounds in favor of the smooth-coated cows. In the temperate region it is 41.8 pounds. This stresses the importance of smooth-coatedness in a region where ease of heat dissipation is a prerequisite.

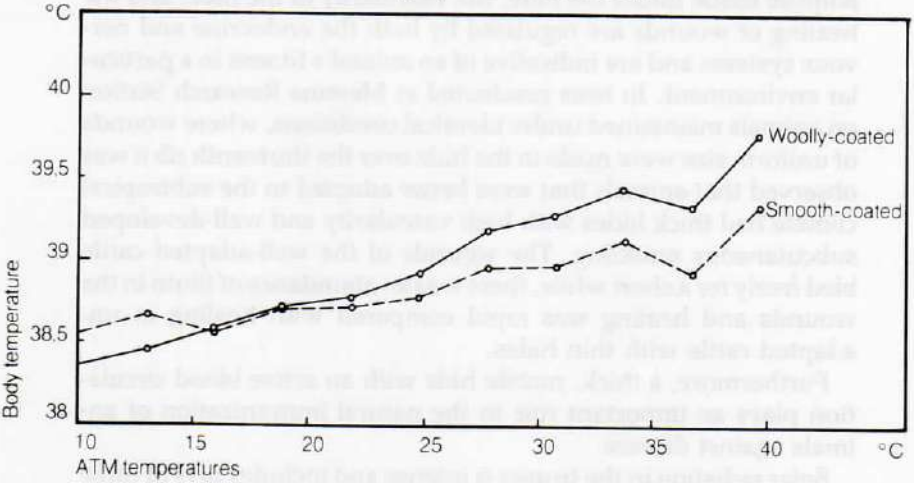
The efficiency of feed utilization depends to a large extent on the ability of cattle to adapt to subtropical regions. Hyperthermia is a powerful suppressor of appetite and hence the main cause of tropical degeneration.

Graphs 5 and 6 are based on body temperature data obtained from the study of smooth- and woolly-coated Hereford cattle.

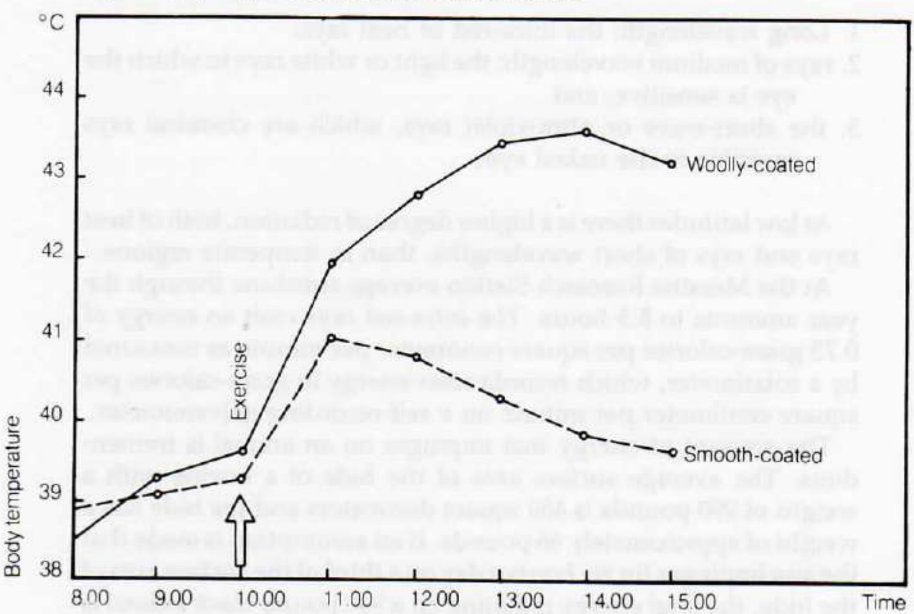
It is tragic and disappointing that the recommendation to breed smooth-coated cattle for the subtropics and tropics has not been universally adopted. Forty years ago I first stressed the importance of breeding cattle for smooth-coatedness in the subtropics and tropics.

It was my considered opinion during the late 1930's and early 1940's that the function of the hair and hide is most important in the adaptability processes of the bovine in various climatic zones. This was based on measurements each three months of hair and hide thickness over the shoulder and ribs of animals used in climatological studies from birth until maturity or until the animal

Graph 5: *Body temperatures of two groups of exotic beef breeds.*



Graph 6: *Body temperatures: woolly- and smooth-coated.*



left the herd. Fourteen body measurements, two of which were hide-thickness measurements on the shoulder and thirteenth rib, were taken. (See Chapter 2.)

The condition of the hide, the growth of the coat, the amount of adipose tissue under the hide, the vascularity of the hide, and the healing of wounds are regulated by both the endocrine and nervous systems and are indicative of an animal's fitness in a particular environment. In tests conducted at Messina Research Station on animals maintained under identical conditions, where wounds of uniform size were made in the hide over the thirteenth rib it was observed that animals that were better adapted to the subtropical climate had thick hides with high vascularity and well-developed subcutaneous muscling. The wounds of the well-adapted cattle bled freely for a short while, there was an abundance of fibrin in the wounds and healing was rapid compared with healing in unadapted cattle with thin hides.

Furthermore, a thick, mobile hide with an active blood circulation plays an important role in the natural immunization of animals against disease.

Solar radiation in the tropics is intense and includes rays of three different wavelengths, namely:

1. Long wavelength: the infra-red or heat rays;
2. rays of medium wavelength: the light or white rays to which the eye is sensitive; and
3. the short-wave or ultra-violet rays, which are chemical rays invisible to the naked eye.

At low latitudes there is a higher degree of radiation, both of heat rays and rays of short wavelengths, than in temperate regions.

At the Messina Research Station average sunshine through the year amounts to 8.5 hours. The infra-red rays emit an energy of 0.75 gram-calories per square centimeter per minute as measured by a solarimeter, which records solar energy in gram-calories per square centimeter per minute on a self-recording galvanometer.

The amount of energy that impinges on an animal is tremendous. The average surface area of the hide of a bovine with a weight of 990 pounds is 450 square decimeters and the hide has a weight of approximately 66 pounds. If an assumption is made that the sun impinges for six hours a day on a third of the surface area of the hide, the total energy radiating on a 990 pound black animal is 15,000 cm^2 × 0.75 g-cals per minute x 360 minutes = 4,050,000 gram-calories.

To raise the temperature of one quart of water from 68°F to 212°F requires 80,000 g-cals. Hence, the amount of energy impinging on a black animal, based on our conservative assumptions, can boil

13,162 gallons of water. It is therefore clear that cattle must dissipate a tremendous amount of solar energy over and above metabolic energy to remain in a state of thermal equilibrium in a tropical environment.

Depending on the nature and quantity of rays impinging on the animal, the effect may be good or bad. Some animals that are not resistant to intense radiation may be adversely affected, with skin irritations and injury to the mucous membranes such as those of the eyelids and eyes.

Some cattle are endowed with hair and hide color and other characteristics that afford protection against the injurious effect of excessive radiation. Color and type of hair have a direct influence on effectiveness of reflection of both the infra-red and white rays or light rays.

To determine to what extent differences actually exist in the quantity of light reflected from animals of the same breed under constant environmental conditions, various tests were carried out on Afrikaner cattle of various colors but in the same condition and stage of coat-shedding. Six distinctive coat colors were available: dark red-brown, red-brown, light red-brown, golden-yellow, yellow and white. The light reflection from these cattle was recorded during summer and winter with a Weston photometer Model 603, specially adapted to measure light reflection from a constant distance from the hides of these animals in direct sunlight with the angle of incidence exactly the same in each case.

The animals were tested during summer and subsequently again in winter. During the winter months the coats were longer and duller, which gave the impression that the animals were darker in color. Animals actually reflect much more light during summer months than during winter.

The smooth-coated cattle of the breeds adapted to the subtropics and tropics reflect more light during summer and winter than woolly-coated cattle of the same color.

Table 15: *Light intensity: Summer 18 500 F.C. Winter 9 000 F.C.*

Breed: Afrikaner	Percentage light reflected Summer	Winter	Percentage light reflected 11 000 Foot-candles	
Dark red-brown	11	3	Red Brown	13
Red-brown	13	4	Afrikaner	
Light red-brown	13,5	4,5	Red brown	4,6
Golden Yellow	14	5	Shorthorn	
Yellow	14,5	7	Black	3,7
White	15	10	Aberdeen Angus	

It is clear that both infra-red rays and light rays are effectively reflected by white, yellow or reddish-brown hair, but not by black hair.

The short-wave ultra-violet rays, in turn, are effectively resisted by yellow, brown and black hide colors. It is apparent, therefore, that a white, yellow or red-brown coat with a dark hide is the ideal combination to render an animal resistant to the temperature and intense radiation of the short-wave and heat rays.

It is, moreover, this combination of hair and hide color that is found among cattle breeds of the tropics.

White hair and a hide without pigmentation are a real hazard to cattle in the subtropics and tropics. Such cattle are often injured and develop cancer of the skin from irritation by short-wave rays. In contrast, black hair and a black hide are a good combination to eliminate rays of short wavelength. Black hides get hot in open savannah country: hide temperatures of 113°F to 122°F and higher have been measured on black cattle when the atmospheric temperature was 90°F.

Settlers from Britain and other European countries in the tropical and subtropical ranching areas favored, through sentiment and conservatism, cattle that originated in their home countries of England, Scotland and Germany.

Many of these operations owned and operated by settlers went bankrupt due to the high mortality rate of the unadapted cattle in the subtropics and tropics. Table 16 illustrates this assertion clearly.

These data reveal that the factors limiting adaptability of cattle in the tropical and subtropical climates are climate- and location-specific diseases caused by ticks and other ectoparasites rather than feed, because the crossbred cattle (*Bos taurus* ♂ × *Bos indicus* ♀), although large and heavy and therefore demanding high maintenance requirements, thrived well.

On ranch C in one year, Table 16, 6,858 head of cattle died, of which 5,131 or 74.8 percent of the deaths occurred from September to January. The unadapted cattle lacked heat tolerance and resistance to tick-born diseases and consequently succumbed readily.

