Some Benchmark Papers of PROFESSOR JAN CORNELIS BONSMA

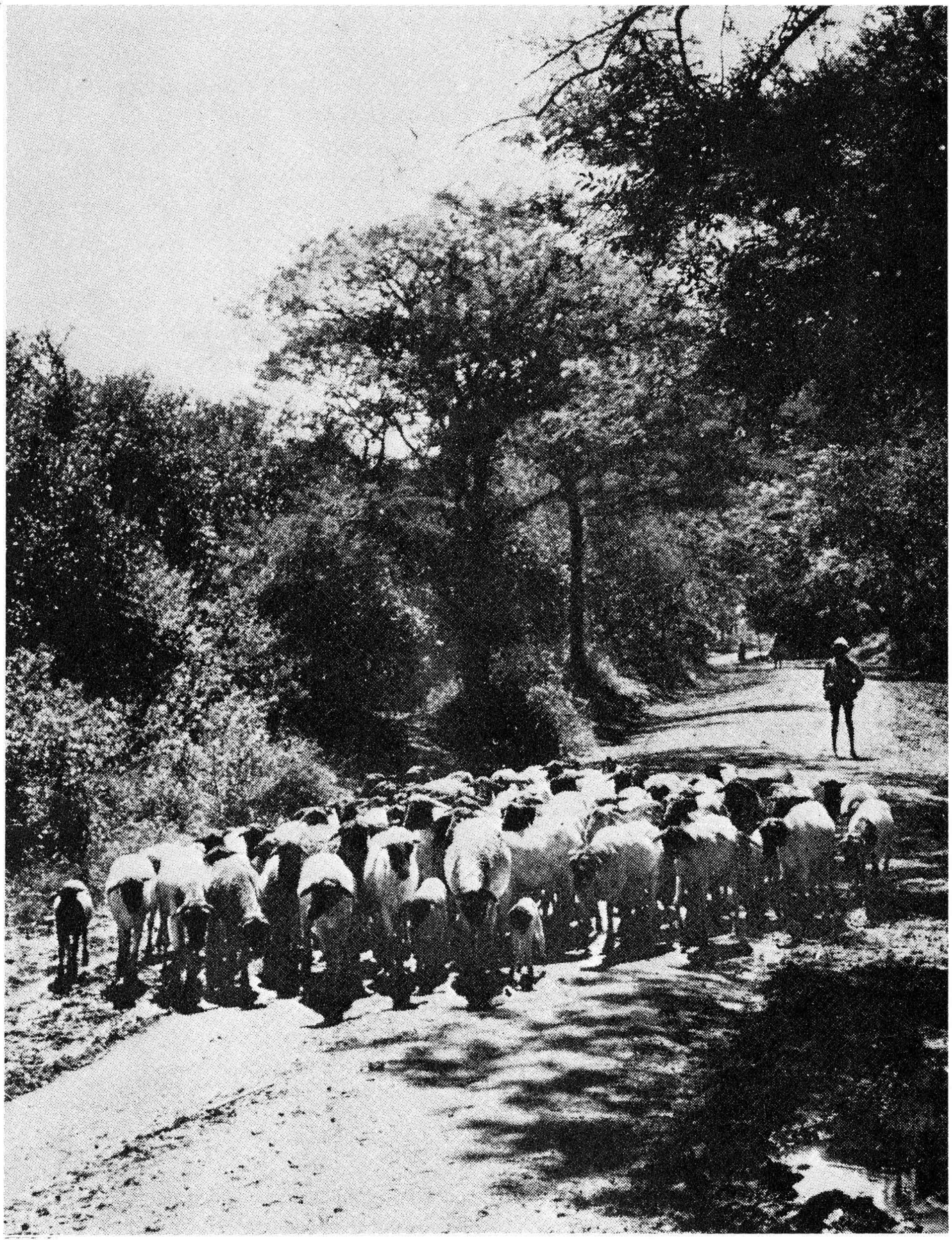


Fig. 1

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 the sheep and the 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.

Some Benchmark Papers of

Professor Jan Cornelis Bonsma

to commemorate his Eightieth Birthday

in Pretoria, 22 March 1989

UNIVERSITY OF PRETORIA

PRINTED BY CTP BOOK PRINTERS, CAPE

BD9397

Contents

Some Benchmark Papers of Professor Jan Cornelis Bonsma to commemorate his 80th birthday in Pretoria on 22 March 1989

Preface

Professor Jan Cornelis Bonsma is truly one of the outstanding scientists produced by this University and South Africa. To appropriately honour him on his 80th birthday, the University of Pretoria undertook to publish a selection of his research papers which reflect his important scientific contribution to the animal industry of, particularly, the tropics and subtropics.

The editors took the liberty of selecting, metricating and editing nine of his vast output of scientific and technical papers for reproduction in this volume. These papers cover the field of his endeavours in the ecology of domestic animals — of which he, together with A. O. Rhoad, was decidedly a pioneer and leading exponent in the 1940s and 1950s — as well as environmental physiology — where his keen observational powers were the basis of many advances which ultimately led to, inter alia, the creation of the Bonsmara breed of cattle. This name, indeed appropriate, was suggested by his lifelong friend Jim Galpin, and marks a monument to his scientific capabilities. One wonders if any other scientist in the field of animal breeding and genetics has been thus honoured!

Jan Bonsma seriously entered the arena of livestock ecology with a paper published in 1940 in *Farming in South Africa*, then a reputable professional journal. The title was "The influence of climate on cattle. Fertility and hardiness of certain breeds", and the contribution was co-authored by his early assistants at the Messina Experimental Farm in the dry-tropical Limpopo basin, G. D. J. Scholtz and F. J. G. Badenhorst. However, he clearly made his mark in international science with a paper which appeared in the renowned Cambridge *Journal of Agricultural Science* in 1949, entitled "Breeding cattle for increased adaptability to tropical and subtropical environments".

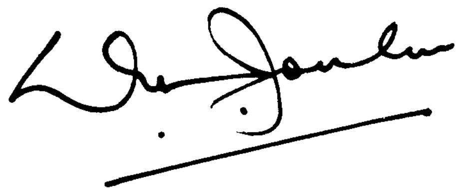
Two of the papers included in this volume, too, are co-authored. Although in his prime and even later Jan Bonsma published most of his research alone, this does not detract at all from his significant contribution to the animal sciences through the training of under- and post-graduate students. In fact, while he was at the helm of the Department of Animal Science, the majority of agricultural students opted to major in Animal Science, partly because of opportunities in this field, but certainly also because of his inspiration as a teacher. Students' reminiscences over him are indeed legion for he was relentless in his pursuit of excellence. Although his lectures and practicals could often serve as a model for modern-day academics, it was probably through a select band of post-graduates that Jan Bonsma made his greatest contribution to the training of students. During the past two decades many have themselves built on these early experiences with their mentor to become scientific leaders in their own right.

It will forever remain a tragedy that circumstances prevented Jan Bonsma from continuing to direct the scientific research programme at the Mara Reseach Station and Messina Experimental Farm after the early 1960s. Had this not been the case his contribution to applied animal ecology would undoubtedly have been even greater. Moreover, it is a great pity that there was no protégé to succeed him on his retirement from his particular area of excellence. As a result, his pioneering research in for example environmental physiology was never significantly continued at the University of Pretoria or in the Northern Transvaal after 1974.

Jan Bonsma was and remains exceptionally proud of and loyal to his lifelong connection with his Alma Mater. Nothing gave him greater pleasure than to expound his scientific views and hypotheses from the lecture podium in the Faculty of Agricultural Science. A brilliant lecturer, he was equally at home on the international rostrum as evidenced by ceaseless invitations to lecture in a score of countries. Indeed, many foreign universities and ranching associations bestowed honours on him. It is perhaps fitting that the greatest of these – his election to the Stockman's Hall of Fame — came from Texas, USA which must surely rank as his favourite stamping ground after his beloved Northern Transvaal Bushveld.

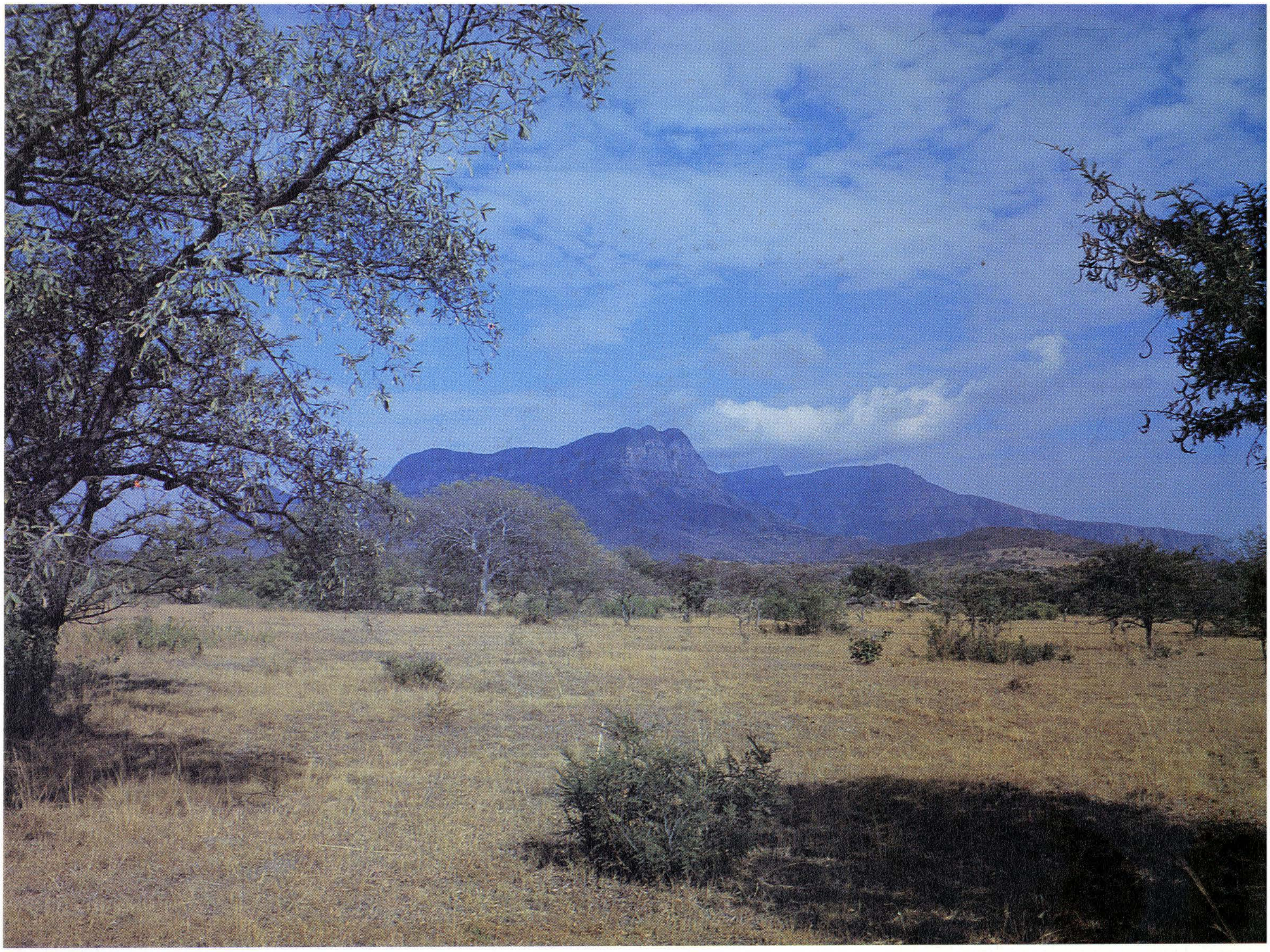
Jan Bonsma has received numerous accolades from South African institutions, including the Senior Captain Scott Medal of the South African Biological Society, the Gold Medal of the South African Society of Animal Production and the coveted Medal for Scientific Achievement of the Suid-Afrikaanse Akademie vir Wetenskap en Kuns — all awarded for his outstanding scientific contribution to the animal industry. For his achievements in the field of student training, he was furthermore awarded honorary doctorates of agricultural science by the universities of Natal and Pretoria, whilst in 1987 the State President bestowed on him the Order for Meritorious Service — the highest civilian award available to South African citizens.

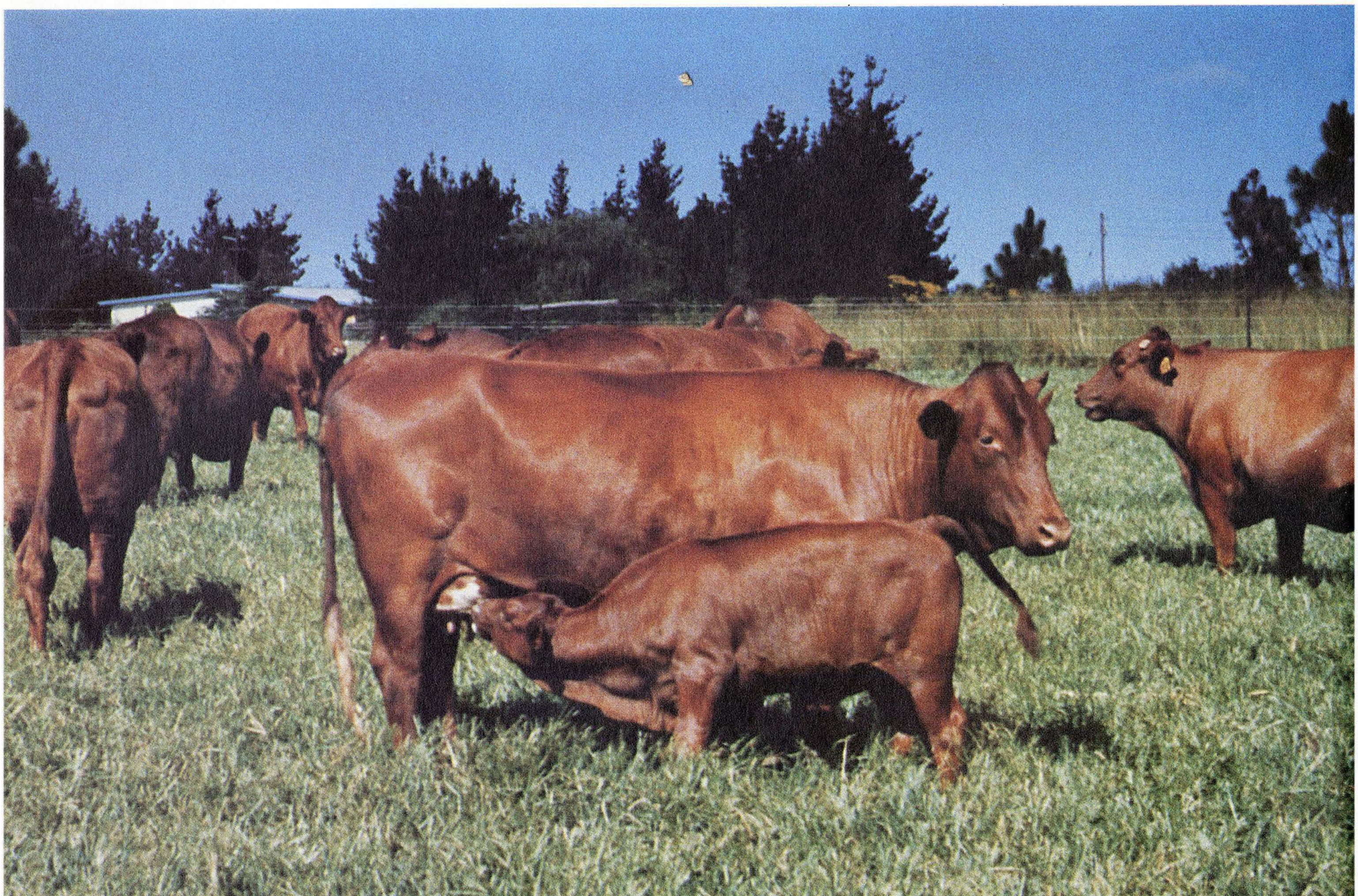
With the publication of these benchmark papers, the University of Pretoria and his former students once more honour an outstanding son and a great citizen of South Africa. For its timely appearance the devoted assistance of Mrs Patsy Skinner is gratefully acknowledged.



Prof D. M. Joubert
VICE-CHANCELLOR AND PRINCIPAL

March 1989





J. C. Bonsma

Livestock Philosophy

University of Pretoria Publications, New Series, No 5

After studying livestock production in various parts of the world, especially among the Bantu tribes, one cannot but come to the conclusion that this type of agriculture is influenced mainly by the cultural background of the people who practise it. Throughout the world one finds that those races who are superstitious, who have no real cultural background of the kind known to the Western Civilisation, have made little worthwhile contribution to livestock betterment.

Considering Bantu agriculture as an example, it is apparent that, to the Bantu, the animal is a token of wealth, a means of acquiring a wife and, therefore, a necessity under the Lobolo system. The native has never regarded livestock production as a means of benefiting mankind, since he has never practised it with the object of producing more and better food for his people. Likewise the Hindu, whose whole outlook on the animal is that it is holy. As a result he is not permitted to castrate those bulls which are useless, or carry out selection to improve his herds.

The people of the Western Civilisation have both a cultural and a religious background. It is worthy to note that in the Bible in Psalm 8, David sang 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 the sheep and the 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 those who practise livestock husbandry, these few verses place a tremendous responsibility, as is illustrated in the words "They are put under man's feet." They imply that it is the duty of Westerners and Christians to improve that which has been given to them, if they fail to do so, they are failing in their responsibilities.

Thus man may be regarded as the axis around which the wheel of livestock production revolves.

Management

Man has tamed and domesticated animals for thousands of years and as a result they have become dependent on him. "They have been put under his feet", as the Bible says and over the generations have become his close complement.

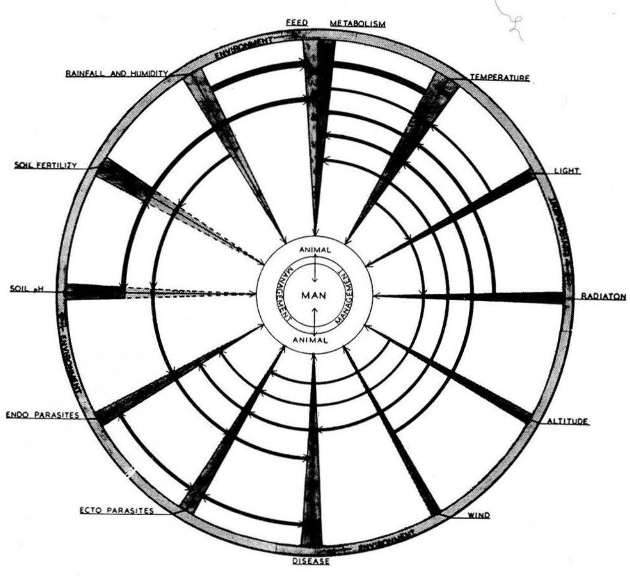


Fig. 2

The wheel which is the schematic illustration of our livestock philosophy.

"Man" is the axle of the wheel. The Animal which is kept in close symbiosis with man is the nave of the wheel. The lubricant which reduces friction between man and beast is management. The running surface of the wheel is the total environment and each spoke of the wheel is an environmental factor interacting on the nave of the wheel. The spokes also interact one upon the other.

Should some catastrophe eradicate human life on earth and the domestic animals be left to themselves, it is most probable that within a very short time none of these animals would manage to survive with the possible exception of a few breeds, indigenous to that particular locality; certainly the better-bred animals would soon become extinct.

As illustrated, the nave of the wheel is the animal, but to have the nave rotate round the axle without friction, there is need of a lubricant, supplied in this case by management. We often hear the saying, "The eye of the master fatteneth the beast", this is management.

Those who are disinterested in animals, will never make a success of animal husbandry. The successful livestock producer is one who knows his animals and who treats them with care and love. Only then, will the nave be lubricated and move with ease round the axle of the wheel.

Environment

In this livestock philosophy the environment is the running surface of the wheel, a large concentric circle immediately round the axle of that wheel. As in every wheel, this running surface is attached to the nave by spokes each of which has a direct action on the nave. Each environmental factor having a direct influence on the animal, is indicated as a spoke directed from the running surface of the wheel to the nave.

Nutrition together with metabolism, which affects the transformation of food into products, such as meat, milk and eggs, form the mightiest spoke in the wheel.

Temperature

The next spoke is temperature. Temperature if it is excessively high is a tremendous problem in animal production. Low temperatures on the other hand do not constitute the same problem, provided the animal is supplied with sufficient food. In hot rooms at the Missouri University, the late Dr. Samuel Brody carried out some remarkable experiments in which Friesland, Jersey and Zebu cattle were kept in rooms where the temperature varied from −15 °C to 40 °C. The fact must be noted here that the Zebu can withstand high temperatures very well and low temperatures less well than the European breeds of cattle.

In Brody's experiment the animals were kept in chambers at a temperature of 18 °C and their food intake was measured. When the temperature was raised to 40 °C these animals all showed acute symptoms of distress, even the Zebus. Later, when the temperature was lowered to −15 °C, the men working in the rooms, although dressed in furlined boots and clothing fit for the Arctic, were most uncomfortable. The cattle however, even the Zebus, showed no signs of real distress. The results of this experiment showed that at −15 °C the Frieslands consumed 8 per cent more food, the Jerseys 26 per cent more and the Zebus 36 per cent more than they did at a temperature of 18 °C. Although the smoothcoated Zebu types could withstand the cold and were not uncomfortable, they had to consume relatively much more food than had the other breeds in order to maintain their heat balance at a temperature of −15 °C. At 40 °C the appetites of all the animals were greatly reduced and all showed symptoms of distress. In this case the fact must be noted that the Friesland being a large animal would require more food for maintenance than would the Jersey, for instance.

Since temperature plays such an important role, an attempt has been made to develop a new type of animal adapted to the hot climate such as prevails at Mara. The point realised was that animals should be bred in such a way as to promote their adaptability to high temperatures. For this reason the Bonsmara cattle have more indigenous blood than that derived from the exotic breed.

If an animal cannot withstand high temperatures, various complications arise. The first is that the animal does not grow out properly. It experiences a rise in the body temperature on a hot day, which, if sufficiently high, will cause damage to the pituitary gland. The pituitary is a small gland attached to the brain, and controls growth and sexual activity. If this gland is damaged, to all intents and purposes the animal has been ruined, and will never grow or reproduce normally. These observations indicate why an animal must be bred smooth-coated to overcome problems associated with high temperatures.

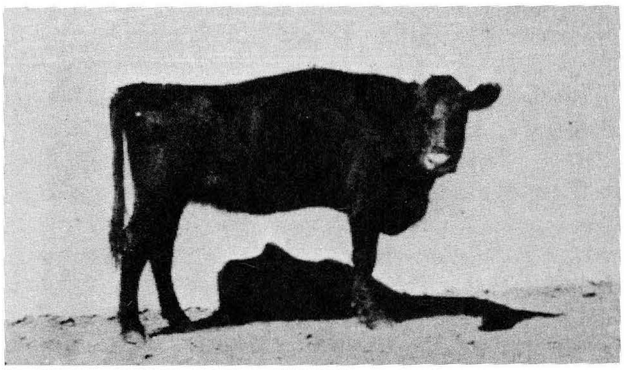


Fig. 3

A typical tropical degenerate. Note the early maturing parts of the body are large, for example the head and forequarters. The late maturing parts such as the loin, and rump are relatively small. The degenerate animal always has a small pelvis.

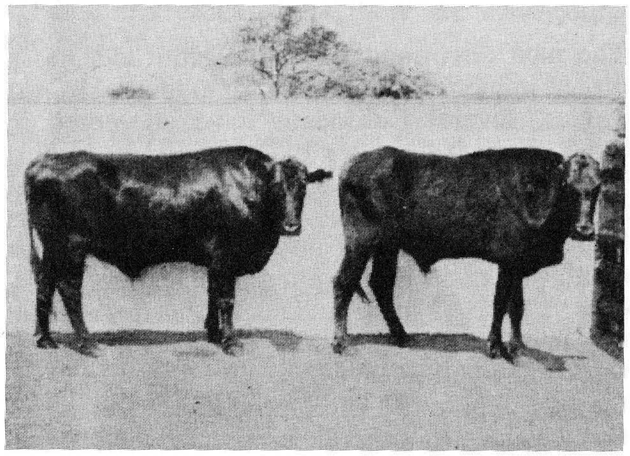


Fig. 4

Afrikaner × Aberdeen Angus crossbred steers which are full brothers, both were produced by mating a woolly coated Afrikaner bull with an Aberdeen Angus cow.

The woolly Afrikaner × Aberdeen Angus crossbred ox is a year older than the smooth-coated one.

The weights are for the smooth-coated ox 602 kg at seven years and for the woolly-coated ox 393 kg at eight years.

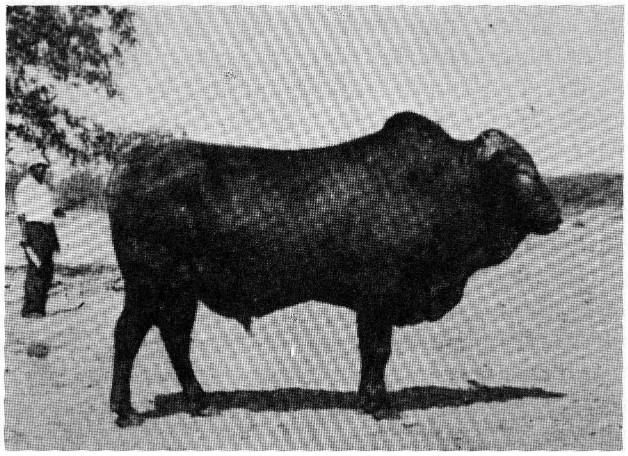


Fig. 5

The woolly-coated Afrikaner bull which was used in many cross and pure breeding experiments to prove how important coat cover is in connection with adaptability to tropical and sub-tropical regions. The woolly-coated Afrikaner × Shorthorn cross bred calves which were born woolly-coated became tropical degenerates and showed no hybrid vigour. The smooth-coated ones developed into normal cattle and showed hybrid vigour.

Radiation

The next spoke in the wheel is radiation, that is to say, the rays from the sun. Sunlight comprises a series of rays differing in wavelength, composition and action. If sunlight is split into the spectrum, thermometers will indicate that temperatures become progressively higher from violet to red, the hottest part of the spectrum being the invisible section just beyond the red, namely the infra-red region. Red rays are heat rays and when they impinge on the animal's hide they make it warm, so warm on a hot day in the case of some black cattle that one cannot touch them. During the hottest part of the day most animals require shade, which is one of the limiting factors on many ranches. More trees should be planted or shelter provided for animals, to enable them to find shade and avoid the problem of infra-red radiation. In a hot climate, radiant heat energy absorbed by the body must be dissipated before the animal can consume sufficient food for maximum growth.

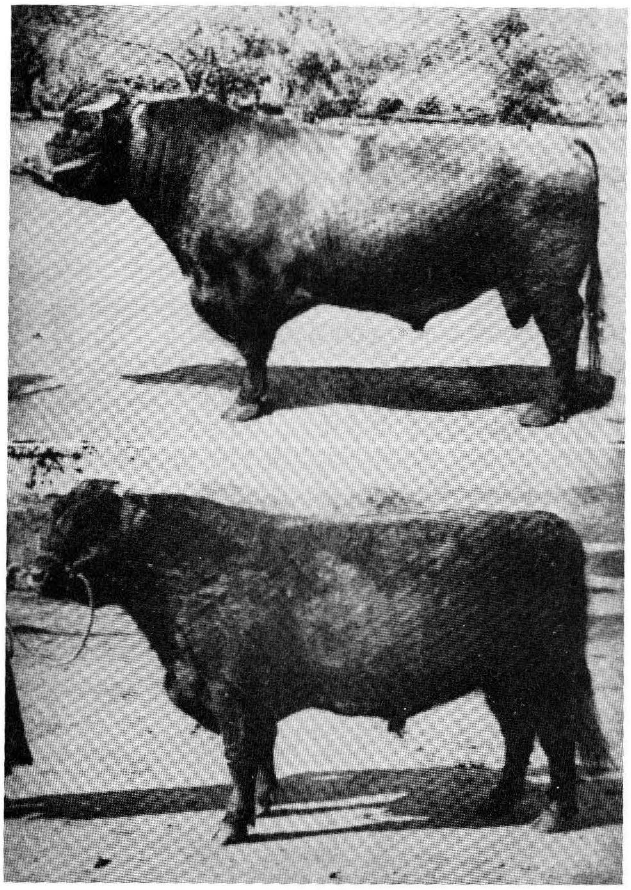
Light waves also cause chemical reactions and of these waves the ultra-violet beam has the strongest oxidising action. The effect of the ultra-violet beam is demonstrated when people walk out on a slightly cloudy day and say, "What a nice day, no sun," but when they have been out for two hours they complain of sunburn.

If an animal is predominantly white without, or with areas lacking pigment in the hide, as is the case in some Ayrshires, ultra-violet rays cause hyperkeratosis of the hide and the animal suffers.

In livestock breeding, temperature and radiation play an important role. This is where the hide, that amazing organ, comes into play. In addition to its other functions, the hide is a temperature regulating organ containing a thermostat so efficient that it can control to a very marked degree the body temperature of an animal. If the animal were not protected by a hide, which controls its body temperature to a certain degree and which enables it to overcome the hazards of certain infections, it certainly would die prematurely. From observations, it seems that smooth-coated, thick skinned animals do not die so readily from heart water, as the unadapted, thin skinned animals.

Light

The next spoke in the wheel to consider is the influence of light on the animal. Light rays cause an impulse or stimulus on the pituitary gland and hence a reaction in which the animal sheds its hair. As the days become shorter and the nights longer, cattle begin growing longer hair and develop their winter coats. Conversely, as the nights shorten and the days lengthen, they shed their winter coats and become smooth-coated. In Britain, whence so many of our breeds come, the difference between the longest day in summer and the shortest day in winter is at least 12 hours, whereas, in South Africa, it is two hours and on the equator only two minutes. Those animals which shed their winter coats and become smooth-coated, are the ones which can adapt themselves and breed more regularly in a hot climate.



Figs. 6 and 7

These illustrations are of two Shorthorn bulls imported into South Africa from Scotland. The photographs were taken in the summer when the bulls had been in South Africa for approximately two years. It was indicated to the prospective buyers at the time that the one would become smooth-coated and the other not.

The smooth-coated bull produced progeny that did well in the sub-tropics while the other bull's progeny were very disappointing from an adaptability point of view.

A smooth-coated Hereford herd was bred at Mara in the Northern Transvaal by using only those individuals which reacted to a stimulus of only three hours difference in daylight between the longest and the shortest days of the year. Four smooth-coated Hereford heifers were transferred from Mara research station to Mpapwa research station in Tanganyika on the equator. These heifers never shed their hair there.

To investigate the marked influence of light on animals, two pigeons were taken, one placed in a light bell jar and the other in a dark coloured bell jar. Both were starved. The pigeon in the light bell jar died after 12 days, while the one in the dark bell jar survived for 24 days. This illustrates the influence of light on the metabolic activity of the animals.

Light has a direct influence on metabolism. For this reason extra light is used in chicken runs to facilitate rapid feathering and earlier egg production in winter.

Altitude

The next environmental factor, altitude, has a direct influence on man and animals. In the Andes, several Europeans have attempted to mine silver at altitudes of 3 500 m and higher. However, when they settled Europeans there, they found that the men could work for a while but the women could not work at all as they could not stand the rarefied atmosphere. However, a tribe of small Indians live in this region, the men weighing on the average 52 kg. At these high altitudes where the soils are acid, they grow potatoes of comparatively low nutritional value. In general, crops are very low in calcium, hence the small stature of the people. It is interesting to note that members of this small tribe have huge chest capacities. This is because in breathing they have to inhale a tremendous volume of air to obtain sufficient oxygen to feed their tissues. All the cats the Europeans took up with them died at 4 500 m. There are some animals which can live in this area, the most important being the llama, which has a blood count twice as high as that of man. Their blood also has twice the power of absorbing oxygen from the rarefied atmosphere.

One might ask what this has to do with animal breeding. These facts are however extremely important. The Germans have carried out blood tests on various breeds of cattle in Europe. Their results show that high-altitude cattle, such as the Brown Swiss, have by far the highest blood count of all breeds. The tropical adaptability of the Brown Swiss breed centres round this point, since both at high altitudes and at high temperatures the animal must contend with rarefied air.

A number of tests conducted on the cattle at Messina showed that the Afrikaner had the highest blood count of the breeds there.

At high altitudes ultra-violet impingement is tremendous as it is in the tropical regions. At the same time infra-red radiation is intense and a dark coloured rather than a light coloured animal is preferable especially at the higher altitudes where infra-red radiation is required as a source of energy. In the tropics, however, infra-red radiation is not required as a source of energy and is therefore a problem.

Because of these common ultra-violet and infra-red radiation problems, there are many similarities between the animal adapted to the low altitude sub-tropics and the animal adapted to very high altitudes.

Another aspect worthy of consideration is that at high altitudes the soils are more acid, and it is certain that there under natural conditions one will never raise large animals. They will always be smaller than those bred on the plains, in regions where there are usually lime deposits in the soil.

Wind

The problem of wind is not nearly so severe in South Africa as it is, for instance, in New Zealand or in the north of Scotland. On the eastern seaboard of New Zealand where the wind blows continuously, a herd of Angus cattle which has been bred for a period of 40 years in the area carries hair as long as that of Galloway cattle to withstand the wind. The Highland cattle in Scotland must also endure moist cold winds and as a result grow very long hair.

In high altitude areas such as the Highveld of the Transvaal animals lose weight rapidly the moment they are exposed to severe cold winds during the winter. If these animals are to overcome the cold, they must be provided with more heat, in other words with extra feed. If this is not available, they rapidly lose condition. To reduce feed intake at these cold, high altitudes, shelter must be provided, a factor the importance of which few people realise.

Disease

Professor Brock, Professor of Internal Medicine at Cape Town University, once said at a medical conference, "Gentlemen, what we require is that more work should be done on nutrition and housing". He maintained that if nutrition was adequate and housing correct, the disease factor would be relegated into the background. This should be stressed in livestock production too, since if the environmental complex is favourable, the animal will not become diseased readily.

In a memorable series of experiments at Onderstepoort, some badly worm-infested sheep were obtained from the Free State. One half of this group was fed properly, while the other half was poorly nourished, but treated with worm-remedies. Results showed that those sheep which were fed properly were free of internal parasites long before the others.

The malnourished animal is the first to become the prey of internal and external parasites. As early as 1940 and the following two years as many as 30 000 ticks on different animals were counted to find out which animals were tick repellent. The good doers were found to be relatively free from ticks in comparison with the bad doers.

Disease has been relegated into the background in this philosophy as it is not a major problem if management is correct with regard to nutrition and prophylactic immunization, and if animals are bred which are adapted to their environment.

Parasites

A factor having a marked influence on animals is that of external and internal parasites. These can cause disease, but more often are the results of disease. Note that not one of the spokes of the livestock wheel stands free and alone as they do on the sketch shown on page 1. Each spoke interacts on the rest. If the animal is well nourished it is usually healthy, but if undernourished it falls prey to internal and external parasites. If the animal lacks adaptability, it likewise becomes a prey to these parasites, and hence becomes susceptible to tick-borne disease.

Internal and external parasites can be partially overcome in one of two ways. The first, which is preferable, is to breed adapted animals with short hair, smooth coats and thick, movable hides to make them tick repellent. However, it would be foolish not to use the protective measures science has provided in the form of dips, deworming remedies, and therapeutic treatment against internal and external parasites. If there are successful methods of combating disease by immunisation or by therapeutic treatment, they should be employed but these methods should not become the major issue in cattle breeding operations. They must be used only to overcome certain problems.

Rainfall and Humidity

Rainfall and humidity play a very marked role in cattle production. In all the very humid areas of high rainfall, small cattle are found. In Zululand for instance, cattle are small because they must rid themselves of excess heat by evaporation of moisture from the lungs, and in this hot humid climate the problem becomes acute. Animals living under these conditions have a large skin area per unit of weight. The Mashonaland cattle are a typical example. In Swaziland, the indigenous cattle all seek shade under the trees from ten o'clock in the morning and earlier. They grasp every possible opportunity of avoiding or getting rid of excess heat.

In areas of high temperature and rainfall, cattle are also small, since there, though the pastures grow very rapidly, they contain little protein and much fibre and are of low nutritional value. Under these conditions fast growing cattle do not thrive.

Soil

Soil fertility has an indirect influence on cattle welfare through nutrition. Better cattle can be produced on fertile than on infertile soil by virtue of the better crops which provide feed of a higher nutritional value.

Another factor is the pH of the soil or its degree of acidity or alkalinity. No large cattle have been bred on acid soil country, which explains why the Zebu cattle of the high Himalayan mountains, the Welsh Black cattle, most of the cattle on the higher slopes of the Drakensberg and the indigenous Mashonaland cattle are all small. Mashonaland is fertile, but lacks lime and the resulting cattle have small frames.

Interaction

The influence of the different spokes on the nave of the wheel has been discussed. It is now necessary to indicate how the spokes influence one another. Only the first two spokes will be considered, namely the interaction of rainfall, humidity and temperature on nutrition.

In an area of high rainfall and high temperature, active plant growth takes place but the resulting rapidly growing plants comprise mainly crude fibre, called lignin, and their stems are hard, enabling them to stand upright. This is why thatch grass which is $1\frac{1}{4}$ m high, does not fall over. Because crude fibre is almost indigestible, during the winter, animals in the tall-grass areas do not obtain sufficient nourishment from the natural herbage.

Another combination is that of efficient rainfall and low temperature, as in Britain. Although the rainfall there is not high, it is relatively effective since evaporation is much lower than in South Africa and temperatures are low, causing the grass to grow slowly. Under these conditions, the grass has a low crude fibre content, hence the cattle grow faster in Britain than in South Africa.

If both temperature and rainfall are low, virtually nothing exists. In the true Arctic regions, the only animals which survive are the Moose and the Reindeer, which live on lichens and mosses. Very little animal husbandry exists in this area.

High temperatures and low rainfall are encountered in the Bushveld country, of which the open savanna country at Mara is typical. Although in these areas there is very little vegetative growth, it is usually of a high nutritional value; many grasses cure on the stalk as the pastures dry off, providing natural hay. On a farm like Mara the cattle come through the winter better than off many other farms where there is more material but of a lower nutritional value.

Atmospheric temperature affects an animal's appetite, which is reduced during the hot weather. When feeding, steers must be fat when the summer starts, otherwise they will not have the appetite to fatten properly on summer feeding. Feeding must be carried out throughout the colder months if it is to be effective. Feeding should start in April and the cattle should be fat in September. If they are carried through those other months, there should be no further difficulty.

The influence of radiation on cattle is a marked one and in areas where it becomes a limiting factor, cattle should be protected in some way or other. Aberdeen Angus cattle, if exposed to the direct rays of the sun on hot days, will not

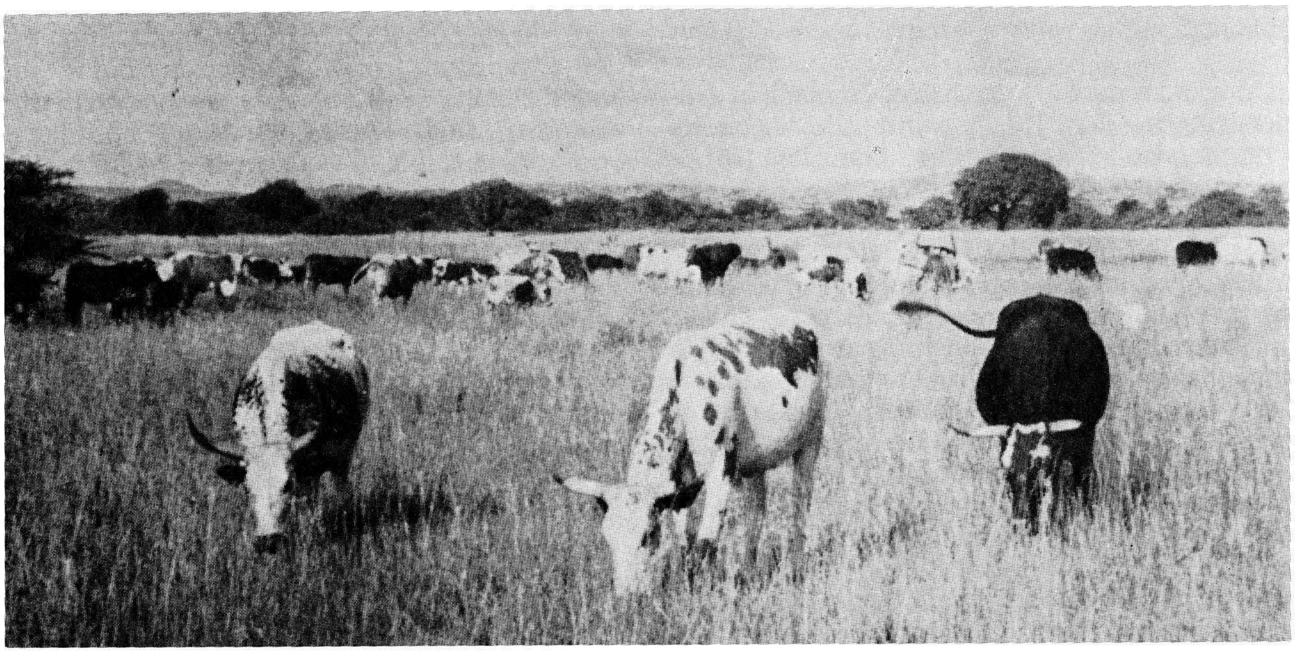


Fig. 8

Swazi cattle: . . . these cattle are well adapted to the environmental conditions of that environment. In areas of high temperature and rainfall where the pH of the soil is low (below 6,5–7) cattle are small. These cattle have not been selected for efficiency of food utilisation, for milk or beef production, to the Bantu, the animal is a token of wealth.

eat properly and will not thrive nearly as well as when shade is provided.

Light as such cannot be readily controlled. However, when fattening cattle, it is advisable to keep their stables as dark as possible, because this facilitates an even distribution of fat over the body and reduces the incidence of flies and ticks, which in turn will influence the amount of feed the cattle consume. Restricted movement will also result in more efficient feed utilisation.

Adaptability

Every spoke has a marked influence on the animal. If it is known how to reduce the leverage of each spoke on the nave, it is possible to shape the nave so that the spokes cannot, through leverage, break it.

How can the problems of low nutritional value of the veld be overcome, or how can cattle be made to utilise feed more efficiently? This is a significant if not the most important single problem that has to be overcome in feeding cattle. Little thought has been given to the breeding of cattle which can utilise feed more efficiently, since it has always been taken for granted that all cattle are equally efficient in this regard. This is not true.

It is commonly held that the animal which loses weight on the veld when nursing a calf, is a good cow because she has a lot of milk. This is a point of view so many people hold. A few years ago a check was made on data collected from the Mara Research Station to test the validity of this contention. It was decided to study all those cows which had produced heavy calves, weighing at weaning between 205 and 270 kg. These animals were divided into two groups, namely those which lost only a little weight and those which lost considerable weight while suckling a calf. There were equal numbers of each group. As a result of this study it is now deemed advisable to breed only from those cows which show a small weight loss at weaning. It can be argued that to raise a heavy calf, these cows must have milk and at the same time they must be more adaptable than the others to maintain their weight in so doing.

If it is known how to select animals which utilise feed efficiently, these will be the ones which will survive when food becomes scarce. These animals have certain common characteristics, such as good stomach capacity and the ability to walk easily. They are always smooth coated and have no difficulty in overcoming high temperatures. They also have good, broad, strong muzzles.

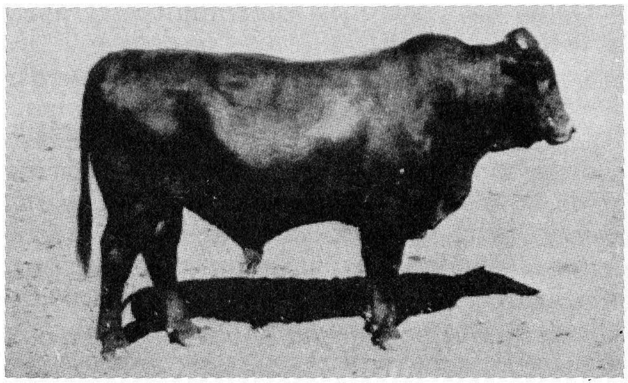


Fig. 9

Edelheer, . . . a young Bonsmara bull. The Bonsmara breed was produced by taking into consideration the interaction of the various "spokes" on the "nave" of the "wheel" depicted in Fig. 2. Selection was based on efficiency of feed utilisation, adaptability to high temperatures, adaptability to intense radiation and on insect repellent hide properties. Once adaptability was achieved, factors such as growthiness, fertility and longevity were selected for.

When selecting young heifers to go to the bull, only those that are well grown are chosen, that is, those that weigh 320 to 410 kg, at two years. These are mated to bulls from cows which wean heavy calves regularly.

Selection

Cattle must be bred for adaptability, which implies that they should be able to utilise the veld grazing efficiently. Without adaptability selection of cattle on a weight for age basis has little purpose.

For the animal to overcome high atmospheric temperatures, it must be smooth coated. It is advisable to select those animals which become smooth coated early in spring. An animal with a low nutritional status comes through the winter with difficulty, and has only a small reserve of Vitamin A in its liver. Even when daylight lengthens, it will not possess the Vitamin A required to assist in shedding its winter coat.

If an animal can shed its winter coat early in spring, it should have little difficulty in overcoming the problem of Vitamin A deficiency. Every heifer that sheds her hair the first year after birth and becomes smooth coated in September and October, is a good one. No degenerate animal is able to do this. If one cannot carry out all these tests of adaptability, it is best to select the early hair shedders, since they are the ones possessing a nutritional reserve at the end of the winter.

Furthermore, it is important to select for smooth-coatedness, which should persist from October until the end of March. It is also necessary to select those cattle with thick hides, since they are the ones which will be more disease resistant.

On the subject of disease, the view has been advanced that if animals are bred for adaptability, they can overcome disease. It would nevertheless be unwise not to inoculate cattle against enzootic diseases such as anthrax and quarter evil. A rancher who neglects to do this is foolhardy. Veterinarians have produced vaccines which are efficient and should be used. After all, livestock production and successful ranching depend on calving percentages, in other words the number of calves produced and raised. The lower the mortality the better.

The next factor to consider is growth rate, reflected by the weight that can be attained at two years, or whatever age the cattle are to be marketed. The aim is to produce the maximum amount of beef per unit area.

Every rancher can breed better cattle than he does at present, and it is essential that he appreciates his responsibility. The rancher must realise that selection is his mightiest tool. God has given him the brain power and if he utilises all his facilities to observe his cattle and tries to appreciate them, he will be able to produce good cattle.

Everyone has the urge to create something. God has created much while we have created little. The livestock breeder feels the satisfaction of a real creator the moment he has produced an animal which is superior to anything he has ever produced before.

Loyalty is another aspect. One ounce of loyalty is worth more than a pound of cleverness. It is the duty of ranchers and ranch folk to be loyal towards those people who have put them in charge. On them has been placed the same responsibility that we find in the Bible in Psalm 8. Ranch stock have been put under the rancher's feet and if he fails to be loyal, he has failed as a man.

J. C. Bonsma

Ecological Animal Husbandry Research and its Application in maintaining a permanent Pastoral Industry

The main object in the management of a permanent pastoral industry is the most efficient utilisation of pastoral resources for the production of animal products such as wool, milk and beef, while at the same time conserving these resources and improving the productivity of the land. This can be achieved only when production is based on ecological considerations only. Therefore animals should be introduced into an environment similar to the one from which they originated and in which they evolved.

Selective breeding of farm animals has resulted in the establishment of types and breeds with modified body conformations and highly specialised functions. The animal's function determines its nutritional requirements; for instance, milk production sets much higher and more persistent nutritional demands than beef production. Pigs, which are rapid converters of feed into edible animal products, have higher nutritional requirements than beef cattle per unit weight.

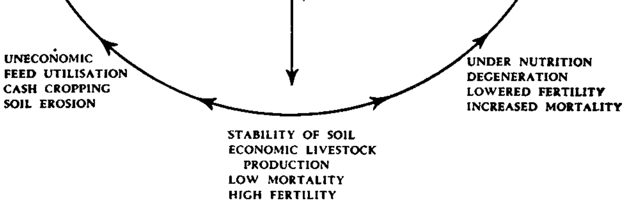


Fig. 1

Diagram illustrating the balance between the animal and its environment.

The pivot on which this balance rests in nutrition. Its sensitivity is a function of the adaptability of the animal to a particular environment.

In other words, those farm animals which are more efficient converters of feed into animal products require higher nutritional levels and the food they frequently consume can be utilised by man too. Hence they can be maintained efficiently only in highly productive areas where grains and other crops are cultivated. On the other hand, beef cattle and sheep do not compete with man for their food unless they are intensively fattened and under ranching conditions utilise veld to produce meat and wool.

The amount and the nature of the feed available for the feeding of livestock are determined by such environmental conditions as rainfall, temperature and soil fertility. The efficiency of the utilisation of the available feed resources in a particular environment again is determined very largely by the adaptability of the animals to such an environment.

In South Africa much research work has been done on the selection and breeding of cattle for adaptation to the semi-arid ranching areas where rainfall varies from 300–500 mm per annum and average annual temperatures exceed 21 °C, resulting in low vegetation density. Such areas can be utilised only for extensive beef production and, due to summer heat, sparse vegetation, parasites, and very often long distances to watering points, only cattle adapted to these conditions are able to use the vegetative resources efficiently.

For cattle to produce and reproduce efficiently in such environments they must be able to maintain a normal body temperature during hot days, move with ease, and withstand thirst for periods of 24 h or more without losing weight or showing anorexia. Under these conditions, highly improved breeds of livestock with high metabolic rates and physical characteristics such as a relatively thin skin and a thick inner heat-retaining coat, cannot maintain normal body temperatures easily, with the result that such animals do not move with ease, and therefore are reluctant to forage over wide areas.

During periods of feed scarcity such animals easily succumb, while in more normal periods they do not utilise the available feed resources as efficiently as would be the case were they able to move with ease. The maintenance of thermo-equilibrium and ease of movement is closely correlated with the animal's ability to maintain itself in a sparsely vegetated region.

Table 1 illustrates how, in an area of low carrying capacity, a slightly less improved breed of livestock adapted to the surroundings can survive and thrive, while the non-adapted animal may die. The latter provides an example of lowered efficiency of pasture utilisation. From the Table it is apparent that unadaptable cattle in a semi-arid ranching zone will succumb in large numbers if they do not receive supplementary feed.

Table 2 clearly illustrates the differences in reaction between breeds and types of cattle within breeds when, in a walking test, the animals were driven at the rate of 3,2 km per hour.

In many semi-arid ranching areas watering facilities have not been well developed yet so that drinking points are often far apart. Under such conditions ease of movement and an ability to withstand thirst are essential. In research work carried out in South Africa on the withholding of water from cattle, it was found that the indigenous Afrikaner breed, seemingly without inconvenience, was able to be denied water for 24 h. Exotic cattle (British beef breeds) showed symptoms of discomfort when water was withheld for 24 h. The tolerance of breeds to the withholding of water is illustrated in Table 3.

Lack of adequate watering facilities causes the less adaptable animals to forage around watering points, with the result that the surroundings become overgrazed and may deteriorate and such animals suffer from malnutrition. In semi-arid areas there are such examples, a clear case of inefficient use of the feed resources of the area.

Some general remarks will be made now on the types of animals and animal production which could be expected in other ecological regions. In the humid tropics, where the vegetation is usually dense, it is not essential for animals to move with ease. The limiting factor as far as livestock is concerned is the ability or otherwise to maintain a normal body temperature, so that normal feed consumption can take place. Hyperthermy due to environmental conditions reduces the appetite of cattle and the efficiency of feed utilisation appreciably.

Physical and physiological factors such as their colour and type, hide thickness, body conformation, red blood cell count, etc., markedly influence the animal's state of homeostasis. It is possible, however, to select livestock which can live in such an environment without suffering discomfort. Selection for increased adaptability to high atmospheric temperatures is based mainly on such characteristics as thickness and movability of hide and smoothness of coat.

In research work carried out in this country it was found that calves from the British beef breeds which were born with woolly coats, had a low Heat Tolerance Coefficient during the first year or more after birth; such animals usually grew very slowly, had low fertility and usually developed into tropical degenerates (see Fig. 2). Calves born with woolly coats often do not shed their winter coats during early spring. Some

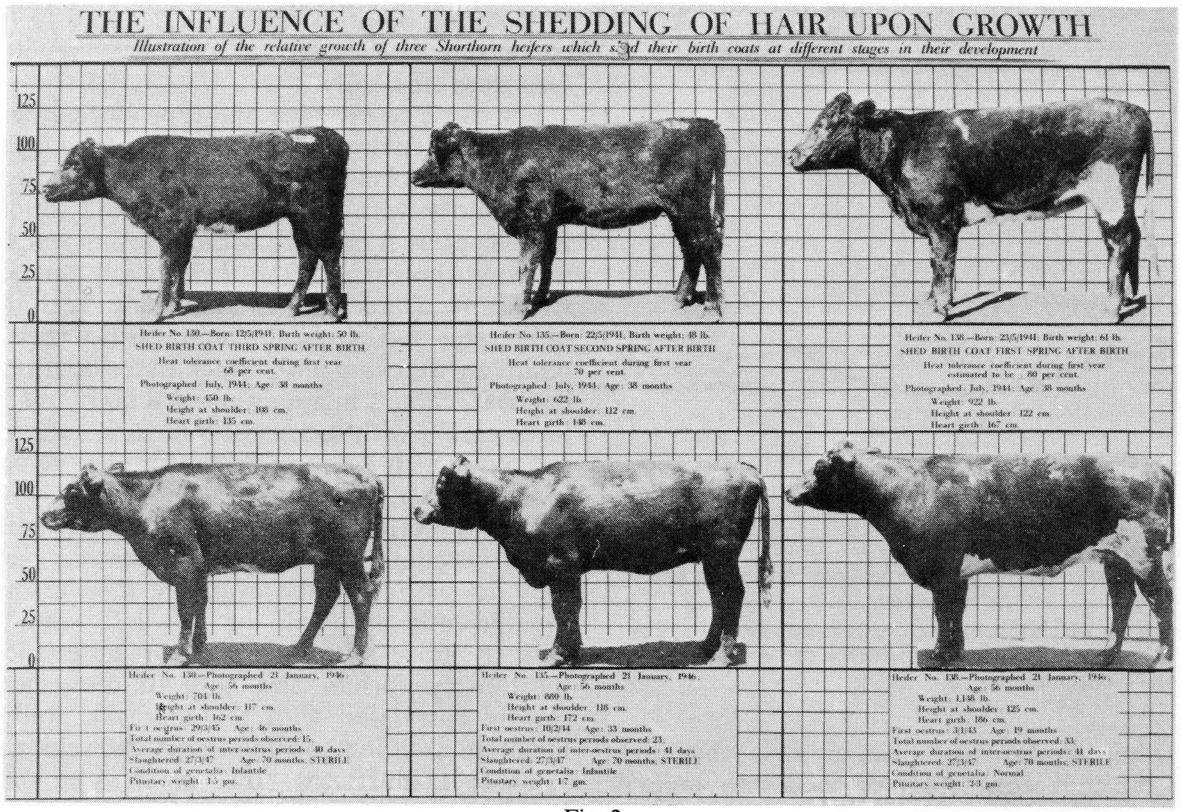


Fig. 2

These three animals are also representative of distinct groups for this characteristic calves often refrain from shedding their birth coats for periods of two or three years.

Early hair shedding, especially during the first spring after birth, is certainly one of the most positive bases of selection for animals adapted to the tropics and sub-tropics. If a prediction is to be made as to whether a calf will grow out in the tropics or not, a hair sample can be clipped from the side of the animal, moistened and vigorously rubbed.

If the hair sample felts into a tight mass, such an animal in all probability will become degenerate. Such animals usually have a mixed coat of inner heat-retaining hair and an outer protective coat of straight hair.

The heat tolerance of cattle changes with age, and it is therefore advisable to determine the Heat Tolerance Coefficient during the animals' first year (see Figs. 3, 4 and 5 and Table 4).

An animal with a high H.T.C. during its first

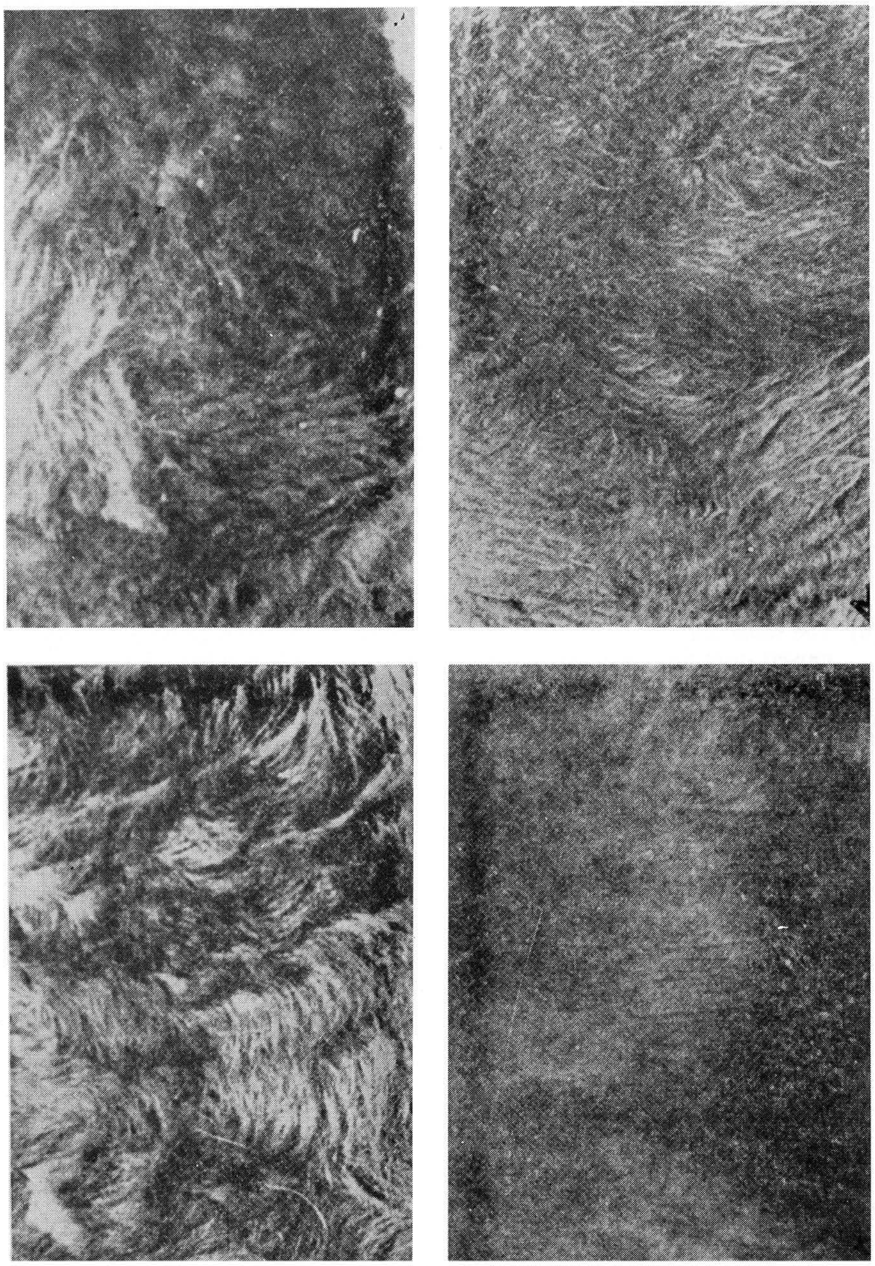


Fig. 3

Photographs of sections of hides of calves on which felting tests were done.

(1) Coat of calf No. 103, taken at 3 days, the felting quality of hair from which is poor.
(2) Coat of calf No. 103, taken at 3 years, when the animal had become very smooth-coated.
(3) Coat of calf No. 107, taken at 3 days, the felting quality of which was very pronounced.
(4) Coat of animal No. 107, at 3 years. This animal maintained an inner heat retaining coat and became a typical tropical degenerate. (Refer to Figure I).

Fig. 4

Illustrations of the difference between smooth and woolly coats in a pure breed.

(a) Smooth coated Shorthorn cow No. 078 before clipping.
(b) The same animal, No. 078, after close clipping. The average weight of hair removed from four such animals was 14 ounces. The hair removed had poor felting properties. (See Fig. V.).
(c) Woolly coated Shorthorn cow, No. 084, before close clipping.
(d) The same animal, No. 084, immediately after close clipping. The average weight of hair removed from four similar animals was 52 ounces. This hair had good felting properties. (See Fig. V).

year is well adapted to the tropics and sub-tropics. In such regions livestock should also be tick-repellent and resistant to parasites. These characteristics can be selected for in the breeding programme in the sub-tropical regions of South Africa.

An animal, to be tick- and fly-repellent, should have a very sensitive pilo motor nervous system, so that the hide moves most vigorously with the slightest irritation. Such animals usually have well developed panniculus muscles.

The humid tropics and sub-tropics can produce an abundance of feed in the form of oil-cakes, silage, and the like. An even supply of feed in the form of the above-mentioned can be provided to livestock, so that beef and milk can be produced if suitable types of cattle are selected and improved.

In the temperate zones, where the rainfall, temperature, and soil fertility are such that large amounts of feed can be produced and an even nutritional plain maintained, livestock such as dairy cattle, pigs, and poultry, which are efficient utilisers of feed, should be kept. Livestock have no difficulty in maintaining thermo-equilibrium and therefore can consume large amounts of feed, which enables them to maintain a high level of production. Efficient livestock production should go hand in hand with efficient crop production.

The climatic pattern and soil fertility of a region determine the type of farming which can be practised in a zone, and ecological animal husbandry aims at placing animals in the appropriate regions so as to enable mankind to make the most efficient use of the available food resources without damage to the land.

The schedule in Appendix 1 summarises some of the ideas considered necessary to maintain an efficient, economic, and stable pastoral industry.

Table 1. Relationship between different cattle breeds and types, and the need for supplementary feeding during a period of severe drought*

Breed	Type	No. of animals	Age	Maximum average weight during summer kg	Minimum average weight during summer kg	Weight loss kg	Percentage weight lost	Date at which supplementary feeding became essential to prevent cattle from dying	Remarks
Shorthorn	Woolly-coated	6	7	396,3	305,9	90,4	23	1/4/47	Cattle with furry coat – inner heat retaining hair. Well adapted to cold temperature zone.
Shorthorn	Smooth-coated	6	7	433,2	384,1	49,1	12	18/6/47	Cattle with straight hair, much lower percentage inner heat retaining coat. Well adapted to mild temperature zone.
Aberdeen Angus	—	6	7	340,9	322,3	18,6	5,5	15/5/47	Black cattle with straight hair. Adapted to fairly high altitude humid temperature regions.
Hereford	Smooth-coated	6	7	459,1	446,4	12,7	2,6	1/9/47	Cattle adapted to temperate ranching conditions. Feeding became necessary after winter season when average weight dropped to 410 kg
Afrikaner	Smooth-coated	6	7	513,6	440,9	72,7	13	Did not come in for feeding	Smooth-coated hardy cattle adapted to hot semi-arid regions. Loss in weight due to suckling calves. Other cattle weaned calves 1/3/47.

* The average rainfall over a period of 17 years at the Messina Experimental Farm was 333 mm per annum; of this amount 320 mm is precipitated during the period September to March. During the 1946–47 drought the rainfall during that period was 58 mm. During this period of 18 months the highest precipitation for a month was 28 mm.

Table 2.

Breed	No. of animals	Type	Distance walked before showing symptoms of severe distress	Average body temperature at discontinuation of test	Maximum atmospheric temperature during day of test	Remarks
Shorthorn and Hereford	15	Woolly-coated	6,4–9,6 km	41,5 °C	34,4 °C. In case of these cattle walking discontinued at 10 a.m. Atmospheric temperature 29,4 °C	3 out of 15 animals could not proceed beyond 6,4 km. All other animals were reluctant to move further than 9,6 km.
Shorthorn and Hereford	10	Smooth-coated	21,6 km	40,5 °C	34,4 °C	All 10 smooth-coated beef cattle could walk 21,6 km without showing symptoms of severe distress. Five animals had body temperatures above 40,6 °C.
Afrikaner	10	Smooth-coated	21,6 km	38,9 °C	34,4 °C	All animals could walk 21,6 km with ease. A group of Afrikaner cattle walked 64 km in 12 hours without showing symptoms of distress.

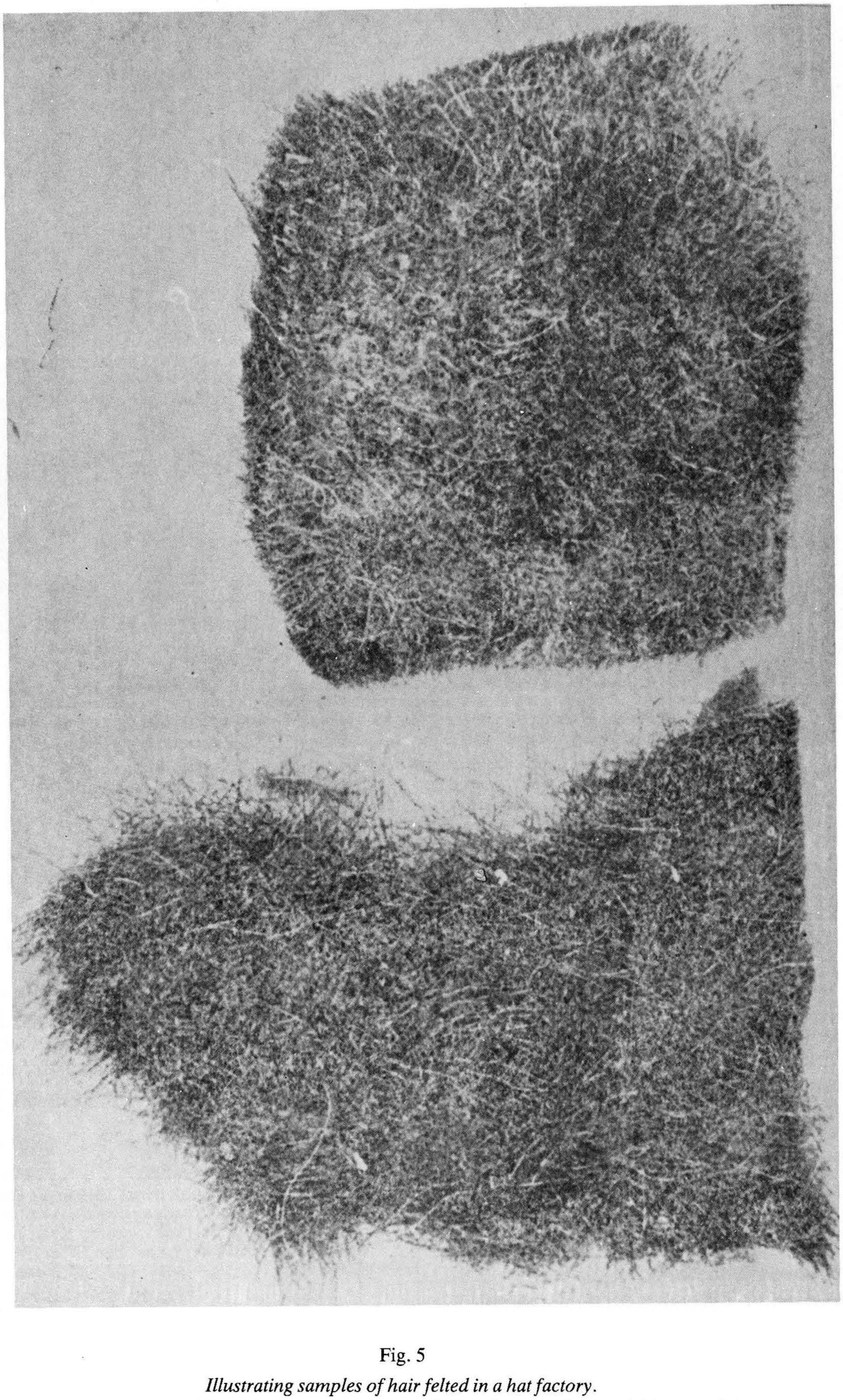


Fig. 5

Illustrating samples of hair felted in a hat factory.

The hair sample taken from a smooth-coated Shorthorn had poor felting qualities [V (a)], and could be pulled apart with a 4 pound strain.
The hair sample taken from a woolly-coated Shorthorn had good felting qualities and felted into a close mass which required a strain of 26 pounds to pull apart [V (b)].

Table 3. The tolerance of breeds to the withholding of water

Breed	No. of animals in test	No. of tests	Weight loss per cent after 24 h water withholding	*Percentage reduction in feed consumption after 24 h	Weight loss per cent after 48 h water withholding	Percentage reduction in feed consumption after 48 h	Percentage weight recovery at end of two weeks
Afrikaner	4	3	1,5 % (6,8 kg)	0 %	9 %	56 %	96,5 %
Exotic beef	4	3	15 % (47,7 kg)	24 %	21 %	62 %	92,0 %

* Feed intake previously determined in two groups. Percentage reduction in feed intake calculated on intake of control group receiving feed and water.

Table 4. Heat-tolerance data, atmospheric temperature °C

Group	4–7	8–10	11–13	13–16	16–18	19–21	22–24	24–27	27–29	29–32	33–35	36–38	38–41	41–43	Avg. body temp. for atmosphere above 29,4 °C	HTC (%)
Afrikaner × British Beef Cattle (5)																
1. Age: 0–1 year	...	...	38,3	38,3	38,4	38,5	38,7	38,7	38,9	39,0	39,0	39,0	38,9	38,7	39,0 °C	
Avg. body temp.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	89
No. observations	...	...	5	12	29	60	93	119	142	156	156	121	55	27		
Age: 1–4 years	...	...	38,2	38,3	38,3	38,4	38,4	38,5	38,4	38,5	38,5	38,5	38,4	38,5	38,5 °C	
Avg. body temp.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	97
No. observations	...	...	8	25	52	83	189	210	206	190	190	131	43	11		
British Beef Breeds: Hereford (9), Aberdeen-Angus (4), and Shorthorn (8)																
2. Age: 0–1 year	...	...	38,4	38,6	38,6	38,7	38,9	38,9	39,2	39,3	39,4	39,5	39,7	40,8	39,4 °C	
Avg. body temp.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	79
No. observations	...	...	16	49	134	205	377	395	446	419	353	162	85	6		
Age: 1–4 years	...	38,00	37,9	38,2	38,1	38,3	38,4	38,6	38,6	38,8	38,9	38,7	38,7	...		
Avg. body temp.	...	...	...	...	...	...	...	...	...	...	...	...	...	...		
No. observations	...	11	26	129	351	414	856	1 048	985	843	682	252	68	...		
British Beef Breeds (smooth-coated): Hereford (7), Aberdeen-Angus (2), and Shorthorn (2)																
3. Age: 0–1 year	...	...	38,2	38,6	38,5	38,7	38,8	38,9	38,9	39,2	39,3	39,3	39,5	40,2	39,2 °C	
Avg. body temp.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	83
No. observations	...	...	4	11	31	49	94	116	120	109	104	49	24	2		
Age: 1–4 years	...	38,1	38,1	38,3	38,2	38,4	38,4	38,6	38,6	38,7	38,8	38,5	38,6	...	38,7 °C	
Avg. body temp.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	93
No. observations	...	4	10	54	130	156	324	392	366	312	255	91	26	...		
British Beef Breeds (woolly-coated): Hereford (2), Aberdeen-Angus (2), and Shorthorn (6)																
4. Age: 0–1 year	...	...	38,2	38,4	38,5	38,6	38,9	39,0	39,3	39,4	39,5	39,7	40,8	41,3	39,5 °C	
Avg. body temp.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	77
No. observations	...	...	7	17	58	82	148	179	194	181	149	74	40	4		
Age: 1–4 years	...	38,00	37,8	38,2	38,2	38,4	38,5	38,7	38,7	38,9	...	38,9	38,9	...	39,0 °C	
Avg. body temp.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	89
No. observations	...	4	12	55	124	172	367	433	417	353	278	99	27	...		

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 as against 1 and 3 other comparisons ($P < 0,05$).

Literature cited and references for further reading

Bonsma, J. C.—1940. The Influence of Climatological Factors on Cattle. Farming in S.A. 15: 373–385.

Bonsma, J. C.—1943. Influence of Coat colour and Coat Cover on adaptability of cattle. Farming in S.A. 18: 101–120.

Bonsma, J. C.—1944. Hereditary Heartwater-resistant Characters in Cattle. Farming in S.A. 19: 71–96.

Bonsma, J. C.—1947. The Influence of Climate on Animal Production and its effects on human Nutrition. The Leech, April, 1947.

Bonsma, J. C.—1948. Increasing adaptability by Breeding. Farming in South Africa, Vol. 23, 439–452.

Gaalaas, F. R.—1947. A study of Heat Tolerance in Jersey Cows. Jour. Dairy Sc. 28: 555–563.

Hammond, John—1945. Constitution in Cattle in relation to pests and diseases. Ann. App. Biol. 32: 278.

Kelly, R. B.—1943. Zebu-Cross Cattle in Northern Australia. Australian Council Sc. & In. Research Bull. Phillips No. 172.

Philips, R. W.—1948. Breeding Livestock adapted to unfavourable Environments. F.A.O. Agric. Studies No. 1, pp. 182.

Rhoad, A. O.—1938. Some Observations on the Response of Purebred Bos taurus and Bos indicus Cattle and their Crossbred Types to Certain Conditions of Environment. Amer. Soc. Anim, Prod., proc., pp. 284–295.

Rhoad, A. O.—1940. Absorption and Reflection of Solar Radiation in Relation to Coat Color in Cattle. Amer. Soc. Anim. Prod., Proc., pp. 291–293.

Rhoad, A. O.—1944. The Iberia Heat Tolerance Test for Cattle. Tropical Agric. 21: 162–164.

Rhoad, A. O.—1941. Climate and Livestock Production. Washington: U.S. Dept. of Agric. Yearbook. Climate and Man. pp. 508–516.

Rhoad, A. O. and W. H. Black.—1943. Hybrid Beef Cattle for Subtropical Climates. U.S. Dept. of Agric, Circ. No. 673.

Riemerschmid, G.—1943. Some Aspects of Solar Radiation in its Relation to Cattle in S. Africa and Europe. Onderstepoort, Jour. Vet. Sci. 18: 327.

Riemerschmid, G. and J. S. Elder.—1945. The Absorptivity for Solar Radiation of Different Coloured Hairy Coats of Cattle. Onderstepoort Jour. Vet. Sci. 20: 223–234.

Seath, D. M. and G. D. Miller— 1947. Heat Tolerance Comparison Between Jersey and Holstein Cows. Journal of Animal Science 6: 24–34.

Wright, Norman C.—1945. Report on the Development of Cattle Breeding and Milk Production in Ceylon. (British) Colonial Office. Eastern No. 179.

Appendix 1. Summary of the regionalisation of the livestock industry on an ecological basis

Zone	Productive capacity and type of vegetation	Plane of nutrition	Type of livestock farming advocated on ecological grounds	Physical characteristics of livestock which are recommended for a particular zone colour, condition of hide-thickness, mobility and pigment	Physiological requirements of livestock to fit the environment	Level of production
Arid, annual rainfall 250 mm. Av. an. temp. above 18 °C. Tropical and subtropical desert	Low. Desert type of shrub and bush	Low, but even, supply of protein, carbohydrates low, fibre high	Sheep farming, especially mutton sheep of fat tailed types. Level of nutrition too low for cattle production	Sheep should have hair rather than wool. Loose, thick skin desired. Respiratory type of sheep, i.e., large skin area per unit of weight. Pigmented hide to overcome photo sensivity — fat tailed.	Fat tailed to increase endogenous water metabolism if necessary. . Need not be parasite resistant due to arid climates. Basal metabolic rate low	Low weight of mutton produced per unit area. Sheep skins produced will be heavy and excellent quality — of gloving type.
Arid. Annual rainfall 250 mm. Av. an. temp. below 18 °C. (Middle-latitude desert)	Low. Desert type of shrub and bush	Low, but slightly higher than above. Even supply of proteins, carbohydrates	Sheep farming for wool production	Woolled sheep . . .	Parasite, such as blowfly resistant if possible. Basal metabolic rate low	Wool of even tensile strength throughout the fibre.
Semi-arid. Annual rainfall 375–500 mm; average annual temp. above 18 °C (Tropical and subtropical steppe)	Low. Bush and shrub and mainly annual grasses. Carrying capacity lower than 1 beast to 16 hectares	Low, with great seasonal variation in protein content. Fairly high in carbohydrates and high in fibre	Beef cattle production. No sheep farming or pig production	Respiratory type. Colour and hair should preferably be red, fawn, yellow and white. Straight, short medullated hair. Loose hide, dewlap and umbilical fold. Thick pigmented hide. Mobile. Animals should move with ease.	High haemoglobin index. Low basal metabolic rate	Low weight of beef produced per unit area. Hides thick, heavy and of good quality.
Semi-arid. Annual rainfall 375–500 mm. Average annual temp. 18 °C (Middle latitude steppe)	Fair. Bush shrub and better grasses than above perennial. Vegetation density better than above. Carrying capacity 10 to 16 hectares	Large seasonal fluctuations especially in protein. High in summer, low in winter. T.D.N. fair throughout the year	Beef cattle production and dairy ranching during the summer months	Beef type. Colour of hair should preferably be red, fawn, yellow, white, smooth coated in summer, fair amount of inner heat retaining coat in winter. Respiratory type dual purpose cattle for dairy production.	High haemoglobin index. Higher metabolic rate than above. Tick repellent due to well developed sebaceous gland formation	Fair amount of beef produced per unit area. Butterfat and milk production high and economical during summer months. Hides good.
Humid mesothermal. Annual rainfall above 325 mm. Average temp. below 18 °C	High. Various crops are grown under intensive cultivation	High and can be maintained at a high level if provision is made for storage of feed and silage	Dairy cattle. Beef cattle for intensive fattening. Pigs for bacon production	Temperate zone cattle. Any colour including black. Pigmented hide to overcome ultra-violet radiation. Beef cattle of typical beef type conformation. Hair should have felting properties during winter. Bacon type pigs. Highly improved.	High metabolic rate	High
Humid mesothermal with dry summer. Mediterranean climate	Not as high as in zone described above. High in winter cereals and deciduous fruit production	Low in T.D.N.	Dairy cattle maintained under very intensive artificial conditions. Pigs to utilise waste and by-products of the cereal and deciduous fruit enterprises. Fat lamb production	Dairy cattle of efficient production. Cattle which had their origin in a mediterranean climate will be best adapted. Pigs which are of a folding type to be recommended. Crossbred lambs which are rapidly growing	High metabolic rate	High
Humid microthermal climates. Covered winters Northern hemisphere.	Very high during summer. Large amounts of feed must be stored for winter	High in proteins and carbohydrates and low in fibre.	Dairy cattle, beef, cattle, pigs, fat lambs production	Temperate zone dairy cattle developed in a continental climate. Highly productive beef cattle if stable fed, black cattle preferred. Highly improved rapid growing type bacon pigs.	High metabolic rate. High milk production. Efficient beef production. Efficient bacon production	Very high

J. C. Bonsma, J. van Marle and J. H. Hofmeyr

Climatological Research on Animal Husbandry and its Significance in the Development of Beef Cattle Production in Colonial Territories*

Empire Journal of Experimental Agriculture, 21

During recent years countries such as Great Britain, Spain, Portugal and Belgium, which need to encourage emigration in order to alleviate their over-population, have shown great interest in developing their tropical and subtropical colonies. If such development policies are to be successful, it will be necessary for the colonies to provide not only ample food and income for their new settlers, but also export surpluses of food and raw materials.

Many of the colonial territories in the southern hemisphere have a semi-arid, subtropical climate: such areas are pre-eminently suitable for livestock farming, especially ranching. Past experiences have proved beyond doubt that to make livestock farming a success in any particular area a thorough knowledge of that environment and the adaptability of the livestock are essential.

That many of the types of livestock originating in the northern hemisphere do not thrive in tropical and subtropical environments can no longer be denied. So much has been published during the past decade or two on the degeneration of the British beef-breeds in the semi-arid sub-tropics that it is hardly necessary to quote extensively from the literature to illustrate this. Of greater importance is the need to indicate how these problems of degeneration can be overcome.

In recent years South Africa, in common with many other countries and colonial territories, has shown great interest in the improvement of indigenous breeds and types of cattle. A committee was appointed by the Secretary of Agriculture in 1947 to survey the nature and numbers of indigenous cattle and the desirability and means of improving such stock. Their first report *N'guni-cattle: Report on Indigenous Cattle in South Africa*, has been published recently. It is hoped that many other countries and colonial territories which have hitherto not given this aspect of their animal-husbandry industry the necessary attention, will in the near future, take steps to preserve and improve their indigenous livestock.

*The colonial territories of 1953 are now in 1988 mostly independent countries of the Third World (developing countries).

In order to select and improve indigenous breeds and types of livestock, it is necessary to study their reactions to specific environmental stimuli. Physiological processes are correlated primarily or secondarily with environmental fluctuations; not only is energy for life derived from the environment but rates of growth, development, fertility, and mortality all bear a relationship to certain characteristics of the habitat. In addition behavioural patterns of animals are also indicative of responses to environmental stimuli. Since the distribution of plants and animals is determined by variations in environmental stimuli and conditions, these have acted as selective agents in determining the survival of particular types and breeds of livestock in specific areas.

Ecological research on animal husbandry now in progress at the Mara and Messina research stations has as its object the determination of the interaction between types of cattle and their environment (both the physical and the biotic), and emphasises interspecific as well as intraspecific relationships. Precise observations on the reactions and behaviour of types and breeds of livestock in their physical and biotic environment make a useful contribution to the essential ecological information required to ensure the establishment of different types and breeds of cattle in the appropriate environment.

Two aspects of animal husbandry ecology to be constantly borne in mind are that both a proper bearer of heredity and a suitable environment are necessary for development. Due attention should also be given to plants growing in a particular region because the environment in which animals are sustained is largely conditioned and controlled by the nature of the vegetation. That is why Köppen's classication of world climates, based on the manner in which temperature, humidity or rainfall influences vegetation types, can be applied in the regionalisation of animal husbandry (see Köppen's map, Fig. 1).

The relationship between the average monthly atmospheric temperature and relative humidity of various climographic regions in which livestock are maintained is illustrated in Fig. 2.

Köppen's classification of climates (see *An In-*

troduction to Weather and Climate by Glenn T. Trewartha, appendix A, plate ii) is very useful from the point of view of animal husbandry regionalisation because it takes climate and vegetation into consideration.

The BShw (hot steppe areas of average annual temperature > 18 °C) and BSkw (cold steppe areas of average annual temperature < 18 °C) regions are suitable for ranching, the latter being a transitional area where livestock fattening can take place. Both BWhw and BWkw areas are suitable for extensive production of woolled sheep while the Cwb region is suitable for crop production and intensive livestock production, especially milk production.

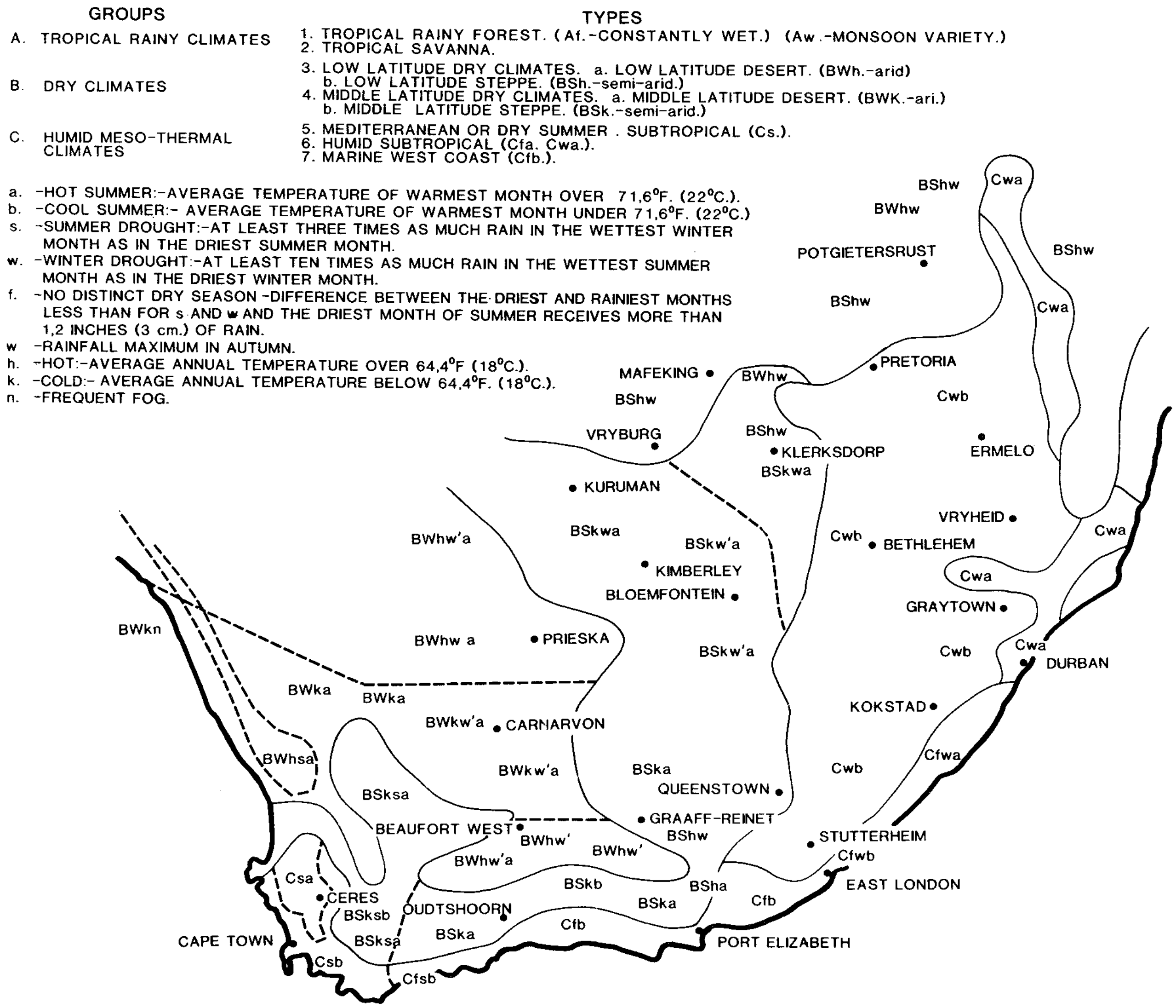
Csa and Csb regions are suitable for viticulture, deciduous fruit, wheat, etc, and intensive dairy production and Cwa regions for tropical and subtropical crop- and fruit-production and extensive indigenous livestock production — *Bos indicus* types (Sanga).

The senior author has previously drawn attention to the response of individuals, types and breeds of cattle, to temperature, radiation and other physical factors. In the present paper an attempt is made to discuss in greater detail the interaction between the animal and its nutritional environment as influenced by climatological factors. In other words, whereas toleration physiology has been discussed in previous papers, the present contribution is concerned with response physiology (see Plates 3, 4). The line between them is not necessarily sharp, nor are they mutually exclusive.

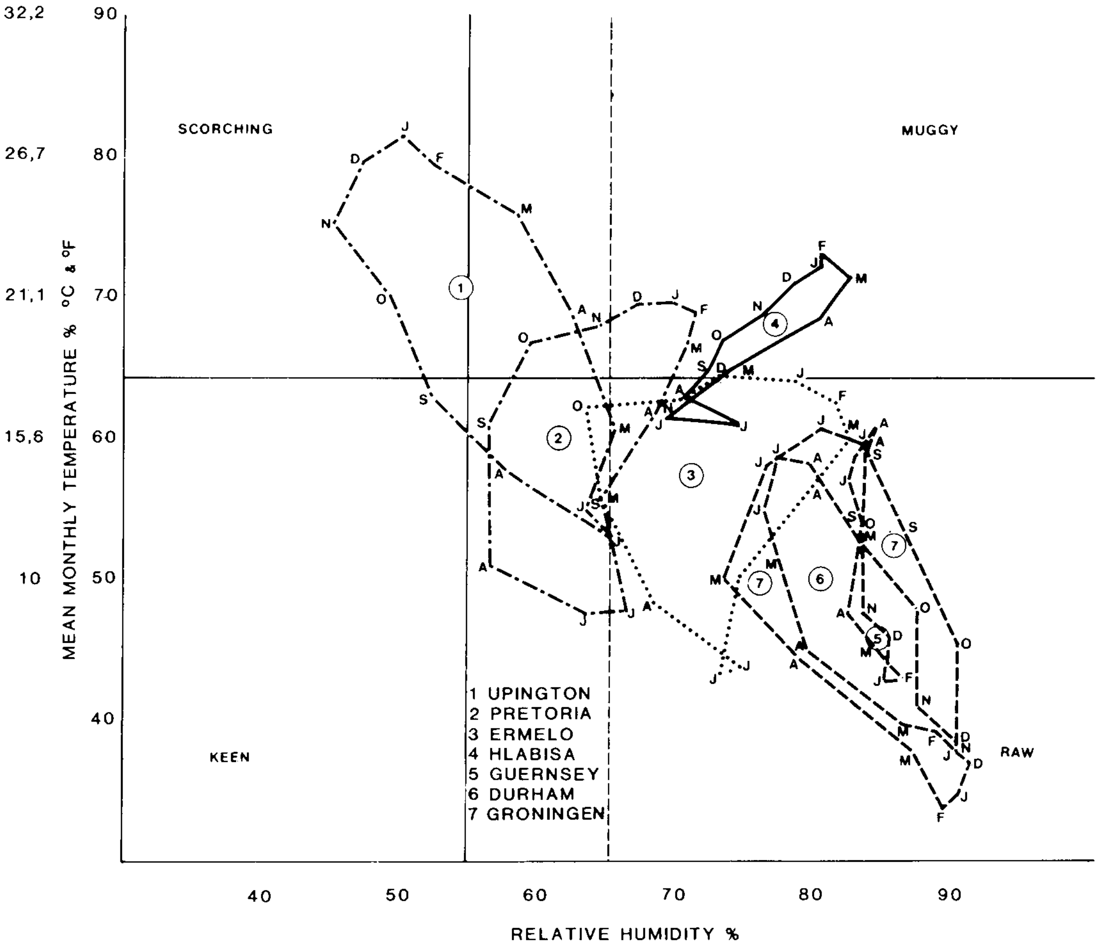
The British and European breeds of cattle *(Bos taurus)* have evolved in a relatively cold and humid climate ("raw" in map). The *Bos indicus* (Zebu) types of cattle had their origin and evolution in hot and dry (scorching) and hot and humid (muggy) climates.

It is considered that cattle can adapt to areas where not more than six points of the climo-

KÖPPEN'S CLASSIFICATION OF CLIMATES . KEY TO SYMBOLS USED



CLIMOGRAPHS ILLUSTRATING AREAS SUITABLE FOR INDIGENOUS AND EXOTIC BREEDS OF CATTLE



graph fall outside the climographic area in which the breed had its origin and evolution. "Scorching" connotes suitable for Afrikaner cattle *(Bos indicus)*; "muggy" suitable for N'guni (Sanga) types of cattle *(Bos indicus)*; "raw" suitable for British and European beef and dairy breeds of cattle *(Bos taurus)*.

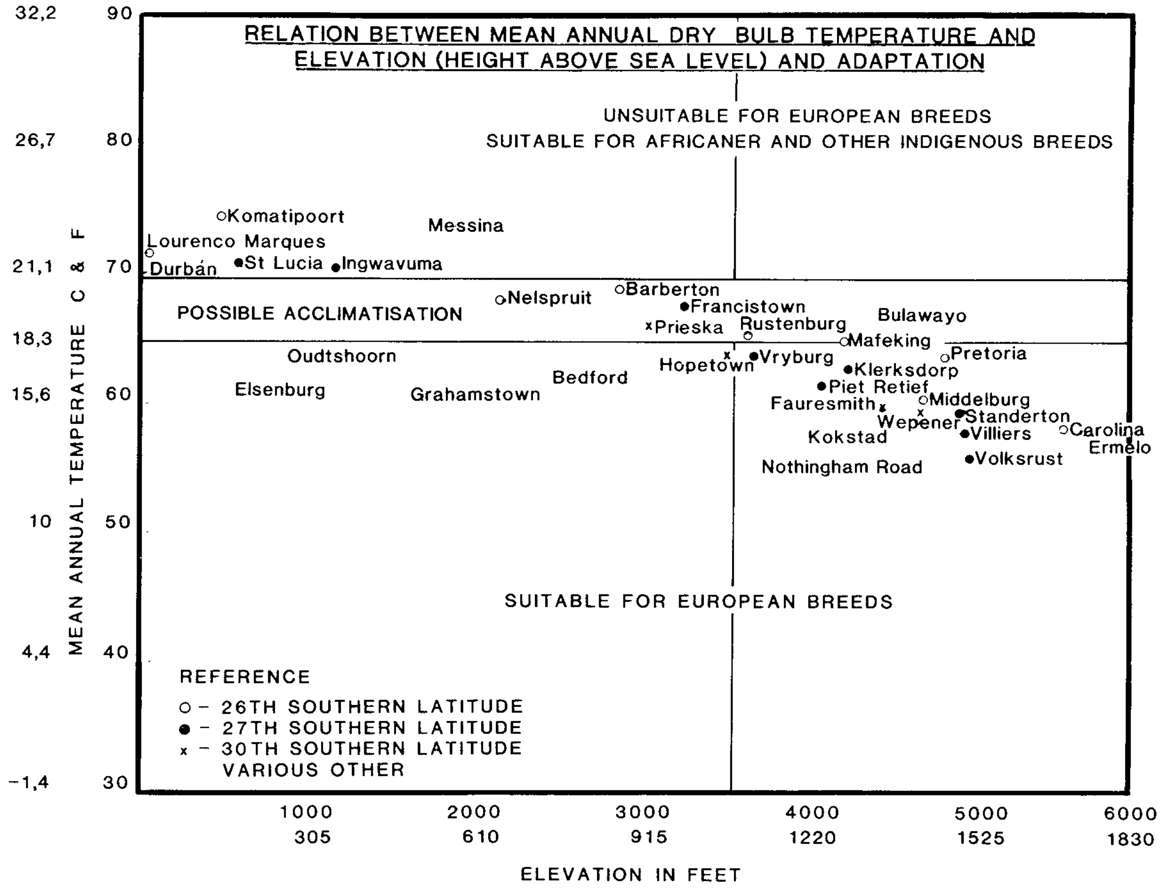
Fig. 3 indicates the relationship between altitude and average annual atmospheric temperature. Degeneration of exotic cattle breeds seldom occurs at altitudes >1 075 m. On the other hand, such breeds of cattle have difficulty in adapting to average annual temperatures > 18 °C.