At Mara Research Station (Lat. S 23°09′; Long. E29°34′) where work on the creation of the Bonsmara breed was in progress from 1937 onwards, accurate data were taken on the mortality rate of different breeds and types of cattle as well as monthly tick counts which were taken on 12 *Bos taurus* and 12 *Bos indicus* cows over skin

Table 16: *Calving percentages and mortality rates on cattle ranches*

	Ranch A	Ranch B	Ranch C	Ranch M
Locality	Long.E 26°53' Lat. S 24°21'	Long.E 28°21' Lat. S 24°56'	Long.E 29°45' Lat. S 20°45'	Long.E 29°34' Lat. S 23°09'
Altitude (m)	853	1 100	1 360	894
Average annual temp. °C	20,6	18,5	18,3	19,6
Average annual rainfall (mm)	405,0	602,5	615,0	410,0
Breed of cattle	Hereford	Aberdeen Angus	Sussex	Adaptable cattle
Average no. of breeding cows	1 477 22 years	3 143 5 years	17 400 20 years	416 6 years
Average percentage calf crop	39	56	55	83,53
Calf mortality percentage	18	23	14	10,59

areas of 1,000 cm^2 in extent. These observations proved beyond doubt that smooth-coated animals with thick, movable hides of high vascularity are far more tick-repellent than animals with thin and woolly-coated hides. The hide with medullated, glossy hair has a larger number of functioning sweat- and sebum-glands.

Table 17 provides a summary of the tick counts on the 12 *Bos indicus*, smooth-coated, thick-hided cattle with well-developed subcutaneous muscling, and the 12 *Bos taurus* cattle with woolly coats and thin hides.

It was further obvious that ticks evade direct solar radiation, hence many more ticks were counted on the escutcheon and under the tail. Furthermore, the ratio of ticks on the 4×200 cm^2 areas on the bodies of the 12 *Bos indicus*: 12 *Bos taurus* cattle was 1:7.5. Proportionately a much greater number of large, fully engorged ticks were taken from the *Bos taurus* type cattle.

The mortality rates amongst the two groups of cattle were therefore closely reflected in the tick counts and also in hide thickness,

Table 17: *Tick counts on 1 000 cm^2 on Bos indicus and Bos taurus cattle*

	Smooth-coated Bos indicus	Woolly-coated Bos taurus	Ratio Bos indicus: Bos taurus	Total per unit area
Body: Number of ticks on 4×200 cm^2 areas i.e. 800 cm^2	237	1 775	1:7,5	2 012
Escutcheon: Number of ticks on 200 cm^2	1 529	4 397	1:2,9	6 926
Number of ticks under the tail	2 140	4 789	1:2,2	6 929
Total number of ticks counted on 1 000 cm^2	3 906	10 961	1:2,8	14 867

Total number of ticks counted per annum: 14 867 subcutaneous muscling, and sleekness or woolliness of coat.

Since the tick-counts on the cattle were made during three successive years in the early 1940's, selection pressure was put on thick, movable hides, well-developed subcutaneous muscling, and sleek, glossy coats with high vascularity to breed cattle that were tick-repellent with a concomitant high heat-tolerance coefficient.

These cattle had a lower mortality rate and immunized much better against tick-born diseases.

The diseases of cattle in the subtropics and tropics tend to be location-specific. For example, heartwater, a tick-born disease, is location-specific because heartwater ticks (*Amblyomma hebraeum*) flourish in an ecological niche where the temperature and humidity are within the limits of the tropics and subtropics.

The incidence of internal parasites in livestock in the subtropics and tropics is also location-specific. High temperatures and moisture or high humidity being instrumental in high parasitic infestations. Poor management around watering points can cause tremendous infestations of liver-fluke and intestinal parasites.

Parasites such as ticks, mosquitoes and stinging flies are frequently vectors of disease and have a specific ecological milieu in which they flourish. Humidity and high temperatures are the most important elements of this ecological niche.

A Summary

The following principles must be given due consideration in an effort to increase red-meat production in the tropics and subtropics:

1. The first essential for the cattle breeder to operate a ranch in the tropics and subtropics efficiently is to know his environment. He should have a thorough knowledge of what the average annual temperature (the isotherm) is, the average annual precipitation, the average daily sunshine hours and the soil pH. These factors determine carrying capacity.
2. Select and breed for greater adaptability in cattle. This can be done by performance and progeny testing and with accurate records on calving percentages and mortality rates.
3. Guide-lines to select for adaptability in young cattle are the following:

(a) Select calves that are born smooth-coated with hair that does not felt.

(b)Select for early hair-shedding early in spring: early hair-shedding the first spring after birth is a positive selection criterion.

The young heifer that comes through the first winter in a good nutritional and hormonal condition is a potentially highly fertile, adaptable heifer. This is probably a most positive selection criteria.

4. Select red-brown, yellow or white full-colored, smooth-coated cattle with pigmented hides for the open savannah subtropics. For densely forested subtropical and tropical areas, select smooth-coated black or dark-brown cattle; they function best in the diffused ultra-violet radiation in the shade.
5. Select smooth-coated cattle with thick movable hides in an effort to breed cattle that are tick- and fly-repellent. Cattle with thick hides have a higher vascularity of hide; wounds in their hides heal rapidly and they immunize better than cattle with thin hides and woolly coats.
6. Finally, the greatest increase in production of red meat in the subtropics can be brought about by improved management. Carry out a thorough inoculation and dipping program.

   By timely therapeutic treatment when animals are ill, the mortality rate can be reduced. By proper pasture management and by providing ample watering facilities the proper nutritional status of adaptable animals can be maintained with optimal expression of their genetic potential for growth, reproduction and milk production. These are the three growth functions that play the most important role in the profit of the ranching enterprise, especially if by proper management the mortality rate among cattle is kept down to the minimum.

Chapter 11

Livestock Production in the Southern Hemisphere

The problems of livestock production in the Southern Hemisphere had their origin on the third day of creation, as described in the Book of Genesis 1:9-10:

> And God said, Let the waters under the heaven be gathered together unto one place, and let the dry land appear: and it was so. And God called the dry land Earth; and the gathering together of the waters called He Seas: and God saw that it was good.

At that time four-fifths of the land-mass that appeared on earth was situated in the Northern Hemisphere and only one-fifth in the Southern Hemisphere. (See Figure 11.1, color section.)

It was during this epoch that the major climatic zones on earth had their origin. As a result of the differences in proportion of the earth's land-masses and of the ocean areas surrounding the two hemispheres, the climatic conditions in the two hemispheres differ greatly. Owing to the high latent heat value of water the temperature fluctuations in the Southern Hemisphere are far less than those in the Northern Hemisphere because the land-masses of the Southern Hemisphere are surrounded by much larger volumes of water.

These differences in the climates of the various zones on earth cause the natural flora and fauna of the two hemispheres to differ greatly.

The four major climatic zones of the earth may be classified as: Keen, Raw, Muggy and Scorching. (See Figure 2.2.) The plant and animal life in these different climatic zones varies greatly, adaptability phenomena being responsible for the morphological, physiological and compositional differences in plants and animals.

More than a hundred years ago Darwin formulated the theory of natural selection. Darwin's theory of evolution and his stress on the differences in morphology between plants and animals in the different climatic zones of the world intrigued me immensely: obviously there was a close correlation between climatic factors and adaptability phenomena in plants and animals.

In the Livestock Ecology Wheel (see Figure 2.1), the fifteen spokes running from the hub of the wheel to the rim represent fifteen environmental factors which have a direct influence on man and beast: **nutrition, temperature, radiation, light, altitude, barometric pressure, wind, disease, external parasites, internal parasites, soil pH, soil fertility, rainfall and humidity, supersonic sound and noise, pollution and stench**. By measuring them we can correlate the limiting factors of each environment with the clinical reactions of animals maintained in these environments.

I began my livestock research in 1937 at the University of Pretoria where research on the first and most important spoke of the wheel—nutritional research—was done on cattle. Results of this research proved beyond doubt that *Bos taurus* cattle fed on identical rations at

Ermelo (ϕ = 26°31′S, Y = 29°59′E, H = 5,603ft, Tm = 58.5°F)
Pretoria (ϕ = 25°45′S, Y = 28°14′E, H = 4,518ft, Tm = 62.9°F)
Messina (ϕ = 22°16′S, Y = 27°54′E, H = 1,723ft, Tm = 71.6°F)

respectively gained 299 pounds, 218 pounds, and 101 pounds during a 140-day summer feeding trial. There can be no doubt that the coefficient of digestibility of the feed in *Bos taurus* cattle is lowered by increased ambient temperatures.

Similar results were obtained by feeding white rats a constant ration at ambient temperatures of 65°F and at 85°F. The coefficient of digestibility of the ration dropped from 72 percent at 65°F to 59 percent at 85°F.

The chronic malnutrition or tropical degeneration of livestock in the tropics is for *Bos taurus* cattle due to hyperthermia and a depressed appetite as a result of voluntary reactions, standing in the shade and eating less on hot days. (See Figure 2.4) For indigenous *Bos indicus* cattle, the animals are small owing to natural selection over a long time.

The soil pH in the humid tropics is low, hence the availability of calcium and phosphorus in the natural pastures is low. The high crude fiber and lignin content of the pastures, with its concomitant high heat-increment values, makes it essential that heat dissipation from the body take place readily. (See Chapters 2 and 10.) Thus, if the intention is to produce large cattle in the tropics, it is essential to feed the cattle concentrate rations with a low crude fiber content and a low heat-increment value. It is on this principle that Israel produces milk in an area with high temperatures.

At Messina Research Station there was very obvious subtropical degeneration of the *Bos taurus* cattle owing to chronic malnutrition, which in turn was due to hyperthermia. From December 1937 to 1957 body temperatures of many cattle were taken and respiration and pulse rates were measured every two hours from 6 a.m. until 6 p.m., one day a week from birth to maturity. On hot days these observations were taken from 6 a.m. one day until 6 a.m. the following day. To correlate these physiological reactions with morphological factors, hide thickness and hair counts per square centimeter as well as hair-type studies were made on cattle of various types. The hair diameters (6,000 per animal) were determined with a lanameter. Complete hair coats of animals were shorn close to the hide and the whole hair weight from different types of cattle was accurately determined in grams. The complete coats of the different types of cattle were put through felting machines at a hat factory in Johannesburg in an effort to determine the ratio of medullated to non-medullated hair in the coats of the different types of cattle.

The hide thickness was also determined as routine measurements with the twelve other body measurements taken every three months from birth until the animal died or left the herd.

This work proved beyond doubt that the animal whose coat does not felt usually has a thick, movable hide with high vascularity and medullated, glossy hair. The hide growing medullated hair has a larger number of functioning sweat- and sebum-glands per unit area. Only one hair grows from a primary hair-follicle, whereas in cattle with woolly coats containing both medullated and non-medullated hairs, several non-medullated hairs grow from the secondary hair follicles, which contain few functional sweat- and sebum-glands.

At the Mara Research Station (Mara $\phi = 23°09'S$; $Y = 29°34'E$; $H = 2{,}950ft$; $Tm = 67.3°F$), where the breed creation was in progress from 1937 onwards, accurate data were taken on the mortality rate of different breeds and types of cattle under the subtropical ranching conditions in this region.

In Table 18 it is interesting to note how high the mortality rate was among all types of cattle before the sophisticated drugs and antibiotics came on the market.