Through the present research work on adaptive physiology it has become possible to predict with reasonable accuracy the reaction of certain types and breeds of cattle to a particular environment. The parameters affecting populations that were studied, and on which data are presented, are fecundity, fertility and rate of development, differential resistance to disease and mortality. The values in Table 1, obtained from ranches on which accurate data were kept, will illustrate clearly how lack of adaptability in a livestock breed to a particular environment results in low fertility, slow growth and high mortality. The Mara Research Station figures are included for comparison.

On ranch C (Table 1), during the period 1946–1950, 6 858 head of cattle died, of which 5 131 or 74,8 per cent of the deaths occurred from September to January. During September and October the grazing is poor and as the unadapted cattle cannot range with ease they die as a result of starvation. From December to February the cattle in poor condition lack heat-tolerance and resistance to tickborne diseases, with the result that they readily succumb.

The weight changes that have taken place in different types and groups of cattle following transfer from Mara to Messina (a poorer environment as indicated in Table 2), are shown in Table 3. Moreover, the maximum average weight attained by mature cattle at Mara and Messina is illustrated in Table 4. Cattle 6 years and older are considered to be mature.

It is evident from Tables 3 and 4 that the more adaptable, less improved, indigenous breed of cattle — namely the Afrikaner — suf-



fered less in the poorer environment than the more improved, exotic breeds. The more adaptable breed therefore, under poor environmental conditions, can give better expression to its genetic potential than the exotic beef breeds.

The data reveal that the factor limiting the adaptability of cattle in this environment is climate rather than feed, because cross-bred cattle — although large and heavy and therefore demanding high maintenance requirements — thrive well, since they are adaptable and are also very efficient utilisers of feed.

Under the poorer nutritional and drastic climatic conditions pertaining at Messina, the Afrikaners are on an average 8,2 kg heavier than the cross-breeds; at Mara, where the climatic and nutritional conditions are better, the cross-breeds attain an average weight 26,8 kg heavier than the Afrikaners. Thus, under the Mara conditions the cross-bred cattle do better with respect to efficiency of feed-utilisation than the Afrikaners, since the dominant characteristic of efficiency of feed-utilisation has been inherited from the exotic beef breed, whilst the adaptability characteristics such as thick hide, smooth-coatedness, high heat-tolerance coefficient have been inherited as dominant characteristics from the Afrikaner breed.

These factors enable the cross-bred cattle to survive under adverse climatological conditions, where as a result of the lack of grazing it is difficult to get enough feed. To obtain adequate feed the animal is subjected to severe physical exertion, so that the animal not capable of dissipating large amounts of waste energy, becomes hyperthermic and will not walk farther in search of feed. Self-preservation is the paramount instinct in animal behaviour, and if the animal's existence is endangered as a result of heat, the first shady bush or tree is selected to protect it from direct exposure to the sun's rays. Thus it is found that the unadapted bull will stand in the shade and will not serve cows on heat, nor will it go out grazing on hot days since its existence is endangered as a result of high atmospheric temperatures (Graphs 1 and 2). During periods of drought when feed becomes really scarce, it requires more physical exertion on the part of the heavier animal to obtain enough feed for maintenance requirements. This results in the animals with the poorest adaptability losing most weight, having by far the lowest fertility and highest mortality rate.

The average calving percentages and the fluctuations in weight of mature cows of different types and breeds of cattle at Messina and Mara

Table 1. Calving percentages and mortality rates on cattle ranches

Ranch	Locality	Altitude (m)	Average annual temp (°C)	Average annual rain-fall (mm)	Breed of cattle	Average no. of breeding cows	Average % calf crop	Calf mortality %
A	Long. E. 26° 53′ Lat. S. 24° 21′	853,4	21°	412	Herefords	1 477 for 22 years	39,00	18,00
B	Long. E. 28° 21′ Lat. S. 24° 56′	1 112,5	19°	612	Aberdeen Angus	3 143 for 5 years	56,00	23,00
C	Long. E. 29° 45′ Lat. S. 20° 45′	1 371,6	18°	625	Sussex	17 400 for 20 years	55,00	
Mara	Long. E. 29° 34′ Lat. S. 23° 09′	914,4	20°	419	Adaptable types	416 for 6 years	83,53	10,59

At the request of the owners or directors the names of the ranches have been withheld.

Table 2. Effect of transferring cattle from the Mara to the Messina Research Station

Research station	Location	Altitude (m)	Average annual temp. (°C)	Average annual rainfall (mm)	Carrying capacity: cattle per acre (approx)
Mara	Long. E. 29° 34′ Lat. S. 23° 09′	914,4	20	419	1:20
Messina	Long. E. 29° 54′ Lat. S. 22° 16′	518,2	22	320	1:50

research stations are shown in Table 5.

During the drought year 1952 the exotic cattle lost, on a percentage basis, less weight than the Afrikaners and N'guni cattle for two reasons. First, they had an appreciably lower calving percentage and secondly, from a management point of view, it was found advisable during a severe drought to place the exotic beef cattle as well as the cross-breds in the best camps where the least effort is required to reach the watering facilities.

The statistical analysis of the data on the weight loss of cattle of the different breeds and types which calved, shows that the Shorthorn cattle lost significantly more weight than the cross-breds, Afrikaners, Herefords and N'gunis ($P < 0{,}05$). Moreover, the Herefords and cross-breds lost less weight than the Afrikaners and N'guni cattle, as a result of breeding for increased adaptability. For example, there has been strict selection for smooth-coatedness. They may have been placed in paddocks with better grazing.

The senior author has shown previously that selection for smooth-coatedness is necessary to improve the adaptability of the British beef breeds to the semi-arid subtropical conditions. Woolly-coated Afrikaner cattle, the progeny of a mutant pure-bred Afrikaner bull, had very low heat-tolerance coefficients during the first year after birth; thereafter they improved. As shown in previous publications, cattle have a much lower heat-tolerance coefficient at a very young age and they grow slowly; hence the low weaning-weight of woolly-coated Afrikaner cattle. On the other hand, smooth-coated calves by the woolly-coated Afrikaner bull grow as fast as the other smooth-coated Afrikaner calves. There can be no doubt that smoothness of coat is a valuable asset to cattle in the tropics and sub-tropics.

Statistical analysis of the data discloses that there existed very large differences in the weight-loss for different individuals within the same breed. This variation for cows with calves in respect of Afrikaners, cross-breeds and British beef breeds ranges from 25 kg (5,8%) to 191 kg (35%), 4,5 kg (1%) to 157 kg (31%), and 27 kg (6,3%) to 193 kg (38,5%) respectively. Such variations in weight loss can form a useful basis for selection of cattle for increased adaptability. For instance, it was found at Mara that notwithstanding the fact that certain cows produce more milk and have heavier calves at

Table 3. Weight changes of cattle following transfer from Mara to Messina

Research Station	Breed or type of cattle transferred	No. of animals in group	Average weight when transferred 17.11.48 (kg)	Average weight July 1952 (kg)	% difference in weight	Average age in months
Retained at Mara	Hereford	45	229,3	525,5	23,5	54
Transferred to Mara	Hereford	33	229,3	401,8		
Hereford × Afrikaner retained at Mara	Hereford	18	288,2	543,6	5,7	54
Transferred to Messina	Afrikaner	27	288,2	512,7		54
Shorthorn × Afrikaner retained at Mara	Shorthorn	66	280,3	506,8	5,4	54
Transferred to Messina	Afrikaner	24	280,3	480,0		
Mara*	Afrikaner	9	280,3	345,5	1,0	27
Messina*	Afrikaner	9	280,3	341,8		

* Cattle born at Mara and Messina — not transferred.

Table 4. Maximum mature weights of three types of breeds of cattle

Breed or type	Research station	Age mature over 6 years	No. in group	Maximum average weight (kg)	Difference in weight Mara–Messina (kg)	Weight of Messina cattle % of mature Mara weight
Hereford Hereford	Mara Messina	Mature	62 34	536,8 441,4	95,9	82
Cross-bred Afrikaner × Exotic	Mara Messina	Mature	108 51	585,9 507,7	78,6	87
Afrikaner Afrikaner	Mara Messina	Mature	152 22	559,1 515,9	43,2	92
Average	Mara Messina	Mature	322 107	563,6 488,2	75,5	87

weaning, they lose less weight during drought periods than other cows of the same breed in the same group.

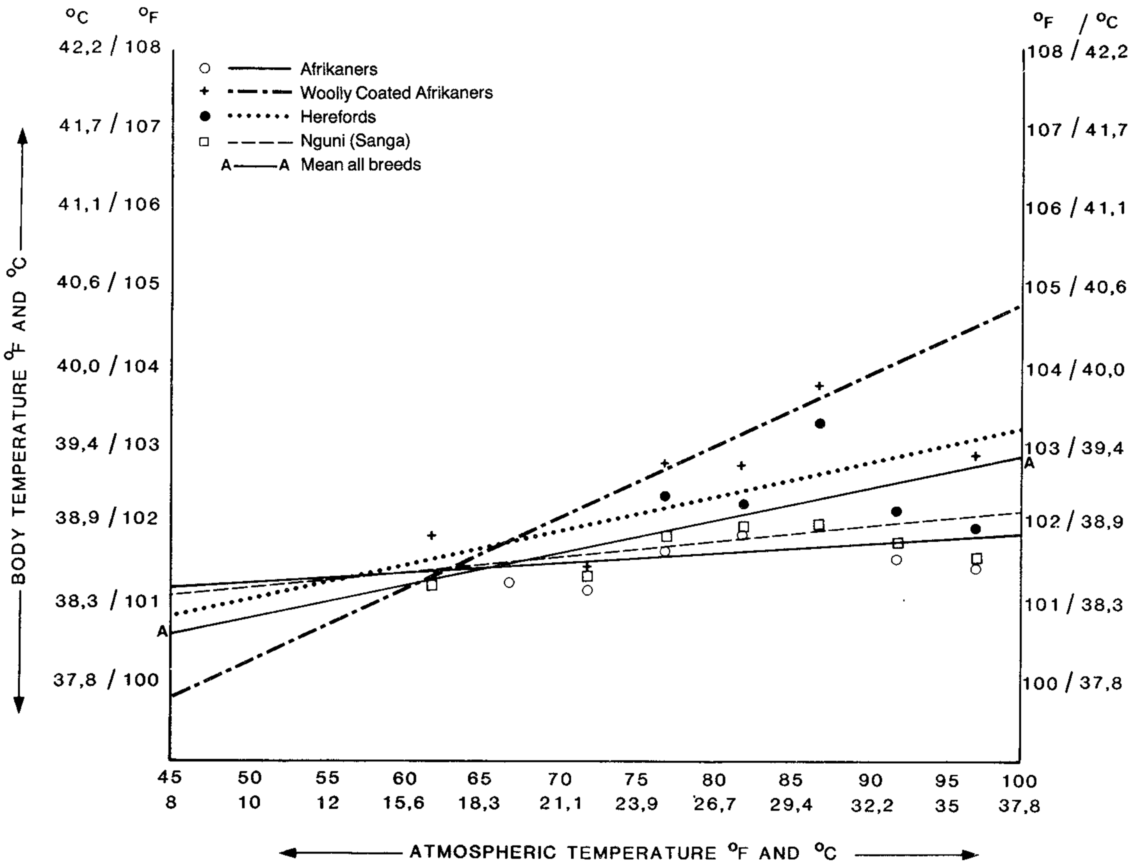
Lowered calving percentage is the first response to adverse climatological and nutritional conditions. From the calving percentages in Table 5 it is apparent how the Messina environment adversely affects the improved breeds (British) of livestock, as well as an indigenous breed (the N'guni) of livestock adapted to the humid sub-tropics.

Weight fluctuations of mature cows of different breeds and types at Mara are listed in Table 6. Statistical analyses of the data reveal that Herefords lost significantly ($P < 0{,}05$) more weight during the 1952 drought year than did the cross-breeds or Afrikaners. There was no significant difference between the weight-losses of Afrikaner and cross-bred cattle. It is, therefore, apparent that the indigenous cattle and the cross-breds survive the hazards imposed by severe drought better than the exotic beef breeds, notwithstanding that the latter have been selected for greater adaptability to tropical and subtropical environments for three generations. Such Hereford cattle are still not as robust and resistant as the indigenous stock.

The data in Table 8 show that the mortality rates of the cross-breeds and Herefords have been lowered by selection and breeding for increased adaptability. It is especially marked in the Herefords, where the average rate for calves has been reduced from 34,8 to 27,4 per cent. It has not been possible during the past 10 years to reduce the mortality rate among Afrikaner calves as a result of breeding for increased adaptability. Rather, the selection and breeding policy have been directed towards increased fertility, milk production, and capacity for growth.

During the past season the Mara Research Station experienced one of the severest droughts in its history: only 290 mm of rain in 50 precipitations were recorded from October 1951 to October 1952, compared with an average of 422 mm. Only once, in April 1952, was a substantial precipitation of 33 mm recorded (Graph 4).

From all the data presented so far it is apparent that adjustment to semi-arid subtropical environment involves in livestock not only a high



Graph 1 illustrates the body-temperature reactions of different types and breeds of cattle. Note the drastic reaction of woolly-coated Afrikaner and even smooth-coated Hereford cattle to high atmospheric temperatures. The Afrikaners and N'guni cattle do not suffer when exposed to the direct impingement of the sun. From the scatter-graph it is obvious how drastically some individual animals react on hot days.

heat-tolerance coefficient, but also efficient utilisation of the available feed (Graphs 5 and 6).

At the Messina station where the climatic and nutritional conditions are really stressful, large breeds and types of livestock such as the Afrikaner and the cross-bred Afrikaner cattle do exceedingly well, and cows averaging 500 kg and more can be economically maintained (Plate 3).

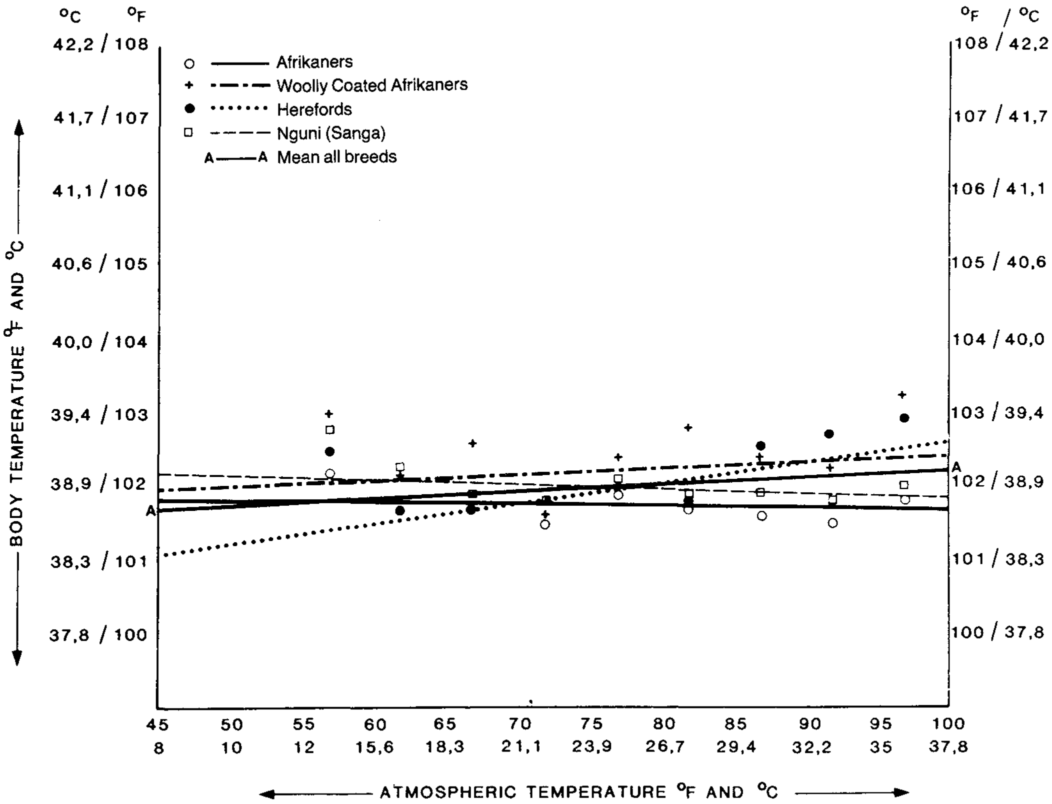
From this data it is also clear that in an effort to produce more beef per unit area in our subtropical, semi-arid ranching areas, breeders should determine the limiting factors in both their environment as well as in their cattle. Cattle should be selected for adaptability to high ambient temperatures and for efficiency of feed-utilization. It is remarkable how well cross-bred cattle do under the Mara conditions.

It is also remarkable that the N'guni cattle, a small breed, generally considered very hardy, should lose weight so rapidly during the drought conditions at Messina, and it would appear that the N'guni is not a breed to be recommended for the semi-arid subtropical regions. Nor is small size an advantage in such areas. During the investigations of the Indigenous Livestock Committee it was observed however, that the N'guni cattle do better in the humid sub-tropics than Afrikaner and other breeds of cattle. Such small-framed cattle are found also in areas where the soils are acid. Measurements taken on N'guni cattle (Sanga) at Mpisi Research Station in Swaziland, indicate that they attain a size some 65 per cent that of Afrikaner cattle (Table 9).

In a preliminary trial small groups of cattle of different types and breeds were fed as much hay as they could consume in addition to a grain-mixture not exceeding 3,6 kg per day. Comparative groups grazed veld without supplementary feed. Comparisons were made of the feed-intake of the different types and breeds of cattle as well as their efficiency of feed-utilisation, and also between the supplementary-fed and control groups. Afrikaner cattle proved to be better adapted to a semi-arid subtropical environment and more efficient utilisers of feed than the N'guni cattle (Table 10).

Table 11 indicates the weight relationship between fed and control groups of cattle of the different breeds.

On 15 December, 1952, when the different groups of cattle were last measured and weighed, the control group of N'guni cattle attained only 73,1 per cent of the weight of the



Graph 2 gives the body-temperature reactions of the same animals (see graph 1) in the shade. By comparing these graphs it is obvious how important the provision of shade is to livestock production in the tropics and sub-tropics. The value of shady shelters cannot be overemphasised.

fed group of N'guni cattle, but with the Afrikaners the controls attained a weight equal to 83,3 per cent of the fed groups (Plates 5, 6, 7). Furthermore, the control group of Afrikaner cattle weighed almost as much as the group of fed N'guni cattle (as shown in Graph 5).

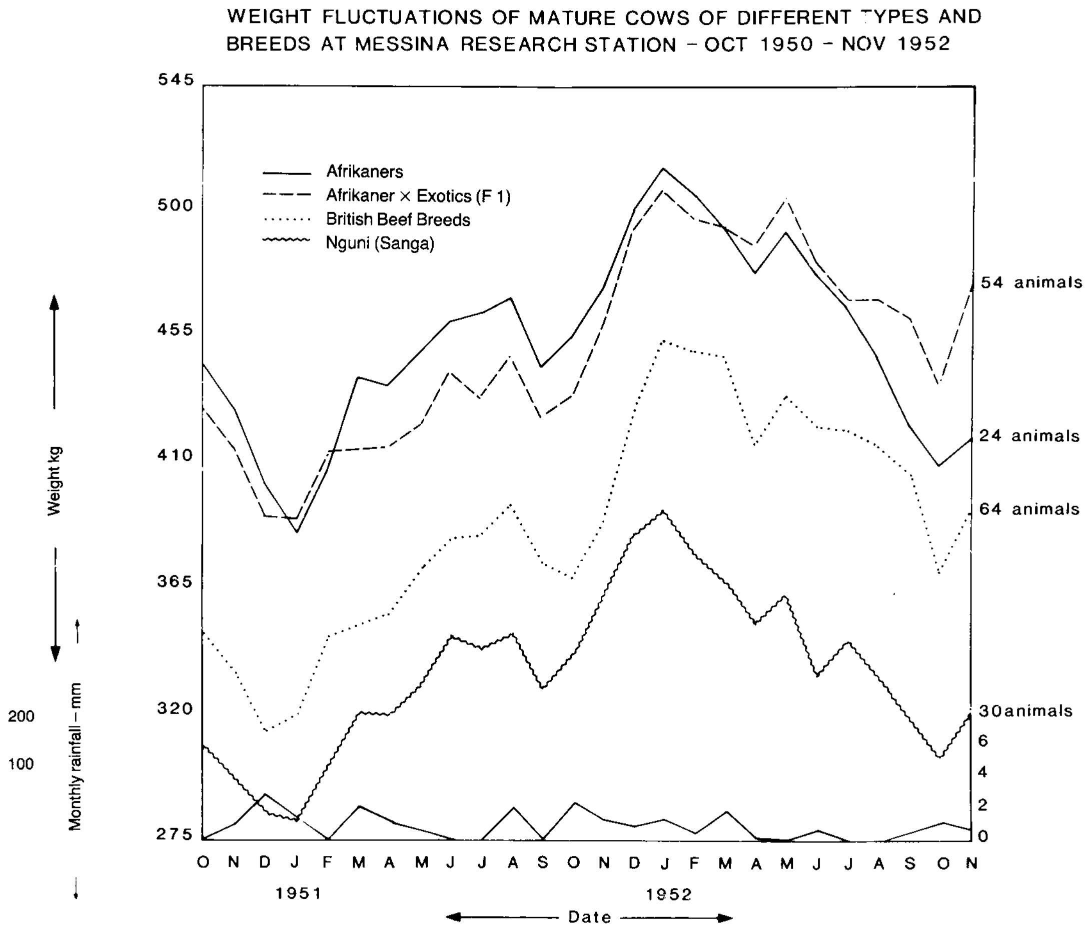
Conclusions

From the climatological research work carried out at Mara and Messina, and from precise observations made on the behaviour and reactions of types of cattle encountered in various climatic regions, certain suggestions can be made concerning the improvement of livestock production. The following principles should govern the selection of cattle adapted to semi-arid subtropical environments:

1. Select cattle with thick, movable hides and a very smooth coat.
2. Select the early hair-shedders, i.e. calves that shed their calf coats early during the first spring after birth. Such cattle are "good doers" in a semi-arid subtropical environment.
3. Select for future breeding cows that are regular calvers and produce calves heavy at weaning age. Cows that are selected on the performance of their calves must be adaptable, because an unadapted cow cannot calve regularly and produce an abundance of milk to enable her to wean a heavy calf.
4. Cows that do not lose much weight during a season of drought and are still able to raise calves that thrive, are good cows. It is an aspect of selection for adaptability which is going to receive much attention in the future selection and breeding policy at Mara.
5. Longevity is another physiological trait which is taken into consideration in breeding for increased adaptability. More than 10 per cent of the Afrikaner cows at Mara are over 16 years of age.
6. Bulls are selected on the basis of the fertility and milk production of their dams, and the progeny of bulls should be tested for growth capacity, efficiency of food utilisation, fertility and milk production.

In an effort to place breeds and types of cattle in environments in which they should be adapted, the following broad suggestions are made:

1. In semi-arid, subtropical savannah environments, where very often alkaline soils predominate, breeds of large cattle such as Afrikaners and Afrikaner cross-breds that are smooth-coated, have thick hides and a well-developed dewlap and umbilical fold, are recommended. Vast areas of the Transvaal bushveld, Botswana



Graph 3 shows the weight-fluctuations of mature cows of different types and breeds at the Messina station. This station lies in a summer-rainfall area. From October until April is the rainy season. A dry spell is experienced every year from May until September. Cattle usually reach their maximum weight in May and minimum weight during October. If summer rains are delayed cattle lose much weight during October and November. The average annual weight-loss varies from 15 to 30 per cent, depending upon the season.

and central and northern Australia have such areas.

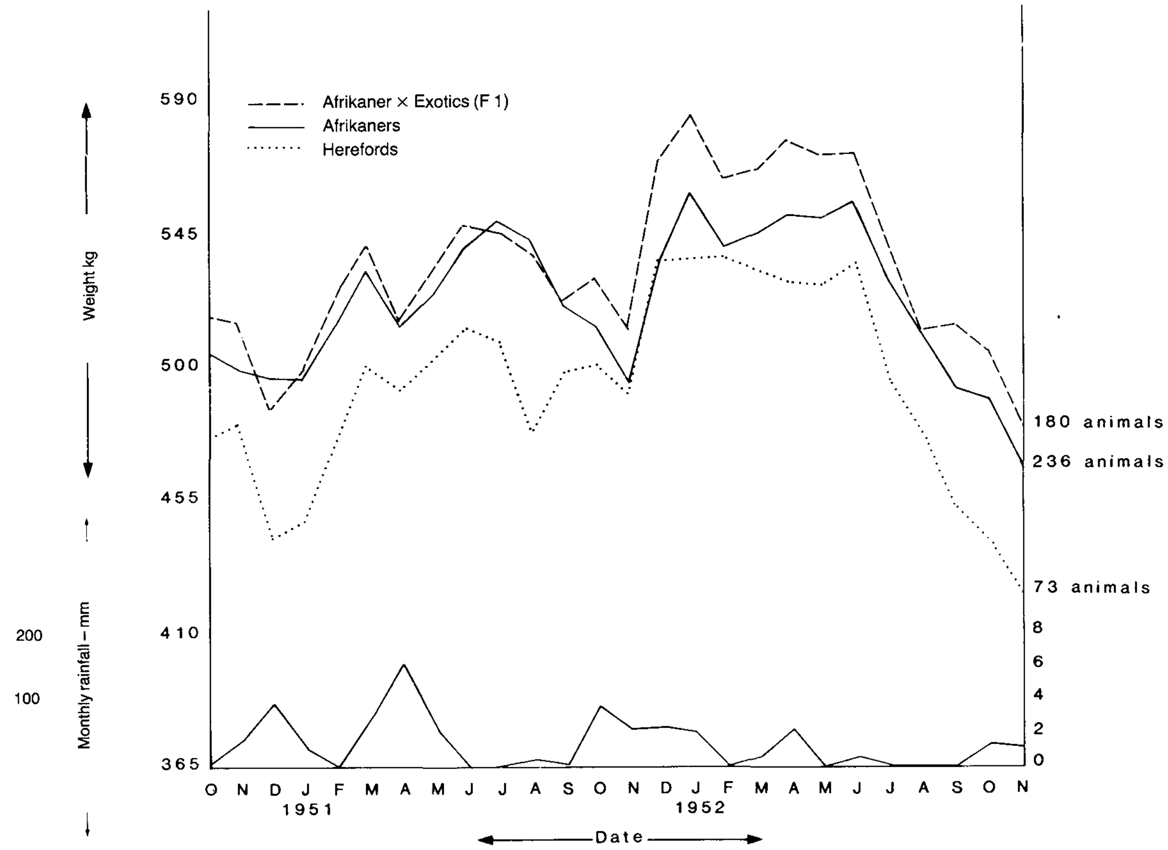
2. In high altitude, semi-arid regions, such as are found in parts of South West Africa, it is suggested that Sussex, Hereford, and Angus cattle be maintained in the areas with a high nutritional level. In areas where the nutritional conditions are poorer and temperatures are higher, Afrikaner and Afrikaner cross-bred types are recommended.

3. In tropical and subtropical humid climates, where acid soils and sour veld predominate, small breeds of cattle of the *Bos indicus* type (N'guni and Sanga) are recommended. These areas include the coastal areas of Zululand, humid areas of Swaziland, Mozambique, etc.

4. In subtropical climates of high altitude and high rainfall such as are encountered in the high-altitude ranching areas of Zimbabwe, Hereford and Aberdeen Angus beef cattle are recommended where intensive crop-growing is practised. In the extensive areas where black *Bos indicus* (Mashona) type of indigenous cattle do best they should be crossed with Aberdeen Angus cattle to improve the conformation as well as the efficiency of feed-utilisation of the Mashona type of cattle. In these subtropical areas of high altitude and high rainfall, the natural nutritional conditions are poor, and small-framed black cattle that are efficient feed-utilisers should do best.

5. In intensive beef-cattle producing areas, as well as in semi-intensive ranching areas where the soils are alkaline, the pastures sweet and nutritional conditions are good, the Shorthorn beef-breed does best.

From all the climatological research work done at Mara and Messina as well as from observations made at Koopmansfontein Research Station in the Northern Cape, Neudamm near Windhoek, South West Africa, and from those made on farms in various parts of the world, there can be no doubt that the Shorthorn is the least adaptable of the British beef-breeds of cattle to semi-arid, subtropical extensive ranching conditions.



Graph 4 illustrates the weight-fluctuations of mature cows of different types and breeds at Mara research station. This station is in a summer rainfall (October–April) area. The winter period (May–September) is dry. During normal years, cattle reach their maximum weight during May and minimum weight during October.

In adopting cattle-breeding policies for colonial (developing countries 1984) development a few salient points should be taken into consideration, namely that all breeds of livestock are moderately adaptable, but beyond certain limits the animal's constitution breaks down and it succumbs or will not reproduce.

The nature of the environment in which cattle are kept, determines the types which should be maintained.

In formulating a breeding policy, full use should be made of the useful dominant characteristics of different breeds of cattle by judicious cross-breeding. The efficiency of feed-utilisation and "beefing" qualities of the improved British beef-breeds of cattle should be combined with the hardiness, heat-tolerance and foraging ability of the indigenous breeds.

In certain areas pure breeds of livestock have been evolved that are adapted to their environ-

Table 5. Calving percentages and Weight Fluctuations of different types and breeds of cattle at the Messina Station

Breed or type	No. of cows in group	No. of calves born 1951	No. of calves born 1952	Calving percentage 1950–1	Calving percentage 1951–2	Maximum average weight 1951 (kg)	Minimum average weight 1951 (kg)	Average weight loss % 1951	Maximum average weight 1952 (kg)	Minimum average weight 1952 (kg)	Average weight loss % 1952
Afrikaner	28	(2) 19	(1) 25	68,0	89,0	468,6	382,7	18	515,9	408,2	21
Afrikaner × Ex. cross-bred	52	(4) 36	(4) 50	69,0	96,0	446,8	387,7	13	507,7	437,3	14
Exotic	58	(1)[1] 9	(8) 36	15,5	68,0	393,2	311,8	21	453,1	369,1	19
N'guni	29	(1) 13	(0) 25	48,0	86,0	346,8	279,1	20	391,8	302,7	22
Total average	161	77	138	48,0	87,0	412,3	341,4	17	468,2	385,9	18

[1] Three out of the 9 calves born in 1951 were stillborn.
The cows tested negative to C.A. Figures in brackets are number dead before age of 1 year.

Table 6. Fluctuations in weight of mature cows at Mara

Breed or type	No of cattle in each group	Calving percentage 1950–1	Mortality percentage 1950–1	Calving percentage 1951–2	Mortality percentage 1951–2	Maximum average weight 1951 (kg)	Mininum average weight 1951 (kg)	Weight loss % 1951	Maximum average weight 1952 (kg)	Minimum average weight 1952 (kg)	Average weight loss % 1952
Afrikaner	236	86,9	7,5	80,7	4,6	550,5	495,9	9,9	559,1	466,4	16,6
Afrikaner × Ex. cross-bred	180	86,8	6,1	80,2	4,2	548,2	485,0	11,5	585,9	480,0	18,1
Hereford	73	98,1	19,8	88,8	14,7	513,2	441,4	14,0	537,3	422,7	21,3
Total average	489	89,0	7,8	82,0	5,7	539,1	482,3	10,5	564,1	464,6	17,6

ment and are efficient utilisers of feed; in such regions cross-breeding is not recommended.

To make livestock husbandry a success, the environment, the animal, and the continuous adjustment between the two sets of phenomena that constitute life, should be studied. By careful selection and proper range management it is possible to produce the maximum amount of beef per unit area.

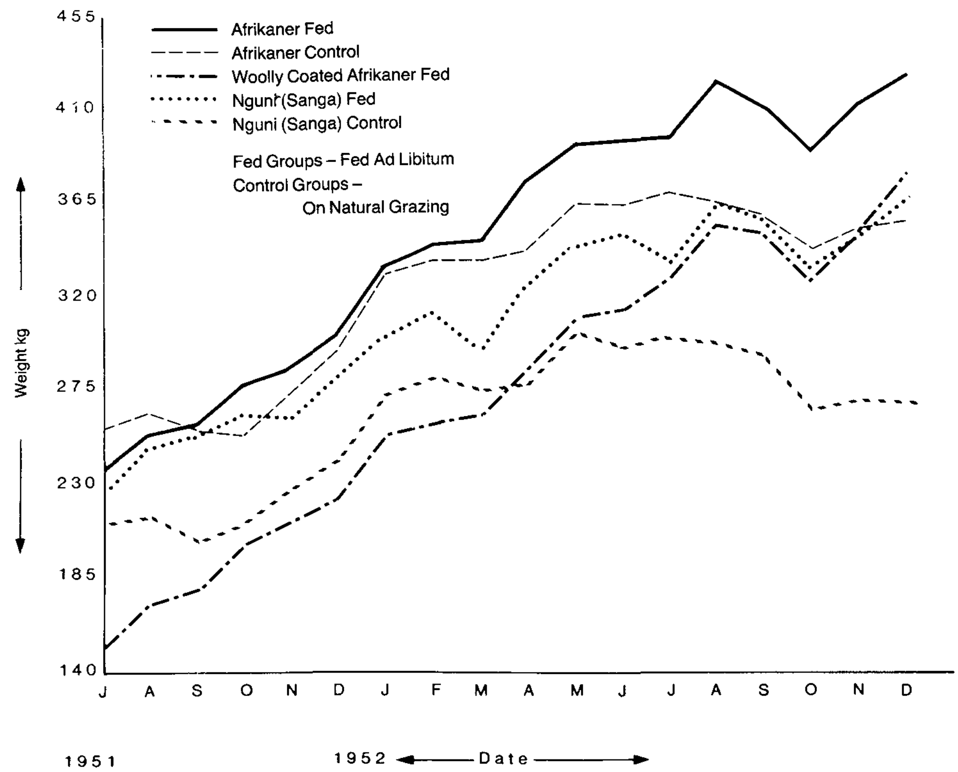
Summary

In this paper data are presented on fertility, rate of development and differential resistance to disease and mortality of different types and breeds of cattle in semi-arid, subtropical environments.

Accurate data clearly illustrate how lack of adaptability in a breed of livestock to a particular environment results in slow growth, low fertility, and high mortality, causing financial failure of ranching enterprises which did not take into account the important relationship between environment and livestock production.

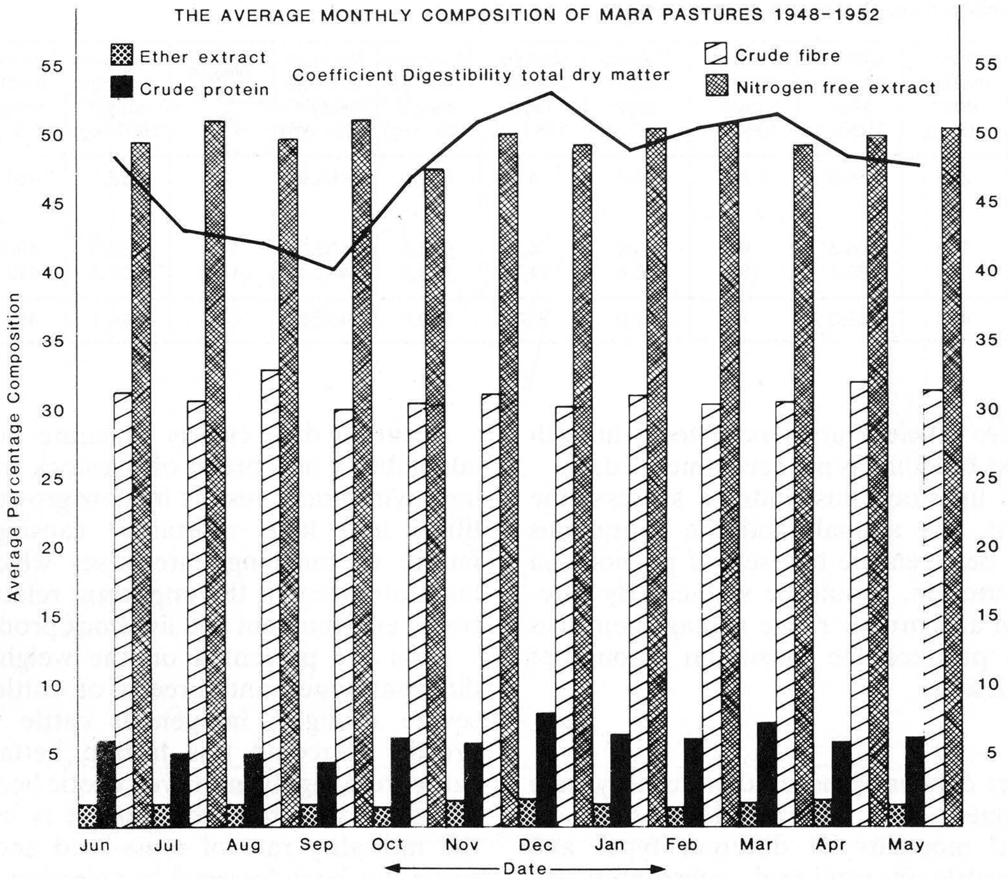
Data are presented on the weight losses of different types and breeds of cattle during a severe drought; indigenous cattle and cross-breeds overcome this hazard better than do cattle from highly improved exotic beef breeds.

From data presented here it is evident that the mortality rate of cross-bred and Hereford cattle has been lowered by selection and breeding for increased adaptability.



Graph 5

Graph 5 illustrates the comparative growth of fed groups of Afrikaner, Woolly Afrikaner, and N'guni cattle, and control groups of Afrikaner and N'guni cattle.



Graph 6

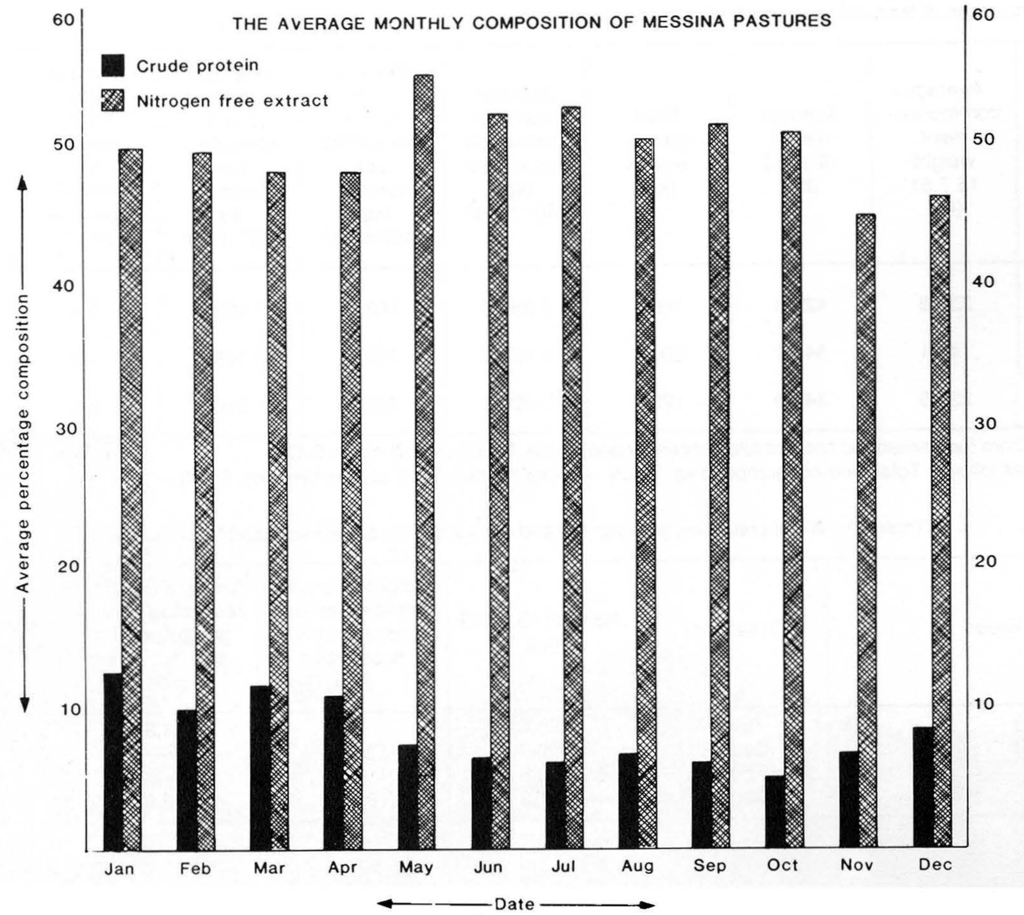
Graph 6 illustrates the 4-year average monthly composition and digestibility of Mara pastures. The limiting factor in livestock production in the semi-arid subtropics is not pasture composition but total digestible nutrients (T.D.N.) per unit area during periods of drought.

Suggestions are made in connection with the improvements of livestock production in semi-arid, subtropical environments and the principles that should govern the selection of cattle adapted to such regions are enumerated.

Broad suggestions are made with reference to the placing of different types and breeds of cattle in environments to which they should be adapted.

Table 7. Summary of the mortality-rate of calves of different types and breeds at Mara up to one year of age born during the period 1936–52

Year	Afrikaner calves born	Afrikaner calves dead	Cross-bred calves born	Cross-bred calves dead	Hereford calves born	Hereford calves dead	Total	Total	%
1936–45	308	24	1 101	149	69	24	1 478	197	13,33
1946	52	5	240	50	31	12	323	67	20,74
1947	67	10	350	31	45	11	462	52	11,26
1948	85	4	324	25	81	16	490	45	9,18
1949	98	12	299	30	74	22	471	64	13,59
1950	135	8	315	57	50	16	500	81	16,20
1946–50	437	39	1 528	193	281	77	2 246	309	13,70
1951	159	12	342	21	51	10	552	43	7,79
1952	151	7	289	12	68	10	508	29	5,71
1951–2	310	19	631	33	119	20	1 060	72	6,79
1936–52	1 055	82	3 260	375	469	121	4 784	578	12,08
Average percentage		7,77		11,50		25,80			12,08



Graph 7

Graph 7 depicts the average monthly composition over a 3-year period of Messina pastures in respect of protein and nitrogen-free extract. Grazing cattle were followed, and grab samples were taken of edible bush, shrub and pastures as consumed. The protein-content of Messina pastures is high because so much of the available grazing is composed of the leaves and pods of bush and shrubs.

Table 8. Average percentage mortality-rate of calves up to 1 year of age for the different types of cattle

Period	Breed	Total born	Total dead	Percentage dead
1936–45 (10 years)	Afrikaner Cross-bred Hereford	308 1 101 69	24 149 24	7,79 13,53 34,78
1936–45	All breeds	1 478	197	13,33
1946–50 (5 years)	Afrikaner Cross-bred Hereford	437 1 528 281	39 193 77	8,92 12,63 27,40
1946–50	All breeds	2 246	309	13,76
1951–2[1] (2 years)	Afrikaner Cross-bred Hereford	310 631 119	19 33 20	6,13 5,23 16,81
1951–2	All breeds	1 060	62	5,85
Total 1936–52 (17 years)	Afrikaner Cross-bred Hereford	1 055 3 260 469	82 375 121	7,77 11,50 25,80
Grand total	All breeds	4 784	578	12,08

1 The figures for 1951–2 are not complete as the calves born during the calving season June–July 1952 are not 1 year old. Only during the years 1951 and 1952 were the calves inoculated against heartwater before the age of 2 weeks.