From the data obtained from counting ticks on different types of cattle in the periods 1941-1942 and 1942-1943 (Table 19), it was obvious that cattle with thick hides, well-developed subcutaneous muscles, and short, glossy hair always had fewer and much smaller ticks on them than the thin-skinned, woolly-coated cattle. The mortality rates amongst the two types of cattle were closely correlated to hide thickness and sleekness of coat. The percentage of thin-hided, woolly-coated cattle that died was much greater than that of the adapted cattle.

Since tick-counts on the cattle were made in the early forties, selection pressure was put on thick, movable hides and sleek, glossy coats—hides with high vascularity—to breed cattle that were tick-repellent and adapted to tropical and subtropical conditions. These cattle had a lower mortality rate and immunized much better against tick-born diseases.

That there are marked differences in hide thickness between different types of cattle is shown by data taken on hide thicknesses with calipers that slip at constant pressure to eliminate the subjective approach of the research worker on the measurements of hide thickness (see Table 20).

In the selection of improved types of livestock for the subtropics, the fundamental aim must be to achieve hereditary adjustment or adaptation of the animal to its environment. That the hair and hide of the bovine is an important organ in determining the adaptability of livestock cannot be doubted.

In the extensive data taken on respiration rate, pulse rate and body temperature in many cattle of various types and breeds, it became obvious that the morphology of the animal—respiratory versus digestive type and thick, smooth-coated versus thin-hided, woolly-coated—was of paramount importance in determining the reactions of the animals on hot days. (See Graphs 1, 2 and 3, Chapter 10.)

At the official British Commonwealth Scientific Conference held in Australia during August, 1949, I delivered a paper entitled "Ecological animal husbandry research and its application in maintaining a permanent pastoral industry." From the data presented at this conference it is obvious that young cattle, i.e. calves under

Table 18: *Mortality rate amongst all types of cattle before modern drugs and antibiotics*

Breed	Number born	Number dead	Number survivors	Percentage dead	Average age at death
Afrikaner	246	13	233	5,3	11 months
Bonsmara type	483	44	439	9,1	7 months
Exotic *Bos taurus*	28	17	11	60,7	5 months

The differences in mortality between Afrikaner and Afrikaner crosses in comparison with the exotic breeds is highly significant.

(Table 18 adapted from 'Hereditary Heartwater-resistant Characteristics in Cattle', February, 1944; Reprint No. 13. J.C. Bonsma.)

Table 19: *Summary of tick-counts on 12 Afrikaner* **(A)** *and 12 Exotic (Bos taurus)* **(E)** *beef cows for the period* October, 1941, to September, 1942

Month	Body Number of ticks on 800 cm^2		Escutcheon Number of ticks on 200 cm^2		Tail Number of ticks under tail		Total number of ticks on 12 animals of each breed		Total number of ticks counted per month
	A	E	A	E	A	E	A	E	
Oct. 1941	0	44	2	113	82	217	84	374	458
Nov. 1941	32	144	248	784	390	393	670	1 621	2 291
Dec. 1941	32	141	120	905	211	1 046	363	2 092	2 455
Jan. 1942	8	89	269	303	573	610	850	1 002	1 852
Feb. 1942	16	151	176	379	199	459	391	989	1 380
Mar. 1942	0	60	80	108	198	285	278	453	731
Apr. 1942	24	127	120	416	106	380	250	923	1 173
May 1942	4	279	80	392	75	245	159	916	1 075
June 1942	24	201	61	264	52	202	137	667	804
July 1942	12	199	149	253	58	237	219	689	908
Aug. 1942	77	152	212	282	106	247	395	681	1 076
Sept. 1942	8	188	12	198	90	168	110	554	664
TOTAL	237	1 775	1 529	4 397	2 140	4 789	3 906	10 961	14 867
	1 :	7,5	1 :	2,9	1 :	2,2	1 :	2,8	

Table 20: *Skin thickness measurements of cattle in cm*

Double-skin (skinfold) measurements in **cm** on various parts of the hide	Breed or type of cattle			
	Afrikaner	Cross: *B. indicus* × *B. taurus*	Exotic *B. taurus*	Averages
Brisket	0,687	0,521	0,582	0,600
Lower front rib	0,676	0,607	0,584	0,620
Upper front rib	1,100	1,150	1,025	1,100
13th rib	1,230	1,070	0,967	1,100
Flank	1,280	1,060	0,976	1,100
Escutcheon	0,781	0,699	0,699	0,725
Averages Thick-skinned areas	1,203	1,093	0,989	1,095
Averages Thin-skinned areas	0,715	0,609	0,622	0,649

one year old, suffer much more from heat stress than older cattle. It is also clear that the animals with thick hides and sleek coats, the *Bos indicus* types, are much more heat-tolerant than the *Bos taurus* types of cattle.

From Graphs 1, 2 and 3 of Chapter 10, probably the most valuable attribute possessed by stock indigenous to the tropics and subtropics is their ability to withstand excessively high temperatures.

The study of the morphological and physiological characteristics which are associated with heat-tolerance is an aid in the selection of breeding stock to promote greater adaptability and tick-repellency and hence greater resistance to location-specific problems such as heartwater and other tick-born diseases. Stock selected in this way also develop fewer subcutaneous abscesses.

The differences in hide thicknesses on cattle of different breeds, as well as differences within breeds, enabled me to select cattle with thick hides for breeding. The skinfold measurement on the shoulder and on the thirteenth rib gives a fairly accurate indication of the average thickness of the hide. The cattle breeder who does not want to go into the details of measuring hide thicknesses can select thick-hided cattle by observing the number of downward skin-folds in the hide and the prominence of the subcutaneous muscle development in sleek-coated cattle.

In 1953, in a paper read at a symposium presented at the King Ranch Centennial Conference, I made the following statement: "In tests conducted at the Messina Research Station (on animals maintained under identical conditions) where wounds of uniform size were made in the hide over the thirteenth rib, it was observed that animals which were best adapted to this tropical climate had thick hides, the wounds bled freely for a short period, there was an abundance of lymph fluid in the wounds and healing was rapid in comparison with unadapted cattle with thin hides which did not bleed freely."

A thick, mobile hide with an active blood circulation plays an important role in the natural immunization of animals against disease.

By strict selection for hide thickness and sleek-coatedness in Hereford cattle at Mara Research Station, the mortality rate was reduced from 34.8 percent for the period 1936-1945 to 27.4 percent for the period 1946-1950.

It is an established fact that longevity (the duration of productive life) is a constitutional trait that varies in different breeds and families. Animals with a long productive life may be regarded as well adapted and should be selected for future breeding purposes.

For reasonable growth-rate, reproduction and finishing, productive animals must have genotypical potentialities to resist cold and storm in the cold countries of the Northern Hemisphere, dissipate radiant and metabolic heat in warm countries, and maintain normal body temperature, pulse rate and appetite. The bison and the water-buffalo are beautifully adapted to their respective environments (Figures 11.2 and 11.3).

Proper management and provision of shade in the hot areas and shelter against cold and blizzard conditions in parts of the Northern Hemisphere are essential to improve the red-meat production of the world.

Light intensity and solar radiation in both hemispheres have a direct influence on animal production. The photoperiod has a direct influence on the sexual activity and hence the breeding seasons of livestock. Observations should be made on livestock to determine the most favorable breeding seasons. Solar radiation includes rays of different wavelengths, namely:

1. Long-wave rays—the infra-red or heat rays. The energy emitted from this source in the Southern Hemisphere is tremendous. Solar energy data measured at the Messina Research Station on a solarimeter (which recorded solar energy in gram-calories per square centimeter per minute) indicated that measurements of 0.75 gram-calorie per square centimeter per minute at noon on days with light intensities exceeding 10,400 - 10,500 foot-candles were a regular occurrence.
2. Rays of medium wavelength—light or white rays to which the eye is sensitive.
3. The short-wave or ultra-violet rays invisible to the naked eye.

At low latitudes there is a higher degree of radiation, both of heat rays and of short-wave rays, than in temperate regions. In fact, in parts of the world near the Equator, the intense radiation may have a most injurious effect on animals.

Depending on the nature and quantity of the rays impinging on the animal, the effect of radiation may be good or bad. Some animals that are not resistant to intense radiation may be adversely affected when the intensity and nature of the radiation exceed certain limits, with resultant skin irritations or injury to the mucous membranes such as those of the eyelids and eyes. Con-

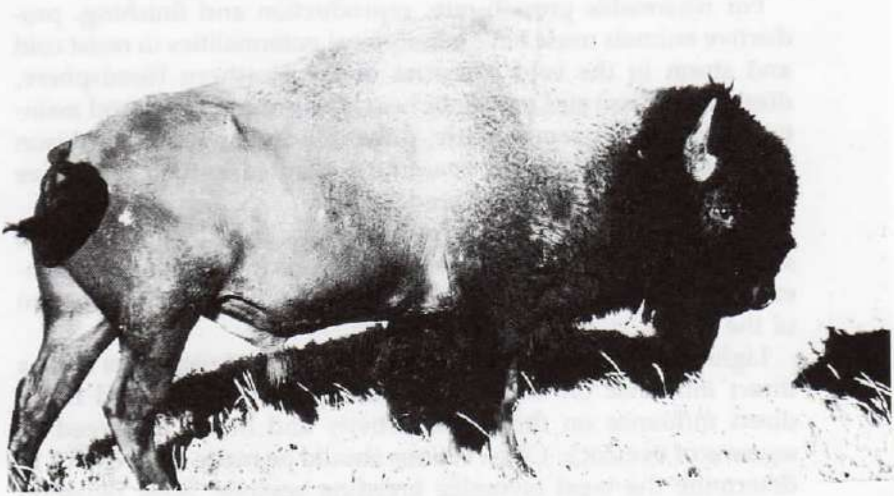


Figure 11.2 A bison beautifully adapted to a cold climate.

sequently, indigenous cattle are frequently endowed with hair and hide color and other attributes such as hair characteristics and sebaceous and sweat-glands designed to give them protection against the injurious effect of excessive radiation.

Thus, both the infra-red rays of long wavelength and medium-length light rays are effectively reflected by white, yellow or reddish-brown hair, but not by black hair. The short-wave or ultra-violet rays, in turn, are effectively resisted by yellow, reddish-brown and black hide colors. (See Chapter 6.)

In the open savannah grazing areas of the Southern Hemisphere a glossy, short-haired coat of white, yellow or red with a dark hide is the ideal combination to render an animal resistant to temperature and intense radiation of the heat and short-wave rays. At high altitudes a dark-brown or black hide is advantageous. It is important that breeders give adequate attention to the selection of appropriate hair and hide color to breed animals that are well adapted to overcome the hazards caused by intensive infra-red and ultra-violet radiation.