Table 9. Weights and measurements of N'guni (Mpisi) and Afrikaner cattle (Mara)

Cattle	Age group	Average live-weight (kg)	Length of body (cm)	Height at hips (cm)	Height at withers (cm)	Chest circumference (cm)	Depth of chest (cm)
Afrikaner } Females	1 year	219,1	115	113	108	136	46
N'guni } Females	1 year	143,2	98	104	99	120	40
Afrikaner } Females	2 years	354,1	140	130	126	164	61
N'guni } Females	2 years	207,7	118	118	113	138	53
Afrikaner } Females	Mature	540,9	154	134	132	187	68
N'guni } Females	Mature	328,6	135	122	122	157	60
Afrikaner bulls	Mature	909,1	175	142	146	224	76
N'guni bulls	Mature	629,6	152	132	133	177	67

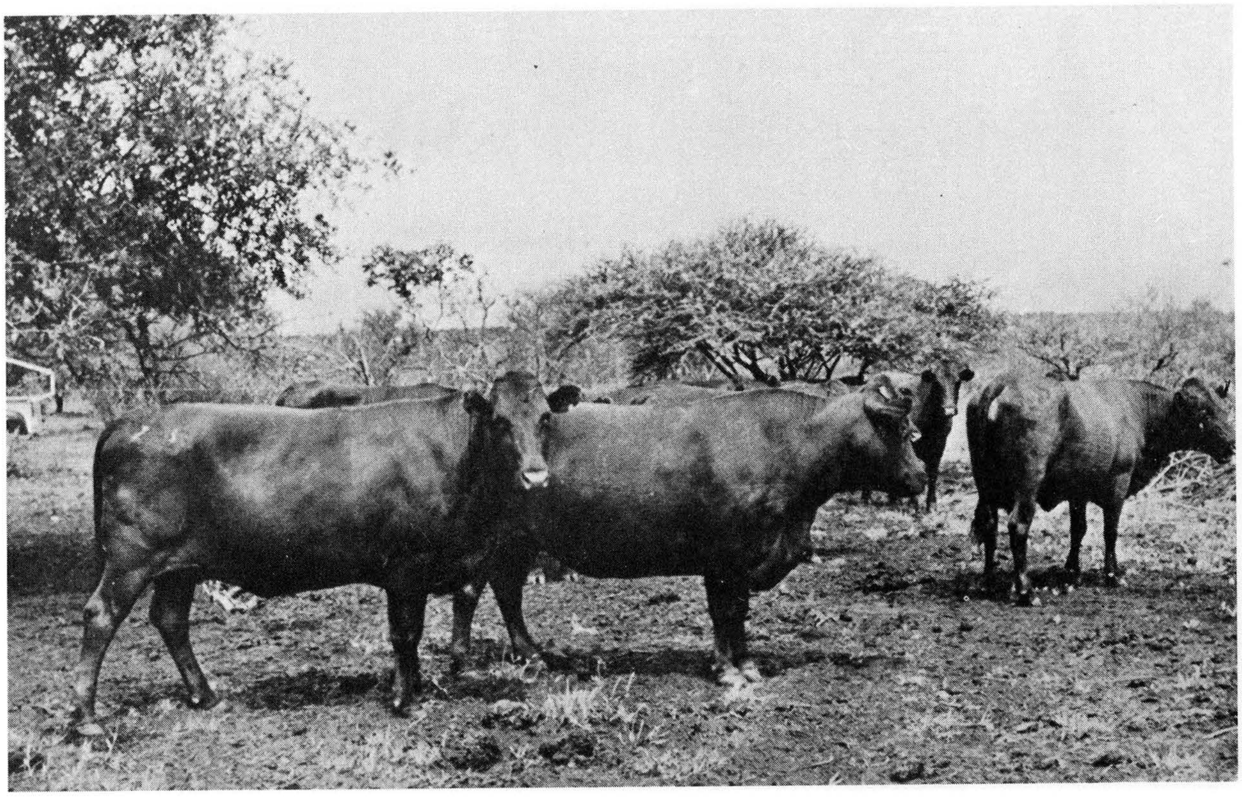
Table 10. Comparison of feed-utilization by Afrikaner and N'guni cattle

Breed	Average commence-ment weight 15.7.51 (kg)	Average weight 15.11.52 (kg)	Total gain in weight (kg)	Average total hay consumed per animal (kg) (487 days)	Average total grain consumed per animal (kg) (487 days)	Average total T.D.N. consumed per animal (kg) (487 days)	Average total T.D.N. needed for main-tenance (kg) *	kg. T.D.N. above maint. required 2,2 kg live-weight gain **
(Smooth) Afrikaner	233,6	420,5	186,8	2 390,5	763,6	1 963,6	2,9	1,4
(Woolly) Afrikaner	149,1	349,1	200,0	2 023,2	763,6	1 748,6	2,3	1,5
(Very smooth) N'guni	223,6	348,6	125,0	2 304,1	760,9	1 910,9	2,6	2,4

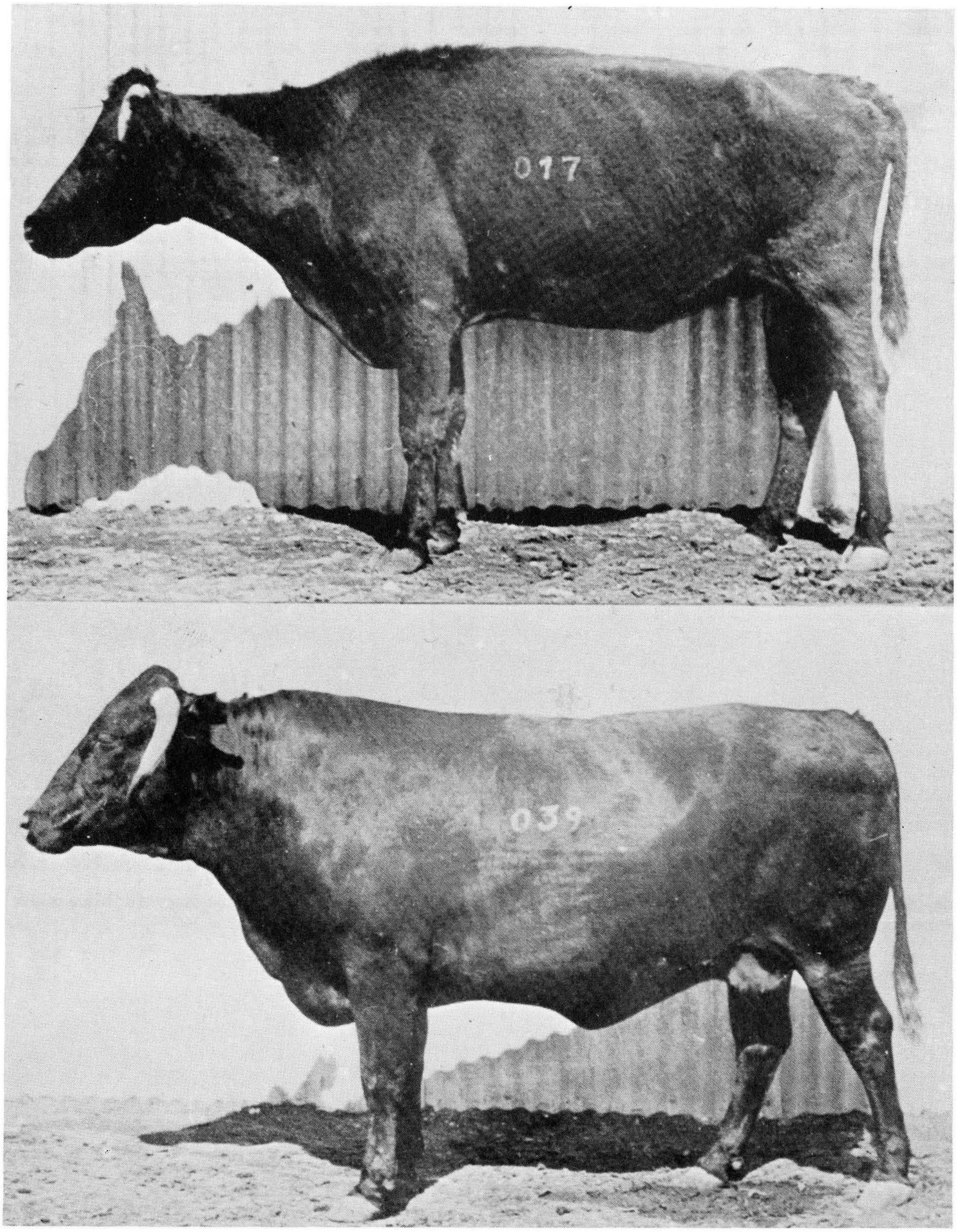
* Calculated from recommended nutrient allowances for beef cattle, N.R.C., Washington D.C.
** Calculated as follows: Total feed-consumption kg. T.D.N. — Total maintenance requirements kg. T.D.N.

Table 11. Weight relations between fed and control groups of Afrikaner and N'guni cattle

Breed	Treatment	Average 15.12.52 (kg)	Weight-difference between fed and control groups in each breed (kg)	Average weight of respective control groups as % of aver. wt. of fed group	Average weight of N'guni cattle as % of the respective Afrikaner
Afrikaner (4)	Fed	426,4	—	83,3	86
Afrikaner (4)	Control	355,5	70,9	—	—
N'guni (4)	Fed	366,8	—	—	75
N'guni (4)	Control	267,3	99,5	72,8	—



Smooth-coated crossbred cattle adapted to subtropical semi-arid regions. These cattle were maintained at Mara under veld conditions and were photographed at the end of the drought in 1952.



Differences in body conformation between adapted and non-adapted cattle. These cows were maintained under identical environmental conditions, and were fed a maintenance ration during periods of poor veld conditions.

017—Pure-bred Shorthorn. Born 26/12/39. Photographed 14/12/52. Age 13 years—had 4 calves. Weight 30/11/52—348 kg.

039—$\frac{3}{4}$ Africander × $\frac{1}{4}$ Shorthorn. Born 26/12/39. Photographed 14/12/52. Age 13 years—had 8 calves. Weight 30/11/52—475 kg.

Cattle unadapted to the sub-tropics develop ewe-necks, slack loins, and small rumps; become deep and flat through the chest and lack stomach capacity (Response physiology).

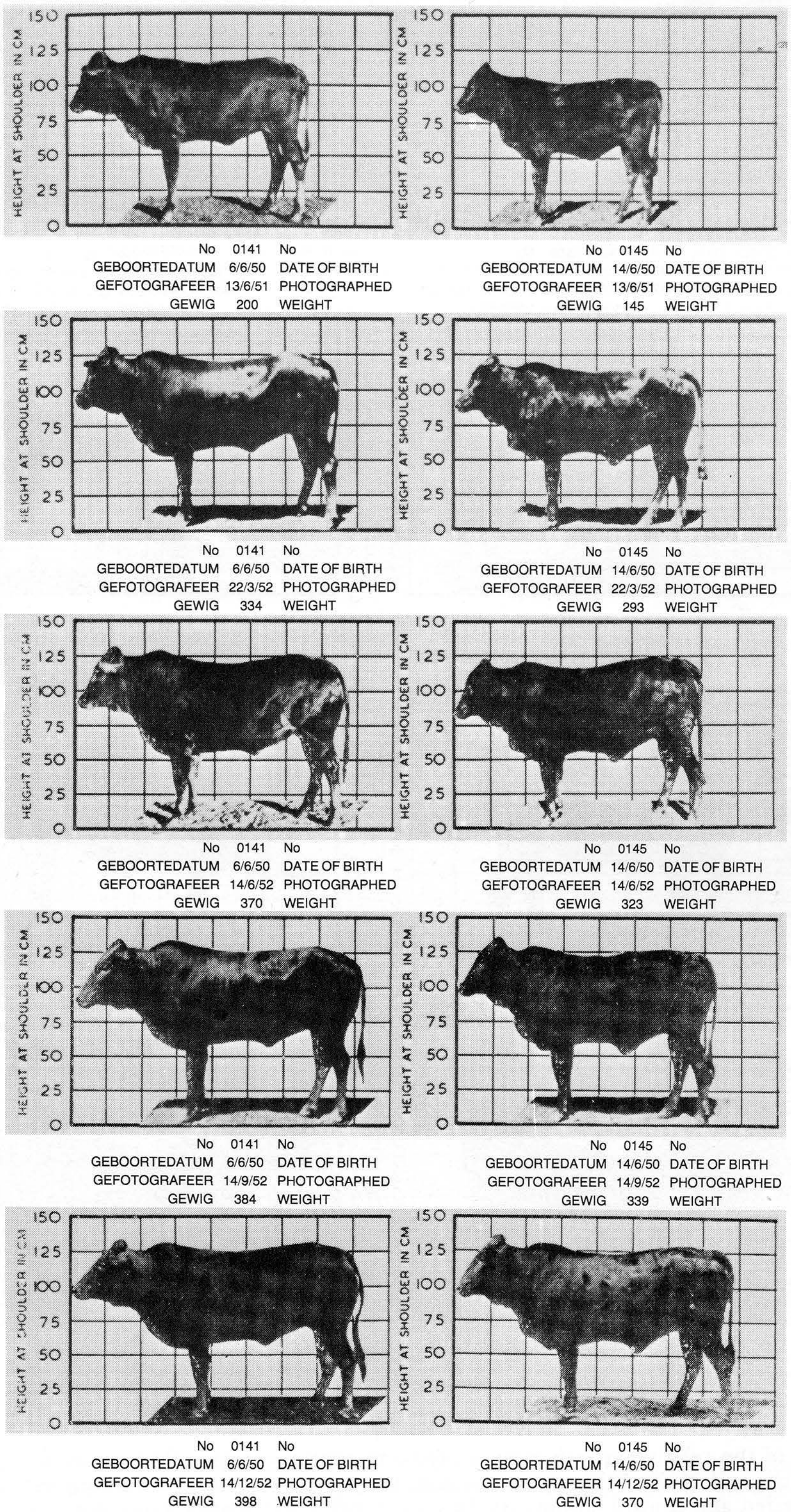
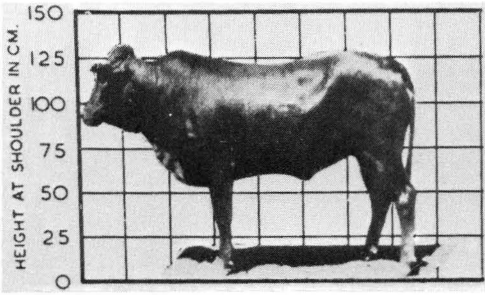
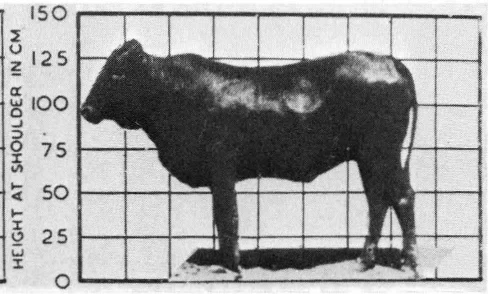


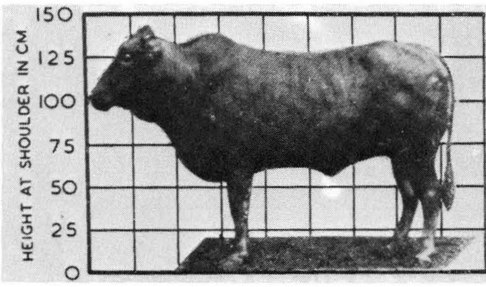
Illustration of the relative growth of fed smooth-coated and woolly-coated Afrikaner cattle. The woolly-coated cattle have a low heat-tolerance coefficient during the first two years, with the result that growth is retarded.



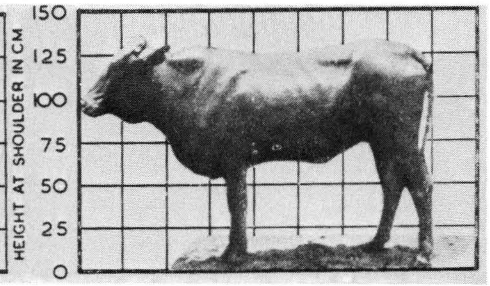
No 0118 No
GEBOORTEDATUM 3/2/50 DATE OF BIRTH
GEFOTOGRAFEER 22/3/52 PHOTOGRAPHED
GEWIG 375 WEIGHT



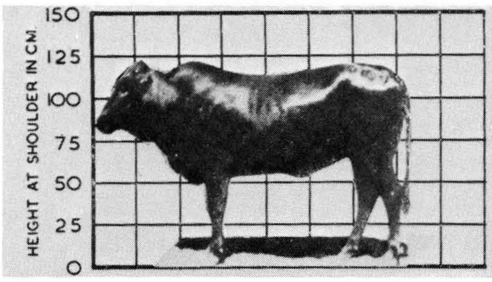
No 053 No
GEBOORTEDATUM 23/12/49 DATE OF BIRTH
GEFOTOGRAFEER 22/3/52 PHOTOGRAPHED
GEWIG 340 WEIGHT



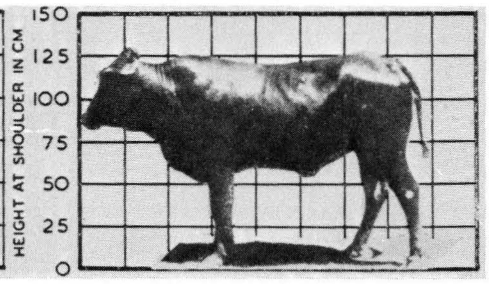
No 0118 No
GEBOORTEDATUM 3/2/50 DATE OF BIRTH
GEFOTOGRAFEER 14/12/52 PHOTOGRAPHED
GEWIG 465 WEIGHT



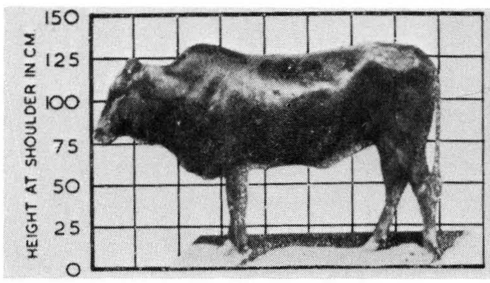
No 053 No
GEBOORTEDATUM 23/12/49 DATE OF BIRTH
GEFOTOGRAFEER 14/12/52 PHOTOGRAPHED
GEWIG 343 WEIGHT



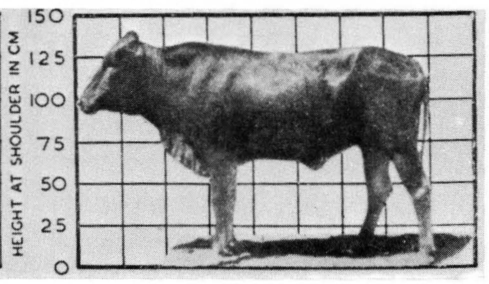
No 0107 No
GEBOORTEDATUM 22/1/50 DATE OF BIRTH
GEFOTOGRAFEER 22/3/52 PHOTOGRAPHED
GEWIG 352 WEIGHT



No 042 No
GEBOORTEDATUM 12/12/49 DATE OF BIRTH
GEFOTOGRAFEER 22/3/52 PHOTOGRAPHED
GEWIG 364 WEIGHT



No 0107 No
GEBOORTEDATUM 22/1/50 DATE OF BIRTH
GEFOTOGRAFEER 14/12/52 PHOTOGRAPHED
GEWIG 432 WEIGHT



No 042 No
GEBOORTEDATUM 12/12/49 DATE OF BIRTH
GEFOTOGRAFEER 14/12/52 PHOTOGRAPHED
GEWIG 370 WEIGHT

Illustration of the relative growth between fed and control groups of Afrikaner heifers. At the end of March, end of the 1952 summer season, there was only 8,6 kg or 2,5 per cent difference between the fed and control groups. At the end of 1952, that is after a drought, the average differences between the fed and control groups was 60 kg or 14,6 per cent. Note the difference in development between the two groups. The control group (right) are long legged and short bodied, and they lack loin and rump development.

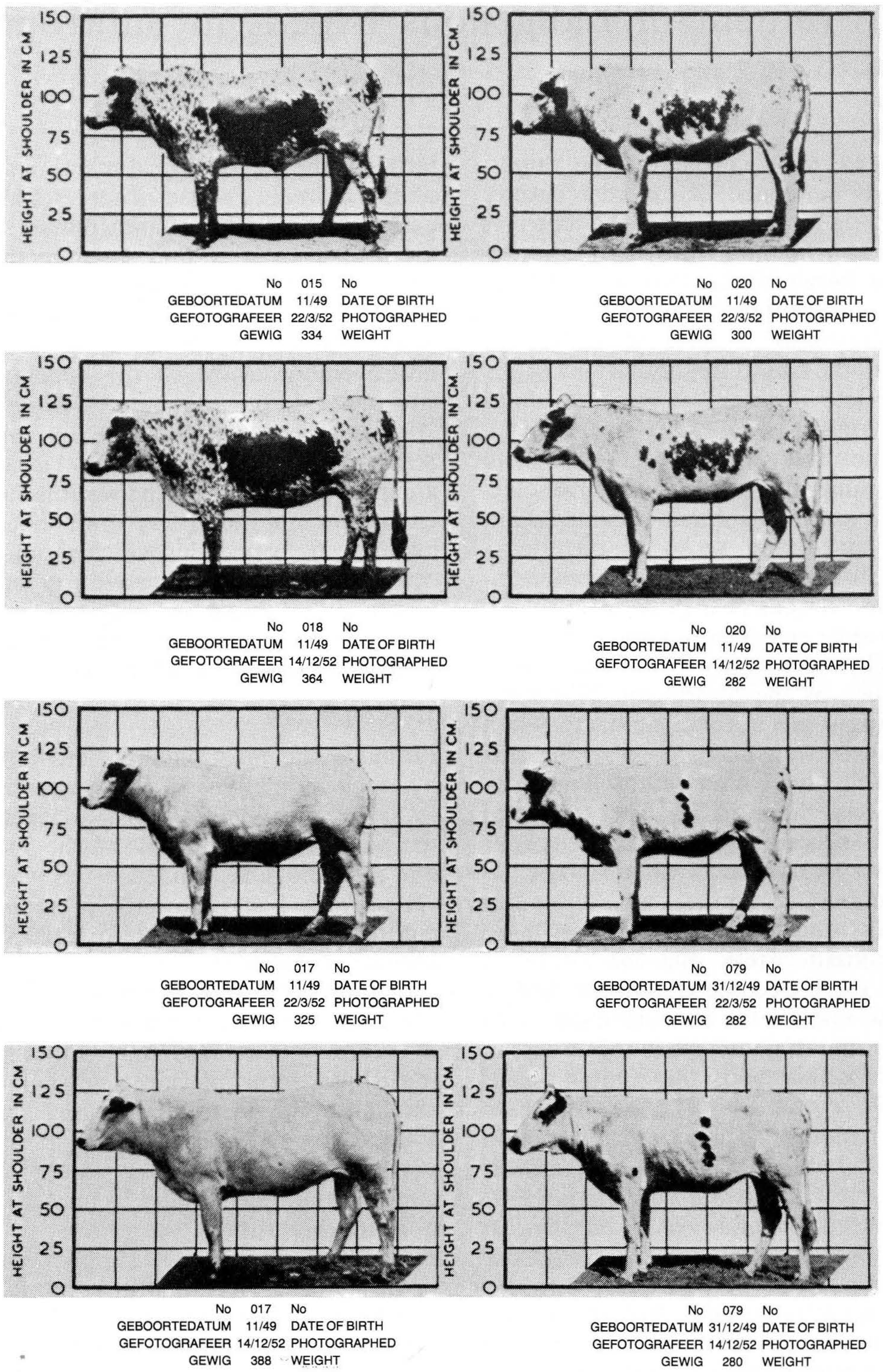


Illustration of the comparative growth of fed (right) and control (left) Nguni cattle. At end-March 1952, the average difference in weight between the fed and control groups was only 20 kg or 6,8 per cent. At the end of the 1952 drought-year (November 1952) the average difference was 80 kg or 22,9 per cent. Note that in the control group of Nguni cattle the same developmental changes occur as in the control group of Afrikaner heifers, namely the loin and rump development is retarded and length of leg and height at shoulder increased. The body conformation is, however, not changed to the extent of that in the Shorthorn cow.

J. C. Bonsma

The Improvement of Indigenous Breeds in Subtropical Environments

"To study life we must consider three things: first, the orderly sequence of external nature; second, the living organism and the changes which take place in it; and third, that continuous adjustment between the two sets of phenomena which constitutes life" (Carnap). It is upon the recognition of this precept — the subordination of animal life to the limitations of the habitat — that improvement of the indigenous breeds must be founded.

Each individual breed of livestock evolved in a specific environment to which by natural selection through the ages the animals became adapted, gradually developing those characteristics which distinguish the breeds today. Further improvement within breeds (which is but a speeding-up of natural selection) must therefore continue to follow ecological principles. Thus, while breeds such as the Shorthorn, Hereford, or Aberdeen Angus are not indigenous to South Africa, they can be transposed to environments successfully within the Union resembling those in which they had their origin. The extent to which they can succeed under more rigorous conditions, however, is largely determined by their range of climatic tolerance, which is wider for some breeds than for others. It is in these unfavourable climatic areas that the merits of the indigenous stock become dominant, and in such regions the task of the breeder must be to strive to attain the highest plane of livestock production compatible with the limitations of the environment.

In order to achieve its maximum production and development, an animal must adjust itself to many aspects of its natural surroundings — not only to the feed available but to all physical stimuli such as temperature, radiation, and humidity. The interaction between an organism and its environment is specific, continuous and reciprocal. In nature the environment has acted as a selective agent; only those animals retaining the specific morphological and physiological attributes which ensure adaptability possess the genetic constitution necessary for propagation and survival.

Consequently, in endeavoring to improve the indigenous breeds still further the breeder must select for those characteristics which enhance adaptability and lengthen productivity. In order to determine these criteria, the effect of specific environmental factors must be interpreted in terms of the physiological reaction and response of the animal. Precise observations on individuals within groups of indigenous stock enable the breeder to ascertain which animals have superior qualities and which are most economically productive, such animals being subsequently used as breeding stock for herd improvement. Most of the conclusions in this study are based on studies undertaken with Afrikaner cattle (*Bos indicus*, indigenous to South Africa). Arising out of this correlation of animal reactions with the various unfavourable environmental factors, recommendations can be made on the principles which should govern selection for breeding improved types. Suitability to an environment is indicated by heat tolerance, growthiness and efficient utilisation of feed, high fertility, and low incidence of disease.

Heat tolerance

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 indispensable aid in the selection of breeding stock to promote greater adaptability.

From all the observations made on cattle at the Messina Research Station over a period of 15 years it is certain that smooth-coatedness, thick hide, large dewlap, and high hemoglobin index are the factors most directly related to adaptability in the subtropics. It has not been possible to determine the extent to which the large dewlap plays a part in heat dissipation, for it is almost impossible to remove the dewlap surgically as it is so well supplied with blood. It is, however, an organ with very little volume in comparison to surface area, and hence heat dissipation is facilitated. I do not intend to dilate further upon these qualities except to present some graphs and data to show how valuable an asset is a short, sleek coat of hair in making an animal heat tolerant.

In a previous publication in 1943 it was shown that smooth-coated individuals amongst the exotic breeds showed a far higher degree of tolerance to high temperatures than woolly-coated members of the same breed. In 1948 a mutant woolly-coated purebred Afrikaner bull was obtained. By using this bull on purebred Afrikaner

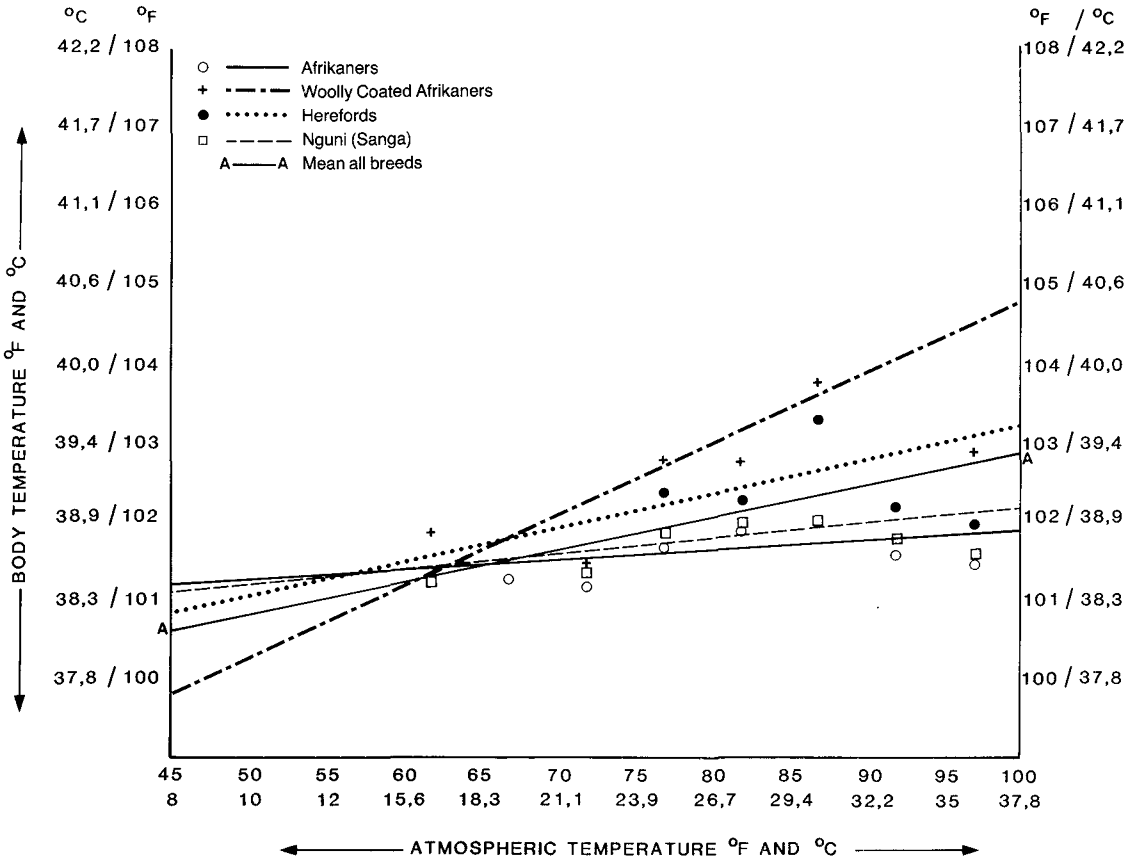


Fig. 1
Note the drastic reaction of woolly-coated Afrikaner and even smooth-coated Hereford cattle to high atmospheric temperatures. The Afrikaner and N'guni cattle do not suffer when exposed to the direct impingement of the sun. From the scatter graph it is obvious how drastically some individual animals react on hot days.

cows a number of woolly-coated, as well as a number of smooth-coated, Afrikaner calves were obtained. The former subsequently proved to have low heat-tolerance coefficients, and several died as a result of hyperpyrexia, or heat stroke, when moved from one paddock to another on a hot day. Figures 1 and 2 show the differences in temperature reaction between smooth- and woolly-coated Afrikaners as well as between N'guni, or Zulu, cattle and smooth-coated Hereford cattle. Not only did the woolly-coated Afrikaner heifers grow more slowly than the smooth-coated ones but they had a lower calving percentage, and those that calved gave a very low milk yield (Fig. 3).

Body conformation, size, and shape are also indicative of adaptability. Thus breeds and types of cattle found in, and adapted to, semi-arid subtropical regions are not small-framed cattle, these being found instead in the humid subtropics and also in areas where soils are acid. Heat dissipation in the humid tropics is more difficult than in the drier tropics; hence a large skin area per unit weight is desirable, this being characteristic in a small breed of the respiratory type such as N'guni (Fig. 4).

From body-temperature data taken at the Messina Research Station early in the morning (about an hour before sunrise) it appears that there are marked differences in the normal body temperatures between breeds. The differences between the body temperatures are as follows: Shorthorn, 37,6 °C; Afrikaner, 38,2 °C; N'guni, 38,4 °C. (All differences are statistically significant at 0,05 level). It appears that animals of a breed like the N'guni originating in an area where heat dissipation is the most difficult have a higher normal body temperature early in the morning than animals, of, say, the Shorthorn breed, which had its origin and evolution in a cool, temperate climate.

This phenomenon complicates Rhoad's Heat-Tolerance Coefficient, H.T.C. = 100 − 10 (B.T. °F − 101° F), since not only does age of the animal influence body temperature, but it would also appear that there are marked differences in the normal body temperatures of cattle of different breeds. The temperature of 101° F taken as the average normal body temperature of cattle is true of some breeds, but not of all. It can safely be said that Rhoad's method of determining the Heat-Tolerance Coefficient is a valu-

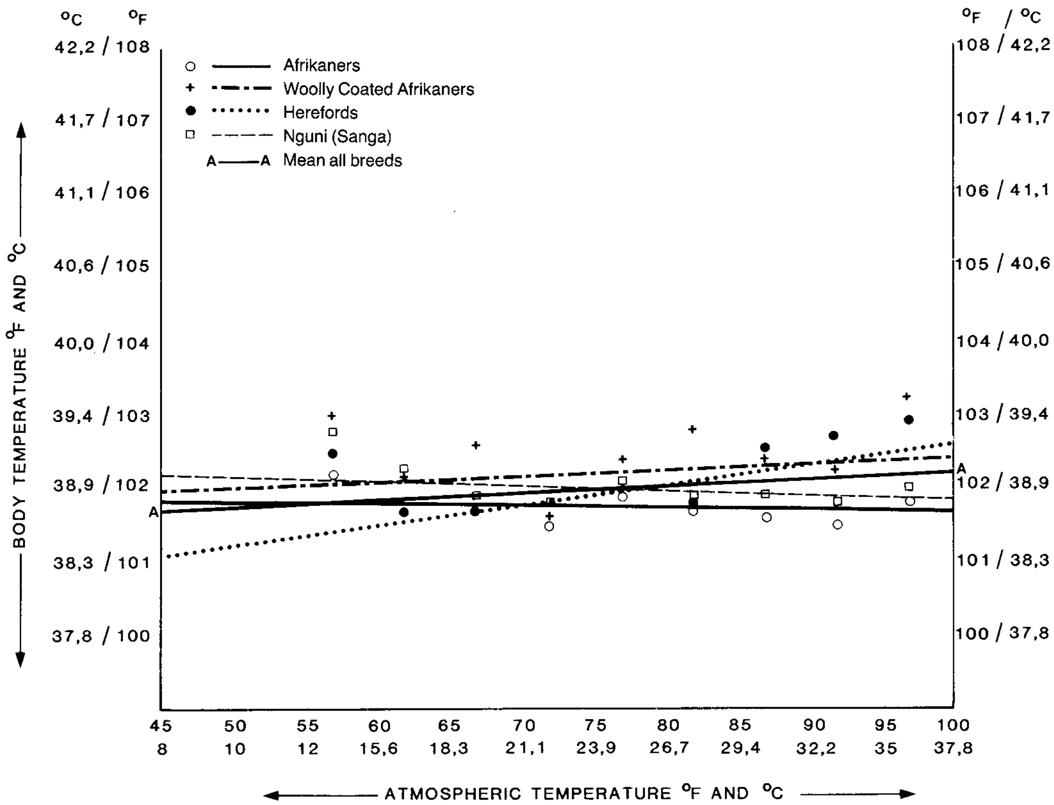


Fig. 2

A comparison of this graph with Figure 1, in which the same animals are studied, shows the extreme importance of providing shade for livestock in the tropics and subtropics.

able guide to selection for heat tolerance within a breed. The H.T.C.'s obtained by Rhoad's method are correct, or slightly too low, for indigenous types or breeds, but for the exotic breeds such as the Shorthorn they are definitely too high.

Efficient utilisation of feed

The abundance, composition, and distribution of plant growth is largely determined by variations in the environmental complex. In South Africa there are some 160 000 square miles of semi-arid, subtropical savanna where the vegetation not only is sparse (giving a low production of feed per unit area), relatively high in crude fibre and protein, and very low in ether extract, but is also subject to extreme seasonal variations in nutritive value and abundance.

At the Mara Research Station (23° 09′S, 29° 34′E, altitude 3 000 feet, average annual temperature 19,5 °C), a study has been made of the weight fluctuations of all mature cows (six years old and over) which calved during the past two years. It is apparent that within any breed there are tremendous differences in weight loss during periods of drought and of feed scarcity. The variation for cows with calves ranged from 25 kg (5,8 per cent) to 190 kg (35 per cent) for the Afrikaners; from 4,5 kg (1 per cent) to 157 kg (31 per cent) for crossbreds; and from 27 kg (6,3 per cent) to 193 kg (38,5 per cent) for the exotic beef breeds. These variations in weight can form a useful basis for selection of cattle within a breed for increased adaptability and higher production (Fig. 5).

In a study of the weight loss during lactation of 140 ranch cows of different types and breeds at Mara, namely, 50 Afrikaners, 50 crossbreds, and 40 smooth-coated Herefords, it was found that the average weight loss of all the cows was 23,8 per cent (Fig. 7 and Table 1).

These figures pertain to the very dry season 1951–52, and it was difficult to account for the lack of significance between the weight losses of

Table 1. Average percentage of weight loss of 140 ranch cows during lactation

Breed	No. of cows	Maximum weight (avg., kg.)	Minimum weight (avg., kg.)	Percentage of loss (avg.)
Hereford	40	561	416	26,0
Crossbred	50	617	472	23,5
Afrikaner	50	590	456	22,7
All breeds	140	591	450	23,8

the different breeds until it was discovered that in spite of immunisation against heartwater (rickettsiosis) before the age of three weeks, calf mortality for the Herefords was approximately 10 per cent more than for Afrikaners and crossbreds. As a result, relatively more Hereford cows had curtailed lactations and in consequence lost less weight than they would have done had their calves not died.

Within the breeds there is much variability, and it is evident that there is still much scope for the selection of superior animals, even among the indigenous stock. The fifty lactating Afrikaner cows fall fairly easily into three classes: those which lost less than 16 per cent of their maximum body weight while suckling a calf, those which lost between 16 and 26 per cent, and those which lost more than 26 per cent. On further investigation it is found that it is mainly the smaller cows which lost the least weight. This tendency is brought out by Figure 8.

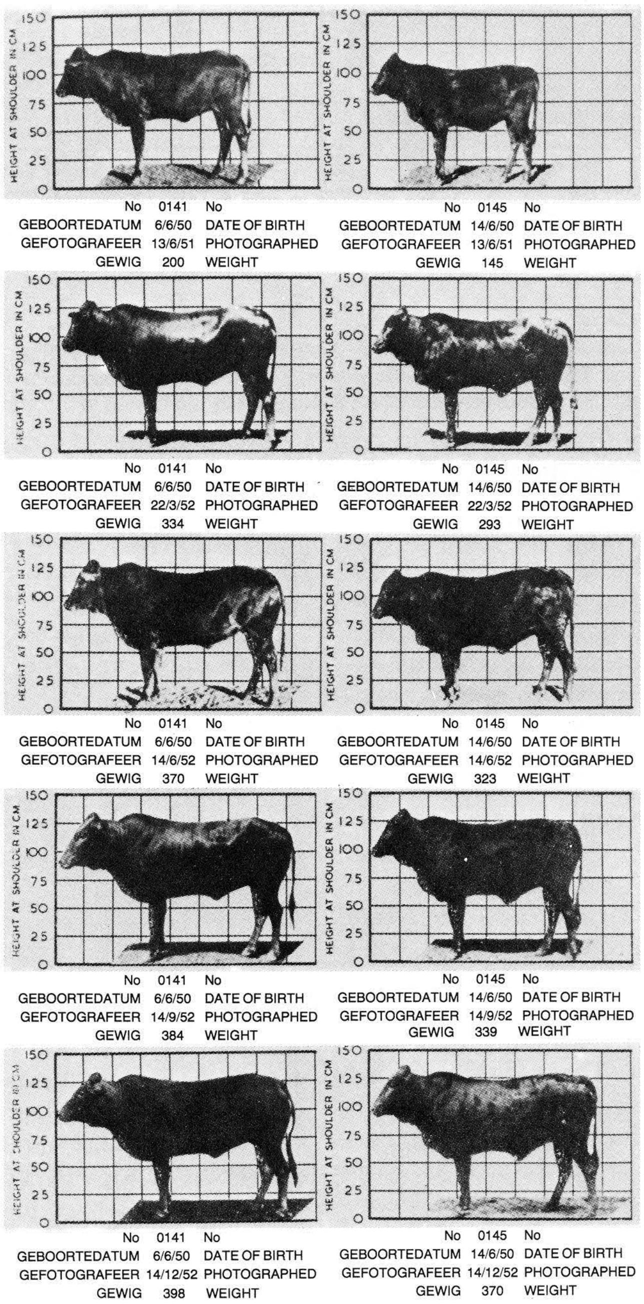


Fig. 3

Each individual is representative of a group of four.

COMPARATIVE SIZES OF MATURE AFRIKANER AND NGUNI (ZULU) COWS

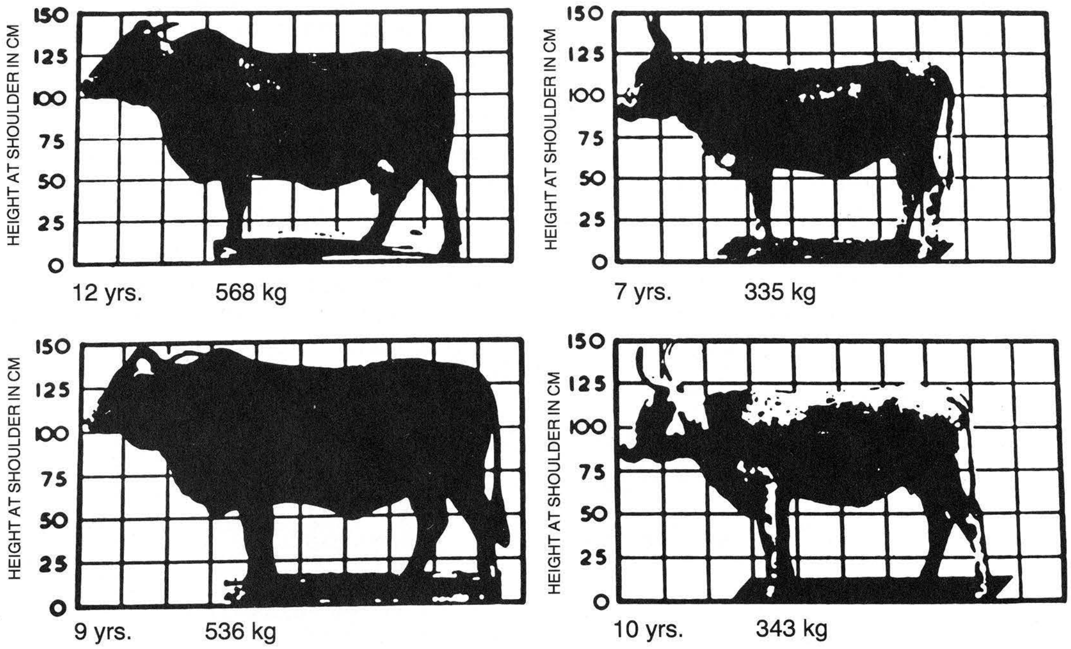


Fig. 4

The average weight of a mature Afrikaner cow is 540 kg; of a mature N'guni cow, 329 kg. The Afrikaner is adapted to a semi-arid subtropical environment; the N'guni, also an indigenous breed, is adapted to the humid subtropics.

In developing the policy to be followed in improving the indigenous stock in the semi-arid subtropics, it must yet be decided whether it is more economical to increase the numbers of slightly smaller stock which maintain a fairly even weight throughout the year, or to propagate large animals notwithstanding the fact that they may suffer greater seasonal weight fluctuations. There are, beyond question, marked genetic differences in foraging ability and efficiency of feed utilisation between individual animals within a type or breed, which can serve as one basis for selection for increased adaptability.

The correlation between weight losses and milk production provides yet another basis of selection worthy of consideration. At the Mara Research Station large groups of ranch cows were tested for milk production by separating the calves from their mothers for one day each week and weighing the calves before and after each suckling twice a day. These data revealed marked differences in milk production between individuals within the same breed. So we find that the milk production of a group of 83 Afrikaner cows tested over a period of 23 weeks averaged 5,3 kg daily. Of these cows 27,8 per cent gave less than 4,5 kg, 55,4 per cent produced 4,5 to 6,8 kg, while 16,8 per cent yielded more than 6,8 kg daily. The histogram (Fig. 9) indicates the average milk production of these 83 Afrikaner cows over the 23-week period.

As a matter of breeding policy we lay down the rule that cows which produce an average of less than 4,5 kg of milk daily during the eight-month period when the calf is suckling should be discarded for future breeding. Such low milk producers should be culled because they do not produce heavy calves at weaning. In heavy producers, however, the udders often break down as a result of mastitis or other infection, or as a result of injury due to large size. It is therefore suggested that the cows selected for ranching purposes should have fairly small, compact udders producing not more than 11,4 kg of milk daily during the period of maximum production.

That high average milk production is necessary for a high calf weight at weaning (eight months) is to be expected and is well brought out by the fact that the correlation coefficient between average milk production and weaner weight has been found to be in the region of $r = 0{,}75$. But that there should be only a low correlation, $r = 0{,}18$, between weaner weight and weight lost by the dam during lactation is surprising and will be the subject of further study.

The milk-production studies carried out on these animals has disclosed that some of the animals which lost the least weight were amongst the highest producers and the ones weaning the heaviest calves. For example, it is possible to divide all the Afrikaner cows at Mara into two

GRAPH 3 WEIGHT FLUCTUATIONS OF MATURE COWS OF DIFFERENT TYPES AND BREEDS AT MESSINA RESEARCH STATION - OCT 1950 - NOV 1952

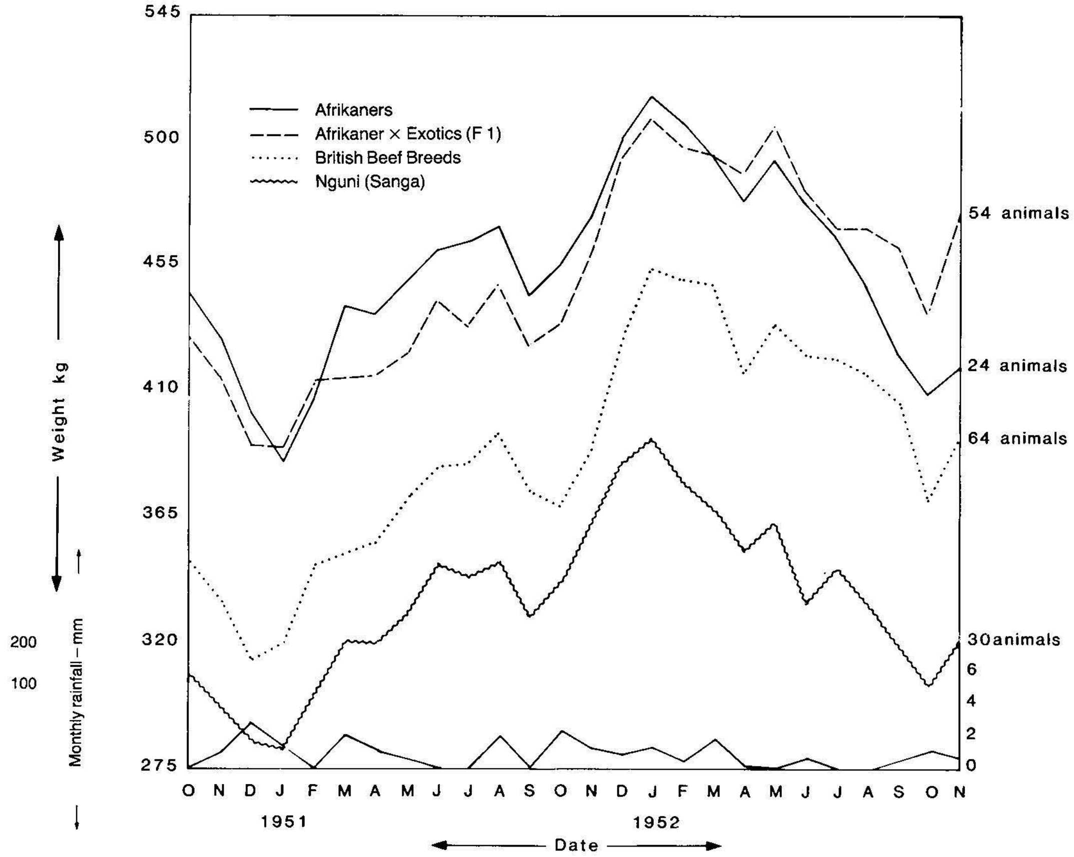


Fig. 5

The 1951–52 summer-rainfall season was a very dry one; the 1952–53 season was exceptionally favourable and livestock attained very high weights.

groups: those which wean heavy calves weighing on the average more than 196 kg at eight months, and those which wean light calves weighing on the average 164 kg at eight months.

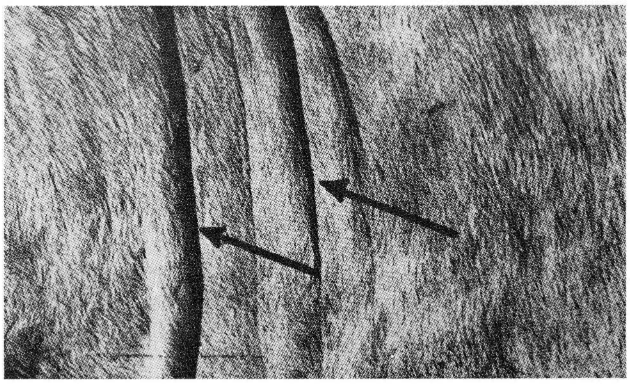


Fig. 6

A thick hide showing vertical skin folds, which are also indicative of looseness and mobility of hide.

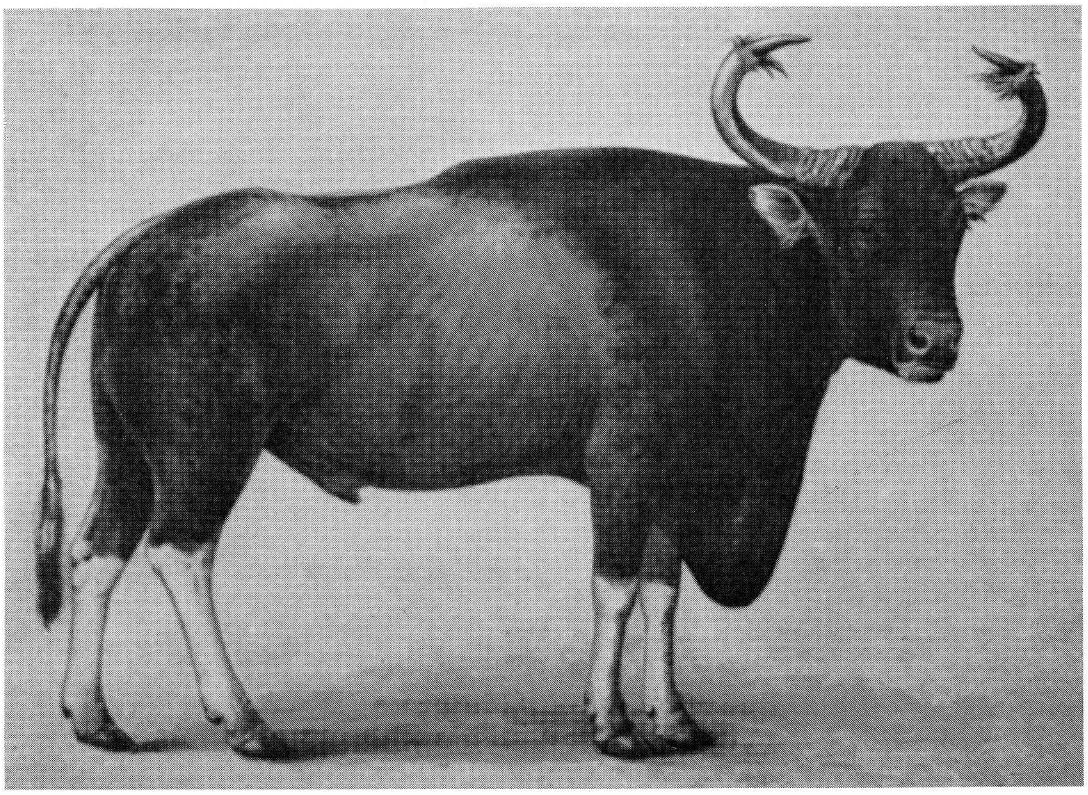
The heavy-calf cows lost 25 per cent (range 15,4–38,7 per cent) of their weight during their lactations as against a 22 per cent loss (range 15,0–34,1 per cent) among the light-calf cows. The difference is barely significant, and we are faced with the striking fact that the cow which weans the heaviest calf is not necessarily the one which loses the most weight. That high weaner weight in conjunction with low body-weight loss on the part of the dam is controlled genotypically is a distinct possibility and presents itself as yet another basis of selection.

Fertility

Since fertility, and thereby reproduction, have considerable economic significance in that they largely regulate the annual turnover in livestock numbers, selection for high fertility is worthy of special consideration. As yet the fertility of the indigenous cattle is characterised by variability rather than by uniformity. A calving percentage of over 100 per cent has been obtained in some cases, whereas 50 per cent and lower is not uncommon for others.

Cows which do not calve regularly should be eliminated. It is laid down as a general rule that cows which do not produce two calves every three years or cows which skip two consecutive seasons must be done away with. Bull calves for future breeding purposes should be selected from cows which calve regularly, give adequate milk, and produce heavy calves at weaning.

From preliminary tests carried out at Mara it



Novibos sauveli (Urbain), an old kouprey specimen in the Museum of Comparative Zoology Harvard (see p. 110). From *The Indo-Chinese Forest Ox or Kouprey*

is obvious that there are very marked differences in the testicular volumes of different bulls. There are also very marked differences in their ability to contract their scrotums (which is an indication of cremaster muscle tonus). Long, pendulous scrotums are prone to injury; if a varicocele develops in the spermatic vein, the thermoregulatory function of the testes is impaired and the bull becomes sterile. The elongation of the scrotum is often also the result of disturbance in the thermoregulatory function of the testes. Most bulls disposed of because of infertility at ages of from four to six years have excessively large testes. Observations made on numerous bulls at the Mara Research Station have led to the conclusion that bulls adapted to tropical and subtropical environments should not have large testicles. The scrotum should be relatively small and the action of the cremaster muscle well developed.

Disease resistance

In tropical and subtropical regions parasitic infestations (especially ticks and stinging flies) not only cause great irritation and discomfort to livestock but are also responsible for the spread of diseases such as redwater (piroplasmosis), gall sickness (anaplasmosis), and heartwater (rickettsiosis). Thickness and mobility of hide are valuable assets in making an animal tick repellent. An animal with such a hide has numerous vertical skin folds and a well-developed *panniculus* muscle, and should be selected for breeding purposes (Fig. 6). Secretions from the hide, such as sebum, may also have insect-repellent properties, but unfortunately it is difficult to measure the comparative amounts of sebum secreted by different animals.

The condition of the hide, the growth of the coat, the amount and distribution of adipose tissue under the hide, and the healing of wounds

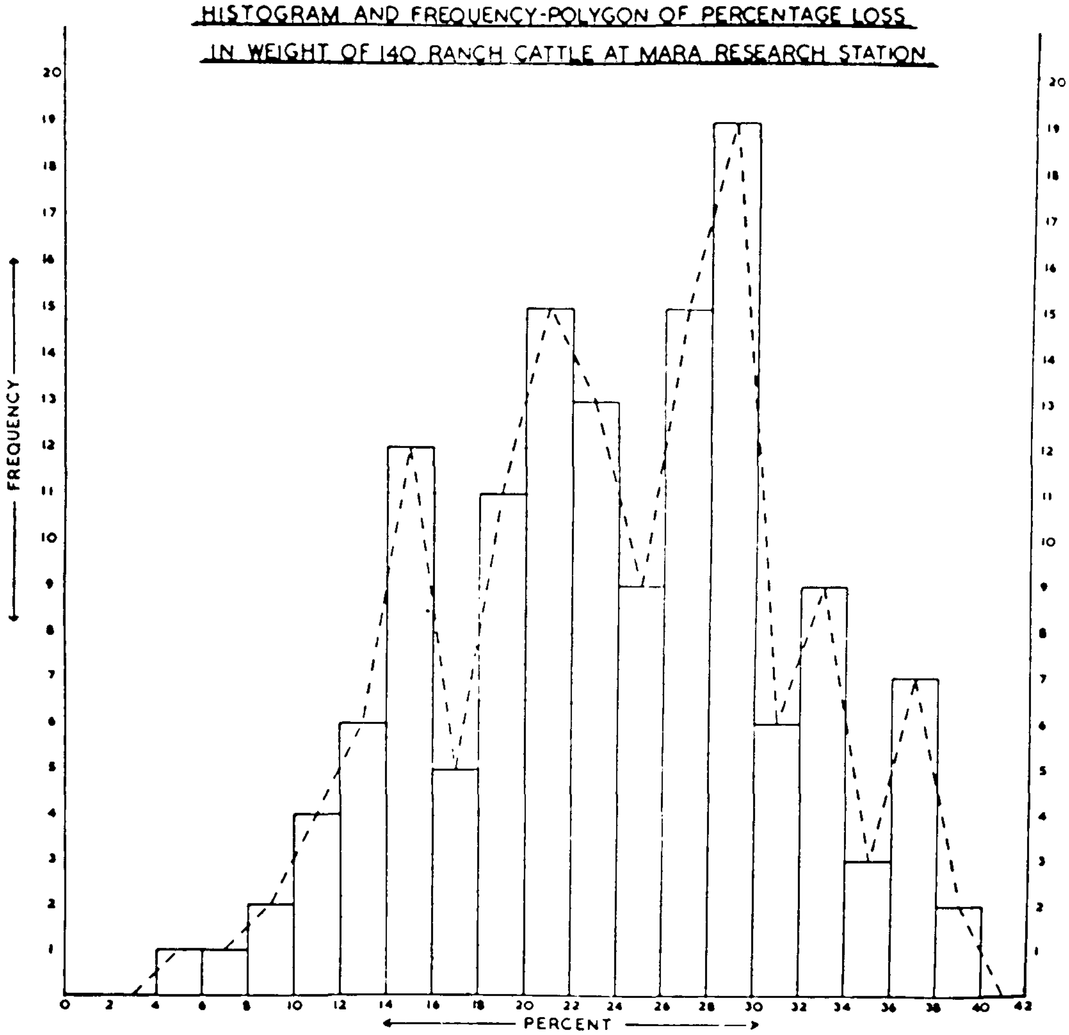


Fig. 7

Those cows which lose the least weight during a drought and during the lactation period are the ones with the greatest powers of recovery after a drought.

are regulated by both the endocrine and nervous systems and are indicative of an animal's constitutional fitness in a particular environment. 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 the best adapted to this subtropical climate had thick hides; the wounds bled freely for a short period, there was an abundance of lymph fluids in the wounds, and healing was rapid in comparison to unadapted cattle with thin hides.

Table 2. Mortality rate of different breeds of cattle at Mara Research Station 1936–52

Breed	Total born	Total died	Percentage died
Afrikaner	1 055	82	7,7
Crossbred	3 260	375	11,5
Hereford	469	121	25,8
All breeds	4 784	578	12,8

It is fully realized that the plane of nutrition at which cattle are maintained has a marked influence on the thickness of hide, the distribution of adipose tissue, and the quality of hair. In stabled cattle maintained under artificial conditions, the light intensity and temperature in the stable and the humidity of the hair as a result of brushing with a wet brush have a marked influence on the growth, i.e., length, density, and quality of the coat.

A thick, mobile hide with an active blood circulation plays an important role in the natural immunisation of animals against disease. It is an accepted fact that recovery from intradermal infection gives better and more lasting immunisation than recovery from subcutaneous infection. The result is that far fewer adapted animals (i.e., those with thick hides) die as a result of tick-borne diseases; they also develop fewer subcutaneous abscesses.

Ranch animals showing marked susceptibility to various pathological processes should be regarded as constitutionally inferior, but they can

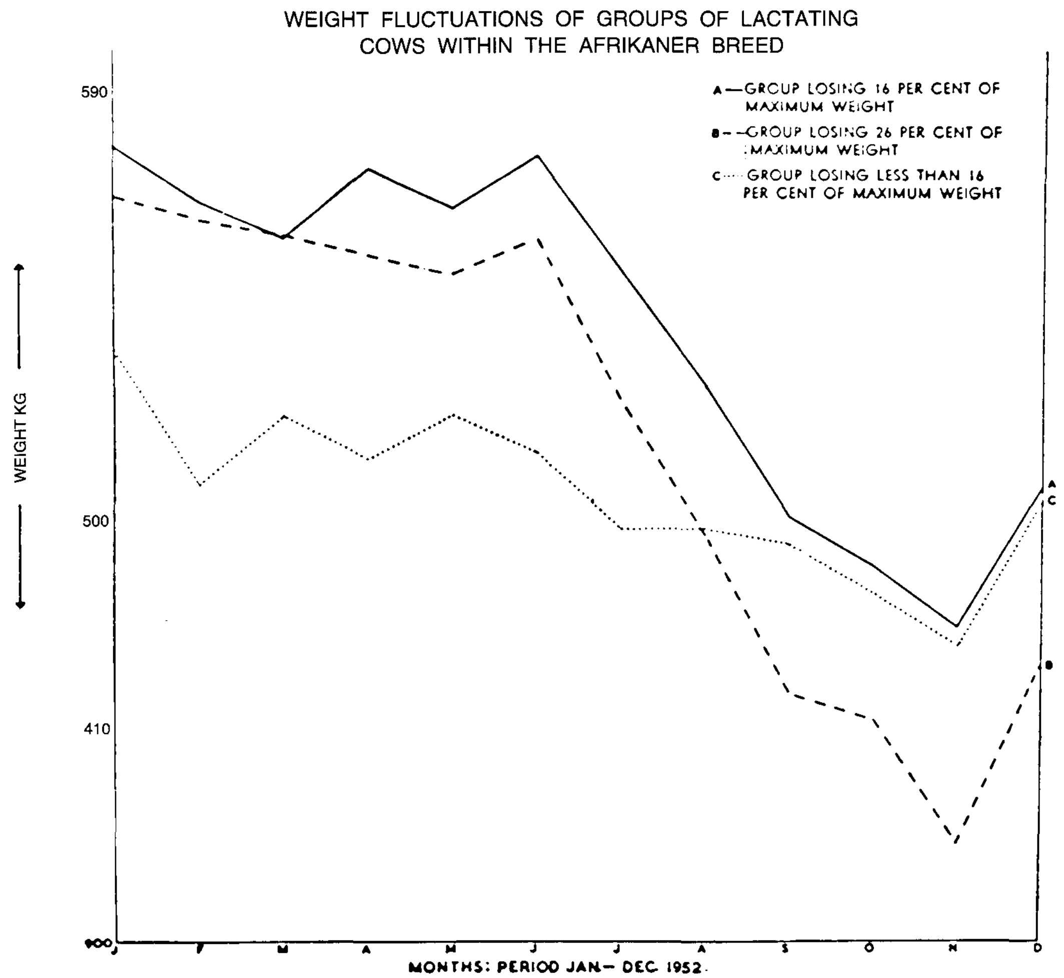


Fig. 8

Interaction between genes and the phenotype.

be detected only be intelligent study of disease from the genetic standpoint. At the Mara Research Station there are many records to indicate variations in the mortality rate between different types and breeds of livestock. Table 2 summarises the average percentage mortality rate of calves up to one year of age for the various breeds of cattle. After the age of one year very few cattle die of disease. By selecting for increased adaptability the mortality rate of Herefords was reduced from 34,8 per cent for the period 1936–45 to 27,4 per cent for the period 1946–50.

A register is now being kept at Mara which records the incidence of disease in the different types and breeds in order to determine individual constitutional predisposition to disease. It is an established fact that longevity — the productive duration of 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.

Conclusion

Notwithstanding the fact that the Afrikaner is well adapted to the semi-arid subtropical regions of South Africa by virtue of its constitutional vigour and hardiness and its ability to withstand high atmospheric temperatures, the breed is not without certain defects. It has, for example, a relatively low production of beef and milk as compared with the crossbreds, coupled with a tendency towards irregular breeding habits. Such limitations are of considerable economic significance, so that there is ample scope for effecting improvements within this indigenous breed.

Experience has shown that it is essential that selection and breeding for improvement be founded on ecological principles. The livestock breeder must, therefore, endeavour to correlate the morphological and physiological characteristics of these indigenous stock with the more important environmental factors in order to establish the basis for selection. And further, it is necessary to determine by careful study just how, and to what extent, the functioning and response of individual organs and parts of the body to environmental stimuli affect the general adaptability of the animal as a whole. The further this study progresses, the more apparent is

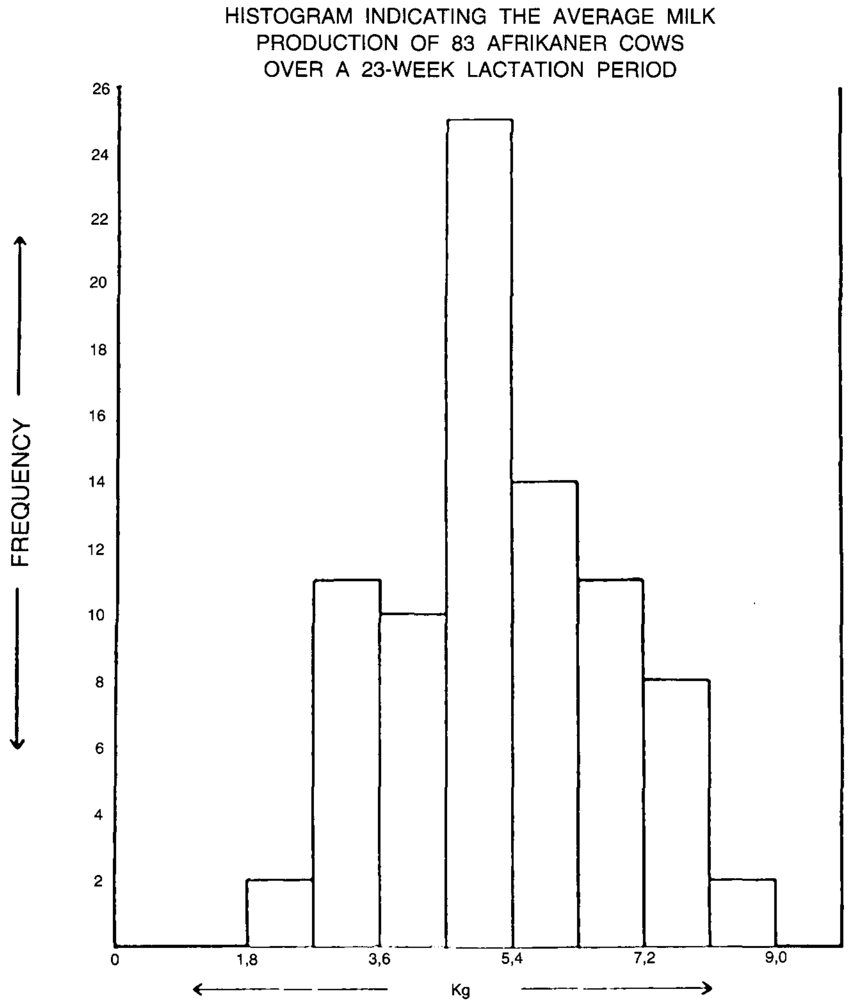


Fig. 9

The cows were maintained under ranching conditions, the milk production being determined by weighing the calves, previously separated, before and after suckling twice a day.

the lack of knowledge about the reaction of such vital internal organs as the kidney, the liver, etc., to environmental controls, and the more evident is the need to expand the scope and techniques of such investigations.

Close study of livestock behaviour has strengthened the conviction that numerous phases of animal reaction are adaptive. In the selection of improved indigenous types of livestock, therefore, the fundamental aim must be to achieve hereditary adjustment or adaptation of the animal to its environment.

Discussion

To questions from Mr. Williams, Mr. Bonsma replied that there was no correlation between loss of weight in cows and weaning weight of their calves, but that on the contrary the cows that gave more milk weaned heavier calves, that free-moving animals — those that move easily, are calm, and graze readily — seem to fare the best; also that he had not correlated measurements of depth of body in the Afrikaner with width of body in European breeds. To another question Mr. Bonsma replied that, though he had no definite studies on relations between loss in weight and subsequent heavy performance, the relevant figures were available in his records. However, he suggested there would probably be little correlation, owing to the fact that in South Africa there are two different breeding seasons — March to April and August to September — and that those cows that had previously lost weight regained it in time to be served at the later, if not at the earlier, breeding season. To this discussion Mr. Robert Kleberg contributed the suggestion that a bulletin of Texas Agricultural and Mechanical College dealing with phosphorus deficiency on his Encino Ranch had pertinent information on respective weights of cows and calves.

J. C. Bonsma

The Influence of Climate and Nutrition on the Adaptability of the Jersey throughout the World

Proceedings IV International Jersey Conference, Pretoria

Living organisms universally exhibit adaptation. Ecologists are particularly concerned with exo-adaptation and physiologists with endoadaptation, but the two aspects of adaptation are fundamentally similar and have similar causations.

Adaptation is almost always complex combining many biological mechanisms within an integrated pattern. Perfection of adaptation is not to be expected.

Complex adjustments to complex factors invariably involve compromise solutions. Any single measurement of adaptation results in an oversimplification of the concept. It is necessary for the organism to be adjusted not only to the average conditions, but also to the rare extreme environmental fluctuations. (*Principles of Animal Ecology*, Alee, Emerson Park, Park and Schmidt.)

In the animal husbandry courses given at the University of Pretoria much stress is laid on the ecological approach to livestock production.

We are convinced that successful livestock production is based on a thorough understanding of the interaction between the heredity of the animal and the environment in which the animal is kept.

As all domesticated animals are kept in close symbiosis with man, man as a husbandman forms an integral part of the animal's environment. Through good or bad management the performance of dairy cattle can be markedly influenced.

In this paper an endeavour will be made to indicate how we feel about the influence of the total environment on your breed of cattle — the Jersey.

Total environment is made up of a number of individual environmental factors each of which has a direct influence on the animal's exo- and endoadaptation.

In the total environmental complex we intend considering the most important individual environmental factors namely nutrition (i.e. nutrition in the broad sense comprising the food and its metabolism); temperature, radiation, light, altitude, wind, disease, ecto- and endoparasites, soil fertility, soil pH and rainfall.

That nutrition *per se* has a very marked influence on Jersey cattle cannot be doubted for a moment. In the work done by McMeakan and his co-workers at the Ruakura Research Station in New Zealand on twin heifers where one of each pair of twins was well fed and the other not it was found that the well-fed heifers or cows were appreciably larger than the control animals and that the well-fed animals yielded more milk than the controls. In the case of twin Jersey bulls the twins kept on good rotated pastures weighed on an average 30 per cent more at 3 years than their mates which were kept on a continuously grazed pasture.

In the work done by Joubert and co-workers at the University of Pretoria Experimental Farm some years ago, it was shown that the Jersey could withstand adverse nutritional conditions better than any of the other three breeds tested, namely the Friesland, the Shorthorn and the Afrikaner.

The influence which nutrition has on the size of animals is often confused with the influence which temperature has on the size of cattle. Temperature has a very marked influence on the metabolic rate of cattle and hence on their efficiency of food utilisation and appetites.

So many people lose sight of the fact that

1. In animals, as external temperatures rise and loss of body heat becomes more difficult, growth slows down, sexual maturity is delayed, adult form becomes lean, flat and leggy and the animal has a much lower mature weight.

Animals living under conditions where heat loss is difficult are in the main healthy but have a low adult death rate and longer life span than on the average in a more invigorating climate, in other words, they are less susceptible to metabolic disturbances.

In cooler environments where body heat can be dissipated more easily, growth is much more rapid, maturity is reached earlier, body weight and size are greater and the body conformation much more balanced.

2. Another factor which we have to accept is that warm blooded animals follow the laws of Bergmann and Allen, viz: "Homothermal animals from colder climates tend to be larger in size and hence to have less surface in proportion to body weight than do their relatives from warmer regions. This phenomenon occurs widely even though not universally among birds and

Table 1. Jerseys, highest lifetime producers

Country	Name of cow	Milk in kg	Butterfat in kg	Age
U.S.A.	Silken Lady's Ruby of Ferndale	103 836	5 965	21–4
U.K.	Hockley Lia	88 840		20
U.S.A.	Opal Crystal Lady	85 550	4 596	15
U.S.A.	Coronation Lucky of S.V.	77 883	3 547	19
U.K.	White Hill Dainty Edna	76 468		
New Zealand	Maori Blush	74 427	4 106	21
U.K.	Sonata	74 142		
U.S.A.	Silken Rose Lass	73 305	4 033	16–7
U.S.A.	Sybil Owl Verinda	70 167	4 336	17–6
U.S.A.	Silken Lad's Lass	69 402	3 818	16–5

mammals and is usually interpreted in relation to heat conservation in cold climates and to heat radiation in warm climates." This is Bergmann's rule.

Allen's rule is correlated with it and is concerned with the marked tendency toward the decrease in lengths of extremities in colder climates.

That the average Jersey breeder does not accept the implications of these laws is clearly shown in a letter received from the late Secretary of the American Jersey Cattle Breeders' Society. I quote:

> "There is no evidence to indicate that Jerseys in the northern part of the United States grow any bigger than those in the southern part of the United States. It is a matter of feed. There are several herds in the south, in the far north west and in the far north east that are very large in size as compared to the average of the breed and it is volume of feed consumed rather than climate and location."

From data obtained from one of the largest feed manufacturing firms in the United States of America, it is obvious that the Jersey cows in the colder parts of the U.S.A, namely in the north, consume more concentrate feed per capita than those in the south. The cows in the south-eastern parts of the United States will not eat as great amounts of feed in general as will those in the northern sections where the climate is not so hot.

Cows with exceptionally high production records are in general larger than the breed average for a particular country.

The data received from those countries which responded to our questionnaire reveal that there are at present 49 Jersey cows with a lifetime production of 45 456 kg or more of milk. Of these 49 cows 45 are in the northern hemisphere and 4 in the southern hemisphere. The close correlation between high milk production and body size forces me to conclude that Jersey cows in the cold temperature climates are appreciably larger than those in the warm temperature or subtropical climates.

Well over a hundred Jersey cows in the Brigham herd at St. Albans, Vermont weigh on an average 409–500 kg and the average production of the herd is no less than 4 837 kg of milk on twice a day milking. At least 55 cows of the Brigham Farm have produced more than 45 456 kg of milk.

A list of the ten highest lifetime producers is given in Table 1.

If the records of some outstanding cows are not included, it is as a result of not having had replies from all the countries here represented. Therefore it will be appreciated if the information could be forwarded to me so that omissions may be rectified.

According to the available data the American Jersey Cow, Silken Lady's Ruby of Ferndale with a life time production of 103 836 kg of milk and 5 965 kg of fat is the record holder for life time production for Jerseys. This cow reached the ripe old age of 21 years.

That high producers within a breed are larger than the average is clearly illustrated by the accurate weights of record breaking cows of several breeds. The Holstein Friesian cow Carnation Ormsby Madcap Fayne which produced nearly 19 091 kg of milk on one lactation, weighed nearly 909 kg when in full production. The cow Carnation Ormsby Inka Mutual which produced 636 kg of butterfat in one lactation weighed 1 000 kg when in full production. The world record breaking Jersey cow on 2 times milking per day viz. Opal Crystal Lady weighed 625 kg when in full production.

The following Table 2 is of interest.

From all the high production records obtained from different parts of the world, it is very obvious that all the record breaking cows have exceptionally large appetites and that this high feed intake is only possible in cold climates. The cow Brampton Basilua Violet of Middlebrook Farms, Asbury Park, N.J. consumed 13,6 kg of concentrate feeds apart from being on ladino and orchard grass pastures, during the lactation at the age of 5–2 in which she produced 7 330 kg milk and 374 kg of butterfat.

The data obtained on the average weight of Jersey cows in different parts of the world indi-

Table 2. Record breaking Jersey cows and size

Name of cow	Production		Weight kg	Av. weight for country	Country
	Milk kg	B.F. kg			
Moor's Pacified Diana	9 882	(54,5 on 1 day)	409	386	U.K.
Stranges Musical	11 673 11 245	679 671	398	386	U.K.
Baring's Flower	11 407	682	420	386	U.K.
Opal Crystal Lady	10 784	562	625	432	U.S.A.
June Volunteer Fantasy	9 135	599	455	432	U.S.A.
Critale No. 2	5 974	376	600	386	France

cate that cows in the cold climates are larger than those from the temperate zones.

The data on the Jersey cows with the highest productions per lactation throughout the world (America excluded) reveal that of the 28 cows listed with productions of 5 455 kg and over per lactation, 24 are in the cold temperate zone of the northern hemisphere and four are in the southern hemisphere. It is unfortunate that this list is not complete, and an appeal is made to Jersey Cattle Breeders' Societies of every country to assist us by providing relevant important data which would complete the picture on this. The available data are given in Table 3.

Table 3. Jerseys high production records

Country	Animal	Milk in kg	B.F. in kg	%	Age
U.K.	Stranges Musical	11 673			
U.K.	Baring's Flower	11 216	682		
U.S.A.	Opal Crystal Lady	9 129	483	5,29	12
Jersey	Maharaja's Promising Lady	8 940	440		10
Canada	Brampton Basilua	8 690	568	6,54	7
Canada	Brampton Basilua Aim	8 370	485	5,79	5
Australia	Berry Bank Petunia	7 926	440		9
Canada	Brampton Lua Pinn	7 867	420	5,34	5
Canada	Fairy Raleigh Zana	7 612	409	5,37	8
Denmark	No Name	7 535	501		
Canada	Lady Basilua	7 495	492	6,57	7
South Africa	Queen of Liberation	7 470	484	6,48	
Jersey	Itaska's Fillpail Dream	7 458			9
Canada	Brampton Basilua Violet	7 330	374		5
Jersey	Melpomene Daisy 3rd	7 108			9
Canada	Brampton Twice Basilua	7 107	370	5,21	7
Denmark	No Name	6 912	495		
Jersey	Una's Designer's Lady	6 860			8
Canada	Brampton Standary Violet	6 707	403		6
Denmark	Gaarstedaard	6 700	528		
U.K.	Embely Kohaka's Fairy	6 652			16
Canada	Galgarth Starlight	6 426	378	5,88	10
Canada	Brampton Lady Bas Pinn	6 221	357	5,74	6
France	Critale No. 2	5 973	376		
U.K.	Hursley Madame's Butterfly	5 927			15
Jamaica	Jamaica Hope (Jersey/Zebu)	5 909			
France	My Dream	5 791	357		
Canada	Hillside Marjorie	5 460	297	5,48	16

From the data obtained on the average size of Jersey cattle throughout the world, it is again obvious that animals on an average are larger in the cold temperate zones than in the warmer climates.

Country	Climate	Average weight of bulls kg	Average weight of cows kg	Remarks
U.S.A. (North)	Cold	—	432–500	Opal Crystal Lady 625 kg
U.S.A. (South)	Temperate	—	341–386	
*Canada	Cold	—	425	Brampton Basilua 432 kg
Australia (Victoria)	Mediterranean	682	455	Best producers heavier
Australia (Queensland)	Hot	523	318	On Darling Downs 23 kg heavier
New Zealand	Marine (Mild)	500–545	318–409	
U.K.	Cold/Temperate	568	386	
Jersey	Mediterranean	—	341–364	Soil pH less 6,5
France	Temperate	545–600	375–400	Critale No. 2 600 kg
Brazil	Hot	—	236 at 2 yrs.	
Denmark	Cold	700	377–420	

* Stables in the case of the largest herds are air-conditioned.

Of interest from a climatic point of view is that there is little doubt that the Jersey breed of cattle, which is inherently small and which probably had its early evolution in Asia, migrated through Southern Europe to the coasts of Normandy and Brittany in France and from there to Jersey Island and is therefore well adapted to Mediterranean and temperate climates.

The following climatological data on the home countries of dairy cattle are interesting:

Table 4.

Breed	Normal annual rainfall mm	Average monthly temperature		Average annual relative humidity	Average annual hours of sunshine per day
		Min. °C	Max. °C		
Jersey	850	6	17	82	5,9
Friesland	747	1,6	17	80	4,0
Ayrshire	1 140	2,2	14	86	3,0

In Victoria (Australia) with a Mediterranean climate, 72 per cent of all the dairy cattle are Jerseys and the highest average butterfat yield is produced by Jerseys.

In New Zealand over 85 per cent of the total dairy cattle population belong to the Jersey breed.

The following table, although not complete, gives some interesting information on the distribution of Jerseys in certain countries.

Table 5. Table giving the number of registered Jerseys, average herd size and breeder membership in various countries

Country	Number of registered Jerseys	Average herd size	Breeder membership	Remarks		
					1954	1958
United Kingdom	100 000	20	5 000	England	4 500	4 300
				Wales	240	250
				Ireland	120	250
				Scotland	140	200
Jersey Island	10 427	11	950	All Jerseys		
France	2 700	12	225	Mainly Western France		
Denmark	60 000	10	6 000	56% Jutland		
				20% Funen		
				16% Zealand		
Australia (Victoria)	71 388		1 000	70% of cow population		
Australia (Queensland)			598	80% of cow population on coast		
				30% of cow population inland		
Australia (South)			400			
Tasmania	4 000	20	200	Main breed		
New Zealand	70 000	20	3 488	North Island 2 976 breeders		
				South Island 413 breeders		
				85% of cow population		
Brazil	8 139		206	Breeders		
				91 Rio Grande do Sul		
				43 Rio de Janeiro		
				37 Sao Paulo		
				45% Jerseys Crossbred		
South Africa	30 702		1 742			
U.S.A.	440 228	20	20 000	There are approximately 5 000 000		
				Jersey cows in America		
Kenya	6 750	20	450	Mostly grades		
				20% of cow population		

There is no doubt about the fact that Jersey cattle are appreciably better adapted to temperate and mediterranean climates than to severe cold climates. From the above table too it is clear that of a membership of 5 000 Jersey breeders in the United Kingdom only 200 are in Scotland. The author questioned several dairy cattle breeders in Scotland about this phenomenon and in practically every instance the answer for the lack of popularity of Jerseys in Scotland was that the Jersey calf is born relatively small, and these small calves cannot withstand cold.

In the work done by the late Dr. Samuel Brody and his co-workers in the psychrometric rooms at Missouri State University, it was found that the Jerseys could withstand high temperatures much better than Frieslands. The Jerseys and Brown Swiss cattle were very similar in their reactions. One of the Jersey cows in this test could endure high temperatures very well, and it was found that this cow consumed large amounts of water. At a temperature of 10°C she drank 50 litres of water, whilst at a temperature of 35°C she drank 195 litres of water.

On lowering the temperatures in the psychrometric rooms from 18°C to 10°C, no change took place in the body temperatures of Friesland, Jersey or Zebu cows, but their respective food consumptions increased by 8, 26 and 36 per cent of that for each breed at 18°C. The milk production of the Jersey cows showed a slight decrease but the lowering of the temperature had no influence on the production of the Friesland cows.

From data obtained from the Gordon-Walker farms in America, it seems that cows produce most milk at temperatures between 4,4 °C and 18 °C.

When the temperatures in the psychrometric rooms were increased to 41 °C, all the cattle showed severe symptoms of distress, even the Zebu cattle could not stand such high temperatures.

At this stage is is necessary to stress the point that all bovines have a much greater cold tolerance than heat tolerance providing they have sufficient feed to eat.

Continuous cold will cause the animals to consume much more feed, and in cold climates cattle grow to a larger size as a result of the cold and because of the greater feed consumption.

In tropical and subtropical countries such as Jamaica, there are three times as many Jersey cows as all other dairy breeds put together, but notwithstanding the fact that the Jersey is a relatively heat tolerant dairy breed, they are not very suitable for milk production in the unfavourable sub-tropical climates.

Lecky in Jamaica tested various Jersey families for milk production and found very marked differences as indicated by the following results:

Milk yields of Jersey cattle in the West Indies

Family	No. of Animals	Average 305 day lactations yield		Maximum Milk kg
		Milk kg	Butterfat kg	
Honeybelle	29	2 421	120	3 315
Perfection	23	2 357	117	3 350
Norbrook	20	2 943	161	5 179
Dolly	11	2 326	122	3 409
Madge	18	2 083	109	3 549
Ada	16	2 163	102	3 153

From the above it is obvious that the performance of the Norbrook family under the tropical conditions of Jamaica is far superior to that of any other family.

From a strain such as the Norbrook family one could perhaps make selections to produce proven strains or lines which perform fairly satisfactorily under tropical conditions. It was impossible however to find a strain of Friesland cattle which possessed hardiness and milking ability under the ruling tropical conditions.

In Jamaica the breed Jamaica-Hope is being developed which is three-quarter Jersey and one-quarter Zebu. In Brazil at least 45 per cent of the dairy cattle are Jersey crossbreds.

A fairly detailed discussion has been given on the influence of temperature on the size, feed consumption and production of Jersey cattle.

The next environmental factor which will be discussed briefly is light. Very little is known of the effect of light intensity and changing daylight length on the adaptability of cattle. Extensive experiments are at the moment in progress here at the University of Pretoria, the object being to determine how differences in daylight length (i.e. approximately 6 hours; 18 hours; and normal Pretoria daylight length) influence the efficiency of feed utilisation, water consumption, length of gestation period as well as milk production and composition.

We know that changing daylight length has a marked influence on the shedding of hair of cattle. It also has an influence on sexual activity and fertility.

The following quotation from *Progress in the Physiology of Farm Animals*, Hammond, Volume I, page 372, proves beyond doubt that changes in daylight length have a marked influence on milk production:

> The reason for the definite progressive rise in the milk yield of dairy cattle during the two or three months prior to their being turned out to grass in the spring in England (Sanders 1927) has not yet been established. Newer knowledge of the sensitivity of farm livestock to light change allows formulation of the hypothesis (Hammond 1952) that milk secretion is regulated to some extent by light, through an effect on the lactogenic hormone of the anterior pituitary gland. This hypothesis receives support from Rako and Marinic (1952) who attributed to light the increased milk yield in a group of cows turned out of a barn for several hours each day in spring into an enclosure in which the light was 20 times as strong as that in the barn.

There is also some evidence from the growth data taken on many cattle at the Mara and Messina Research Stations that growth in stature of animals is proportionately greater in spring during lengthening daylight and that weight increase and the deposition of fat takes place during the period of shortening daylight in the autumn.

Similar data exists for human beings, I quote from Clarence Mill's book *Medical Climatology*: "In our Northern States there are two seasonal peaks in many physiologic functions — spring and fall. These become quite manifest in body growth, for in the late spring months growth in height is much more rapid than at other times of the year while in the fall growth in weight is at its maximum."

As far as the sexual activity of our cattle is concerned, there is sufficient evidence to prove that cattle are sexually more active during the equinoxial periods, namely during spring and autumn.

The influence of radiation on cattle has not been studied in great detail. That ultraviolet and infra-red radiation have a marked influence cannot be doubted. Ultraviolet radiation impinging on cattle lacking pigment in their hides often causes damage resulting in hyper keratinisation of the hide, which often becomes sensitive to touch. White or very light coloured animals are often very sensitive to ultraviolet radiation if they are washed regularly and the natural fats in the hide and hair are removed. If such animals eat plants which cause photosensitivity, the white areas slough and large open sores develop.

Jerseys have a very good colour which enables them to overcome the hazards of ultraviolet radiation. Also due to the high sebum content of the hide and hair this breed suffers no ill effects when subjected to intense ultraviolet radiation.

Intense infra-red radiation in the case of dark coloured animals causes the absorption of tremendous amounts of heat energy from the hide, which often makes the dissipation of excess heat from the body difficult.

In the case of Jersey cattle a very large proportion of the solar radiation impinging on the animal is reflected because the animals have smooth glossy coats.

Work done by the author in 1943 has shown that in the case of light fawn and fawn Jerseys 10 per cent or more of the total solar radiation impinging on these animals is reflected.

There can be no doubt about the fact that by virtue of its colour and coat the Jersey is very well adapted to overcome the hazards of intense solar radiation.

The influence of altitude on cattle has not been studied in detail. From a climatological point of view, high altitude must present certain problems to animals accustomed to low altitudes. The more obvious of these are those associated with overcoming increased ultraviolet radiation, lowered oxygen content of the air, and problems of topography.

The colour of the Jersey will assist it in overcoming the problems of radiation, but I doubt whether the Jersey has the ability to move well in mountainous country.

In the communication received from France special mention is made of the observation that the Jersey breed is not well adapted to mountainous country.

The influences of wind on livestock production is not known. Continuous moist wind has the effect of stimulating hair growth. In moist windy regions cattle are inclined to have long hair. The short hair and the lean body conformation of the average Jersey cow suggest that it would be advisable to protect it against cold winds.

It is not my intention to discuss disease as an environmental factor. However only a few remarks will be made concerning data obtained from numerous communications. It appears that the Jersey shows as a result of its hereditary make up a predisposition for certain ailments. One communication mentions that of 44 female descendants of a very high-producing Jersey cow 24 contracted milk fever during the first or second lactation.

Other communications mention that mummified foetus is encountered in some herds. I have a feeling that this condition is often caused by feeding minerals and trace minerals in the wrong proportions.

One communication mentions that Jerseys are particularly prone to "arthritic faults".

Whether Jerseys are more or less susceptible to the attacks of external and internal parasites than other breeds of cattle is not known. The Jersey breed of cattle when brought into the heartwater areas of South Africa is very susceptible to this disease.

At the Mara Research Station where cattle are regularly immunised against heartwater, it has been the experience of the men doing the immunisation that the Jerseys react sooner and more drastically than the other breeds and that immunity breaks down more easily too.

As I am no Veterinarian and as disease does not really enter into my livestock philosophy, I will no longer labour on the aspects of disease and parasites.

An aspect of the environment which I wish to discuss in some detail is the influence of soil pH and soil fertility on the size of cattle.

The effect of pH (acidity or alkalinity) and soil fertility on cattle must of necessity be an indirect one, viz. through the vegetation which is consumed by these animals.

In general the pH and soil fertility follow the rainfall pattern remarkably closely with few exceptions and the vegetation is the result of an interaction between these three factors as well as temperature which plays an important role.

Generally speaking the lower the pH the less available are the macro elements nitrogen, phosphorus, calcium and magnesium, while the micro elements become more available with the exception of molybdenum.

A most important phenomenon related to the effect of pH on the availability of minerals is the fixation of the phosphate ions. The greater portion of the arable soils in this country is acid with readily available iron and aluminium salts; on the application of phosphatic fertilisers to these soils, the Fe and Al salts precipitate the PO_4 ions in insoluble form.

This simple reaction must cause tremendous loss of PO_4 to the Union and subsequent loss in the production of plant material for consumption by man and his animals. This is also one of the reasons for the endemic deficiency of phosphorus in the Union. Nitrifiers, i.e., the nitrifying bacteria in the soil which transform NH_4 to nitrites and nitrates, become progressively less active as the pH drops. This results in less nitrogen being mobilised for plant growth and a lowered protein content of the vegetation it supports.

The most striking example of the effect of pH and soil fertility on the animal is the relation between these factors and the size of the animal.

The general assumption is that in areas of low pH the animals are smaller in stature and finer boned than in areas where the pH is high, more Ca and P is available and hence the vegetation also has a higher protein content.

In lime deficient regions we actually find small cattle such as the Kerry, the Black Welsh and the Jersey. In the Himalayan Mountains of India where the soil is very poor in available lime because of high rainfall, we find the very small Lohani and Ponwar Zebus, mature cows of these breeds weigh between 295 and 318 kg.

In an ecological study undertaken by the Animal Husbandry Department of the University of Pretoria, Afrikaner cattle were measured and weighed in many regions of this country. At the same time soil samples were taken and analysed for pH, available phosphorus and available calcium. The following results were obtained:

Table 6. Soil pH, soil fertility and size of Afrikaner cattle

Region or zone	Average mature weight of cows kg	Average height at whithers	Percentage available phosphorus	Percentage available calcium	pH
Zululand	593	132 cm	0,0026	0,144	6,28
Highveld of Transvaal	482	120 cm	0,0014	0,076	5,44
Bushveld of Transvaal	536	130 cm	0,0030	0,094	6,46
Orange Free State	522	128 cm	0,0027	0,097	6,53

These figures confirm the general assumption, namely that the soil pH and fertility pattern follows rainfall patterns and that cattle in areas of low soil pH and little available phosphorus and calcium, are smaller than those in regions where the rainfall is lower.

From the above table it is also clear that soil pH and available lime and phosphate in the soil have a very marked influence on the size and weight of cattle. I wish to stress again that low pH is closely associated with high rainfall which in turn often results in nutrient leaching and subsequent low soil fertility.

As a result of its influence on the total environmental complex rainfall has an indirect influence on the growth and reproduction of cattle. By controlling the soil pH and fertility rainfall exerts direct influence on vegetation. Under high rainfall conditions, especially when these are accompanied by high temperatures, the herbage grows swiftly and becomes unpalatable early in the season due to rapid lignification. Such pastures are low in protein, calcium and phosphorus which again has a depressing influence on the reproduction and milk production of dairy cattle.

The most accurate measurements of the adaptability of cattle are growth, reproduction and production. If an animal is not in complete harmony with its environment the three paramount functions of livestock production, namely growth, reproduction and production, are impaired.

Summary and conclusions

1 The nutritional level at which Jersey cattle are maintained has a marked influence on the size of the animals. To maintain a high nutritional level the feed must be balanced and the metabolism must not be suppressed by high temperatures.

2 Jersey cattle in cold temperate climates are larger than those in hot climates for two reasons namely,

(a) they follow Bergmann's and Allen's rules, and

(b) high atmospheric temperatures impair the metabolic function of cows and cause tropical malnutrition.

3 Light apparently has a stimulating influence on milk production, through its effect on the lactogenic hormone of the anterior pituitary gland. Light also has an influence on hair shedding.

4 The Jersey colour favours the reflection of the infra-red rays. This is an advantage in tropical adaptation. No data are available to indicate that ultraviolet radiation from the sun has a harmful effect on the Jersey.

5 From the meagre data available, the Jersey breed of cattle does not appear to favour mountainous country.

6 Due to the size of the Jersey and its smooth coatedness, it is considered that cold wind will have a disadvantageous influence on these animals.

7 The Jersey breed of cattle is very susceptible to tick-borne diseases.

8 Jersey cattle are not inherently very small, but on soils of low pH and low in soluble calcium and phosphate, the cattle of this breed are small and much better adapted than the larger breeds.

End of Paper as circulated to Delegates

Professor Bonsma then continued:

Since I have taken over the Department of Animal Husbandry at the University of Pretoria, I have tried to make this an Institute of Animal Ecology. We feel that all animal husbandry is based on inter-action between heredity and environment, and we furthermore realise that all adaptation is complex. Hence we have worked out a livestock philosophy in which we feel that the environmental factors form a complete complex and all adaptation to complex factors must of necessity be complex. And hence, if you want to make it simple, you will always fail. Statements like so many we see in breed journals as "a breed totally adaptable" is utter nonsense as far as I am concerned. There is no breed, not even a Jersey, that is universally adapted. They change in form and shape as environment changes. There is no doubt about it and we'll show you slides to prove that.

The first environmental factor which I want to discuss shortly is nutrition. That nutrition is probably one of the most important environmental factors, cannot be doubted for a moment. We have enough proof to show that whenever an animal is malnourished, whether it be malnourished due to insufficient feed or not well-nourished as a result of climatic factors not enabling the animal to assimilate its food or eat enough, it doesn't matter what type of malnourishment you get, it is reflected in the body conformation, in the size of the animal. I saw such beautiful examples of that when I was in New Zealand, where Dr. McMeaken at the Ruakura Research Station, New Zealand, had no fewer than 222 pairs of identical twins. He used these twins in nutritional experiments, one of a twin was well-fed and the other not well-fed and in the case of the cows the well-fed heifers weighed at 3 years of age approximately 30 per cent more than the poorly nourished ones. In the case of the bulls, the difference was probably slightly more. In any case, we'll show you slides of these animals. But an aspect of nutrition which so few people do realise, is although you have the feed available (and very often you have the feed available), your cattle cannot use that feed because they are not adapted to a particular climate. Especially if temperature rises to about say 27°, 29°, 32°C and higher, animals will not be able to eat as much as they would otherwise have done and the other point which we have got to stress is that those animals in hot environments may have trouble in dissipating the heat and hence their appetites are reduced.