There are many high-altitude regions in the world, but on average the high-altitude plains in the Southern Hemisphere are larger than those of the Northern Hemisphere. In high-altitude regions of both hemispheres, altitudes higher than 8,250 feet, it is essential

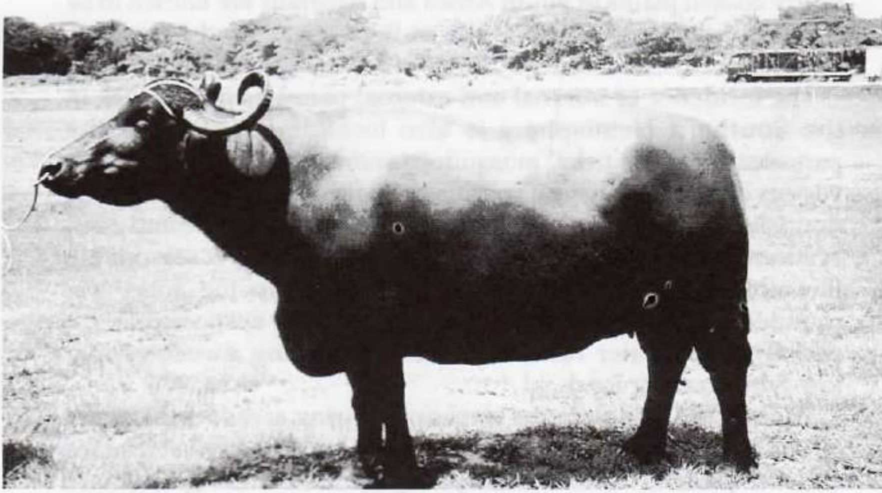


Figure 11.3 A water buffalo beautifully adapted to a tropical climate.

to keep cattle with a high hemoglobin index. Cattle at high altitudes, especially those breeds that had their evolution in the lowlands of Europe and in Britain, tend to suffer from brisket disease. This is also known as La Jara disease because some types of cattle in the feedlots at La Jara, Colorado, often suffer from this heart-failure syndrome. Friesland cattle, at the high altitudes around Bogota, Colombia, suffer from skin cancers whereas full-colored dark-brown cattle and black cattle experience no such problems.

The diseases of cattle in the Southern Hemisphere tend to be location-specific. For example, heartwater, a tick-born disease, is location-specific because heartwater ticks flourish in some of the semi-arid subtropical grassland and ranching areas.

In the developing countries of the world overstocking takes place and plant-poisoning often occurs on an alarming scale. Plants such as gousiektebos (*Pachystigma pygmaeum*), gifblaar (*Dichapetulum cymosum*) and slangkop (*Urigenea burkei*) are location-specific and have for long been known to be poisonous. Indeed, they have often caused serious stock losses, particularly during spring and in times of drought. (See Figures 11.4 and 11.5.)

Deficiency in phosphates in Southern Africa used to cause severe losses in livestock until phosphate supplements was introduced. The phosphate deficiency in the diet of cattle caused pica, a craving in animals for such matter as rotten bones, the consumption of which in turn led to botulism. (See Figure 2.3.) The sandy coastal plains of South Africa and Australia are known to be cobalt-deficient and sheep losses in those areas used to be catastrophic.

The incidence of internal and external parasites in livestock in the Southern Hemisphere is also location-specific. All the parasites—such as ticks, mosquitoes and stinging flies which are vectors of disease—have a specific ecological milieu in which they flourish. Similarly, internal parasites such as liver-fluke and even cysticercosis in livestock are also location-specific. Wet seasons are favorable to the development of liver fluke. In the areas surrounded by black territories, cattle are prone to cysticercosis, especially if rainwater runs from the higher lying dwellings into low-lying grazing land.

The soil pH is high in the semi-arid grazing areas where *Acacia tortilis* grows. The natural pasture grasses are called sweet-grasses and the protein, calcium and phosphorus in these grasses are easily assimilable. This is really good cattle country, especially if the animals are well adapted to high ambient temperatures. The soil pH in the hot, moist subtropics is usually low, the natural pastures grow rapidly, lignification takes place quickly, and hence such pastures are low in protein and high in crude fiber and cellulose and the calcium and phosphorus are poorly assimilable. These pastures have extraordinarily high heat-increment value, hence it is essential for cattle adapted to those areas to be able to dissipate excess metabolic heat readily. Cattle indigenous to the humid tropics and subtropics are small because of the lack of assimilable calcium and phosphorus in their diet.

The next factor to consider is supersonic sound and noise. The effects of noise on man and beast will be the same in the Northern as in the Southern Hemisphere. At the moment it is a greater hazard to livestock production in the Northern than in the Southern Hemisphere, owing to the density of aerial transport lanes in the North and also to the North's greater industrial development. For general purposes noise is measured in decibels—units that describe levels of acoustic pressure, power and intensity. A scale of acceptable noise levels is valuable in judging varying degrees of sound. About 35 decibels is an acceptable level for a classroom and 60 decibels for a sports arena. At a noise level of 80 decibels, the use of a telephone is virtually impossible. The noise of jet fighter planes passing overhead can be tolerated for short periods, although they

Figure 11.4 Illustration of poor nutritional status of autumn pastures in a developing country.

Figure 11.5 Poor water supplies in developing countries.

may be making a noise often exceeding 100 decibels. A jet revving its engines at take-off registers about 130 decibels. This is considered harmful to man and beast causing noise-induced psychological trauma.

The most classic example of how noise can cause tremendous loss of life and milk production in a dairy herd was described in a court case in which a British dairy farmer won his suit against the Air Ministry for killing his cattle while testing new jet fighter planes near his dairy farm. He was paid many thousands in damages. It is also known that severe noise will reduce normal egg production in a poultry-production unit.

Scientists consider that in our "turned-on," mechanized world, noise can become as dangerous a pollutant as smog.

Finally, we have to consider pollution and stench. The effect of pollution and stench of the same intensity will have the same degree of detrimental influence, wherever in the world animals happen to be. The problem of pollution and stench is at the present moment a much more severe one in the Northern Hemisphere than in the Southern, since there are so many more large feedlots and dairy production units in the Northern Hemisphere. A large feedlot feeding 200,000 head of cattle daily produces as much sewage as a city of 2,000,000 people.

In an area such as southern Arizona, where there are many feedlots, urine disposal does not create a great problem owing to the high atmospheric temperatures and the long hours of sunshine. But the disposal of dung is a real problem. I have seen dung heaps with a surface area of five acres and thirty feet and more high. One such dung heap was set alight by lightning and smouldered for a whole year, giving off pungent clouds of smoke that spread to areas many miles away.

The ecological crisis in the modern world has its root in our failure to differentiate between the use of scientific technology as a kind of modern magic and our values of what is right and wrong—knowledge as it relates to man's place in the universe and especially his relation to the earth. Fortunately the peoples of the Southern Hemisphere can benefit greatly by observing the mistakes the cattlemen of the Northern Hemisphere have made as a result of livestock intensification and the accompanying hazards and so learn in advance how to overcome them.

Chapter 12

A Personal Approach to Student Training

More than a decade ago I wrote an article entitled "A personal approach to student training," which was published in the **Wortham Lectures in Animal Science**. Since that article was written the attitude of students towards authority and towards discipline has changed remarkably and the teacher's or professor's approach to student training must therefore be adapted accordingly. At the end of this chapter I will add some remarks on my present approach to student training.

The modern student has, as a result of permissiveness by society, taken the attitude that he or she is a free individual who may question all authority. Young people today have the attitude that they owe the state nothing, but the state and the social order in a country owe them a refuge with tremendous remuneration for little work done. Many of these problems have their origin in the social order prevailing in some countries.

In spite of these changes, however, it is essential that the ideas in the 1965 paper be reprinted ecause so many graduate students have indicated they greatly benefited from the philosophy of teaching that it reflected.

Teaching—A passion and an art

> I do not know that I could make entirely clear to an outsider the pleasure I have in teaching. I would rather earn my living by teaching than in any other way. In my mind teaching is not merely a life work, a profession, an

> occupation, an struggle: It is a passion. I love to teach as a painter loves to paint, as a musician loves to play, as a singer loves to sing, as a strong man rejoices to run a race. Teaching is an art—an art so great and so difficult to master that a man or woman can spend a long life at it, without realizing much more than its limitations and mistakes, and his distance from the ideal.
>
> Billy Phelps, Yale University

Personal interest

It is important for me as Professor Emeritus who enjoyed teaching for 35 years at the University of Pretoria and also as a guest professor at several American universities, to indicate to my many students how I felt about student training.

The teaching and educating of students have intrigued me since my earliest childhood. I am the son of an educator and come from a family in which, for three generAtions, the members on one side of my family were university professors in South Africa or Holland. The other half of my pedigree stems from cattle farmers. It will be clear to my readers that higher education, and especially higher education in animal production, is something sacred to me.

Youthful introduction

When I was ten years old, my father asked me to give a lesson to a senior class at the Teachers' Training College in Heidelberg, Transvaal. I had to teach them what I knew about silkworms. I took my illustration material—worms, moths, eggs and cocoons—to the room where I was to lecture. The lecture had to be prepared by reading a book on silkworms.

This lesson was given by a child to adults and I thought no more of this incident until many years later. Then I asked my father why I had to give that lesson to his students. His reply was: "I wanted to teach those budding teachers two things: first, you cannot bluff students even if they are children; many of the pupils may know more about a subject than the teacher, so never try to bluff them by pretending you know more than you actually do. Second, you must always prepare your lessons or lectures so that you know your facts about a chosen subject or area of study. You have to know your facts if you want to train students."

Respect for the young

I learned at a young age to have a wholesome respect for young people and students. The American philosopher, Elbert Hubbard, put this so beautifully:

> I have a profound respect for boys; grimy, ragged, tousled boys in the street often attract me strangely. A boy is a man in the cocoon; you do not know what he is going to become, his life is big with many possibilities. He may make or unmake kings, change boundary lines between states, write books that will mold characters or invent machines that will revolutionize the commerce of the world. Every man was once a boy (a student). I trust I shall not be contradicted; it is really so.
>
> Very distinctly and vividly I remember a slim freckled boy who was born in the "Patch," and used to pick up coal along the rail-tracks in Buffalo. A few months ago I had a motion to make before the Supreme Court and that boy of the "Patch" was the judge who wrote the opinion granting my petition.
>
> Yesterday I rode (on) horseback past a field where a boy was ploughing. The lad's hair stuck out through the top of his hat, his form was bony and awkward, one suspender held his trousers in place, his bare legs and arms were brown and sunburnt and briar-scarred. He swung his horses around just as I passed by and from under the flapping brim of his hat he cast a quick glance out of dark half-bashful eyes, and modestly returned my salute. His back turned, I took off my hat and sent "God bless you" down the furrow after him. Who knows I may go to that boy to borrow money yet, or to hear him preach, or to beg him to defend me in a lawsuit. Or he may stand with pulse unhastened, bare of arm, in a white apron, ready to do his duty while the cone is placed over my face, and night and death come creeping into my veins.
>
> Be patient with boys, you are dealing with soul stuff, destiny awaits just around the corner.