Furthermore a factor which we've got to stress again is that climate *per se* has a direct influence on the body shape of your animals, on the conformation. It is a general rule in nature that animals in cold environments are much more square, have shorter legs and shorter extremities, e.g. take the Emperor Penguin, which is an Arctic bird, has no wings so to say, very short extremities, and very short feet or legs. All animals in colder climates have a body conformation which is aimed at heat conservation. All animals in tropical environments have a body conformation which is aimed at dissipating heat. If you take any animal and you place it in a particular environment, the amount of feed consumed by the animal is in relation to the temperature to a certain extent, not totally. But the laws of climate which I have just got to mention here, are the law of Bergmann and the law of Allen. Bergmann's law says that in all cold climates, animals tend to be square, to have a smaller surface area per unit weight. That is they are square, and they hence have a smaller surface area per unit weight.

Allen's law says that all animals in cold environments have short extremities, that is short legs, and shorter wings or arms or front legs or whatever the case may be.

Now climate also has a direct bearing on the food consumption of animals. In those psychrometric rooms which the late Samuel Brody had at Missouri University, he kept animals of various breeds. He kept Friesland, Jerseys, Zebus and Brown Swiss. When he changed the temperature of those psychrometric rooms from 18 °C to 10 °C, the amount of feed consumed by the Frieslands increased by 8 per cent. The amount of feed utilised by the Jersey increased by 26 per cent. The amount of feed utilised by the Zebu increased by 36 per cent.

I'll repeat that. If you take the amount of feed an animal consumed at a temperature of 18 °C and the amount a particular animal or a particular breed utilises at 18 °C — if that temperature is now slowly reduced to 10 °C, the amount of feed consumed by these different breeds, changed. In the case of Frieslands — it increased by 8 per cent. In the case of the Jersey it increased by 26 per cent. In the case of the Zebu it increased by 36 per cent.

There is no doubt about it that the animal which is heat tolerant, is the one that as soon as temperature is reduced, will proportionately increase its food consumption.

But we come to another point. People always say cattle are big because they consume much feed, but cattle are big because they can consume much feed in certain environments. That is why the size of animals in different environments changes appreciably.

Now, to prove this I wrote to several feed manufacturing companies in the United States of America and asked them — "where do your Jerseys consume more feed, in the North or the South?" and every company — and one of the companies was a real big company — informed that in the North the Jersey consumed appreciably more feed than in the South. But apart from that, it is not a general idea generally accepted by Jersey cattle breeders. They say the Jersey is the same size throughout the word — or they think so. But the amazing thing is that even the late Secretary of the Jersey Cattle Society of America, Floyd Johnson, wrote me a letter and he said — look, the size of the Jersey is not determined by environment, it is a question of nutrition, and you know the people in the north feed more, hence their cattle are bigger. I say they can feed more because it is a cold and invigorating climate and hence those cattle consume more feed and can dissipate excess heat more readily.

Now we come to the interesting thing that all animals that are really large of the various breeds, are in the far northern hemisphere, and all the world record breaking Jersey cattle, are in the northern hemisphere. The highest producing cow in the world ever — a Jersey cow — is Silken Lady's Ruby of Ferndale. This cow produced 103 836 kg of milk in a lifetime and 5 965 kg of butterfat and she reached the good old age of 21 years 4 months. It is interesting to note that in the 10 highest producers that I indicate in this paper, nine are in the northern hemisphere and one in the southern hemisphere, and those are cows which have produced well over 68 182 kg milk in a lifetime.

There is another factor which is very definite, and that is milk production is closely associated with the size of the animal. All the world's highest milk producers in every breed are larger than average for the breed, but here is one thing that's got me slightly stumped and that is the few very highest Jersey breeders in the world are in Great Britain and the average size for Jersey cows in Great Britain is approximately 386 kg.

Moor's Pacified Diana, one of the very high producers, which produced 9 882 kg of milk in one lactation and as much as 54,5 litres a day, weighed 409 kg which is 23 kg heavier than the average for the breed. The amazing cow, Stranges Musical, which in one lactation produced over 10 909 kg of milk and in the next lactation well over 11 364 kg of milk, and went up in butterfat production up to something like — I think it is 68 kg — I am not quite sure — is only 11 kg larger than the average for the breed. But then the American cow Opal Crystal Lady which is the highest producing Jersey cow in the world at the moment on twice a day milking, is 625 kg — that is almost 227 kg heavier than the average size of Jerseys, and you get the same phenomenon in all breeds.

The American Holstein Friesian cow, Carnation Ormsby Madcap Fayne, which produced 19 091 kg of milk in one lactation, weighed 909 kg when in full production, and the cow Carnation Ormsby Inka Mutual, which produced 6 823 kg of butterfat in a year, weighed 1 000 kg when in full production.

Another interesting thing is that these very high producing Jersey cows also consume a tremendous amount of feed. The cow Brampton Basilua Violet consumed as much as 13,6 kg of concentrates a day when she made a lactation of 7 330 kg of milk. Another interesting thing —of the 28 Jersey cows which produced over 5 455 kg of milk during a lactation, apart from those in America (unfortunately I got the American figures too late and there are very many Jerseys in America that produced over 5 455 kg of milk) but of the 28 Jerseys that produced over 5 454 kg of milk during the previous year, 24 are in cold temperate climate and 4 are in the milder climates.

I have given a list of the highest producing Jersey cows and of that it is again amazing that the United Kingdom cows, which are relatively small, produce very much more milk. A cow like Stranges Musical only weighs 398 kg as compared with Opal Crystal Lady which weighs 625 kg, apparently the climate or something in Britain enables those cows, notwithstanding the fact that they are relatively small, to produce tremendous amounts of milk. If you think of it there is one cow Baring's Flower, which produced 682 kg of butterfat and she is less than half the size of the cow Carnation Inka Mutual. Now I'll just read the sentence — From the data obtained on the average size of Jersey cattle throughout the world, it is again obvious that animals on an average are larger in the cold temperate zones than in the warmer climates.

I've got the average size of Jersey cattle throughout the world and we get the interesting phenomenon that in the northern states of America the average size of the Jersey cows is on an average 432–500 kg, with cows like Open Crystal Lady weighing 625 kg. In the southern United States the average size of the Jersey cow varies from 341 to 386 kg. A good 91 kg less than in the north.

In Canada we could not get accurate data but from the data I received, it appears that the average size of the Jersey cows in Canada is 425 kg but they mention that most of their bigger breeders have air-conditioned stables. Now unfortunately I've not been in Canada so I do not know whether that information is correct and perhaps somebody here could tell us.

In Victoria, Australia, which has a temperate climate, the average size of Jersey cows is 455 kg while in Queensland, where it is really hot, the average size of Jersey cows is 318 kg. In New Zealand, with its marine climate, and a mild climate, the average size of the Jersey cow varies from 318 kg to 409 kg. On Jersey Island it is 341 to 364 kg. In France, it is 375 to 400 kg. In Brazil we have not got the data on mature Jersey cows but they've given us the data on the two-year-olds and their two-year-olds on an average weigh only 236 kg. In Denmark the Jerseys are 377 to 420 kg. Unfortunately I have not got the figures for South Africa.

Of interest from a climatic point of view is that there is little doubt that the Jersey breed of cattle which is inherently small, and which probably had its early evolution in Asia, migrated through southern Europe to the coasts of Normandy and Brittany in France and from there to Jersey Island and therefore is well adapted to Mediterranean and temperate climates.

I have given the data for the three countries from which we get our most popular, or a few of our most popular dairy breeds, namely the Friesland, Jersey and Ayrshire and from that data it is very clear that the difference in the adaptability of those three breeds cannot be due to differences in the climate where they come from. There are slight differences, it is true, but the average sunshine hours per day per year on Jersey Island is 5,9 hours, in Friesland it is 4 hours and in Ayrshire it is only 3 hours, but the differences in temperature between those countries, maximum and minimum, vary by only two or three degrees. So the difference in the adaptability of the Jersey as compared with the Friesland is in all probability due to selection within those breeds by the human being himself. If we select for smaller size, we will get animals which are tropically better adapted than larger animals.

Apart from that I have worked out a table indicating the average number of registered Jerseys in each country and also the number of members and the average size of the Jerseys. In the United Kingdom, they have 5 000 members belonging to the Jersey Breeders' Society. Interesting to note there that out of the 5 000 breeders of Jersey cattle in the United Kingdom, only 200 are in Scotland. I questioned several Scottish breeders — why do you people not keep Jerseys, and in every instance the answer came back — Jersey calves are born relatively small and it is really difficult to keep a Jersey calf healthy in a cold climate. As a matter of fact I've got a letter from Canada making a very similar statement, saying that most of their Jersey calves die of pneumonia when they are very small.

On Jersey Island there are 10 427 registered Jersey cattle, 950 breeders and every breeder has got approximately 11 cattle in his herd.

France has only got 2 700 registered Jerseys and a membership of 225, and the French people made a very interesting statement on which I will touch later on, and it is that there Jersey cattle are not popular in mountainous country, they do not do well in mountainous country. And furthermore they make a statement that in our calcareous soils the Jerseys are much larger than the average for France, which is approximately 375 kg, but they indicate the type of soil has a marked influence on the size of the Jersey cattle.

In Victoria, Australia — unfortunately I haven't got the figures for Queensland and South Australia — there are 71 000 Jerseys, 60 000 in Denmark, 4 000 in Tasmania. In New Zealand there are 70 000 registered Jerseys, a membership of 3 500 and over 85 per cent of all the cattle in New Zealand are Jersey cattle.

In Brazil they have 8 130 registered Jerseys and the Brazilians make a special note of the fact that over 45 per cent of all the dairy cattle in Brazil are Jersey crossbreds. Apparently the higher temperatures in certain areas cannot be tolerated by the Jersey. Again, unfortunately, I haven't got the figures for South Africa — I've got the membership — it is 1 742 members and they have 30 702 registered Jersey cattle.

And in America, always bigger and better, they have 440 228 registered Jerseys, a membership of 20 000 and there are approximately 5 000 000 pure-bred Jersey cows in America.

Kenya has got 6 750 registered Jerseys, with a membership of 450.

Now, there is no doubt about it that Jerseys are appreciably better adapted to temperate and mediterranean climates than to severe cold. As indicated previously, the membership in Scotland is only 200.

I have made mention of the fact that in the psychrometric rooms of Sam Brody at Missouri University it has been proved beyond doubt that the Jersey cannot withstand cold as well as for instance the Friesland. But then we've got to make another statement immediately thereafter and that is that all animals are much better cold tolerant than heat tolerant, because you can make an animal overcome severe cold by giving it more feed, and giving it shelter.

On the other hand in a country like Trinidad they tried to keep Jerseys and they failed. Trinidad is trying to produce milk by using water buffaloes. In a country like Jamaica, they tested out very many different Jersey families, and they found appreciable differences within families in their ability to overcome heat. They tested for instance half a dozen families and none of the families could produce over 2 500 kg of milk. But one family, the Norbrook family, could produce on an average well over 2 727 kg — almost 2 955 kg — and the highest producers within that family could produce well over 5 000 kg of milk. So from a temperature point of view you Jersey breeders have got to accept it that your Jerseys can stand cold within limits but it cannot withstand cold as well as for instance a Friesland. It cannot withstand a tropical climate as well as most Jersey breeders try to make out. It is very clear that Trinidad and Jamaica have failed with pure-bred Jerseys. In Jamaica they have made a new breed, the Jamaica Hope, by using individuals of the Norbrook family to make cross-breds.

Now, in a country like America, where they practise crossbreeding of Jerseys with Zebus, to create a type of dairy animal which is suitable to their sub-tropical climate, I feel that that is unnecessary, because they really haven't got a subtropical or tropical environment, perhaps with the exception of Florida.

Then we come to another environmental factor which has a marked influence on cattle, and which is very often overlooked by people, and that is the influence of daylight length on animals. At the Pretoria University we are keeping 14 animals — heifers — in a stable which has increased daylight and the daylight will be approximately 22 hours a day towards the time these heifers calve down. The other stable has approximately 2 hours of daylight and another group of 14 heifers are in ordinary daylight. That daylight has a marked influence on the physiology of these animals cannot be doubted. As early as 1927, Sanders in Britain found that as soon as daylight lengthens dairy cows which are kept in stables and where the nutritional level has not been changed, suddenly show an increase in milk production. Two other workers found that if they take their cattle out of a dark or semi-darkish stable, into the open where the daylight is 20 times as strong as in the stable, the milk production is suddenly increased by 15 per cent. That light has a marked influence on function of animals cannot be doubted. In Scotland the difference between the longest and shortest days is approximately 10 hours, at Mara Research Station it is approximately 3 hours, on the equator the difference in daylight length between summer and winter is approximately 2 minutes. Now, at Mara we selected a group of Hereford cattle which reacted to this difference of 3 hours difference in daylight between the longest and shortest days, and they shed their hair. We took 4 of those full-coated Herefords, transferred them to Mapokwa in Tanganyika on the equator and none of those four Herefords ever shed their hair. So there is no doubt about it that daylight length has a marked influence on the physiology of these animals.

Furthermore, we found that cattle in this country have got increased sexual activity during March, April and May and again in August and September at increasing daylight and decreasing daylight at equinox. Another factor which we are not certain of but which looks as if it is so is that in the work we did at Mara and Messina, it appears that cattle grow in size, i.e. height at withers, height at hips, during the spring. They stop towards the end of summer and they put on fat and flesh during the autumn. As a matter of fact this is an aspect of research which I want to test out here at the University of Pretoria.

But I do not want to discuss solar radiation in detail. Many years ago I did quite a bit of work on the influence of solar radiation on cattle and the reflection of light from these different coloured animals, and we found that the Jersey has got a colour which enables it to reflect at least from 10 per cent to 15 per cent of the total solar radiation impinging on the animal, which is of course an advantage. I have never seen a

Jersey animal which shows symptoms of hyperkeratiosis of the hide. I've seen it in Herefords, I've seen it in Ayrshires, and I've seen it in a white mule I have at Mara Research Station. If this animal becomes photosensitive as a result of eating *Tribulus terestus* — it is a weed — the whole animal gets the appearance of a zebra, real thick rings on the animal. Unfortunately I haven't got a coloured slide of that animal yet. I've taken it but unfortunately it has not been developed.

As indicated previously, the colour of the Jersey favours reflection of solar radiation, that is especially the infra-red which is the hot area of the solar spectrum and that enables them to overcome heat fairly well.

The next point which I want to discuss very briefly is altitude. Now altitude has got a marked influence on animals as indicated for instance by the llama. The llama has got a blood count which is twice that of the human being and the affinity of the blood of the llama is twice that of human blood for oxygen. So it is at least four times as efficient in its absorption of oxygen than for instance the human being. Work done in the Andes Mountains has shown that people who try to live there fail, except one Indian tribe which developed chest capacities much larger than the ordinary human being. They can survive in that area.

However from an altitude point of view it appears that the Jersey is not very well adapted to high altitude. I got correspondence from people in France who say that Jerseys are not very popular in high altitudes. Perhaps our friends from Kenya might differ on this. High altitudes I would call altitudes over 2 440 to 3 050 metres.

I do not intend to discuss the constitutional weaknesses of the Jersey. From the information obtained from these various people, it appears that some Jersey families in any case are more susceptible to milk fever than other breeds. One correspondent indicated that they had 44 Jerseys which came from one or two very good families and out of the 44 Jerseys 24 suffered from milk fever. Another thing which came out of the correspondence was that several Jersey families suffered from mummified foetus. We have an idea that mummified foetus is not only a hereditary thing, or perhaps a hereditary defect in the breed, but it is in all probability also a result of wrong nutrition. There are indications that show that the wrong use of trace elements might cause it.

Another correspondent wrote about arthritic faults and that Jerseys suffer from that, but I think the Earl of Jersey will discuss those.

Now I come to an aspect of animal ecology or livestock ecology which intrigues me immensely and that is the influence of soil fertility and soil pH on cattle. Since I have taken over here at the University of Pretoria, we have made a study of the influence of soil fertility and soil pH on the size of cattle. The work on the Afrikaner breed of cattle is completed, and is being written up now. The aspect of soil fertility and pH on the Hereford is also being studied, but the interesting thing is that as soil pH goes down, the size of cattle decreases, and as soil pH goes up, the size of cattle increases. In the work carried out by one of our post graduate students Mr. Arthur de Villiers, we found that on our highveld where the average soil pH is 5,44 and the available calcium and phosphates are half of that in the Zululand Bushveld, the difference in size of the Afrikaner cattle is from 468 kg in the highveld to 590 kg in Zululand. The height at withers of the cattle in Zululand is 132 cm while on the highveld it is 120 — a difference of 12 cm.

Now, the influence of soil pH and soil fertility is of course caused by the effect that as soil pH goes down the available calcium and phosphorus get less, your trace elements get more assimilable but your nitrifying bacteria cannot function as well at a low pH and hence the amount of protein in your natural pastures is lower in those areas where your pH is low, and hence those animals not only get less protein in the natural pastures, but they get less calcium and less phosphorous too. Data obtained from various parts of the world indicate that the soil pH pattern follows the rainfall pattern — or the rainfall pattern is followed by the pH — and in areas where you have a high rainfall and very often high altitude, the soil pH is low and there you find very small cattle. The most beautiful example of that is in the Himalayan Mountains in India where the soil is very poor in available lime because of high rainfall. We find the very small Lohani and Ponwar Zebus. Mature cattle of those breeds only weigh 295 to 318 kg.

Next I give the table of the Afrikaner cattle which we measured in various parts of the country. I might mention here that in this work well over 24 150 km were covered, over 3 000 animals were measured and we only measured animals in herds which were established for 20 years or more. We also made a difference between those animals which were stable kept and those which had to do on the natural vegetation. The Table 6 just indicates the difference between the size of the animals, pH and available phosphorus and calcium on the size.

Rainfall and temperature have got a marked influence on the nutritional value of your pastures. With high rainfall and high temperature growth is very rapid on the pastures, lignification takes place rapidly and you get a feed that is high in crude fibre and low in protein. In the case of high temperatures and low rainfall as we find in so many of our subtropical semi-arid ranching areas, there you find that the growth is fairly slow but you find that the pastures are usually high in protein and the grass is a natural hay and hence cattle do well. On pastures like we find in Britain where your rainfall is fairly low but very efficient and your temperatures are low — there you find growth is slow and the pastures in those countries are high in protein and low in fibre and hence of much higher nutritional value than the pastures in our semi-arid subtropical climates.

To summarise

1. The nutritional level at which Jersey cattle are maintained has a marked influence on the size of the animals. To maintain a high nutritional level the feed must be balanced and the metabolism must not be suppressed by high temperatures.

2. Jersey cattle in cold temperate climates are larger than those in hot climates for two reasons, namely

(a) they follow Bergmann's and Allen's rules, and

(b) high atmospheric temperatures impair the metabolic function of cows and cause tropical malnutrition.

3. Light apparently has a stimulating influence on milk production, through its effect on the lactogenic hormone of the anterior pituitary gland. Light also has an influence on hair shedding.

4. The Jersey colour favours the reflection of the infra-red rays. This is an advantage in tropical adaptation. No data are available to indicate that ultraviolet radiation from the sun has a harmful effect on the Jersey.

5. From the meagre data available, the Jersey breed of cattle does not appear to favour mountainous country.

6. Due to the size of the Jersey and its smooth coat, it is considered that cold wind will have a disadvantageous influence on these animals.

7. The Jersey breed of cattle is very susceptible to tick-borne diseases.

8. Jersey cattle are not inherently very small, but on soils of low pH and low in soluble calcium and phosphate, the cattle of this breed are small and much better adapted than the larger breeds.

J. C. Bonsma

Hormones in the Bovine and the Role of Endocrinology in judging Cattle for functional Efficiency

"The upper and more forward parts of all animals are larger and stronger and more firmly built in the male; the hinder and lower parts in the female. The female is less sinewy, the joints are weaker, the hair is finer, in those with hair; in those without hair its analogues are of the same nature; the female has softer flesh and weaker knees than the male, the legs are slighter; the feet of females are more graceful, in all that have these members."

Aristotle, *History of Animals* Fourth century BC

At the moment of conception the complete genetic potential of the animal is fixed. What an animal is ultimately going to be depends on the following pathways (Figure 1). First, that from the complete genetic potential to the morphology or phenotype of the animal. Breed characteristics such as skeletal size, muscling, fat deposits and hair colour are all genetically predetermined. These characteristics may later be modified by the interaction between heredity and the total environment, which includes that in which the fetus develops. Certain factors act on potential genetic make-up to determine ultimately what an animal will be like. Pathway 1 therefore determines to a large extent the animal's body conformation but, in addition, the genes will help determine how endocrine glands are going to function thereby modifying body conformation.

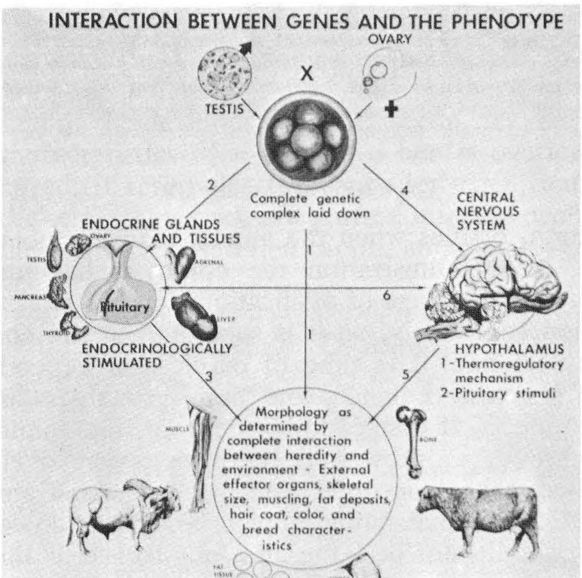


Fig. 1

Interaction between genes and the phenotype.

The genetic potential of the pituitary, the thyroid, the adrenals, the ovaries or the testes is determined at conception. How such endocrine glands will later function is determined by the gene complex along pathway 2. The hormones they produce will, in turn, act on the morphology of the animal through pathway 3. That is, if some of the endocrine glands are in a state of imbalance and function improperly, the resultant hormonal disturbance will be reflected in the whole morphology of the animal and its body conformation will be modified. Total development from conception to maturity is determined through pathways 1, 2 and 3 and also from genes through pathway 4 to the central nervous system, especially the hypothalamus. The influence that the hypothalamus has on the animal is illustrated by pathway 5.

The hypothalamus, itself an endocrine gland, secretes hormones via the posterior pituitary and also Releasing Factors which flow through the portal system to control the secretion of hormones from the anterior pituitary. The latter may also influence the central nervous system modifying behavioral patterns. Pathway 5 extends from the central nervous system directly to the effector organs. This has a marked influence on the animal through the thermoregulatory mechanism and the pituitary stimulus. The expression of animal's genotype in its phenotype (its total morphology being the product of the interaction of the external environment such as nutrition and temperature with the internal environment determined by its genetic make-up) is the result of the action of the hormones on the gene complex laid down at fertilisation.

In addition, the interaction between endocrine glands must also be considered. The anterior pituitary secretes gonadatropins, which stimulate the sex glands, that is the testes or ovaries. A gonadatropin, luteinising hormone, causes the interstitial cells of the testes to produce testosterone, the male sex hormone. Testosterone in turn has a marked influence on secondary sex characteristics as well as the body conformation of the animal concerned. The same holds true for oestrogens in the female. Another pathway of a pituitary trophic hormone is through the corticotropin; its effect on the adrenal cortex is reflected by hair growth and carbohydrate metabolism. The thyroid gland also has a marked influence on metabolism. Should any one of these hormonal functions be in imbalance this will be reflected in the external morphology (body conformation) of the animal.

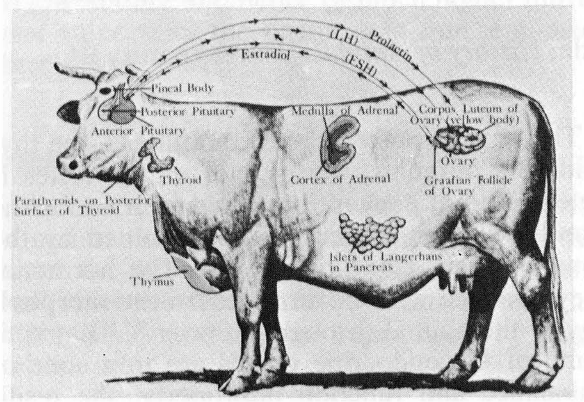


Fig. 2

Figure 2 is a diagrammatic drawing of a cow showing the position of the various endocrine glands and how these glands interact with one another. The interrelationship of these glands is reflected visually in the external morphology of the animal much as is the case in a jigsaw puzzle.

Figure 3 shows the relationship between gonadotropins and their target organs. Testosterone, for example, has a direct influence on the masculinity of the head. The human male develops a beard, and sometimes a receding hairline

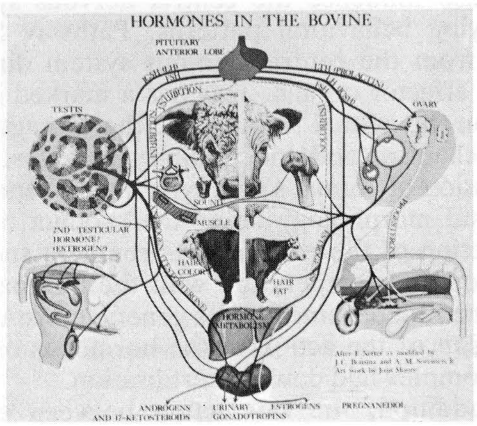


Fig. 3

Hormones in the bovine.

and baldness; in the bull, hair on the head and neck is coarser with a special pattern of hair on the neck, upper shank region, lower midrib region and on the lower thigh. Testosterone also has a direct influence on the sound the animal makes. When an animal bellows, an experienced cattleman can identify the animal as a bull, a steer or cow.

Gonadal sex hormones are steroids. They have a pronounced influence on muscle growth and this is illustrated clearly by the data that have been obtained on feeding steer calves, bull calves and heifer calves. The male calf's rib eye muscle is appreciably larger than either that of the female or the steer due to the effect of androgens. Since the male hormones cause an outward visual expression of masculinity, any imbalance or impairment of secretion of the hormones will cause the bull to lack this appearance of masculinity. In addition, these latter hormones also determine the animal's sex drive.

The ossification of the epiphyses depends on the secretion of testosterone in the bull and oestrogen in the cow. Figure 4 is a composite drawing of a left femur of a heifer that has reached puberty. The epiphysis, that is the epiphyseal cartilage line at which end the bone grows in

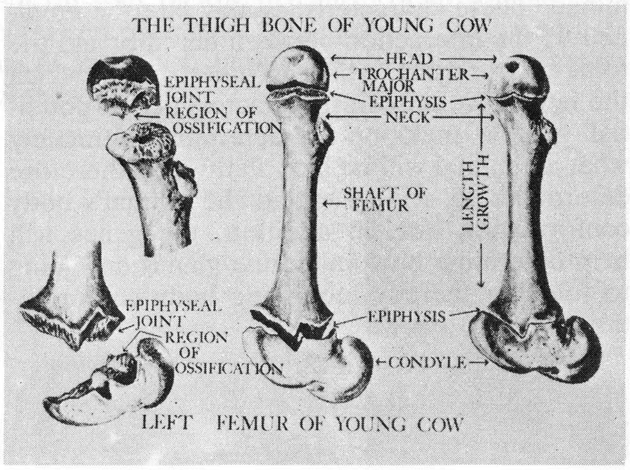


Fig. 4.

Thigh bone of a young cow.

length, ossifies when the animal reaches puberty. In this illustration the epiphysis has just reached the stage of ossification, but has not ossified completely, so it is separated at the epiphyseal line. The time of ossification depends on hormone balance, and bone growth is discontinued. If ossification is delayed, the animal continues to grow and becomes progressively taller, hence the objection to the very tall animal. An animal should appear large lying down, but should not be large and long-legged as this is indicative of an animal with an imbalanced hormonal control.

The basis of judging livestock for functional efficiency was illustrated by the work of a German scientist, Berthold in 1849 (Fig. 5). If a cock is castrated, its whole endocrine system is

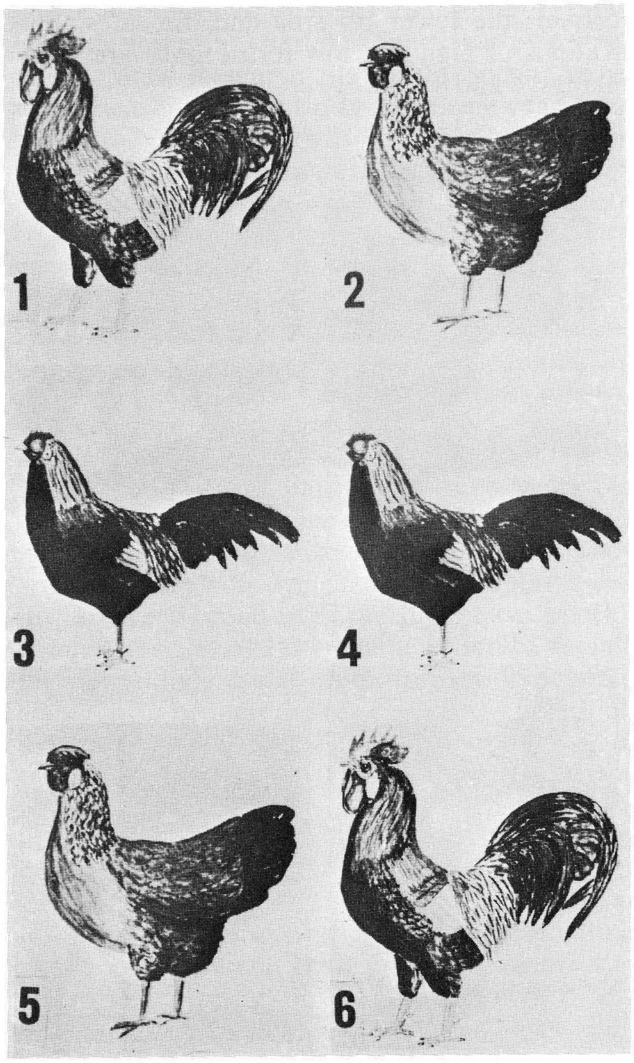


Fig. 5

disrupted and it becomes a capon, but if the ovary of a hen is grafted into the neck of the capon, it develops all the secondary sexual characteristics of a hen. If a hen is ovariectomised, it resembles the caponised cock, and if the testes of a cock are grafted into the neck of the ovariectomised hen capon, an animal is produced with the secondary sexual characteristics of a cock. In other words, secondary sexual characteristics can be experimentally reversed.

The basis of livestock judging by functional efficiency is that if a bull is castrated, it is an ox. If the ox is treated with female sex hormones, the ox will resemble a cow; this was done experimentally for the McGregor Field Day held 4 March 1965 at the Livestock and Forage Research Centre in McGregor, Texas. These same experimental changes may take place in animals under natural conditions. At the same institution, a Hereford bull was treated with a female sex hormone, stilbestrol, by implanation in the neck. The bull started sleeking off after 3 weeks; the hair colour became lighter and his head became completely feminine. He showed the typical syndrome of gynecomastia, the development of female teats in a male, and his hair was completely different from that of the control bulls.

Why have we not judged cattle on a functional efficiency basis sooner? One reason is that textbooks on endocrinology mention that a steer resembles a cow. That is not true — a steer resembles a steer. It is my opinion that the whole livestock judging system has been ruined by the ridiculous attitude of showmen who laid down the ideal breed standards based on the body conformation of a 2-year-old ox for both the male and the female. If show animals are studied carefully for functional anatomy, it is apparent that in show bulls male sex characteristics are less pronounced. The Aberdeen Angus bull sold in Britian in 1963 for £60 000, the highest price ever paid for a bull at that time, was sterile and it was apparent that he was not masculine; his muscling was not clearly defined, and he had fine feminine hair over his body. The three illustrations of a 12-year-old bull, a steer castrated at 2 years and a steer castrated at 6 months, diagrammatically illustrate how male hormones can change body conformation (Fig. 6).

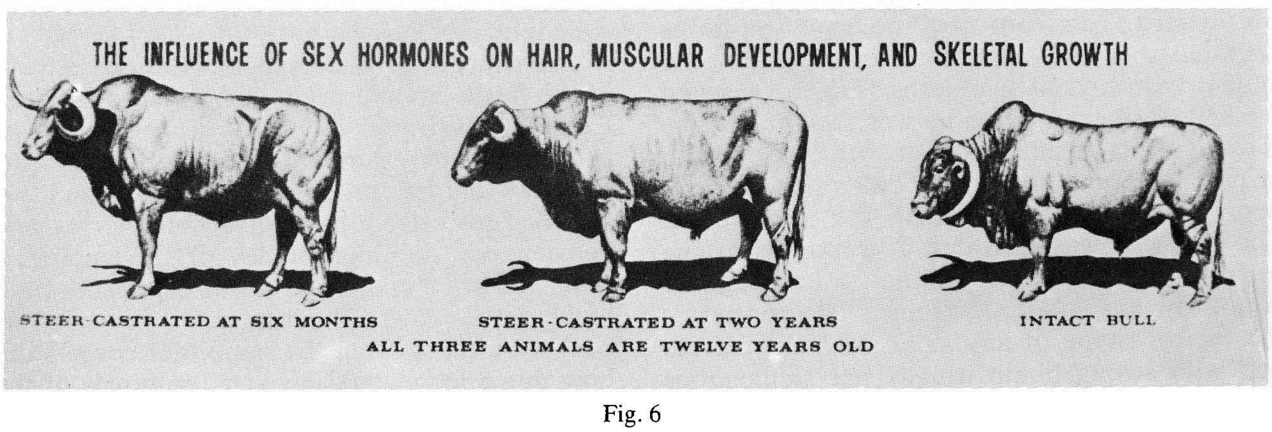


Fig. 6
The influence of sex hormones on hair, muscular development and skeletal growth.

A bull is a bull because his testes are intact and functioning. He has masculine hair on the sheath at the opening of the penis; he has a masculine crest and shows darkening of the hair in the region of the neck and crest, upper shank, lower ribs and on the thighs. He has clear, well-defined muscles on the neck, crest, upper shank, front ribs and on the stifle joint. The bull's colour is not uniform and any breed society that stipulates in its breed standards that bulls should be uniform in colour is in conflict with the natural trend. The testicular interstitial cells secrete the male sex hormone, testosterone, which influences the libido of the animal and has an indirect influence on the darkening of the colour of the hair on the animal. A bull should not be uniformly coloured because he has to have masculine hair in all the regions mentioned. Figure 5 is an illustration of the bull's half brother, also 12 years old, castrated at 2 years of age. Since castration, his colour turned uniform and is a lighter red than that of the bull. He has a rising chine because the ossification of the dorsal processes, that is the front vertebra, has not been completed. In every animal in which ossification is delayed, breast bone or sternum growth, and the growth of the dorsal processes, continue. The dorsal processes will continue to elongate in the region between the cartilage layer and the ossified bone until the animal secretes sufficient hormones to cause cessation of bone growth. The third animal, another half brother of the two previous animals, was castrated at 6 months of age. His long bones are much longer and thinner than those of the bull and the steer castrated at 2 years. Sir John Hammond determined that the rump region and loin is the last part of the body to reach maturity. Actually it is the last part of the body that reaches maturity in the fertile animal. In the animal that is a castrate, or in the infertile female, the front ribs, thorax, chine, brisket and head are the last parts of the body to reach maturity; in other words, the anterior half of the body from the sixth or seventh rib forward. The front ribs, the head and horns continue to grow, apparently until death. The animal castrated at 6 months (Fig. 6) reached the age of 19 years when he was slaughtered; he showed a certain amount of growth in the length of ribs, head and horns. The bull's size was limited by the ossification of all the long bones. The bull that was castrated at 6 months of age became exceedingly tall and flat, overdeveloped anteriorly and underdeveloped posteriorly — the typical shape of any steer. A highly fertile bull with strong libido usually has tremendous darkening of the hair in the regions of the neck, the upper forearm or upper front leg, along the brisket, the lower rib area and the sides. Illustrations of high and low fertile bulls are shown in Figs. 7 and 8.

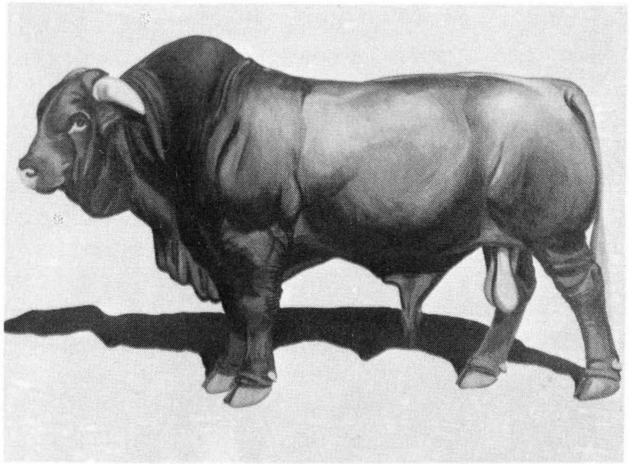


Fig. 7
High fertile bull.

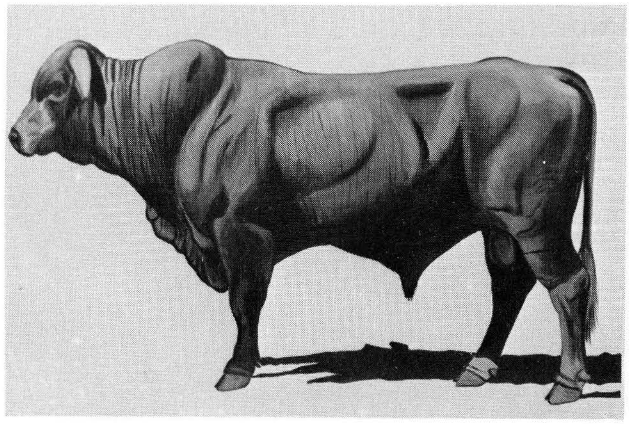


Fig. 8
Low fertile bull.

The stag, or late castrated bull, has a much more muscular upper shank than a steer. The steer's mandible continues to grow since the body of the mandible is made up of epiphyseal cartilage which, in the bovine never completely ossifies. The rump region is relatively small being short from the hip to the pinbones and relatively shallow from the hip to the patella or stifle joint.

The concept of what happens to bone growth in the fertile animal when compared to the subfertile is illustrated in Fig. 9. The scapulae or shoulder blades were taken from two 12-year-old cows that had produced eight calves and two that had no calves. Note how much larger and heavier the shoulder blades of the subfertile cows are when compared to the scapulae of the highly fertile cows. The cannon bones (metacarpus) were taken from the same four cows. Note how much longer and heavier the bones of the subfertile cows are than those of the highly fertile cows.

The horn growth of steers and subfertile cows also continues indefinitely. The horns of a steer at the Mara Research Station in South Africa were measured from tip to tip every year from his fifth year until death at 9 years. Overall horn length increased annually by approximately 8 cm to reach 277 cm at death. Horn growth of cows that calve regularly as well as the horn growth of bulls will be appreciably slower than that of steers.

Every bull castrated at the age of 6 months or earlier will show a well-developed mandible or jaw. The body of the mandible contains epiphyseal cartilage which does not ossify at a young age if the animal is a castrate. If you look at steers, you will not find one 3 or 4 years old which does not have a massive lower jaw.

Eunuchoidal bulls also resemble steers. They are often very tall, with small or hypoplastic testes, are very broad over the hips, have poorly-defined muscles and are characterised by female fat deposition. Bulls with primary hypogonadism (small or infantile testes) possess potentiality for growth in height over a longer period of time than sexually active normal bulls since the deficiency of androgens causes a delayed ossification of the epiphyseal cartilages of the long bones, especially the front limbs and long ribs. Production of hormones by the growth-promoting glands, such as the pituitary and thyroid, which is determined by hereditary factors, continues which results in excessive growth of the extremities. Anterior body proportions when compared to the posterior development can be an indication of hormonal balance.

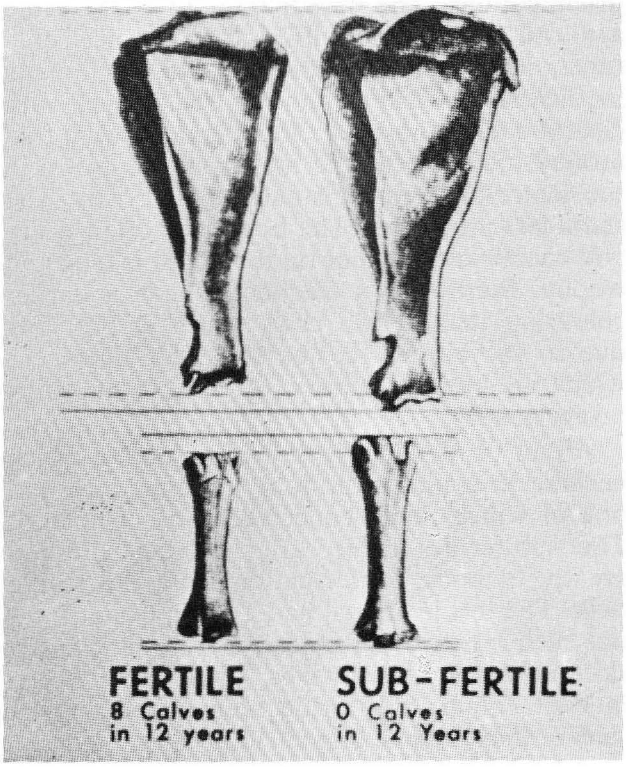


Fig. 9

The scapula and metacarpus of the fertile and sub-fertile cow.

Heifers sired by bulls with hypoplastic testes are frequently tall, bellow like steers and exhibit the same type of body proportions as their sires. The ossification of the long bones in such heifers is delayed as a result of lowered gonadal activity. They often are subfertile animals, cycling irregularly and showing infantile udder development. The udder of a heifer cycling regularly is more prominent.

It is known that the time of ossification of the epiphyseal cartilages depends on the maturation of the gonads, and it has become customary to relate certain skeletal or body proportions to particular endocrine patterns. It is known that, in human beings, certain kinds of growth disorders such as gigantism, partial gigantism, dwarfism, etc. are found in members of the same families. I have seen familial gigantism in cattle and we are still very aware of what happened when dwarfism occurred in cattle in the United States of America.

The body of the highly fertile cow is in perfect proportion; she looks feminine. Her brisket is not full and she has a dewlap running around the brisket. She has a tremendous stomach capacity, is big from the hip to the pin and from the hipbone to the patella or stifle joint. The largest part of this cow's body is the midrib region. If you stand behind such a cow, her midrib region or spring of ribs is the widest part of the body and not the thurls or hipbones (Figs. 10, 11, 12 & 13). Furthermore, she has a good girth of chest with the floor of the chest relatively near the ground. On the rump, the area from the hip bones to the pin bones is large, and from the pin bones to the stifle joints is deep. The depth of chest in a sub-fertile cow that has had three or four calves is appreciably greater than that of the cow that has had nine or 10 calves in

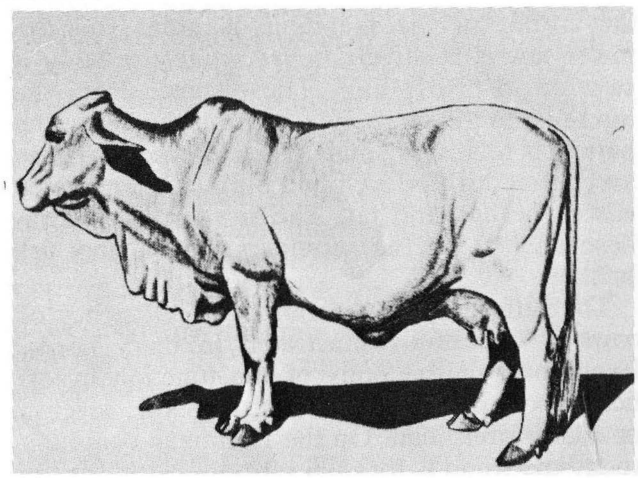


Fig. 10

Highly fertile Brahman cow.

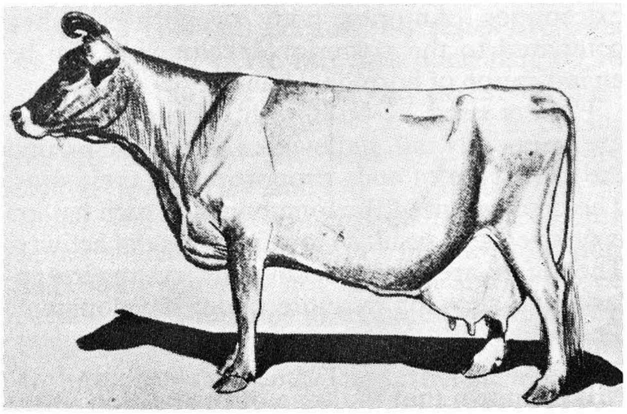


Fig. 11
Highly fertile Jersey cow.

the same time. The sub-fertile cow is relatively short from the hip to the pin and from the hip to the stifle joint where the udder is functionally less efficient. The hair of a sub-fertile cow is strikingly coarser, much coarser than that of a fertile cow, especially from the middle of the back region to the crown of the head. Extremely coarse hair from the middle of the back to the top of the head, especially if that hair is darker and more bristly, often indicates a sub-fertile animal. The shape and skeletal proportions of the front limbs are clearly illustrated by Figs. 12, 13 and 14. The dorsal edge of the scapula is appreciably lower than the dorsal processes of the front vertebrae in the sub-fertile animal with the scapula slanting backwards. The sternum is pushed down and slopes downward. The hair on the neck is masculine, coarse and heavy as compared with that of a fertile cow.

The body conformation of a sterile cow differs from that of a highly fertile and sub-fertile cows. Such cows show great depth through the chest, the brisket is very full and the immediate effect is that it slopes forwards and downwards. The sterile cow also tends to show greater fleshing on the cheeks. The distance from the eye to the corner of the mandible is great and the lower jaw is relatively heavy while the body is covered in bristly hair. The distance from the hip bone to the pin bone and from the hip to the patella is relatively small. The sterile cow has an accentuated well developed buffalo hump which is well fleshed and fat. The sub-fertile cow has flesh and fat on the shoulders, and a very full brisket.

The difference in the functional efficiency of cows is beautifully illustrated in dairy herds. Every part of the body of the functionally efficient cow in front of about the sixth, seventh or eighth rib is lean. On the European continent today the trend is for dual purpose cattle for the production of meat and milk. I believe it is not necessary to acquire dual purpose cattle — just select beef cattle that do not have too much fat on the shoulder, balanced bone growth between the shoulder blades as well as female secondary sex characteristics and hair. Then we will have functionally efficient beef cattle.

The influence of sex hormones on hair growth and hair shedding of cows and heifers is most important. The cow sleeks off immediately when she becomes pregnant and remains sleek throughout lactation. The open cow and sub-fertile cow that is not pregnant does not sleek off; her hair grows and sleeks off only when she is pregnant or is functioning efficiently. We can change the hair coat of an animal artificially by the injection of sex hormones. Heifers treated with sex hormones such as stilboestrol shed their coats within 3 weeks. The moment an animal becomes pregnant, a narrow line on the spine becomes sleek and darker. The thin line along the spine is very glossy, and looks as if the cow has been rubbed with an oil rag. This sleeking off also takes place in the steer or open heifer when they are in good health, have good nutritional status and the climate becomes warmer, but the process is not nearly as well defined as in the pregnant cow or heifer. There is no pattern in the hair of the low fertile or sterile animal and there is often no real sleeking off and no darkening of the hair on the spine on top of the back.

The cow in Fig. 11 is an 8½-year-old Jersey cow that has had seven calves with only seven inseminations. The cow in Fig. 13 is the same age and has had no calves and is typical of a functionally inefficient animal. The functionally inefficient cow has a round muscular neck with clearly defined muscles. There is no dewlap fold around the brisket. The hair from the crown in the centre of the back is darker and bristly. The shoulders are fleshy. The body hair often is dry and coarse and the hair on the udder is long and woolly. Sterile cows frequently have a darker colouring than fertile cows which is probably due to the adrenal cortex secreting androgens which are responsible for the darkening effect on the hair.

A pair of identical twin heifers, one of which became pregnant after four inseminations and one of which never conceived, was compared. The sub-fertile heifer, after calving, differed greatly in body conformation from the sterile twin. The fertile animal had a much leaner face, not such a heavy lower jaw, a lean neck and a skinfold around the brisket. They also differed in coat colour; the fertile animal being much sleeker than the one that failed to calve.

Sex hormones also have a marked influence on the quality and texture of the hair and hair shedding. At the University of Pretoria it was

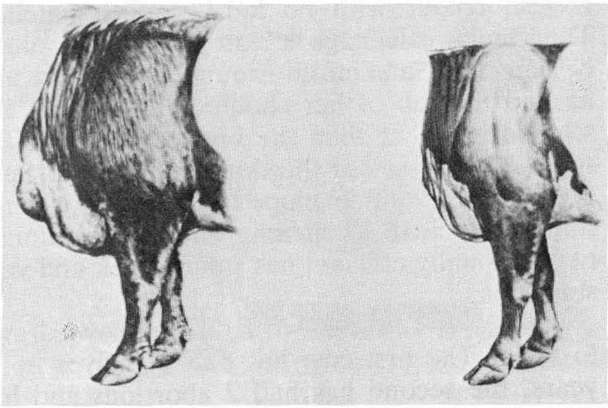


Fig. 12

Left: Front limb of a sterile cow. *Right:* Front limb of a highly fertile cow.

found that Friesland bulls and steers (bulls castrated at 8 months) differed in the quality and texture of the hair and in muscle development. The bulls have sleek, waxy hair, and the steers have dry and longer hair. In the upper shank region the muscles are well developed in the bulls; they have a masculine crest development and clearly defined muscles; the smooth animal is often eunuchoidal. The steer has very little masculine hair around the opening of the penile sheath, his neck is thinner and there is no round and muscular crest development. If a 14-month-old bull is compared with a 14-month-old steer, it is apparent that they differ in size and body conformation, muscularity, hair quality and texture. The hair of the young bull is lively and sleek and that of the steer is dull and not nearly as fly and tick repellent as that of the bull. The relative positions of the shoulder blades differ in these animals. The scapula of the steer slants backwards while that of the bull is directed forwards. The legs of the steer are appreciably thinner than those of the bull. At 14 months, bulls weigh, on an average, 40 kg more than steers.

The colour and texture of the horns of fertile and sub-fertile or sterile animals also differ. The horns of the fertile animal are uniformly coloured and often look waxy. The horns of the sub-fertile or sterile animal are hard and flinty and often have ossified white rings or patches which are very smooth, porcelain-like and very hard.

The cow that has aborted often develops extremely smooth, hard white spots or rings on the horns. The brisket is often well developed with lumpy patches of fat. A buffalo hump is apparent and the hair becomes darker and bristly. The hair on the head, neck, shoulders and lower thigh regions is coarse, dull and dry.

Any animal that has become sub-fertile, sterile or calves irregularly, having intercalving dates of 18 months and more, develops certain characteristics which indicate that the cow's hormones are imbalanced and her normal metabolism has been upset. The cow develops certain characteristic fat deposits on the body. The first is on the lower cheek and the second develops on the brisket. The latter becomes full and the whole dewlap disappears and there is no skinfold around the brisket. The cow develops a buffalo hump on the chine and an oval shaped lump of fat on top of the shoulder blades. Usually a tremendous amount of flesh and fat is deposited between the scapulae or shoulder blades. In addition, an oval fat deposit develops on the lower ribs. A very heavy, solid fat deposit develops on the hip bone. It is a sort of immobile fat which becomes almost as hard as cartilage when the animal is thin and is never utilised as a source of energy when the cow loses condition. If this stage is reached, it is almost certain that it will be improbable, if not impossible, to get such a cow in calf. A lump of fat on the pin bones, an oval lump of fat on the escutcheon about 3 cm below the vulva and usually a lump of fat in the region in front of the udder are typical characteristics of the sub-fertile or sterile cow.

The cow that has been fertile and then ceased calving also shows characteristic changes in her morphology. The brisket drops forward and downward and it loses the skin of the dewlap around it. Such a cow develops a peculiar conformation of the hind quarters being completely round in every direction, from directly behind and from the lateral view. The animal's vulva often becomes infantile and as a result of discontinuing reproductive function, hypoplasia of the genitalia takes place. Her hind quarters resemble a big ball cut in half and put at her rear end. If an animal becomes so rounded in the hind quarters that they resemble a horse's buttocks it is doubtful that she will settle readily. Many typical show heifers have over-developed hind quarters which look as if they are protruding posteriorly. They also have much fat development in front of the udder, too full a brisket and a darkening of the hair, especially in the region of the neck, upper shank, and lower thighs. A cow or heifer that settles with one insemination has a square hind quarter and a tail which hangs down perpendicularly. Her brisket does not protrude forward and downward.

If we examine illustrations of the show-winning cows of 1865 we can show that the livestock industry has had this problem of overfat, sub-fertile cows for 100 years or more. An illustration of a show champion cow in South Holland indicates a sub-fertile cow. She has tremendous development in the front region, is small in the rear, has a heavy crest, a rounded

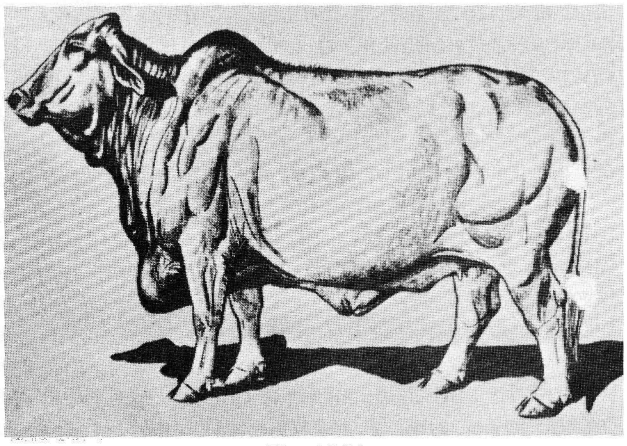


Fig. 12(b)

Sub-fertile Brahman cow.

neck and a full face. This is a problem with which we have been confronted for generations as a result of show standards. Those animals that are regular show winners are frequently those that have impaired fertility. An illustration of a show-winning Shorthorn cow is typically that of a sub-fertile cow with a full brisket, no dewlap or anything around it, a round neck, deep through the region of the chest where it should not be deep, and shallow through the region of the flank where it should be deep. The udder is infantile for that of a large cow. The teats of the sub-fertile cow frequently show that the udder has developed to a certain extent and then receded, indicative that the cow has aborted. In addition, the cow that loses a calf before suckling it for a few months, or the cow that aborts, develops a white porcelain-like mark on the horns. If too much stress is placed on growth in an animal, an imbalance between the somatrotropins (the growth hormones) and the gonadotropins, (the sex hormones) results and fertility is lowered.

The vulva of a cow that has been treated with male sex hormones develops a very large clitoris. If a heifer's vulva points downward and protrudes posteriorly and is very large, it is indicative of an imbalance of the female sex hormones and results in a very large clitoris. Such females often cycle irregularly. However, it is possible to select heifers for functional efficiency before they are put to the bull for the first time. The fertile heifer looks feminine, has a normally developed vulva, the udder is well developed and indicates she is cycling regularly. The sub-fertile heifer usually is larger, looks masculine, has a masculine or steer-like head and an infantile vulva and udder. She has bristly hair on the back, is deep through the chest and has a downward, forward protruding brisket. She does not cycle normally. In an old cow that calves regularly, the horns usually are an even, greyish colour with no hard smooth patches. The regular calver has a lean face and absolutely lean neck, a skinfold around the brisket and around the top of her shoulder blade, and the scapula is higher than the highest points of the spinous processes of the dorsal vertebrae. Such a cow has a well-developed udder that is functionally efficient. The animal that is exceptionally functionally efficient has small, sleek and very shiny teats.

Figs. 10 & 12 show two Brahman cows drawn to scale. The first cow has had 11 calves in 13 years, the second has had 2 abortions and has not raised a calf. The cow that aborted has lumps of fat on the brisket and has an udder that indicates it has not functioned properly. Furthermore, she has developed fat on the shoulder, ribs, and hip bones, the typical conformation of a sub-fertile animal.

A masculine bull should have well-defined muscles on the upper front limb and on the patella or stifle joint. The testes also should be well developed. An excessively loose and extensive sheath development is most undesirable. Viewed from behind, the fertile bull has well sprung ribs, and the lower rib region is the widest part of the body.

In most lectures on the reproductive physiology of bulls, it unfortunately is customary to start with the internal anatomy of the genitalia by showing cross sections of the various organs. But it is much more interesting and much more revealing to judge the external anatomy first and interpret the visual appraisal in terms of sex physiology. The external male sex organs such as the testicles, scrotum, sheath and penis are most important and of great value in evaluating the animal's sexual potential.

The scrotum is a most delicately arranged thermoregulatory mechanism; it has the func-

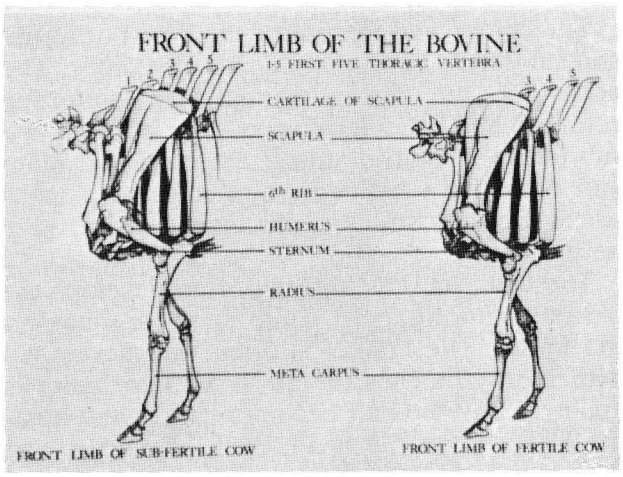


Fig. 13

Left: Skeleton of sterile cow's front limb. *Right:* Skeleton of highly fertile cow's front limb.

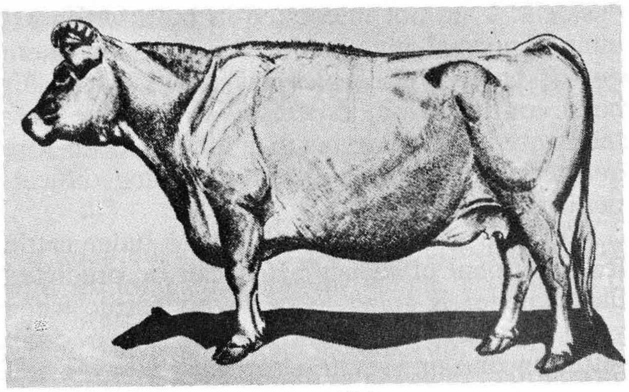


Fig. 13(b)
Sub-fertile Jersey cow.

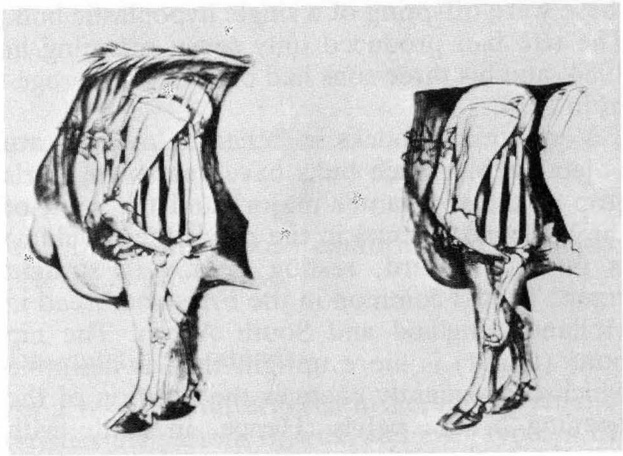


Fig. 14
Left: Sterile cow's front limb. *Right:* Fertile cow's front limb.

tion of keeping the testes cool when hot, and if it is cold, to keep them warm. The skin of the scrotum can pucker up when it gets cold, making the scrotum an appreciably better heat-retaining organ by reducing the surface area and entrapping air in the skinfolds. It also functions to draw the testes against the abdominal cavity of the bull.

Dr Harrison of Liverpool University and I carried out research on the thermoregulatory mechanism of the scrotum and vascular system of the reproductive organs of bulls. The spermatic arteries and veins have a thermoregulatory function. By putting Chlor-bismuth, a radio opaque substance, in the spermatic vein and taking X-rays of the testes, it was apparent that the vascularity of the testes of bulls adapted to temporate zones, differed from those of bulls adapted to tropical and subtropical regions. Bulls with better thermoregulatory mechanisms have more tortuous spermatic vein development thus enabling the maintainance of a lower testis temperature through a physiological phenomenon known as counter current heat exchange. Heat from warm arterial blood is passed to cooler ascending venous blood in the pampiniform plexus situated immediately above the testis. If the testes are grossly large and pendulous they become susceptible to injury and a varicocoel develops that blocks the vein and counter-current heat exchange is impaired. Testicular temperature consequently rises and the animal becomes sterile.

Female-like mammary development (next to the scrotum attachment) in which rudimentary teats develop on bulls is the result of female sex hormones indicating hormonal imbalances; such bulls lack sex drive. A bull with such tremendous sheath development in which the opening in the sheath is large similarly lacks sex drive, and the quality of the semen usually is poor. Gross sheath development is detrimental, as is a large opening in the sheath, which together with prolapse of the prepuce, are hereditary defects.

Hypoplastic testicles are also undoubtedly hereditary. In the Polled Swedish mountain breed, two winning show bulls, with one hypoplastic testicle and one normal testicle, almost ruined the whole breed of cattle by producing sub-fertile female progeny. In an endeavour to overcome this problem, 8 000 heifers were slaughtered and no fewer than 1 070 were found to be sub-fertile and had abnormalities of the genitalia; either one or both ovaries were abnormal.

Fig. 15 illustrates the difference between the development of the hind quarters of a hypoplastic eunuchoidal (steer-like) bull and a normal bull. The normal bull has a pair of normal functioning testicles with a well formed epididymis, while the eunuchoidal bull has a pair of hypoplastic testicles. It cannot be doubted that this syndrome is hereditary. Recently I encountered several hypoplastic bulls on one ranch, and all

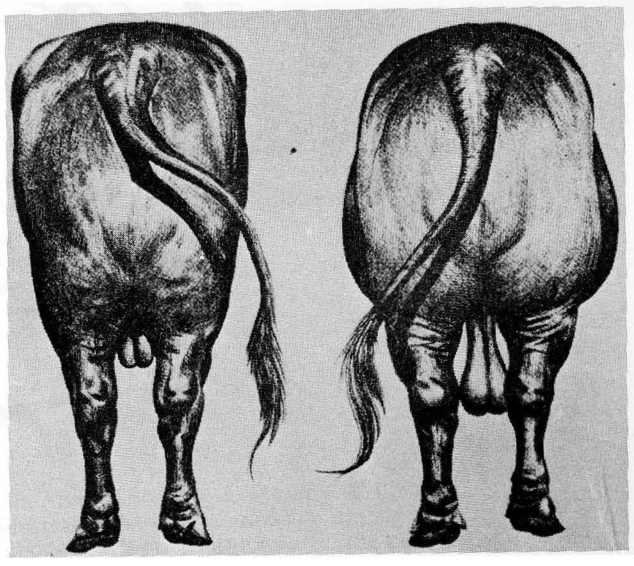


Fig. 15
Left: The sub-fertile (eunuchoidal) bull. *Right:* The highly fertile bull.

these were offspring of a single hypoplastic bull. The sire had produced only seven offspring in 1964, and his three sons had produced no progeny in 1964.

Very straight hocks in breeding animals are objectionable. Such bulls have very high thurls (top of the trochanter major) and the joint of the hip bone (femur) in the pelvis (acetabulum) is pushed upward, resting in a very straight rump. That is common in the Friesland breed in Holland, England and South Africa. The hip bone (femur) is more upright than is desirable which consequently changes the position of the opening of the pelvis. Hence, in cattle with straight hocks and very square or level rumps, dystocia, or calving difficulty results because of anatomic changes resulting from wrong selection methods. The pelvis of the animal has a larger opening if the ilium slopes downwards.

Heritable defects such as weak pasterns interfere with the bull's ability to serve; so do weaknesses such as corns between the rear hooves. The semen testing of bulls is not an index of their ability to settle cows, unless we are certain they have no defects which will interfere with their serving ability. The bull must also be inspected to determine whether he has certain physical disabilities and to determine whether he has sex drive. Arthritis is another heritable defect; it is caused by a disturbance in steroid metabolism. It is closely correlated with reproductive impairment.

Double muscling in cattle is a serious problem; not only are double muscled cattle less fertile, but calves by double muscled bulls cause dystocia. I am not interested in bulls which exhibit abnormal muscle development anywhere on the body. Bulls which are not balanced for body conformation, especially when they have relatively large, long heads and very deep fore quarters, are inclined to cause calving difficulties in the cows.

Why does it help to know how to judge cattle for functional efficiency? If it can be predicted that a heifer is going to be highly fertile when you select her, and you know that a heifer will settle on one or very few services, it saves bull power on the ranch and it increases calving percentage. On a particular ranch on which cattle were selected for functional efficiency for many years, they had an average calf crop of 70 per cent for 13 years running. Then, in 1956, all animals were appraised for functional efficiency and all animals, heifers, cows and bulls, that seemed functionally inefficient were culled resulting in 349 cows of 2 669 being butchered. The owner, understandibly, was perturbed at the high cull-percentage expecting never to achieve a large calf crop again. However, the calf crop jumped to 87 per cent and never declined lower than this in the following seven years, reaching a peak of 93 per cent. The year after the culling, this ranch produced 170 calves more than they had ever produced and the overall income increased by R30 000.

By applying our knowledge of judging livestock for functional efficiency, and by using this tool hand-in-hand with performance and progeny testing, we will greatly improve our livestock production.

J. C. Bonsma

Crossbreeding for Adaptability

An adapted animal is one in perfect harmony with its total environment which, according to our present livestock philosophy, composes fifteen environmental factors: nutrition, temperature, light, radiation, altitude, barometric pressure, wind, disease, ectoparasites, endoparasites, soil pH, soil fertility, rainfall and humidity, noise, and pollution.

Of all the interrelated factors influencing the environment, climate and soil pH are probably the most important, affecting not only the vegetation and parasitical fauna but likewise the density of human population, its need, and culture.

To be comprehensive, a study of the climatological influence on animals must include the response of species, breeds, types within breeds, land as well as aquatic animals, steppe and mountain animals, and existing animals as well as those of historical importance that no longer exist. The ecology with which the animal breeder is concerned aims at the influence of climate, with its constantly recurring phases and topography upon the animal (in this case the bovine). The reaction of any animal to a particular external environmental stimulus is closely correlated with the animal's body conformation and its efficiency of production.

Adaptability of animals

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 the result of natural selection.

If removed from their orginal environment to a new one, certain individuals within the breed succeed better than others in adapting to new conditions. The degree of success in adaptation of such animals is accurately reflected in the first instance by their ability to shed their hair early in spring and furthermore in their ability to grow, to reproduce regularly, and to produce, whether it be milk, meat, or fat.

The manner in which an animal reacts to meteorological conditions — the rise and fall in temperature, wind velocity, rainfall, and the duration and intensity of sunlight — is information

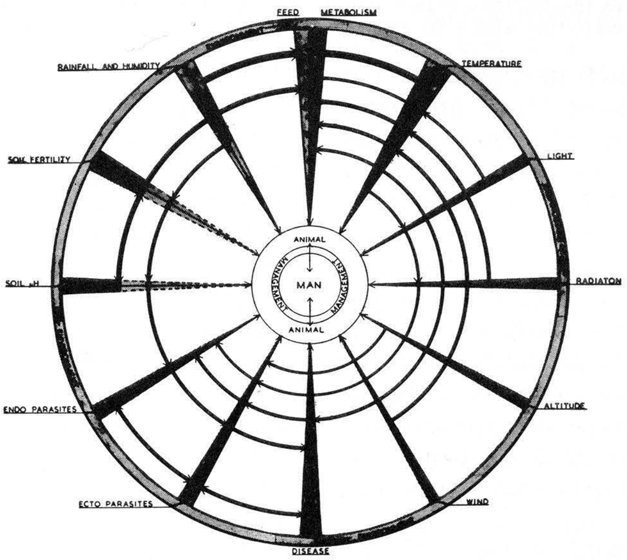


Fig. 1

The livestock philosophy of the Department of Animal Science, University of Pretoria, Pretoria, South Africa. In the wheel, which illustrates the interrelationship among man, beast, and total environment, man is the axis about which everything rotates; the nave or hub of the wheel is the domesticated animal in close symbiosis with man. The running surface and rim of the wheel are the total environment, and each spoke is an environmental factor which has a direct leverage on the nave of the wheel. The lubricant which makes the wheel rotate with ease around the axis is management.

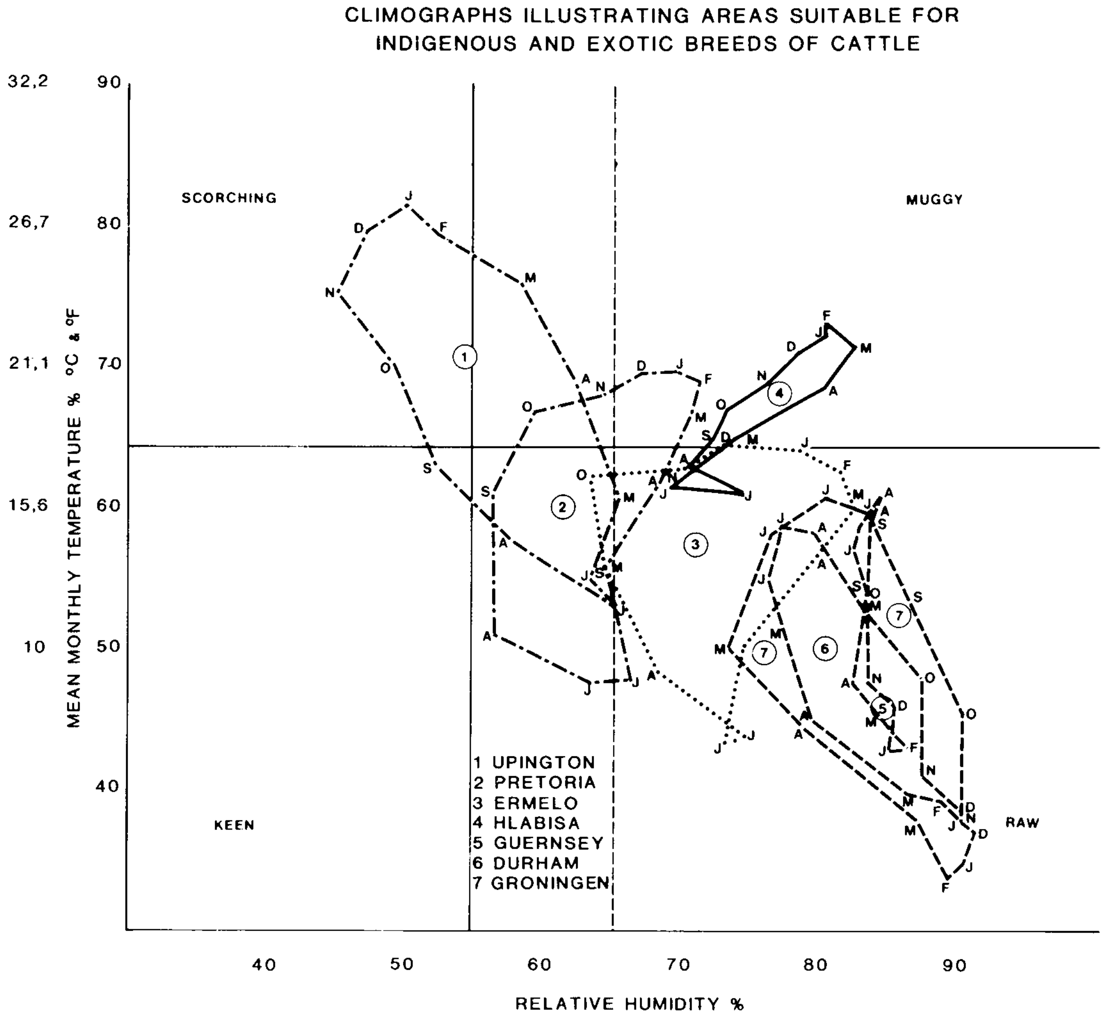


Fig. 2

The difference between the climatic regions where British and European breeds of cattle originated and evolved as compared to that where the *Bos indicus* breeds originated and evolved.

of value to the cattle breeder as a guide to the selection of cattle possessing those attributes which promote adaptability. The interpretation of the reactions of climate upon animals gives a good indication of the morphological and functional differences existing among breeds and even between individuals within breeds. The animal which is well adapted to a certain environment often possesses distinctive breed characteristics indicative of adaptability. If these qualities are known, the cattle breeder is able to select accordingly; the process of natural selection is thereby accelerated, and the danger of introducing unadaptable types into a new environment can be avoided.

Livestock which originated in the northern hemisphere, such as the British and European breeds of cattle *(Bos taurus)* which evolved mainly between the latitudes of 45° and 60° north, had completely different environmental stimuli (such as nutrition, summer and winter temperature fluctuations, summer and winter photoperiod and radiation) than did livestock *(Bos indicus)* which evolved in the southern hemisphere. The vast differences between the nutritional and environmental status of the northern versus the southern hemispheres had equally vast evolutionary influences on the breeds of cattle evolved in these two hemispheres, especially with regard to morphology and physiology.

In order to determine what anatomical and physiological characteristics are coupled with adaptability, it is necessary to study the effect of specific environmental factors on special organs or parts of the body. The animal breeder in the subtropical regions must first determine what effect light (especially the differences between summer and winter photoperiod), radiation, temperature, humidity, and soil pH have on cattle. Further, it is necessary to find out whether differences exist among different breeds and types of cattle in their ability to find feed in a certain environment and in their ability to utilize such feed. Likewise, animals must possess qualities which will increase their powers of resistance against prevailing diseases. To mention only a few, they must be resistant to parasites, especially the tick, and must be immune to maladies caused by photosensitivity, such as eye cancers and keratosis of the skin. It is my considered opinion that coat colour and the colour of the hide is of the utmost importance to the adaptability of cattle to solar radiation. A quality far more strongly developed in some breeds than in others is the ability to avoid noxious plants.

There is every indication, therefore, that by the careful selection of certain qualities it is possible to develop cattle breeds, and types within breeds, possessing hereditary characteristics that will ensure their adaptability to specific climatic conditions. In the subtropics, such animals are endowed with resistance to intense radiation, high temperatures, and parasites; furthermore, they can make the most effective use of the variable feed conditions typical of the semi-arid subtropics and can be economically productive under these conditions. On this basis, therefore, it is possible to subdivide the world into climatic zones in each of which a breed or type can be found, or developed, which is in harmony with its environment. The environment and the animal and its production potential will determine the breeding policy.

Observations were recorded in the semi-arid subtropics at the Messina Experimental Farm (11 330 hectares): 29°54′ east longitude; 22°16′; south latitude; altitude, ± 1,000 m; average annual temperature, 22°C; and at the Mara Agricultural Research Station (9 713 hectares); 29°34′ east longitude; 23°09′ latitude; altitude, 600 m.; average annual temperature, 19.5°C. in the northern Transvaal, South Africa. These research stations are representative of the hot, semi-arid, and sub-tropical bushveld regions characterized by sweet grass. (Sweet grass is a grass which forms a natural curing hay during the winter. Examples of such grasses are *Cyncrus ciliares* [blue buffalo grass] and *Panicum maximum* [buffalo grass]).

Reactions to various environmental factors were measured.

Resistance to direct solar radiation

Solar radiation includes rays of three different wavelengths, namely: (1) long-wave rays — 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 shortwave or ultraviolet rays, invisible to the naked eye.

Radiation is a variable factor, fluctuating during the day and with seasonal changes in humidity; it is likewise modified both by latitude and altitude. Radiation in the northern hemisphere differs very markedly from that in the southern hemisphere. The nature of the radiation received near the earth's surface is determined largely by the penetration of the sun's rays through the atmospheric strata which act as filters, admitting or excluding long- or shortwave rays in particular. Thus, shortwave radiation is most intense at high altitudes while at low altitudes there is a higher degree of radiation, both of heat rays and of shortwave rays, than in temperate regions. In those parts of the world near the equator the intense radiation may have a most injurious effect upon animals.

The radiation during the southern summer is appreciably more intense than during summer in the northern hemisphere because the sun is closest to the earth during summer in the southern hemisphere. On July 4 (northern summer) the sun is at aphelium, the greatest distance from the earth, namely 152 000 000 km. On January 3 (southern summer) the sun is at terehelium, the shortest distance from the earth, namely 147 000 000 km.

Radiation is indirectly the source of all energy supplied to man and beast, for it sets up in the plant cell certain chemical reactions which make possible the absorption of the sun's energy. Further, radiation not only increases the rate of the metabolic processes and stimulates the growth of certain animal tissues, it also has a sterilising influence.

Depending, therefore, on the nature and quantity of the rays impinging on the animal, the effect of radiation may be good or bad. Some animals which are not resistant to intense radiation may be adversely affected with resultant skin irritations, or injury to the mucous membranes such as those of the eyelids and eyes, if the intensity and nature of the radiation exceed certain limits. Consequently, cattle indigenous to the subtropics and tropics are frequently endowed with hair, hide colour, and other attributes (such as hair characteristics) which protect the animal against the injurious effect of excessive radiation.

Thus, both the infra-red rays of long wavelength and light rays are effectively reflected by white, yellow, or reddish brown hair, but not by black hair (Bonsma, 1943; Rhoad, 1940; Riemerschmid and Elder, 1945). The shortwave or ultraviolet rays in turn are resisted effectively by yellow, reddish brown, and black hide colours. It is apparent, therefore, that a white, yellow, or red coat with a dark hide is the ideal combination to render an animal resistant to the temperature and intense radiation of the heat and shortwave rays. It is, moreover, this hair and hide colour which are found among cattle and horse breeds of the tropics. One thinks, for example, of the Indian cattle breeds, the Afrikaner cattle, and the Arabian horses (Olver, 1939; Ware, 1941).

White hair and unpigmented hide often permit injuries to the skin due to irritation caused by the shortwave rays. An example is the severe damage done to the white udders of cows by light reflected from the snow in the spring in the northern hemisphere. In contrast, black hair and black hide is a good combination for eliminating shortwave rays. As long as an animal is not exposed to the sun, a dark, heat-radiating colour is advantageous in disposing of surplus heat acquired during exposure and through metabolic processes. Black cattle breeds are, therefore, the best adapted in those regions where shortwave radiation is intense, for example, at high altitudes and where mist frequently occurs. Shade or cloudiness is an essential condition for dark colours to operate efficiently. Parker (1935) has indicated that black animals thrive particularly well in subtropical regions, provided they are not exposed for long periods to the direct rays of the sun. Consequently, in warm, relatively dry regions with savanna vegetation, a white or brown hair colour with a pigmented hide is preferred to a black colour.

Therefore, it is obviously important that breeders give adequate attention to the selection of appropriate hair and hide colour, with a view to breeding animals which are well adapted to a particular region. This should replace the indiscriminate breeding of animals of certain colours because of prejudice, taste, and tribal dictates.

Resistance to high atmospheric temperature

In climatic regions where cattle breeds have to contend with high atmospheric temperature, various reactions occur which maintain the animal in a condition of thermostability. Apart from the alteration in the metabolism of the animal, physical phenomena, such as the latent heat of vaporisation of water from the lungs, play an important part in the dispersion of superfluous heat.

Likewise, both evaporation of moisture from the hide's surface and radiation of heat are effective in cooling the animal's body, and both processes are dependent upon the quality of the coat cover (Bonsma and Pretorius, 1940; Rhoad, 1936).

Smooth-coated animals which have mainly primary hair follicles, from which straight hair emerges, have better developed sweat and sebaceous glands, and they lose more moisture from the hide as a result of evaporation. Animals with furry coats have hides with two kinds of hair follicles, primary and secondary (from which curly or semicurled hair emerges). The thin curly hair forms a mat on the animal's body and little evaporation of moisture from the skin takes place. Thus, furry-coated cattle with their heat-retaining layer of external protective cover cannot dispose of heat effectively through radiation. These animals readily become hyperthermic during hot weather.

The disposal of surplus heat by radiation is affected not only by the quality of the coat but also by the conformation of the animal. Thus, the Indian cattle breeds and the Afrikaner cattle have large, well-developed dewlaps and umbilical folds which act as radiators of heat. Tropical breeds of cattle, being relatively deep although slightly flat, are respiratory types. The body conformations of British beef breeds unadapted to tropical conditions frequently change so that the animals develop into respiratory types; the lateral depth of the chest increases, the belly is contracted, and the animals become flat-ribbed.

In subtropical regions the hides of smooth-coated animals are usually thicker than those of the woolly types; they have a better flow of blood to the hair follicles, consequently, radiation of heat in these types is more effective. In order, therefore, to develop types which will radiate heat effectively in the subtropics, smooth-coated animals should be used for breeding purposes.

In the cold temperate regions of the northern hemisphere, a thick coat is an advantage because heat retention instead of heat dissipation is important in maintaining thermal equilibrium.

If samples of hair are taken from young calves, dampened with water, and rubbed between the hands, the hair of the smooth-coated type will rub away while that of the woolly-hair type will felt and form a firm mass. A calf with hair revealing the latter characteristics does not shed its hair normally in the subtropics and reacts drastically in hot weather. Calves with woolly or mossy coats are preferred in countries like Scotland.

The entire coats of 8 adult British beef-breed cattle belonging to both the smooth- and woolly-coated types were clipped with hair clippers as close to the skin as possible. From the 4 smooth-coated cattle an average of 400 g of hair was removed, and an average of 1 474,2 g was taken from the 4 woolly-coated types. The coats were subjected to a felting process in a wool factory. The hair of the smooth-coated type did not possess good felting properties; most of it shifted out from under the press during the felting process, and the pieces of felted hair could be drawn apart with a pull of less than 2 kg. In contrast, the hair of the woolly-coated type of cattle felted fairly satisfactorily; it formed strong, firmly matted pieces which required a pull of about 10 kg in order to tear the strips.

Measurements of hair thickness made on samples of hair taken from the different types of cattle within a breed also indicate clearly that the hair of the types possessing felting qualities is considerably thinner. In the numerous hair thickness determinations made on samples taken from various types of cattle, no distinction was made originally between the diameter of inner heat-retaining hair (non-medullated) and hair from the outer protective coat (medullated). Thus, the first data on the diameter measurements of Shorthorn cattle hair gave an average diameter of 30μ, compared with 53μ for Afrikaner cattle; 4 000 diameter measurements were taken of each of the hair samples.

In later work, attempts were made to take separate diameter measurements on both the inner heat-retaining hair (non-medullated) and hair from the outer protective coat (medullated). However, it was almost impossible to separate the two types of hair in the case of woolly-coated beef cattle because the average hair diameter was so small. In the case of smooth-coated exotic British beef breeds it was possible to separate the two hair types, whereas in the case of the Afrikaner cattle only one type of hair exists, namely, medullated straight hair. Two samples of Afrikaner hair were measured.

Table 1 gives the average hide thickness and hair diameter measurements of different types of cattle. The hair diameters of exotic cattle vary greatly. In the case of Afrikaner cattle, while different hairs have a uniform thickness, each hair tapers to a point, and this causes the large standard deviation in the diameter measurements.

Cattle with coats possessing felting qualities always experience difficulty in maintaining thermal equilibrium in a hot environment, and consequently become hyperthermic.

Rhoad (1944) evolved a method whereby the ability of an animal to maintain a normal body temperature is expressed by a heat tolerance coefficient (HTC) formulated as follows: HTC = 100 − 10 (BT° F − 101), where HTC is the heat tolerance coefficient and BT the body temperature on a hot day.

All the animals were exposed to direct sun radiation, and the temperature reactions of cattle for atmospheric temperatures above 29,4 °C were considered in the calculation of the HTC. In his work, Rhoad does not distinguish between age groups. Work done in South Africa, however, indicates beyond all doubt that an animal's HTC increases considerably, especially after the second year. The animals were placed in the shade and body temperatures, respiration, and pulse rates were determined every 2 hours during one day every 2 weeks until the animals were 5 years old. In the HTC calculations body temperatures taken at atmospheric temperatures of 29,4 °C and higher were considered. Table 2 indicates how the HTC changes with age. The average reactions are for the same animals taken over a period of 4 years. In the case of purebred Afrikaner cattle, the differences are still smaller than for crossbreds.

It will be seen therefore that heat tolerance increases with age, and if a calf has a high degree of resistance and can tolerate, during its first year, atmospheric temperatures above 29,4 °C then its powers of resistance to tropical and subtropical conditions will undoubtedly be high. Furthermore, the calf is a sensitive organism, and selection for resistance to tropical conditions can be made with greater confidence on such a young animal than on an older one; the best method of selection for breeding animals able to maintain thermal equilibrium under environmental conditions of high atmospheric temperature is to test the animals before they are a year old at temperatures above 29,4 °C and then to breed only from those with a high

Table 1.

Breed	Type	No. animals	Avg. skinfold measurement (cm)		No. fibres measured/ animal	Av. diam. all fibres measured (μ)[a, b]	Inner hair diameters (μ)	Outer hair diameters (μ)	Remarks
			Shoulder	13th					
British beef cattle +	Woolly	4	0,45	0,68	2 000	41,0 ± 17,8	40,0 ± 20,9	39,3 ± 16,0	Very difficult to separate types of hair.
British beef	Smooth	4	0,61	0,90	2 000	43,9 ± 19,7	41,0 ± 19,7 +	46,9 ± 21,0	No difficulty in separating hair types.
Afrikaner	Very smooth	4	1,10	1,60	2 000	53,7 ± 30,4 =	52,2 ± 32,1 =	55,3 ± 32,1	Only one type of hair.

a. +, Mainly non medullated.
b. =, All hair medullated, no inner or outer hair diameters were taken. Two samples were measured.

Table 2. Heat-tolerance data, atmospheric temperature °C

Group	4–7	8–10	11–13	13–16	16–18	19–21	22–24	24–27	27–29	29–32	33–35	36–38	38–41	41–43	Avg. body temp. for atmosphere above 29,4 °C	HTC (%)
Afrikaner × British Beef Cattle (5)																
1. Age: 0–1 year	...	...	38,3	38,3	38,4	38,5	38,7	38,7	38,9	39,0	39,0	39,0	38,9	38,7	39,0 °C	
Avg. body temp.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	89
No. observations	...	...	5	12	29	60	93	119	142	156	156	121	55	27		
Age: 1–4 years	...	...	38,2	38,3	38,3	38,4	38,4	38,5	38,4	38,5	38,5	38,5	38,4	38,5	38,5 °C	
Avg. body temp.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	97
No. observations	...	...	8	25	52	83	189	210	206	190	190	131	43	11		
British Beef Breeds: Hereford (9), Aberdeen-Angus (4), and Shorthorn (8)																
2. Age: 0–1 year	...	...	38,4	38,6	38,6	38,7	38,9	38,9	39,2	39,3	39,4	39,5	39,7	40,8	39,4 °C	
Avg. body temp.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	79
No. observations	...	...	16	49	134	205	377	395	446	419	353	162	85	6		
Age: 1–4 years	...	38,00	37,9	38,2	38,1	38,3	38,4	38,6	38,6	38,8	38,9	38,7	38,7	...		
Avg. body temp.	...	...	...	...	...	...	...	...	...	...	...	...	...	...		
No. observations	...	11	26	129	351	414	856	1 048	985	843	682	252	68	...		
British Beef Breeds (smooth-coated): Hereford (7), Aberdeen-Angus (2), and Shorthorn (2)																
3. Age: 0–1 year	...	...	38,2	38,6	38,5	38,7	38,8	38,9	38,9	39,2	39,3	39,3	39,5	40,2	39,2 °C	
Avg. body temp.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	83
No. observations	...	...	4	11	31	49	94	116	120	109	104	49	24	2		
Age: 1–4 years	...	38,1	38,1	38,3	38,2	38,4	38,4	38,6	38,6	38,7	38,8	38,5	38,6	...	38,7 °C	
Avg. body temp.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	93
No. observations	...	4	10	54	130	156	324	392	366	312	255	91	26	...		
British Beef Breeds (woolly-coated): Hereford (2), Aberdeen-Angus (2), and Shorthorn (6)																
4. Age: 0–1 year	...	...	38,2	38,4	38,5	38,6	38,9	39,0	39,3	39,4	39,5	39,7	40,8	41,3	39,5 °C	
Avg. body temp.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	77
No. observations	...	...	7	17	58	82	148	179	194	181	149	74	40	4		
Age: 1–4 years	...	38,00	37,8	38,2	38,2	38,4	38,5	38,7	38,7	38,9	...	38,9	38,9	...	39,0 °C	
Avg. body temp.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	89
No. observations	...	4	12	55	124	172	367	433	417	353	278	99	27	...		

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 as against 1 and 3 other comparisons ($P < 0,05$).

HTC. The higher the HTC of an animal during its first year, the more effective is the use such an animal makes of the feed conditions of the environment and the better it grows. Schleger and Turner (1960) estimated the heritability of coat type as high as 0,63.

Resistance and humidity

Seath and Miller (1946) have indicated that the part played by humidity in the reactions of the animals is of little importance as compared with that of temperature. It was found that a rise of 1° in air temperature was responsible for 13–15 times as great a rise in body temperature as was a rise of 1 per cent in relative humidity.

Adaptation and feeding

In consequence of the irregular rainfall and high temperatures of the semi-arid subtropics (Fig. 3) natural grazing is deficient in protein and moisture and high in crude fibre for the greater part of the year. The more the animal has been improved from the animal husbandry point of view, the more difficult will it be for it to utilise such poor grazing. Fodder high in crude fibre and low in protein value has a high heat increment value which puts an extra load of heat (due to metabolic processes) on the animal; the animal does not dissipate heat easily and, hence, becomes hyperthermic. Owing to the periodic droughts the animal must also be able to search for food and, if much walking is required, to reach the feed or watering places. The animal that does not move with ease will have difficulty in obtaining its maintenance needs. These poorly-adapted cattle also cause severe denudation of the pastures around the drinking troughs, leading to soil and wind erosion. Table 3 clearly illustrates the difference in reaction among breeds of cattle, and types within breeds, when the animals were driven at a rate of 3,2 km per hour in walking tests.

If watering places are far apart, cattle, especially those which do not move with ease, often suffer as a result of water deprivation. Such animals succumb in years of drought. The tolerance of breeds of cattle to the withholding of water is illustrated in Table 4.

Appropriate, effective, and adequate nutrition afford a partial but by no means complete solution to the problem of adaptation to the tropics and subtropics. In the economic breeding of stock it is essential that the most effective use be made of the vegetation available in the region. Thus, while in cool temperate regions the problem of adaptation and environment is easily solved by feeding and shelter, a system of supplementary feeding in the subtropics where the necessary fodder is supplied to the animals in sufficient quantities is neither a practical nor an economic proposition.

In other words, it is possible for a breed adapted to a warm region to develop normally in a temperate climate, provided it receives adequate feed and shelter, especially during

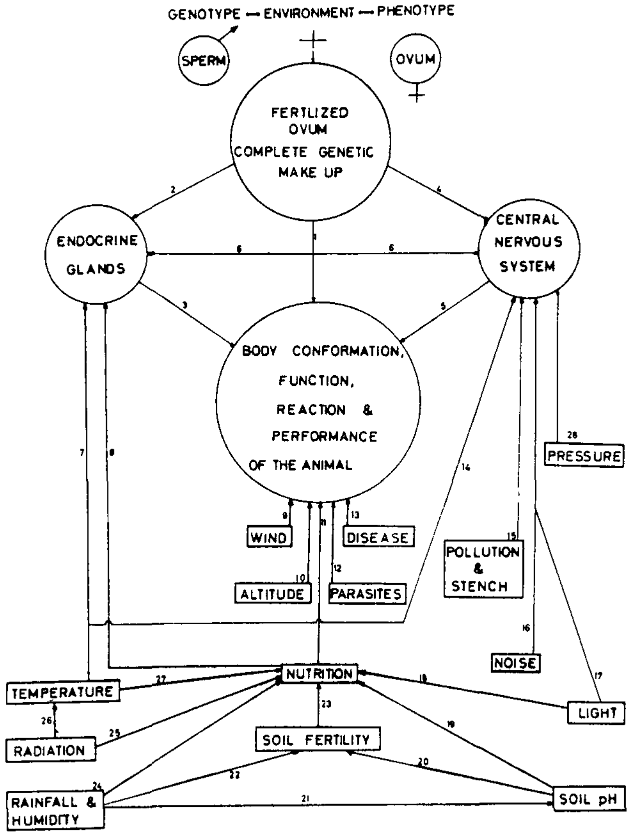


Fig. 3

The interaction among the total genetic make-up of the animal, the total environment, and the animal.

winter. The maintenance requirements of such animals, as a result of a greater power of radiating heat, will be greater than those of an animal possessing a coat of heat-retaining properties, but, provided it is well fed, it can maintain a normal body temperature.

However, the converse is not true. A cattle breed developed in a cool temperate region will not thrive in the subtropics, notwithstanding good feeding. Such animals tend to become hyperthermic as a result of high environmental temperatures and lack of adaptability; they automatically eat less, and the whole process of normal metabolism is disturbed.