It is essential for teachers to have a wholesome respect for students. By encouraging them by imbuing them with enthusiasm, we can get them to do so much more.

A running stream

To be a successful teacher one must remain a student. It is so important to remain scholarly, read widely and discuss academic problems with people in one's own area, as well as with people in other academic fields.

As one philosopher put it: "He who learns from one who has learnt all he has to each, drinks from the green mantle of stagnant pool, but he who learns from one engaged in learning, drinks from the clear water of a running stream." To be a good teacher it is essential to be engaged on a research problem. That is the only way you can give something of yourself to the student. Then the student can drink from the clear water of a running stream. Your enthusiasm and devotion are infectious.

Danger of a superior attitude

So often a professor assumes so superior an attitude that his students will not feel free to discuss their problems with him openly. This superior attitude acts as a smoke screen. Fortunately, I may say that I have not come across much of this in America but it is far too common at Continental and British universities.

Setting an example

A professor should not be afraid that his students will get to know him better and so discover his ignorance and inability. The greater the teacher, the less he must use his status to impress the students. John Ruskin, great educator that he was, stressed the function of the teacher beautifully.

> Education does not mean teaching people what they do not know; it means teaching them to behave as they do not behave; it is not teaching the youth the shape of letters and the tricks of numbers and then leaving them to turn their arithmetic to roguery and their literature to lust. It means, on the contrary, training them into the perfect exercise and kingly continence of their bodies and souls. It is a painful, continual and difficult work to be done by watching, by warning, by precept and by praise, but above all, by example.

There can be no doubt that in the training of our students the setting of an example is an important tools to be used.

As professors we hold in bondage the idealism of so many students, so many potentially great men. We are entrusted with their guardianship, and we have to set the example for them.

Confident

We have to do our teaching and research in such a way to imbue our students with confidence. This concept is described so aptly in a hymn:

> Whatever way my days decline
> I felt and feel though left alone
> His being working in my own,
> The footsteps of His life in mine.

Love of subject

Another essential prerequisite for a good animal husbandry teacher, besides being able to teach and do research work, is that he must also be a real cattleman—have a natural understanding of livestock. He must be able to appreciate the beauty of livestock and it must give him real enjoyment to be amongst his animals.

Equanimity

The famous surgeon and medical teacher, Sir William Osler, in his book *Aequanimitas, with Other Addresses,* puts the function of the teacher boldly:

> The teacher must be approachable; his students must have the confidence to come to him for counsel at all times. The most important attribute of the great teacher is equanimity, that means he is able to remain calm and dignified even under stress. It is essential to be able to think clearly and to pass fair judgement during periods of danger or difficulty. You are required to inspire confidence in the students entrusted to your guardianship. No moody person can achieve real success in teaching students because the student is always at a loss to know when he may discuss his problems with such a teacher.

> The teacher's sense of humour is his greatest tonic.
> To acquire equanimity—evenness of temper—it is essential not to expect too much from junior students. Knowledge comes fairly soon, but wisdom lingers. It comes only with time. In our search for the truth, the absolute truth, we are aiming at the impossible, We have to be satisfied with each finding, a fraction of the whole truth. Each of us must endeavor to fit together a few sections of the big "jig-saw puzzle."

Discovery

Scientists in films and magazine advertisements are always shown examining test tubes as if on the brink of some great discovery, but I suspect the outside world does not know how rarely one discovers anything. The road to the frontier is long and undramatic, the seeker like someone who finds himself off the trail on a mountain at night with only a small flashlight and an average amount of nerve. The mountaineer wants only to find the trail again, whereas the scientist—well, what does he want? Anyhow, if he gets even the smallest fragment of what he's searching for, then there comes a moment of sheer exhilaration comparable, I suppose, to what an artist feels when he has done something creditable. Next comes the period of doubt, the check and counter-check, and often as not the disappointment. It was not new after all, or else it was not true.

The attitude of professors and research workers must be one of anxiousness to make some contribution toward better agriculture. The greatest possessions of any agricultural institution are the great names of those people who have given themselves to agriculture and to the students—past and present. These men have walked the thorn-strewn paths. They have climbed the steep incline to the top by sheer determination, hard work and sacrifice, and often at the cost of envy and jealousy by their colleagues. The reward obtained is not monetary. It is the appreciation, admiration and respect of students—a sweet reward.

Personal influence

The influence of the teacher gives life to the institution; without it there is nothing. An academic system without the personal influence of the teacher or the professor is like a winter in the Arctic. It is cold, and the coldness petrifies everything; it becomes a cast-iron institute producing learned barbarians instead of educated and civilized citizens.

Enthusiasm

It is the duty of every university to endeavor to put enthusiastic men at the head of the departments, men who have a deep-rooted love for the subjects they have to teach. Each must feel a constant urge to teach his students the subject to which he is devoted.

Not only must the teacher have a thorough knowledge of his subject, obtained by study and research, but he must willingly share his experiences with his students and communicate his enthusiasm to them.

If we had the privilege of seeing foreign countries and the research work done by other workers in our field, it is our duty to convey this knowledge to our students. By doing so, we will imbue our students with enthusiasm. The students' self-confidence and enthusiasm must never be thwarted; they must be developed and guided.

The *Physicians' Bulletin* commemorating the twenty-fifth anniversary of the discovery of insulin contains the following remarks on the value of enthusiasm as opposed to the stifling effects of regimentation:

> In an attempt to sum up Banting's amazing accomplishments I should feel inclined to express the opinion that much of the success that he and Best met with was due to the fact that they did not allow themselves to be deterred by adverse reports and literature. Dr Macleod was frankly skeptical about the whole enterprise, but fortunately was willing to waive his own opinions and to give Banting facilities to carry out the experiments which he outlined with the collaboration of Dr Best. I think that this is most important. We should avoid undue regimentation of scientific research. In wartime it is obviously necessary. In peacetime the development stages of any program may, of course, be regimented; but in the initial stage of the breaking open of a new field, such as the development of insulin or penicillin, young investigators full of enthusiasm should be given

> the greatest possible free hand and should be allowed to carry out experiments as they see fit, in a manner that might not be approved in a thoroughly regimented system. Older men in charge of research laboratories should be extremely cautious about exerting a dominant position or dictating in any way to the younger men working with them. They should simply be advisers. I would venture to guess that had regimentation such as we have seen during the war been practised at the time that Banting and Best were doing their epoch-making work, the discovery and development of insulin might have been greatly delayed.

Since 1941, the memorials to Banting have grown and multiplied. The most important of these are not the institution and lectures and buildings and foundations and ships and other tangible memorials which bear his name. Of importance instead are the miracles that happen every day throughout the world—the miracles of human beings who are brought back to health and hope by insulin.

Freedom from regimentation

My dislike for having agricultural economists at the head of animal science programs is clearly reflected in the following quotation:

> The farm and the factory differ essentially at the point of freedom. If the economist makes a factory out of land for crop and animal production, introducing military control with large-scale units, piece work, specification, he destroys the peculiar character of the yeoman, the man who owns himself, directs himself, and has a judgement based upon independence. Therefore, I would say, let the economist of agriculture begin his plans with a thorough consideration of the human factor, its limitations and ideals, and fit his economic schemes to the character of the farmer.

Sir Solly Zuckerman, eminent British scientist, physiologist and leader, defines academic freedom as follows:

> What first do we mean by academic freedom as it applies to the pure scientist? One means not only the freedom to investigate those problems which one seeks

> oneself, but also the fact that significant advances in scientific knowledge cannot be ordered by decree. Every act of creation requires its special freedom.

Hence the failure of the project system where projects are to be handed in a year or more before the time at which the research worker can commence his research work. Is there anything that thwarts the enthusiasm of the research worker more than this?

Dr. Filmer, retired director of animal husbandry research in New Zealand, concluded a farmers' day speech as follows:

> I will not embarrass my successors by expressing my views on the way agricultural research should be administered in the future, but I do want to emphasize that there is something infinitely more important than administration. Perhaps I can get my point across with three quotations. The first is from *Punch* of 23 years ago: "The greatest of all research problems is the people who do the research."

I would like to add to this—*and to find the people who have a natural aptitude for research work.* During the past 20 years, the Department of Animal Science at Pretoria University has produced almost 350 graduates and I have grave doubts if there are 20 real research workers among them.

The second quotation which Dr. Filmer used in his address came from Sir Henry Tizard's *Nature*, 41115,392:

> The fact is that all really new developments of industry and agriculture are the product of the work of a very few men.

The third is from an address by Sir Ben Lockspeiser, a former Secretary of the British Department of Scientific and Industrial Research, in a 1959 issue of *Science*:

> Let me therefore conclude by underlining the importance of good administration by reminding you also that administration in science will not, of itself, produce a single new idea, and without new ideas science would cease to exist.

Research

Research is based on the original ideas of a few men. If these men can be encouraged to think and if arrangements can be made to test the ideas that arise from their thinking, you will get all you expect from research.

At least eight million people the world over owe gratitude to Best and Banting, but do they realize this? The cattlemen of this country owe much gratitude to the University of Pretoria and other universities where animal science is taught and where important research is done. Who knows the financial benefit they derive from this work? They should show their appreciation by contributing generously toward research. The financial assistance given to research institutes is a sound investment from which all mankind derives benefit.

Continuing contact

It is the duty of each professor of animal science to have his finger on the pulse of the livestock industry. He must be aware of what is happening on the cattle ranches, on the feeder farms, in the meat trade and in the feed trade. Goodwill between the professor or head of the department and the total livestock industry is invaluable. It is that aspect of his work which helps raise funds for research and enables him to place his graduates in better positions.

The task of the professor and head of a department is a most difficult one and does not end with teaching and placement of the students. Long after the student has graduated the professor still guides his past student, for he has inspired the young man with so much confidence that he comes for counsel many years after graduation. The students who have been trained by you realize they have a responsibility to you and the institution. This responsibility prevents the past student from going off the rails and builds tradition for an institution.

Loyalty

An important responsibility rests with the student. He must have loyalty to his university, his professors, his fellow-students and his parents. If a student is loyal to his university or his teachers, he will tell them his feelings about their weaknesses or errors of judgement. He will, with the co-operation of the teachers, try to improve the status of his university. Loyalty to an institution means that the student after graduation will do his duty toward society in general and will endeavor always to uphold the good name of his university.

The parents' role

One aspect of the student-teacher-parent relationship that puzzles me greatly is the lack of interest parents have in their children. For every ten people who come to discuss their animal production problems with me, only one comes to discuss his son's problems.

Discipline

It is, moreover the duty of parents to back a professor in disciplining their son. It is essential that the parents show loyalty to the teacher, but loyalty is a mutual concept: teachers should try to know as many parents as possible.

The word discipline derives from the Latin "to learn." I trust that each student will feel that when the university authorities have disciplined him, he will look on it as part of his learning and not as punishment. Discipline and self-discipline are part of our education.

Investment in education

The education of our students costs the state vast sums of money. It is expensive to build and equip laboratories, and it is the duty of the farmers and of commerce and industry to make grants for that purpose.

Since the Russian Revolution in 1917, we know little of what really happens behind the Iron Curtain and we know little about the Russian educational system. What we do know, however, is that their technological education is of a high order. They were the first to launch manned and unmanned satellites successfully. So, obviously, Russian technological training is not poorer than that of the West.

How good their agricultural training is we do not know, but I doubt whether it equals that of the West, especially that of the United States of America. America had to feed many Russians even until recently. Had it not been for American wheat, many Russians would not have had bread to eat. Scientific and technological leadership must be maintained in the West, and to do this we must devote much time to better teaching.

In Russia the students are considered the most important faction of the population and they are certainly the best cared for group there. In Russia all students in the basic sciences and technology are paid a minimum salary of 300 rubles—approximately $80—a month. Outstanding undergraduate students receive a monthly salary of approximately $200; special concessions are made to these men for their cultural development by allowing them to attend operas and concerts at reduced cost.

The problem of financing our student training is one which should receive much more attention from commerce and industry. It is the duty of the successful industrialist to contribute much more toward creating more and better facilities for student training and research—for both peace and war.

All I can hope for is much closer co-operation in the future between professors, students, farmers and industrialists.

Sir William Hamilton said:

> On earth there is nothing great but Man. . . When you invest in young people you invest in eternity.

The challenge

To live up to those two contentions, the professor must train his students with devotion and make a persistent, intelligently directed effort to a better understanding of young men and women.

> I wondered where my soul might be
> I searched for God but He eluded me
> I sought my brother out and found all three.

The modern student

Owing to the world situation, the modern student is much more difficult to educate and train and the average student much more fatalistic than his counterpart of fifteen or twenty years ago.

The modern student has grown up in an era of urban terrorism, hijacking and tremendous economic instability, as a result of which he has much less respect for his superiors than the student of the past.

Nosmo King, the British comedian who adopted his nom de plume from the many No Smoking signs in the theatres where he appeared, aptly describes the attitude of so many young people in a poem entitled "Values":

The World is full of sons of discontent,
Wealth without work their futile, feverish bent,

Fortune by lucky chance, the chains of toil to sever,
Heedless of primal law - by sweat and stern endeavor.

The task takes second place, the pay is all that matters,
The dream of easy cash their resolution scatters;

Less hours of work, more of uneasy leisure,
Pursuing joylessly the costly myth of pleasure.

What part have I in all this restless quest,
Where only that which costs the most is best,

Where values are in glitter and display,
Where men are judged by what they have to pay?

But to the professor and the serious-minded student the latter half of the poem is of great significance:

There's so much more in life than this to me,
So many precious gifts completely free;

God's bounty which He lavishly bestows -
(Who really knows true wealth who only money knows?)

The rippling moonlight in a woodland pool;
The dimpled, laughing infant at the school;

The long, cool shadows where the elm trees stand;
The swelling bosom of this lovely land;

Cascading roses on a garden arch;
An ancient wall that saw the legions march;

The smell of wood smoke in the evening breeze;
The cawing rooks amongst the distant trees;

A hand-clasp with a comrade of the past,
Renewing bonds that will forever last;

The song of birds at closing of the day,
The fragrant perfume of the new-mown hay,

The sweetness that the walls of home provide;
Your children and a brave wife at your side;

The summer sun—The moon and stars that shine,
What need have I of greater wealth when all this wealth is mine!

At the time I was a student, half a century ago, an anonymous poet wrote the following poem, which we adopted as a motto:

Cheerily, lad, look out on life,
Laughing at Fortune's frowns,
Grit is born of manly strife,
All have their ups and downs;
If you chance mishaps to meet,
Bear as a man should do,
Standing steadily on your feet
Still to yourself be true.
Cheerily, Lad, pursue your way,
Smile tho' your heart be sad,
Help your brothers when e'r you may,
Making the downcast glad;
Do your duty with hand and heart,
So tho' you win not fame,
You should have bravely played your part,
Victor in life's great game.

Future life-task

It is my considered opinion that many of the problems with the modern student are due to the large numbers of students entering our universities who do not really know where they are going. So many students take degrees, majoring in subjects which might have academic value but which do not help the graduate to fill a remunerative post.

The teacher must be a person who "has been around," as the Americans call it, who knows what the job requirements are in his special field of endeavor.

I have always kept contact with the various organizations which could place animal science graduates in remunerative posts, such as the feed trade, the meat trade, livestock auctioneering firms, large ranching organizations and various government institutions.

The serious-minded student comes to a university to qualify himself, to become really proficient in a selected future life-task. Such a person is anxious to learn. Such students are often those who are critical towards the teacher who does not present them with well-prepared lectures to assist in their future life-tasks.

The teacher must not only be widely read and up-to-date in the latest developments in his field of endeavor, but must also maintain contact with many colleagues all over the world to enable him to make his lectures interesting and meaningful and to introduce his students to the wider professional world.

Observation and perception

The teacher must be enthusiastic and encourage the student to do his work well. A most valuable thing I have taught my students is to be observant. Keen observation and thorough, in-depth interpretation of what one observes in animal management and animal reaction are essentials of an able animal scientist. So many of my past students have so often informed me that one important factor in my teaching was the development of their perceptive facilities.

Guidance in communication

Another important aspect of teaching is to teach students to communicate with their fellow-men and especially with prospective employers. So, I took my final-year students once a week to big ranching organizations, stud breeders, stud-book associations, feed manufacturers, packing houses, etc., for practical classes. By so doing, the student is given an opportunity to observe his teacher's attitude towards his fellow-men and towards possible future employers. This helps so much in placing the graduate in a suitable post.

In establishing sound communication, it is essential for the teacher to know his students and as much of their background as is humanly possible.

In the final year it is essential to teach students how to behave, especially towards superiors, as this is so important in getting a useful job. In this whole process the esteem by which the teacher is held in the world of animal science is tremendously valuable to the graduate student in finding a suitable position.

Giving

Finally, the teacher must give himself to his students. Emerson said it so beautifully: in gratitude for God's gift of life to us, we should share that gift with others, our students:

> We give of ourselves when we give gifts of the heart: love, kindness, joy, understanding, sympathy, tolerance, forgiveness...
> We give of ourselves when we give gifts of the mind: ideas, dreams, purposes, ideals, principles, plans, inventions, projects, poetry...

By giving, we receive so much: the friendship, the respect and love of our past students.

> I asked for all things, that I may enjoy life;
> I was given life, that I might enjoy all things.
> I got nothing that I asked for—but everything I had hoped for;
> Almost despite myself, my unspoken prayers were answered;
> I am, among all men, most richly blessed.

The rewards of teaching and research are friendship, love and kindness received from family, friends, fellow-students and the farming community—a truly rich reward.

My final advice to students is: You have at this stage of your career contributed little to a better community. Respect those who have given themselves to students like yourselves in an effort to improve our world. A wholesome respect for each other is essential to make your lives meaningful and your future bright; this will give you a happy, full life.

A final quote from Farrar for graduates:

> Knowledge without common sense is folly; without method it is waste; without kindness it is fanaticism; without religion it is death. But with common sense it is wisdom; with method it is power; with charity it is beneficence; with religion it is virtue and life and peace.

Chapter 13

The Global Approach to Animal Science

The explosion of scientific discovery and knowledge during the past century includes agriculture in general and animal science in particular. Hybridization of corn, wheat and other cereals has increased yields beyond expectation. The breeding of quick-maturing chickens, plus the scientific methods employed in the maintenance of their health and nutrition, has revolutionized the poultry industry, resulting in vast quantities of broiler chickens and eggs to meet the ever-increasing demand for animal protein.

Nevertheless, a tremendous gap remains between the results of agricultural science research accumulated over the past generation or more and their application in practice. The reason for this is that research results are usually published in obscure scientific journals or delivered as highly scientific papers or theses at universities. To a large extent this applies to all scientific research.

For instance, the principles of nuclear fission were known long before the atomic bomb was developed, but a world war was necessary to put them into practice. This was no doubt due to the killer instinct in man which enabled him to assume ascendancy over other animals through his discovery, in an early stage of his evolution, that he could use his hands to wield weapons with which to kill other animals, even those much larger than himself, to eat their flesh, to defend himself against predators, and to kill his fellow-man on various legitimate and illegitimate pretexts. To wield his weapons, man had to walk upright and this changed his anatomy to the extent that there was more room and opportunity for brain development, which in turn led him to the knowledge that enabled him to forge his weapons into more and more sophisticated forms, instead of retaining the rocks, sticks and jawbones of large animals he had used in his primitive stage of development. And so it came about that man eventually learned to forge plowshares to grow crops to feed himself and his domesticated animals, and to make the tools that made modern industrial development possible.

But during the past two hundred years man, in his conquest of the earth, has accumulated such a vast conglomeration of scientific and technical knowledge that highly-trained specialists are needed to shift and develop it for practical purposes. Understandably, few of these specialists have the added gift of translating their knowledge into language understood even by scientists in similar fields, and less so by the layman who has to put it into practice. Thus there are highly qualified and knowledgeable scientists today who are unable to pass on their research results to others simply because they cannot see the wood for the trees.

So, I have subtitled this chapter "The global approach to animal science teaching." Teaching is the key word. A knowledge of animal science is useless unless there are teachers capable of passing on the available knowledge to others, but these teachers must be able to see the whole wood and not only the individual trees in their immediate range of vision: they must have a global approach to their subject.

This is the challenge that faces mankind at the present moment and it is one reason that so much emphasis is placed on the importance of communication media. The problem of communication is not insoluble; it is a challenge to scientists and co-workers in research, teaching and technology who seek to interpret the relevance of theory to the practical in animal and crop production.

A dual challenge faces the teacher of animal science: first, to keep abreast of knowledge in his specific field of animal science; second, to revise and adapt teaching methods and techniques to incorporate, translate and transmit new knowledge, thus enabling the student to apply it in his new career. As Willmott said, "Education is the apprenticeship of life."

If the world is to receive full service from animal scientists, all institutes of learning must turn out trained men. That means a constant reorientation of university instruction and research, not merely for the purpose of increasing technical proficiency, but also to keep abreast of social and economic change. Future leaders in animal science must be trained men.

The aim of education in animal science should be to teach students **how** to think rather than **what** to think; to improve their minds to enable them to think for themselves, rather than to burden their memory with the thoughts of other men.

The most important part of any course is the teacher. Enthusiasm and love of his subject are as essential to a teacher as a high degree of competence. A teacher must have an inborn desire to gather and understand knowledge, and a passion for sharing it with students. One goal of graduate training should therefore be the development of such teachers. The best method to accomplish this is usually the example set by the professor and his graduate teachers. These men must have a philosophy about teaching and also about the subject they teach. True philosophy is that which leads to our sustained improvement and development, both inwardly and in relation to all about us, and at the same time fosters greater contentment, patience and calm, while making us more receptive and appreciative of all decent and pure enjoyment. In other words, it must be a joy to be an animal scientist and a teacher and to be with cattlemen among their cattle where you can apply your knowledge in a practical way.

It is obvious that the effectiveness of any research program is dependent on the training and imagination of research workers. One continuing problem of the developing countries has been the failure to separate the husbandry from the veterinary aspects of animal science; there is a preoccupation with veterinary aspects of animal production at the expense of the all-important and purely husbandry aspects of animal science.

These two aspects are unquestionably closely related, complementary and equally important, but it should be equally clear that they cannot be combined successfully in a single undergraduate professional curriculum. At best such training can be expected to produce graduates who are only reasonably competent in both animal science and veterinary medicine. As the Bible says, "No man can serve two masters: for either he will hate the one and love the other; or else he will hold to one and despise the other." In other words, you cannot serve with full competence both animal and veterinary science at the same time.

It has to be remembered, though, that animal disease control and animal husbandry frequently meet. This is the point where the two professions meet and co-operate and even overlap to the benefit of animal production. Always, however, there should be co-operation and continued dialog between the husbandman and the veterinarian, as there should be among the man who designs a machine, the man who buys it and the man who repairs it.

To understand the complex ecological, biological and socio-economic problems of our times, both the animal husbandman and the veterinary scientist must be well grounded in the basic sciences and the humanities. The husbandman must have additional competence in livestock ecology, nutrition, genetics, physiology, economics, farm and ranch management, and a working knowledge of crop production, pastures and the relationship between trees, pastures and soil. The veterinarian must have training in depth in veterinary anatomy, physiology, biochemistry and the clinical subjects. When these curricula are separated, however, it will become even more important to strengthen communication between teachers and research workers in these disciplines and those engaged in extension activities.

It is generally accepted that the most effective teacher is one who is also a research worker and that the research scientist is most effective if he or she also teaches. Another factor that must be recognized is that the pool of knowledge in both animal and veterinary science grows at a faster rate than the ability of the human mind to assimilate knowledge. It is therefore essential to separate through careful selection the respective fields of knowledge that are required for a veterinary or for an animal production curriculum from the vast amount of available facts.

The question is now: How should the animal scientist of the future be trained?

The following thought-provoking comments are made by the American Commission on Education in Agriculture and Natural Resources Agricultural Board: "The animal science graduate of the future. . . may be defined as one trained in the diverse aspects of production of animal materials for the benefit of mankind, and in the scientific methodology required for the continued investigation and improvement of production techniques."

In my opinion, animal science graduates of the future are not likely to fit a single mold. The objective must be to seek methods of improving the curriculum to give animal science students, through livestock ecology, the extensive exposure to biology necessary to ensure an understanding of new concepts of molecular and cellular biology—concepts such as the role of DNA and RNA (deoxyribonucleic acid and ribonucleic acid) in genetics. Provision must also be made for two distinct student career groupings, namely for those oriented toward livestock production, farm trade and management of the nation's livestock enterprises, and for those students intending to pursue careers in research, education and other exact science activities. The objective in the education of animal sciences should therefore be to serve both the basic science of animal production and the livestock industry. Specialization in either of these directions should be at post-graduate level after integrated pre-graduate study.

The pure scientist is sometimes so narrow in his interests that he becomes isolated and cannot identify the important industry and livestock problems; he is therefore unable to communicate with his colleagues in fields outside his own, let alone to the cattlemen whom it is his mission to serve. Animal science that cannot be applied to practice is like rain on a hot stone; it evaporates and disappears. Exposure to the animal industry during his youth or in his early undergraduate studies is therefore an essential part of the training of an animal scientist.

After many years in animal science teaching and after scrutiny of the curricula of many fields of training and at many universities, I am convinced that the first-year student, although in need of basic training, sadly lacks contact with the applied aspects of his course. This leads to confusion and frustration and frequently to abrupt changes in career or complete academic failure. It is the duty of all teachers of basic subjects to feed the enthusiasm of their young students and to motivate them towards understanding the meaning and eventual application of basic science in their future careers.

The first-year botany course should be redesigned for agricultural students by offering less systematics and taxonomy and more ecology, soil-plant relationships, the botany of crop plants, tree-grass association and the importance of energy metabolism in plants.

As far as the chemistry course is concerned, the first-year agricultural student must appreciate why he is taking this subject. The first-year chemistry course should be shown to be a stepping-stone to agricultural chemistry and bio-chemistry. The student must be activated by teaching him why a thorough knowledge of chemistry will enable him to understand better the chemistry of the living body and plant. He should be made to realize the analyses of feedstuffs, body tissues, hormones, are essentials in a basic course in animal science.

Physics should be taught in a way that stimulates the imagination of the student in the biological sciences. What is light and how does it influence plants, man and beast? Of what importance is radiation in biology in general? How do thermo-couples work? These are but a few examples of the relevance of physics to problems encountered in animal science. At present the agriculture student is only a nuisance to the physics teacher, while physics is often an insurmountable obstacle to the agriculture student. This need not be so, if both the teacher and the student appreciate that the subject has real value for the agriculturist in his future career.

The zoology course should devote much more time to vertebrate zoology, osteology, histology and embryology, so that it can form a sound basis for future courses in anatomy and histology in the agricultural departments. Small domestic animals should be the subjects for dissection study in preference to frogs, for example.

Teachers in the first year should be production-oriented and not necessarily over-specialized in a narrow field of knowledge. In other words, I feel that the first-year course in botany, chemistry, physics and zoology should be taught by animal scientists who have a special aptitude for and special training in those subjects so that they are able to link the theory of botany, chemistry, physics and zoology to animal-husbandry research and production.

I have often had occasion to use physics and chemistry in climatological and ecological research work and to use botany in ranch research work, where bush encroachment, plant succession and pasture management are essential facets of research work.

A one-semester course in journalism can fruitfully replace some of the botany or zoology that has no application in animal science. Communication and the distribution of knowledge are of great importance to the animal scientist and should be studied purposely.

An inter-species introductory course in livestock ecology should be introduced during the first year. This is not only an intensely interesting subject for awakening enthusiasm in students, but it would serve as a useful link between the animal sciences, botany, chemistry, physics and zoology.

The quality of the environment is of great importance. With its deterioration as the populations of man and his domestic animals increase, the ecological balance is becoming a cause for growing concern and calls for greater technological application and know-how on the maintenance of life in restricted space.

The symbiosis of man and his domestic animals is, in fact, older than recorded history as is clearly illustrated by Georges Bataille in **The caves of Lascaux; or, The birth of art**.

Prehistoric man began exercising judicious control over animals and plants in his immediate environment. In the present age, in which cellular and molecular biology are much in vogue, the animal scientist may be in the best position to show students how the total organism responds to its total environment and that manipulation or change of the environment results often in predictable responses and adaptability phenomena.

With these facts in mind, the following concepts should be taught in the introductory course in animal science:

1. Regionalization of agriculture and animal husbandry.
2. Introduction to livestock ecology (homeostasis).
3. Animal products, their characteristics and their utilization by man.
4. Productive life-cycles.
5. Growth and reproduction.
6. Reproductive characteristics.
7. Behavior (pecking order; territorial imperative).
8. Elementary genetic concepts.
9. Nutrition on an inter-species basis.
10. Selection for functional efficiency.
11. Livestock improvement schemes.
12. Animals' relation to man.

For the immediate future the aim should be to devote the utmost in material and human resources to the development of the introductory course since it is the pivotal point for developing an undergraduate teaching program that is sound and likely to attract students. Unless the "how" and the "why" are related, the most important requisites in education—the interest and curiosity of students—are omitted. The curriculum must provide students with an education that contributes to their development into good citizens in a democratic society as well as their development as competent, reliable and productive professional people. A carefully devised animal-science curriculum, coupled with effective teaching, will achieve this ideal.

An essential prerequisite in the compilation of the undergraduate course in animal science is to identify the avenues of employment that the young animal scientist is to qualify for and to train him in a way suitable to finding employment and to making a contribution to animal production. There is no room for differentiation at undergraduate level according to species of livestock such as cattle, horses, pigs, poultry or sheep. Differentiation, or rather, specialization, should be allowed only at post-graduate level, at which it can be either at species level or in any of the associated disciplines, such as reproduction, nutrition, genetics and physiology.

In this approach some essentials can now be explained.

Animal nutrition

Livestock nutrition is an applied science. It is based on biochemical and physiological concepts and the interactions of nutrition and growth and body conformation. The study of animal nutrition leads to feeding systems in the final year and includes the compilation of rations, feed requirements for production systems, the nutritional needs of the domestic livestock species and the evaluation and analysis of rations and feedstuffs inclusive of the economics of feeding and feeds.

These applications are based on a study of feeds, their composition, sources and production. This study includes pasture science, pasture management and improvement, and seasonal and ecological factors affecting pastures.

No undergraduate course in animal nutrition can ever be complete without extensive traveling by student groups to study pastures in various ecological regions of the country. This again includes soil conservation which in turn is based on soil science and basic ecology.

Applied nutritional aspects are based on the metabolic processes relating to the various feed components, inclusive of minerals and vitamins, their functions, the requirements of different species and the sources and economy of these products.

Fodder-crop production forms an important part of animal nutrition training, which means that the entire course is multidisciplinary. It requires purposeful co-ordination and teamwork by lecturers free from vested interests: competent, enthusiastic and motivated in production matters.

Animal nutrition should be taught on an inter-species basis since the principles of ruminant nutrition are the same for cattle, sheep and goats. The emphasis should be on the principles of nutrition in its widest application. The nutrition of pigs and poultry is then included with little trouble.

As little investigation as possible should be done on rats and other laboratory animals. It is rare that an investigator uninitiated in livestock will readily choose to work with rats as experimental

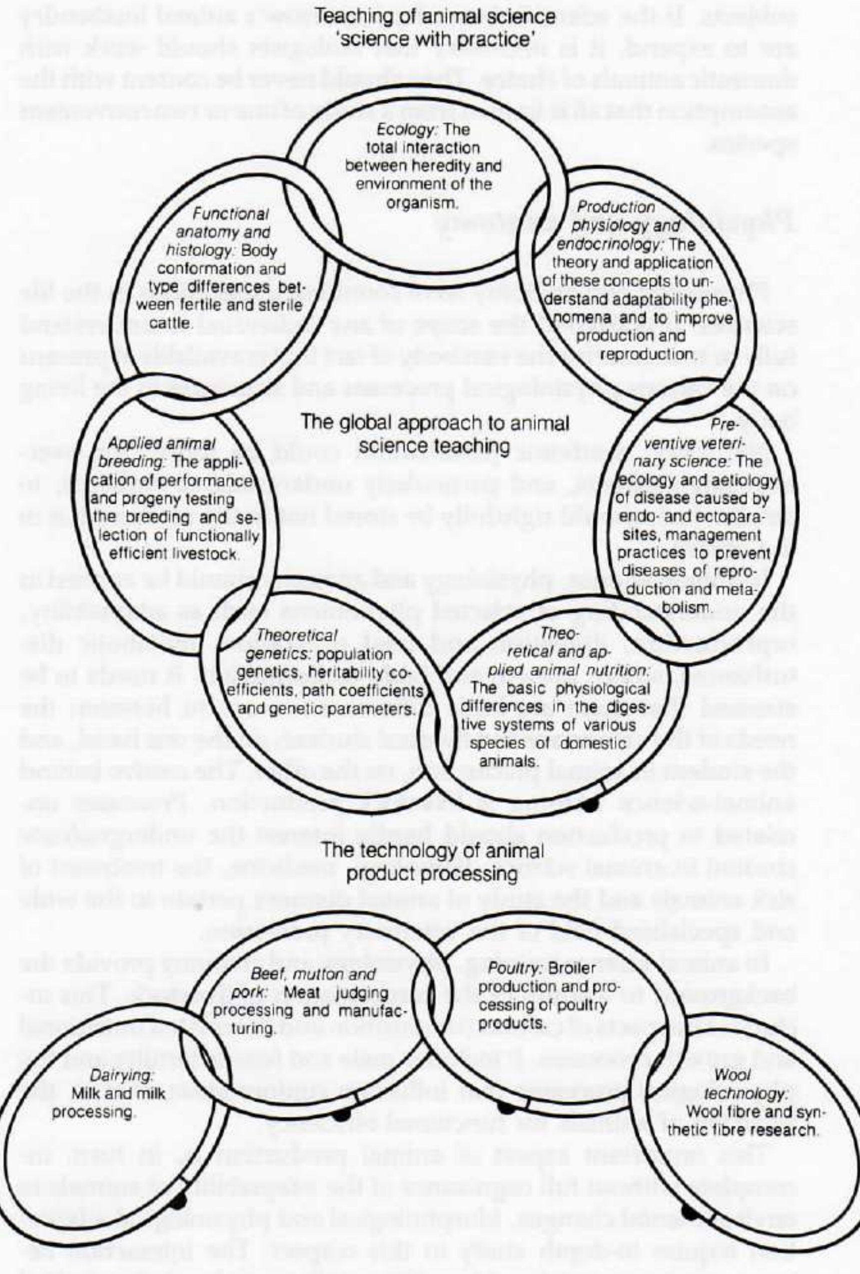


Figure 13.1 Each undergraduate course should be linked with another to form one complete unit. The master links can be linked to the complete chain, if necessary.

subjects. If the scientific bases for tomorrow's animal husbandry are to expand, it is necessary that biologists should work with domestic animals of choice. They should never be content with the assumption that all is known from a study of one or two convenient species.

Physiology and anatomy

Physiology and anatomy have countless implications in the life sciences. It is beyond the scope of any individual to understand fully or to memorize the vast body of fact that is available at present on the various physiological processes and structures in the living body.

Naturally, academic justification could be found for over-exposing students, and particularly undergraduate students, to detail which should rightfully be stored not in the memory but in the library.

In animal science, physiology and anatomy should be applied in the understanding of selected phenomena such as adaptability, reproduction, digestion and feed utilization, metabolic disturbances, stress, growth and body conformation. It needs to be stressed that there are basic differences in accent between the needs of the veterinary and medical student, on the one hand, and the student in animal production, on the other. The motive behind animal-science training is livestock production. Processes unrelated to production should hardly interest the undergraduate student in animal science. Pathology, medicine, the treatment of sick animals and the study of animal diseases pertain to the wide and specialized field of the veterinary profession.

In animal-science training, physiology and anatomy provide the background to a study of the conformation of livestock. This includes all aspects of carcass composition and the related nutritional and growth processes. It includes male and female fertility and the physiological processes that influence conformation, that is, the selection of animals for functional efficiency.

This important aspect of animal production is, in turn, incomplete without full cognizance of the adaptability of animals to environmental changes. Morphological and physiological adaptation require in-depth study in this respect. The interaction between environmental and hereditary influences has to be studied to understand this adaptation.

The theory of heredity, the physiology of adaptation and the conformation of functional efficiency form the corner-stone of animal-science training. It is consequently unwise to demarcate genetics, physiology and anatomy in animal production; they interact and are interrelated. The tutor in any of these directions should teach in full collaboration with those in the other directions to explain the interactions in great detail.

Ecology

A study of ecology is closely related to the subjects mentioned. The environment, in its entirety, has a predominating influence over the organism. It limits the genetic potential through retardation of physiological processes and modifies the conformation accordingly. Or it allows full expression of the genetic potential and the attainment of optimal adult size. This means that production and all related mechanisms are intimately influenced.

It is consequently of great importance to study livestock ecology diligently in the more basic fields in botanical, zoological, physical and chemical courses. The approach, always, should be directed at interaction and behavior and morphological adaptation, rather than that of the frustrating rigors of memorizing taxonomy.

Interweaving these forces with the adaptational reactions of the organism inspires and motivates the undergraduate student to learn more about the ways and processes of nature. This will lead to greater understanding and appreciation of the production processes and will give more meaning to undergraduate training, motivation being the most important component of discipline and dedication.

Animal breeding

The course in functional anatomy brings logic to judging livestock on the hoof. This in turn is closely linked with the courses of applied animal breeding, that is, selection for functional efficiency and adaptability. The undergraduate course in animal genetics should teach breeding as an applied field of population genetics.

Animal breeding is in the throes of a transition from purely subjective methods of judging breeding stock by antiquated empirical standards to more objective means of evaluating animals by performance and progeny testing. Today's animal geneticist and practical breeder is trained to keep accurate records and then to use them to decide how to select animals in a program or plan. The animal-breeding course should therefore teach the following concepts:

1. Genes in a population (qualitative inheritance).
2. Relating gene behavior to measurable population statistics (quantitative inheritance).
3. Breeding program development (the application of the principles taught under 1 and 2).

The mightiest tool in the hands of the livestock breeder is selection; it is the primary force employed in the breeding program to bring about change and improvement. Here again, consolidation of the animal-breeding courses is advocated. Training in animal breeding at the undergraduate level should be on the principles of "how" and "why." Too frequently the biggest living animal in the Department of Genetics—a subdivision of plant and animal genetics—at agricultural facilities is the Drosophila fly!

Technology

Under the umbrella of the animal sciences should be included a course or courses in dairy, meat and wool technology.

In close collaboration with microbiologists and with the department(s) of Plant Production and Horticulture, these courses should be designed for training of food technologists. This should be done in close consultation with the trade and should include the preservation, packing and presentation of all agricultural products, inclusive of animal and plant products.

Such a course means that training in animal production is rounded off by relevant courses in food technology. Likewise, horticultural courses and courses in plant production should be rounded off by appropriate training in the technological aspects of these products. Fully-qualified food technologists, again, can serve as boosters for production because the correct preservation and presentation of all agricultural products serve as a display window for the producers' efforts and provide safe products of quality for the consumer. The reason for this is that there is a strong association between efficiency of production and the quality of the end-product. In the courses on dairy, meat, wool and poultry technology, the sound basic training of the animal scientist should be used to the full. Animal-product students, whether orientated towards research or industry, should have a strong background in mathematics, physics, biochemistry, bacteriology and microbiology.

The curriculum of the meat technology course encompasses anatomy, histology, the physical and chemical composition of muscle and fat, food microbiology, ham-curing techniques, sausage manufacturing, modern preservation techniques and research. This course includes the traditional course in meat grading, judging and carcass evaluation. When technological courses are taught in separate departments in the animal sciences and are duplicated at different universities, it results in several university curricula with low enrollments at high cost.

Training in developing countries

The history of the closing years of the twentieth century will fill many volumes: national boundaries, governments and economies are changing with ever-growing frequency. The demand for self-determination, a vote and a voice in the future of undeveloped peoples has been the main preoccupation of world politics ever since the Second World War. Intrigue and counter-intrigue rule the entire effort of governments. Industrial development and the arms race consume vast funds that are offered in exchange for political pacts and plots.

This has happened at the expense of agricultural development. In **Famine—1975**, the Paddock brothers state:

> In the entire history of Latin-America I know of no president in any of the twenty republics who was educated in agriculture although the area is almost wholly agricultural. This situation will not change in the next ten years. In 1962, of the 10,541 students (tomorrow's leaders) in Central America, only 187 studied agriculture during the past decade. Worse, this slim percentage has been getting slimmer during the sixties. Nearly all Latin-American countries have decreased their enrollment in agriculture during the past decade; in Mexico for instance from 4 percent to 2 percent. Of 105,000 Latin-American students in the United States during the decade 1956-1965 only 5 percent studied agriculture.

Freedom, equality and self-determination are discussed by big men in high-ceilinged and stately council-chambers. Their wars have had to be fought by the little men whose own plight was forgotten. Their leaders could not see their people and how they suffered—from deprivation and hunger. The leaders that were heard were the ones who brought liberation from undefined oppression "through the barrel of a gun." The leaders who tried to liberate with the plowshares were not heard.

There is deep concern about agricultural production and training in the developing countries. In Mozambique, Angola, Zambia and many other countries on the African continent, food production and agricultural training are at an all-time low. Rich soils lie waiting for crops, pastures for livestock, while there is a dire need for food and hunger ravages the population.

It takes many years to establish agricultural production because it starts with education, training, motivation. Reclamation of farm land and conservation farming are tasks demanding many years of dedication and expertise.

Political unrealities and intrigue have laid the foundation for a century of hunger if agricultural training in developing countries does not receive urgent priority. It is needless to give aid without first fostering expertise. Many millions of dollars for humanitarian aid will never solve the problems of ignorance and superstition. The power that armies and armaments bring is false; food is the only weapon that will never betray a nation.

All over the world it has become an obsession with public speakers on agricultural matters to exploit the population-explosion figure and the starvation associated with it in underdeveloped countries as a motivation for increased production in the Western countries. This is unjustified. The salvation of the hungry masses in the underdeveloped countries of the world lies in domestic food production and this needs training. Financial support provides meals but the hunger returns.

A great tragedy of the African continent is that, with all the goodwill and agricultural expertise available in the Republic of South Africa, power politics sees fit that this should be scorned in favor of political change. History will show what man needs most "freedom" or food.