The natural pasturage in the tropics and subtropics has a high crude fibre content, is, on the average, low in protein, and has a very high heat increment. Thus, to breed animals which will utilise the available feed resources in the semi-arid subtropical regions effectively, it is necessary to select those which are in thermal equilibrium with the environment, which can move with ease, and which can make effective use of coarse fodder.

As a result of drought conditions at the Messina Agricultural Research Station in South Africa, the nutritional quality of the grazing deteriorated to such degree that the cattle began to lose considerable weight. As soon as cattle showed a loss in weight of 10–15 per cent or exhibited signs of weakness, supplementary feed was given. Table 5 indicates the difference in breed types. From the table it is clear that the Afrikaner breed and the truly smooth type Hereford can overcome these conditions reasonably well.

Effective utilisation of roughage, leaves and shrubs as well as grass, is fundamental to an economic cattle-breeding industry in the tropics. Thus, if an endeavour is made to locate each breed in those regions which most closely resemble its original habitat, then for the hot, dry climatic zones those breeds should be selected and bred which can advantageously utilise bulky feed and which are able to do without concentrates. Thus, the basis of selection is the ability to thrive on the veld. Cattle must be able to consume pastures with a high heat increment value and be able to maintain thermal equilibrium in such an environment.

Adaptation and reproduction

The function of growth is to a large extent determined by the animal's efficiency in utilising feed, closely correlated in turn with the ability

Table 3. Walking tests on cattle

Breed	Type	Minimum no. animals/ test	Total no. different animals tested	No. tests	Distance walked before showing symptoms of severe distress (km)	Avg. body temp. at end of tests	Maximum atm. temp. during days of test	Remarks
Shorthorn	Woolly-coated	6	15	6	6,4–9,6	41,6 °C	34,4 °C In case of these cattle walking discontinued at 10 a.m., atm. temp. 30 °C	Three out 15 animals could not proceed beyond 6,4 km. All other animals were reluctant to move farther than 9,6 km.
Shorthorn	Smooth-coated	6	10	6	25[a]	40,5 °C.	34,4 °C.	All smooth-coated beef cattle could walk 25,6 km showing symptoms of severe distress. Five animals had body temp. above 40,6 °C.
Afrikaner	Very smooth-coated	6	10	6	25[a]	38,9 °C.	34,4 °C.	All animals could walk 26 km with ease. In one test a group of Afrikaner cattle walked 34,0 km in 12 hrs without showing symptoms of distress.

a. See Remarks.

Table 4. Water deprivation tests

Breed	No. animals	No. tests	Percentage weight loss after withholding water 24 h	Percentage reduction in feed consumption after 24 h[a]	Percentage reduction in feed consumption after 48 h[a]	Percentage reduction in feed consumption after 48 h[a]	Percentage weight recovery at end of 2 weeks
Afrikaner	4	3	1,5 6,8 kg	0	9	56	96,5
Exotic beef	4	3	15 47,6 kg	24	21	62	92,0

a. Feed intake previously determined in two groups. Percentage reduction in feed intake calculated on intake control group receiving feed and water.

of the animal to maintain thermal equilibrium. There is every indication that if the animal is not in thermal equilibrium with its environment then its metabolism is not normal either, and apparently no amount of feeding will stimulate growth. All animals, therefore, so constituted as to be unable to adapt, suffer from chronic undernourishment, owing to the fact that they cannot effectively utilise the available fodder and maintain a normal body temperature.

Chronic undernourishment in the unadapted types can even be detected in newly-born calves. Calves of unadapted breeds born after a summer gestation are puny. The miniature calves of cows of the British beef breeds born in May, June, and July (southern hemisphere, autumn and winter) are 20 per cent lighter than calves of the same animals born in December–January (southern hemisphere summer). The small calves grow slowly and cannot make effective use of the mother's milk as their absorptive capacity is too small. The difference in weaning weights is even greater, namely, 27 per cent. Such small calves were observed not only on the Messina Agricultural Research Station but also in Swaziland, Mozambique, and Botswana. In contrast, the calves of well-adapted animals born in summer and winter show no difference in weight (Table 6).

Underfeeding results in retardation of growth. Since the function of reproduction is intimately associated with growth, all the animals whose growth had been retarded considerably revealed repressed sexual activity, and clinical examinations as well as slaughter tests proved the sexual organs, particularly the ovaries and wombs, to be infantile (Table 7).

At the Mara Agricultural Research Station it is policy to breed as long as possible from cows which show a high degree of longevity. Cows are not culled at a fixed age limit, but as soon as a cow fails to maintain herself on the natural grazing or to reproduce normally or to raise her calf well, then she is sent to the abattoir.

Table 5. Observations on cattle during period of drought

Breed	Type	No. animals	Age (years)	Max. avg. wt. during summer[a]	Min. avg. wt. during summer[a]	Wt. loss	Wt. loss (%)	Date supplementary feeding became essential to prevent cattle from dying	Remarks
Shorthorn	Woolly-coated	6	7	396 kg	306 kg	90 kg	23	4.1.47	Cattle with furry coat, inner heat retaining hair. Well adapted to cold temperature zone.
Shorthorn	Smooth-coated	6	7	433 kg	384 kg	49 kg	12	4.18.47	Cattle with straight hair, much lower percentage inner heat retaining coat. Well adapted to mild temperature zone.
Aberdeen-Angus	Smooth-coated	6	7	341 kg	322 kg	19 kg	5,5	5.15.47	Black cattle with straight hair. Adapted to fairly high altitude, humid temperate regions.
Hereford	Smooth-coated	6	7	459 kg	446 kg	13 kg	2.6	9.1.47	Cattle adapted to temperate ranching conditions. Feeding became necessary after winter season when average weight dropped to 410 kg.
Afrikaner	Smooth-coated	6	7	514 kg	411 kg	73 kg	13	Did not come in for feeding.	Smooth-coated hardy cattle adapted to hot semi-arid regions. Loss in weight due to suckling calves. Other cattle weaned calves 3.1.47.

a. Period: 1 November until 31 March. Summer in the southern hemisphere.

Likewise, all cows which fail to produce a calf for two years are culled. Table 8 gives information on the relative proportions of different types and breeds of cattle in the different age groups.

The reproductive ability of a poorly-adapted animal is low, and selection on a fecundity basis is an effective method of breeding for adaptability. At the Mara Research Station in South Africa, Afrikaner bulls gave an average serviceable life of 8 years and 10 months, while the bulls of the British beef breeds could be used for an average period of only 3 years and 3 months (Table 9).

Adaptation and production

Production of meat, fat, and milk are nothing more than functions of growth, and if the animal does not grow normally, its productive capacity will be reduced considerably.

If an animal in the subtropics is adequately fed but is not in thermal equilibrium with its environment, efforts are made to evaporate as much moisture as possible from the lungs by accelerated respiration and by panting or slavering. Apart from the increased metabolism rate and the hyperthermal condition which make it difficult for the animal to put on weight, the development of protein tissue, which is the most important tissue associated with the weight increases in the early stages of growth, is still more difficult since the evolution of 1 molecule of muscle protein tissue involves the addition of 8 molecules of water.

Fat, a tissue almost free of moisture, is developed during the later stages of growth of the animal. The growth of unadapted cattle is such that muscle tissue, but not fatty tissue, shows signs of suppressed growth. However, there is another cause for this phenomenon, namely, that the adaptation of the unsuitable animal is much lower in the first two years of its life, when protein tissues should be developed, than in the succeeding years.

The function of milk production is also a function of growth. If an animal is well adapted to its environment, it can utilise effectively the available forage and grow normally. It enables the animal to reproduce at an early age, which in turn stimulates the growth of udder tissue and milk production. However, the cow that has a potentially high milk production will not produce efficiently if inadequately fed to supply her needs for maintenance and milk production. However, an animal may receive enough feed and yet be undernourished if the climatic conditions do not permit the effective conversion of the feed. This, then, is one of the reasons why the European dairy breeds do not succeed in giving good milk yield in the tropics.

Where climatic conditions have a restrictive effect upon milk production, the Afrikaner breed produces more milk than do the British beef breeds, and crossbreds between Afrikaner and the British beef breeds produce more milk than do either of the purebreds. In India, Sahiwal and Tharparker Zebus are being successfully bred for milk production (Ware, 1941).

Table 6. Influences of the season of serving upon weight at birth of calves born at Messina Experimental Station

Breed	Winter gestation and summer calves served March–April, born Dec.–Jan. (birth wt.)	Summer gestation and winter calves served Aug.–Sept. born May–June	Differences in wts(%)
British beef breeds	29 kg	22 kg	20
Afrikaner	30 kg	30 kg	0
	Weaning wt.	Weaning wt.	
British beef breeds	180 kg	131 kg	27
Afrikaner	182 kg	182 kg	0

The modern literature on breeding for adaptability in the tropics and subtropics does not include any new principles on how to select cattle adapted to the tropics, hence so many of the results obtained in the 1937–57 research work are quoted in this paper.

N. T. M. Yeates (1965) makes the following statements:

> "Bonsma's early work on the nature of individual hairs was also notable. Not only did he clip and weigh the whole coat of experimental animals of the various types so providing quantitative data, but he measured individual fibre diameter and felting ability of the coat. From this latter technique arose his field test for felting; a snipping of hair is moistened and rubbed vigorously together between the palms of the two hands; a felting type of hair, unsuitable according to Bonsma, for tropical adjustment, forms a dense mat of hair which cannot be pulled apart; a non-felting hair, suitable for tropical cattle fails to mat and readily falls apart when pulled.
>
> More recent work, largely in Australia, has added to Bonsma's findings, particularly as regards histological details, mechanism of shedding and the classification of coat types.
>
> However, the broad principle of Bonsma's work remains unchanged and has been amply confirmed".

The commission to read before a University of Florida Beef Cattle Short Course a paper on "crossbreeding for adaptability" embraces much more than a discussion of breeding for adaptability in the subtropics and tropics. In this chapter we have endeavoured to give a comprehensive review of our research work on such breeding and to give a philosophical approach to crossbreeding for adaptability in the cold and cold temperate regions in the northern hemisphere. The principles expounded in tabular form are based on ecological concepts observed in these areas. Each of the ecological factors enumerated in the introduction of this chapter will be discussed briefly.

In discussing crossbreeding for adaptability, a global approach to this problem is essential. There is no universal crossbreeding system for adaptability because adaptability phenomena, which make an animal adapted to one particular area, might just be those which make it unadapted to another environment.

A beautiful example of this is that the Scottish Shorthorn breeders select cattle with woolly coats (mossy coat), as they call it, because such animals do well in the very cold climate of Scotland. In the subtropics of South Africa's semi-arid ranching areas these animals really do poorly. Their offspring readily degenerate because the woolly coat interferes with the ease of heat dissipation.

Adaptability to a particular environment is closely correlated to body conformation and function. Environment is the force which dictates the economy of all livestock production functions.

To breed livestock adaptable to any particular environment, it is necessary to know two factors well:

1. What are the limiting factors of a particular environment? In other words, one should know the environment well from a climatological as well as from a soil or topographical point of view and, hence, be able to appreciate the plant growth and feed potential of the environment.
2. One should know the physiological, endocrinological, and morphological factors which enable the animal to remain in thermal equilibrium and in a sound nutritional status in a particular environment.

The environmental factors unfavourable to different types and breeds of livestock are numerous, depending on where the breed in question originated. The two main types of livestock *Bos taurus* and *Bos indicus*, originated in two very divergent environments; hence, these two types of cattle are divergent also with regard to their physiology, morphology, and genetic make-up.

The *Bos taurus* types originated in the northern hemisphere, mainly between 45° and 60° latitude. The northern hemisphere is four-fifths land and one-fifth water. This brought about certain environmental, climatological, and nutritional factors which had a direct bearing on the morphology of the animals that originated in those areas. To enumerate a few of the more important environmental factors and how these factors influenced the body conformation, coat cover, colour, and function of these animals is essential to make comparisons with those ani-

Table 7. Findings of clinical examinations of genitalia of animals

	No. of animal	Date of birth	HTC at 1 year (%)	Uterus size and condition[a]	Size and condition of ovaries		Pituitary wt. (g.)	Remarks
					Right	Left		
024	Purebred Shorthorn	12.26.39	82	Infantile	Infantile	Infantile	. . .	Slaughtered at 7 yr. of age on 3.27.47. Permanently sterile.
035	Purebred Shorthorn	1.2.40	79	Infantile	Infantile, inactive	Small, corpus luteum	1,8	Body conformation degenerate. Slaughtered 3.27.47. Permanently sterile.
037	Purebred Shorthorn	1.2.40	77	Uterus small, soft-walled	Infantile, inactive	Small, remnant of corpus luteum	1,6	Body conformation degenerate. Slaughtered 3.27.47. Sterile.
036	Crossbred Afrikaner × Shorthorn	1.2.40	. . .[b]	Uterus distended with fluid	Normal, contains corpus luteum	Normal	2,7	Sterile. Hydrometra. Slaughtered 3.27.47. Body conformation normal. Crossbred.
115	Purebred Shorthorn	1.15.41	73	Infantile	Infantile, static	Infantile, static	. . .	Permanently sterile. Body conformation degenerate.
117	Purebred Shorthorn	1.21.41	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 3.27.47.
130	Purebred Shorthorn	5.12.41	68	Infantile	Infantile, size of pea	Infantile, size of small bean	1,5	Body conformation very much degenerate in form. Sterile. Slaughtered 3.27.47.
135	Purebred Shorthorn	5.22.41	70	Infantile	Small, inactive	Small, contains corpus luteum	1,7	Body conformation degenerate. Sterile. Slaughtered 3.27.47.
138	Purebred Shorthorn	5.23.41	. . .[b]	Normal	Corpus luteum	Small, static	2,3	Body conformation normal. Slaughtered at 7 yr. of age on 3.27.47. Never calved.

a. Clinical examinations of live animals on 3.14.45 by Dr. J. B. Quinlan. Examination of genitalia of sterile cows, slaughtered 3.27.47, by Drs. S. W. van Rensburg and M. de Lange.
b. No climatological observations were made on animals 036 and 138. HTC of animal 036 was above 85 per cent. See Table 2.

Table 8. Classification of breeding cows in age groups

Breed	No. cows in herd	No. cows under $3\frac{1}{2}$ yrs.	Percentage of herd	No. cows $3\frac{1}{2}$–10 yrs.	Percentage of herd	No. cows 10–16 yrs.	Percentage of herd	No. cows over 16 yrs.	Percentage of herd
Afrikaner	289	41	14,2	157	54,3	62	21,5	29	10
Hereford	84	9	10,7	75	89,3	0	0	0	0
Hereford × Afrikaner[a]	79	9	11,4	69	87,4	1	1,2	0	0
Shorthorn × Afrikaner[a]	78	3	3,9	70	89,7	5	6,4	0	0
Total	530	62	11,7	371	70,0	68	12,9	29	5,4

a. Crossbreeding work at Mara commenced during 1936, so it is not possible to have crossbred cows in the age group older than 16 years.

mals evolved in the southern hemisphere and to evaluate breeds in a cross-breeding programme.

Ecological factors considered in breeding cattle for adaptability in unfavourable climates

and

Adaptability phenomena with regard to morphology, physiology, and functional efficiency of cattle for varying ecological regions

Ecological factors: Nutrition

Northern versus southern hemispheres. Cold and cold temperate versus tropical and subtropical conditions.

In the cold and cold temperate regions the rainfall efficiency is high. Natural pasturage has a dense sward, 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) enforce harvesting of pastures and good quality hay and silage is 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 natural curing hay of good quality, but quantity is low. In the humid subtropics the pasture grasses are high in crude fibre, low in protein, and have high heat increment values.

Adaptability phenomena: Body conformation and function

The nutritional status of animals in the northern hemisphere is on the average appreciably better than that of cattle in the southern hemisphere. Management is, on the average, also appreciably better than in the southern hemisphere; hence, the functional efficiency of beef and dairy animals is good.

Animals have very little trouble maintaining thermal equilibrium as a result of ample feed supplies. Body conformation is specialised from a functional efficiency point of view.

Beef cattle are the digestive type with heavy winter coats. Dairy cattle are the respiratory type, mostly smooth-coated. Crossbreeding should be done with *Bos taurus* × *Bos taurus* types. In the southern hemisphere, because the winters are not "closed," cattle suffer from a severe winter nutritional depression. In the semi-arid subtropics fairly large-type cattle can be maintained. In the humid subtropics, cattle will be small-framed. *Bos indicus* × *Bos taurus* cross cattle give best results.

Ecological factors: Atmospheric temperature

Due to the fact that the northern hemisphere is four-fifths land and one-fifth water, the latent heat value of the land mass is low, hence tremendous fluctuations between summer and winter temperatures occur. In many areas the fluctuation between the summer and winter isotherm is 50°. In the southern hemisphere the fluctuation between the summer and winter isotherm is seldom over 20°. 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 latitudes. In the southern hemisphere very little production takes place south of 45° south latitude.

Adaptability phenomena: Type of cattle required for highest efficiency of production

Due to the tremendous fluctuation in temperature between seasons, the cattle which evolved in the far north, especially in the windy areas, have heavy winter coats and relatively smooth summer coats. In the northern hemisphere it is essential that livestock, to retain thermal equilibrium, have heavy winter coats. 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 those breeds which do not have too long gestation periods should be used to prevent dystocia problems.

In the beef producing areas closer to the Equator, shorthaired beef breeds should be crossed with the British and European beef breeds. Between the tropics of Cancer and Capricorn at altitudes below 1 000 m only tropical adapted breeds of cattle should be used for crossbreeding with the European and British beef breeds. Upgrading to the *Bos taurus* types is not possible at average annual isotherms above 21 °C.

Ecological factors: Light — summer and winter photoperiod, northern versus southern hemisphere

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 the areas where livestock are kept, the difference between summer and winter photoperiod seldom exceeds 4–6 hours except in southern South America. The difference in summer and winter photoperiod is the strongest impulse involved in hair growth and hair shedding. Temperature fluctuations are also involved but to a minor degree.

Adaptability phenomena: Hair coat and hair shedding in northern versus southern hemisphere

In the northern hemisphere only cattle that can grow heavy winter coats should be crossed for increased beef production. Hair colour and pigment in the hide is 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 vigour (additive gene effect) for adaptability than randomly selected *Bos taurus* cattle.

Ecological factors: Radiation — ultraviolet and infra-red

The ultraviolet 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 (4,8 million km) during the southern summer than during the nothern summer.

At high altitudes the ultraviolet 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, ultraviolet radiation is intense due to reflection of diffused light from the snow-covered ground.

Adaptability phenomena: In cattle to overcome the hazards of radiation

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 one of the breeds used in crossbreeding is a hazard. Cattle, such as the Brown Swiss, adapted to a relatively cold, high altitude environment with intense ultraviolet radiation, readily adapt to the tropics and are a good dual purpose breed to cross with Brahman and Herefords in a triple cross.

Ecological factors: Altitude

At high altitudes (1 500 m or 4 500 ft. above sea level) ultraviolet impingement 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 relatively high, 6,5–7,5.

Adaptability phenomena: Altitude — coat and hide colour and red blood count

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

Ecological factors: Barometric pressure

It is not clear how barometric pressure changes influence livestock. They might have a direct influence on the water-electrolyte balance.

Adaptability phenomena: Water-electrolyte balance

No suggestions are made with regard to crossbreeding in areas of different barometric pressure.

Ecological factors: Wind

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.

Adaptability phenomena: Hair coat — inner heat retaining and outer protective coat

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

Ecological factors: Disease

Many endemic diseases have an ecological etiology, such as tick-borne diseases, diseases carried by mosquitoes, stinging flies, etc. Cattle indigenous to such areas often have a natural immunity to these diseases.

Adaptability phenomena: Susceptibility and natural resistance

In those parts of the world 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 vigour and mortality will be high.

Ecological factors: Ectoparasites

The incidence of external parasites such as ticks, stinging flies, mosquitos, etc. is primarily controlled by climatological conditions such as high atmospheric temperatures or humidity. There is a very 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.

Table 9. Classification of bulls with regard to useful service life

Breed	No. of bulls used[a]	Avg. age at beginning of first service season (months)	Avg. period useful service (months)	Longest individual period useful service (months)	Shortest individual period useful service (months)	No. of bulls required/ 100 cows
Afrikaner	10	30	106	179	33	3
Exotic beef breeds	29	30	39	95	5	5

a. Three bulls intended for service died at the age of 30 months, immediately prior to being used.

Adaptability phenomena: Tick and fly repellency

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 are 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 unfavourable environment will not give hybrid vigour, and mortality rate is very high.

Ecological factors: Endoparasites

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

Adaptability phenomena: Natural resistance or tolerance

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

Ecological factors: Soil pH

Soil pH has a very marked influence on the availability of nitrogen, calcium, and phosphorus to plants, and 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, and pastures grown in such areas are relatively high in protein value. Alfalfa, clovers, and other 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 very low in protein, calcium, and phosphorus and very high in crude fibre. Due to fast lignification it also has a high heat increment value.

Adaptability phenomena: Skeletal development — type and size of cattle

The soil pH is decisive with regard to the size and type of cattle which can be maintained in any region of the world. In the high pH areas, such as the province of Nevre in France, large cattle can be produced. In all, the temperate areas of the world with a fairly good rainfall (625–750 mm or 25–30 in. per annum) and a pH of 6,5–7,5 can produce large cattle, e.g., Charolais, Simmental, Brown Swiss, Hereford, etc. These breeds can be crossed to produce hybrid vigour 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.

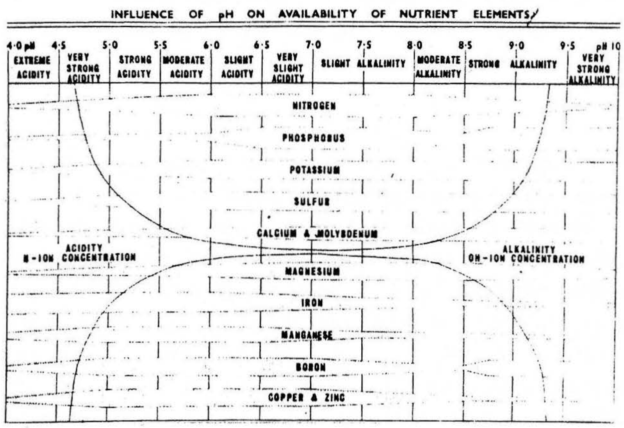


Fig. 4

The influence of soil pH on availability of certain mineral elements to the animal and plant. Soil pH has a direct influence on the ability of plants to absorb nitrogen and on the nitrification process in the soil and hence on the protein value of the pastures. Large breeds of cattle are encountered where soil pH is high and small cattle where soil pH is low. Soil pH has a tremendous influence on the skeletal development of livestock.

Ecological factors: Soil fertility

Soil fertility *per se* has no direct influence on the production of livestock, but indirectly it has a marked influence on the quantity and quality of feed produced. In the cold, temperate areas of the world 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 fibre is produced.

Adaptability phenomena: Livestock production

In the cold, temperate regions of the world where soil fertility is high, large cattle which are efficient feed utilisers 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 very large breeds with British beef breeds is not recommended. The very long gestation periods of some breeds result in late calving, dystocia, and very large calves at birth; a breeding season is often skipped every fourth year.

In the humid subtropics only small *Bos indicus* types should be crossed.

Ecological factors: Rainfall and humidity

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

Adaptability phenomena: Rainfall and humidity

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

Ecological factors: Pollution and stench

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

Adaptability phenomena: Stress syndrome

Stress causes cattle in feedlots and under intensive production to founder. 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 crossbreeding.

To summarise, 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 remove the losses and hazards encountered in natural selection. It is clear, however, that environment is the vital factor which determines the production potential of any region, and that 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.

WEIGHT FLUCTUATIONS OF MATURE COWS OF DIFFERENT TYPES AND BREEDS AT MESSINA RESEARCH STATION - OCT 1950 - NOV 1952

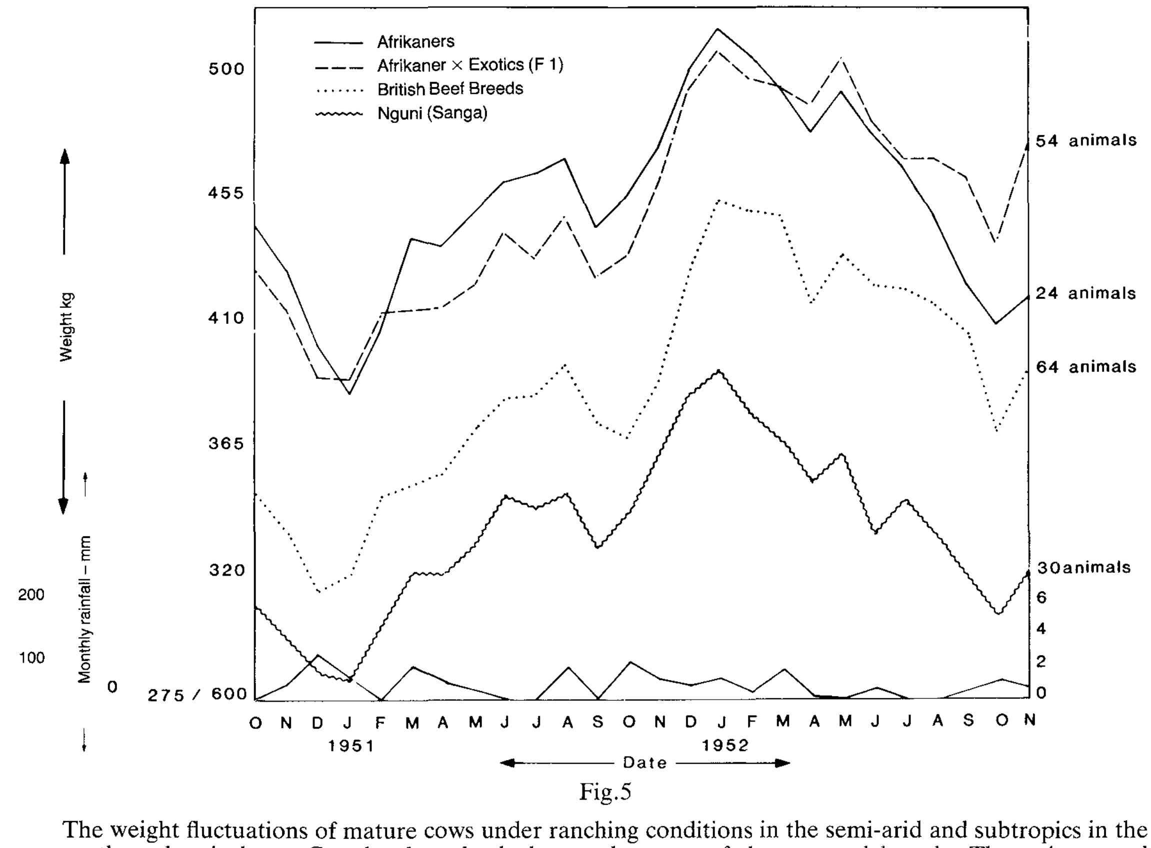


Fig.5

The weight fluctuations of mature cows under ranching conditions in the semi-arid and subtropics in the southern hemisphere. Crossbred cattle do better than any of the parental breeds. The unimproved indigenous (native) cattle do poorest due to the fact that they have never been selected for functional efficiency with regard to utilisation of feed. The British beef breeds do badly because they are not heat tolerant and suffer from hyperthermia.

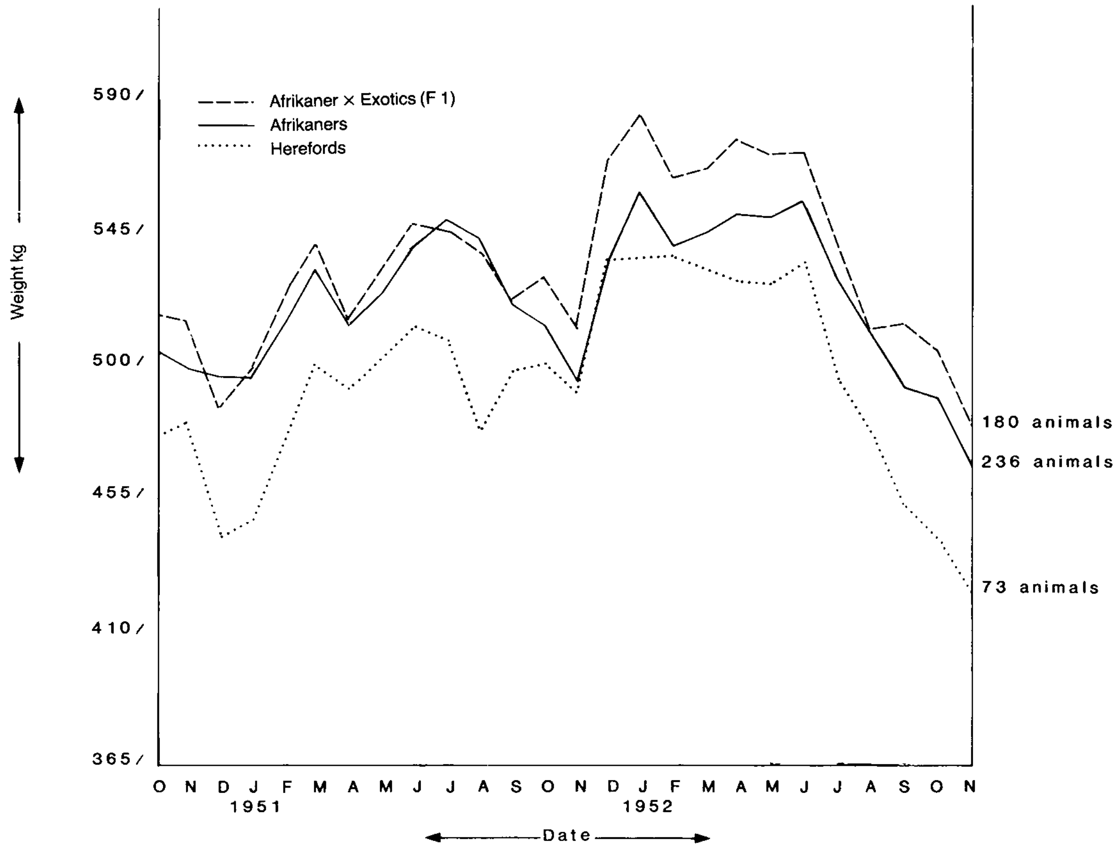


Fig. 6

The weight fluctuations of mature cows of different types; and breeds.
The crossbred cows were not only more highly fertile than the parental breeds, but also reached an appreciably greater mature weight.

References

Bonsma, J. C. 1943. *Farming S. Africa* 18:101.
Bonsma, J. C. 1949. *J. Agr. Sci.* 39:2.
Bonsma, J. C., and A. J. Pretorius. 1940 *T. M. G. South Africa* 15:7.
Olver, A. 1939. *Misc. Bull Imp. Coun. Agr. Res.* (India) No. 17.
Parker, H. W. 1935. *Proc. Zool. Soc. London* 1:137.
Rhoad, O. A. 1936. *J. Agr. Sci.* 26:36.
Rhoad, O. A. 1940. *Proc. Am. Soc. Animal Prod. 23rd Ann. Meeting.* P. 291.
Rhoad, O. A. 1944. *Trop. Agr.* (Trinidad) 21:162.
Riemerschmid, G., and J. S. Elder. 1945. *Onderstepoort J. Vet. Sci.* 20:223.
Schleger, A. V., and H. G. Turner. 1960. *Australian J. Agr. Res.* 11:875.
Seath, D. M., and G. D. Miller. 1946. *J. Dairy Sci.* 29:465.
Ware, F. 1941. *Empire J. Exptl. Agr.* 9:1.
Yeates, N. T. M. 1965. *Modern aspects of animal production.* London: Butterworth.

J. C. Bonsma

Breeding Tick-repellent Cattle

Introduction

In 1937, I was already aware of the classical research on breeding disease-resistant plants and animals. This was a result of having been a post-graduate student in J. L. Lush's class at Iowa State University (1935–36). At that time most cattle deaths in the tropical and subtropical ranching areas in the southern hemisphere were a result of tick-borne diseases.

The success achieved in breeding plants possessing a high degree of resistance to diseases can be attributed to the application of the principles of genetics. Farm animals also possess hereditary characters conferring on them a higher degree of resistance to certain diseases. Unfortunately, however, little has been done to apply this knowledge experimentally in the control of animal diseases, while on the other hand considerable attention is being given to the organisms causing disease and to clinical measures for their control. As a result of the success attained by the use of vaccines, the possible control of certain diseases by hereditary selection has been neglected frequently.

Most animal breeders also believe that the breeding of disease-resistant animals will be too slow and expensive for general adoption. However, the time and costs involved depend mainly on the effectiveness and ease with which the animals concerned can be selected. If any external characteristic of an animal is accompanied by resistance to a disease, the time and costs involved in breeding resistant animals can be considerably reduced. Infectious stock diseases are not heritable as such, but the existence of hereditary factors controlling the physiological functions of the animal body and so affecting the animal's susceptibility to such diseases is fully recognised. Because differences in natural resistance to parasites or diseases are due to genetic differences in the individuals concerned, wild animals have developed an immunity to certain diseases as a result of natural selection.

Several workers have successfully used selective breeding to produce animal strains possessing a high degree of resistance to certain diseases. Lambert's[1] research on fowl typhoid illustrates strikingly how family lines with very low susceptibility to the disease can be bred. After five generations of selective breeding, only 9,4 per cent of the fowls succumbed when inoculated with the disease organisms, while amongst the original population the mortality rate was approximately 85 per cent. Similarly, Hutt & Bruckner[2] developed strains of fowls with an increased resistance to malignant growths. After four generations the mortality rate due to malignant growths was reduced from 26 per cent to 12 per cent. Morever, fowls belonging to the high resistance line succumbed at a higher average age than those of the low resistance line. Natural infection was just as effective as artificial inoculation in distinguishing between high and low resistance groups.

Selective breeding among mammals was used to reduce the mortality rate among mice from rat typhoid from 82 per cent to 24 per cent in six years,[3] and to develop strains of pigs with considerable resistance to contagious abortion caused by *Brucella suis*.[4] Genetic differences in horses control their susceptibility to a certain type of horsesickness (encephalomyelitis),[5] and in the case of sheep it is known that Cheviot sheep are more resistant to wireworm *(Haemonchus contortus)* infestation than breeds orginating in the Lowlands.[6]

As an example of racial differences in the resistance of man to malarial infection, it is practically impossible to infect certain African races with *Plasmodium vivax*, and if they are infected the malaria attack is usually very mild, whereas Europeans are extremely susceptible to infection.[7] Some African tribes may have become resistant to malaria as a result of the heterozygous sickle-cell anaemia condition in areas with a high incidence of malaria. Differences also exist betweeen human races in their resistance to worm infestation (helminthiases). American Blacks apparently possess greater resistance to *Hymenolepsis nana* than do Caucasians, the hookworm larvae penetrating the skin of whites more easily.[8]

Regarding cattle, it has been believed since 1849 that Zebu cattle are immune to redwater (piroplasmosis). Isolated cases occur, however, and Yakimoff[9] was able to induce the disease in Zebus by injecting them with virulent blood or by allowing them to be bitten by infected ticks. He also found that calves were more susceptible than adult animals. In cross-breeding experiments with Zebus and European breeds of cattle, Kelly[10] showed that the former are less infested with ticks and possess greater immunity to tick-borne diseases. He quoted Sir Arnold Theiler as follows:

"Hitherto I was under the impression that Indian cattle are immune to tick-borne diseases because they grew up in tick-infested areas. If this view is correct, the indigenous cattle of Tunisia should also be immune to those diseases, but this is not the case. Zebu cattle actually appear to possess heritable and not acquired characters which confer immunity to these diseases on them.

The tick-borne diseases of North Africa are caused by the following parasites: *Piroplasma bigemimum*, *Babesiella berbera*, *Theileria dispar*, *Theileria mutans* and *Anaplasma marginale*. The most remarkable fact is that Zebu cattle have proved to be protected against all of these parasites."

In experiments in which Zebus were crossed with Red German cattle, Zuravok[11] showed that the cross-bred animals possessed greater resistance to redwater and gallsickness than the pure-bred German stock. Zulu cattle are also believed to possess hereditary resistance to heartwater, redwater and gallsickness.[12]

Cattle used in Mara experiments

In 1936 the Animal Husbandry Section of the Division of Animal and Crop Production of the Department of Agriculture and Forestry began cattle breeding experiments at the Mara Research Station. The aim was to produce a new breed of cattle which would possess greater resistance to tropical and subtropical conditions and perhaps also to tick-borne diseases. The Mara Research Station is situated in the Zoutpansberg district, 48 km due west of Louis Trichardt and 900 m above sea level. The vegetation is typically bushveld, with the result that heartwater (rickettsiosis), redwater (piroplasmosis) and gallsickness (anaplasmosis) are common. Afrikaner cows *(Bos indicus)* were the foundation breeding stock for experiments being conducted at Mara, and because large numbers were required they had to be purchased in various parts of the country. Experts were of the opinion that the mortality rate among animals introduced into the area would be high. Many of the cows sent to the Research Station came from the Highveld areas which are free of heartwater (Potchefstroom and Klerksdorp in the Transvaal, and Hoopstad and Theunissen in the Orange Free State). Others came from Lowveld areas where heartwater does occur (Potgietersrust, the Lydenberg Lowveld, Zoutpansberg district and Pienaars River in the Transvaal, and Adelaide in the Cape Province).

Moreover, since European breeds were included in the cattle sent to the Research Station, a golden opportunity presented itself for determining whether any real differences existed in the incidence of disease (especially heartwater) among the various groups following their introduction.

All animals which died at Mara were thoroughly examined post mortem (in doubtful cases by veterinarians) and the cause of death was determined as accurately as possible. It should be emphasised that the scientists at the Research Station were well acquainted with the symptoms and post-mortem lesions of tick-borne diseases. Where the cause of death remained in doubt, particulars were not included in the data collected.

Of the Afrikaner cows, some were used for the breeding of pure-bred Afrikaner cattle, whilst others were put to bulls belonging to exotic beef breeds. These breeds included Sussex, Aberdeen Angus, Hereford, Shorthorn and Red Polls. The exotic beef breed cows were put to similar bulls for the purpose of breeding pure exotic beef-breed cattle. There were, therefore, three classes of animals at the Research Station: (a) pure-bred Afrikaner cattle *(Bos indicus)*, (b) cross-bred F1 cattle, i.e. exotic beef-breed cattle × Afrikaner cattle, and (c) pure-bred exotic cattle *(Bos taurus)*. All these cattle could also be subdivided into those from heartwater areas and those from heartwater-free areas.

Two hypotheses for resistance to disease

At the time of this research two hypotheses were generally advanced to explain the increased resistance of young animals to diseases to which their dams had already become naturally immunised. These were, (i) that the animals acquired passive immunity from their dams, and (ii) that hereditary differences were involved. A sufficient number of classes of animals was maintained at the Research Station to test both hypotheses.

First, the progeny of immune dams acquire some immunity to disease via the placenta and also through the colostrum. This was shown as long ago as 1892 for young mice acquiring passive immunity to poisonous proteins.[13] Similar observations were made in 1907 with respect to dogs, goats and young guinea-pigs.[14] Famulener[15] showed that the colostrum of sheep is 2–3 times as rich in antibodies as their serum. Other researchers who showed the importance of colostrum in the effective protection of young animals against specific organisms were Little & Orcutt[16], who found that the colostrum of cows provides the agglutinin of *Brucellus abortus* contained in calf blood. Smith & Little[17] also showed that colostrum prevents the kidneys, spleen, liver and small intestines from being attacked by *Escherichia coli*.

If this first hypothesis is correct, we would expect to find a difference in the mortality rate among the calves of cows from heartwater areas and cows from heartwater-free areas. Table 1 shows the mortality rate due to heartwater in all breeds of cattle. There was no significant difference in the mortality rate among the different classes, i.e., dams from heartwater areas, heartwater-free areas or born at the Experiment Station. Therefore the acquisition of passive immunity through, for example, the colostrum of naturally immune dams, does not seem to play an important role in rendering calves less susceptible to heartwater.

Table 1. Mortality among calves due to heartwater

Class of cows (dams)†	Number of calves born	Number of calves died	Percentage of calves died
			Per cent
From heartwater-free areas	389*	30*	7,7
From heartwater areas	224	23	10,3
Born at Mara Research Station	115	7	6,1
Totals	728	60	8,33

† Includes all breeds of cows.
* 70 of the cows from heartwater-free areas calved within two months of their arrival at Mara, and four of these calves died (i.e. nearly 6%).

The alternative hypothesis is that certain animals within a species or even within a breed possess hereditary characters which are closely related to or even responsible for a higher resistance to disease. Within the various breeds there is a large amount of variation in characters such as colour and type of coat and skin. Some of these characters may correspond with the subdivision of a group of animals into two classes: those which are resistant to a disease (heartwater in this case) and those which succumb to it. When the survivors are used for breeding purposes, their progeny should possess proportionately more characters conferring resistance to the disease concerned. If animals of the latter generation are exposed to the disease, there should be a higher proportion of survivors than in the previous generation. Continued breeding from survivors brings about natural selection for characters conferring resistance to the disease, and the mortality rate from the disease gradually decreases.

If the above hypotheses are correct, one would expect that Afrikaner and other indigenous cattle have developed, through natural selection, a higher degree of resistance to the diseases indigenous to South Africa. Since heartwater, redwater and gallsickness are diseases which occur in several of the Lowveld areas, the study of these diseases should throw light on the problem of the inheritance of characters producing resistance. Heartwater, being responsible for a higher percentage of deaths among cattle than the other two diseases, was selected for detailed study.

Hereditary resistance to heartwater

Afrikaner cattle are compared with the exotic breeds in Table 2 (both categories including animals from heartwater and heartwater-free areas) in terms of their mortality due to heartwater. It is clear that Afrikaner cattle are far more resistant to heartwater than the exotic breeds. The table also shows that cattle from heartwater areas where dipping was not carried out regularly had very high resistance to the disease. In fact among 256 head of exotic and indigenous cattle not a single death due to heartwater occurred over a period of several years. In contrast, a number of exotic cattle breeds were obtained from farms where dipping was carried out regularly, and 31,3 per cent of these cattle died from heartwater (Table 2).

Table 2. Mortality among cattle at Mara due to heartwater

A. Cattle from heartwater-free areas

Breed of cattle	Number	Number of deaths	Number of survivors	Percentage deaths
Afrikaner	206	32*	174	15,5
Exotic breeds	34	14†	20	41,2
Totals	240	46	194	—

* 29 of the 32 Afrikaner cattle succumbed within the first 2 years.
† All 14 died within 2 years.

B. Cattle from heartwater areas

Breed of cattle	Number purchased	Number of deaths	Number of survivors	Percentage deaths
Afrikaner	207	0	207	0
*Exotic breeds	19	6	13	31,3
†Exotic breeds	49	0	49	0

* From farms where dipping is carried out very regularly.
† From farms where dipping is not done regularly.
The differences between these two categories are highly significant ($p < 0,01$).

They probably did not possess any natural resistance or immunity to heartwater, but an impression of immunity was created by the fact that the animals were never exposed to real infection. As soon as they were exposed to infected heartwater ticks, a large number succumbed to the disease. Before an animal can acquire any measure of immunity to a disease, it must naturally be exposed to infection.

If there are breeds or types within breeds which are tick-repellent as a result of hereditary characters such as thickness or structure of skin, glossiness and shortness of coat, such animals convey the impression of immunity to heartwater. Since Afrikaner cattle in particular differ greatly from the exotic beef breeds in regard to skin and coat characteristics, it was interesting to determine how the mortality of F1 crosses between the two breeds compared with that of calves belonging to the two parental breeds (Table 3). The data shown here were collected between 1936 and 1940. The differences in mortality between the pure-bred Afrikaners and Afrikaner crosses were not significant, but there was a highly significant difference in mortality between the exotic breeds and the Afrikaners and Afrikaner crosses ($p < 0,01$). All the calves of the various breeds were exposed to the same tick infestation. The fact that Afrikaner calves succumbed to heartwater at a higher average age (Table 3, part C) is also striking evidence that this breed possesses a character conferring a higher degree of resistance to the disease.

The reason why more bull calves than heifers died of heartwater is that after the calves were weaned at eight months, the bull calves were transferred to an isolation camp where they were not dipped until sold at the age of 2–2,5 years. Consequently they were exposed to a greater degree of infestation, but if it became too severe they were protected by hand-dressing. There is no doubt that the bulls acquired a high degree of immunity (apart from hereditary immunity) as a result of this exposure to tick infestation. More than 150 bulls were sold to farmers in heartwater areas, and in spite of regular enquiries not a single death from heartwater was reported.

Table 3. Mortality due to heartwater among cattle born at Mara Research Station up to the age of 2½ years

A. Heifers

Breed of cattle	Number born	Number died	Number of survivors	Percentage deaths
Afrikaners	124	5	119	4,0
¾-Afrikaner and ¼-exotic	48	2	46	4,2
½-Afrikaner and ½-exotic	206	17	189	8,3
Pure exotic	17	8	9	47,1
Totals	395	32	363	8,1

B. Bulls

Breed of cattle	Number born	Number died	Number of survivors	Percentage deaths
Afrikaners	122	8	114	6,6
¾-Afrikaner and ¼-exotic	38	4	34	10,5
½-Afrikaner and ½-exotic	191	21	170	11
Pure exotic	11	9	2	81,8
Totals	362	42	320	11,6

C. Totals

Breed of cattle	Number born	Number died	Number of survivors	Per cent deaths	Average age of calves which died
Afrikaners	246	13	233	5,3	11 months
¾-Afrikaner and ¼-exotic	86	6	80	7,0	8 months
½-Afrikaner and ½-exotic	397	38	359	10,2	6 months
Exotic	28	17	11	60,7	5 months
Totals	757	74	683	9,8	—

The differences in mortality between the pure-bred Afrikaners and Afrikaner crosses are not significant. The difference between the exotic breeds and the Afrikaners and Afrikaner crosses is highly significant ($P < 0,01$).

Tick counts on cattle

During 1939 and 1940 I qualitatively assessed the incidence of ticks on the different types and breeds of cattle maintained at the Mara Research Station. All the cattle at Mara were weighed once a month, and were dipped once weekly when the incidence of ticks was high and once a month when the incidence was low. Every animal was inspected carefully on the weighbridge and also before dipping. From these preliminary observations it was apparent that some cattle are far more susceptible to tick infestation than others. It was decided therefore to count ticks on cattle of different breeds and types within breeds.

Before conducting qualitative experiments, I first had to acquaint myself with the different species of ticks, the sexes and stages of development. I also had to be well versed in which were one-host ticks and which were three-host ticks (Fig. 1). Ticks were classified as heartwater ticks *(Amblyomma hebraeum)*, blue ticks *(Boophilus decoloratus)* and bontleg ticks *(Hyalomma aegyptium)*. Figure 1 shows the life cycle of the heartwater tick.[18] Once the technique of classification was mastered, it became possible to count ticks on individual cows and classify them according to sex and species.

Tick counting experiments commenced in October 1941. Detailed counts were made on 12 Afrikaner *(Bos indicus)* and 12 Aberdeen Angus, Hereford, Shorthorn and Sussex *(Bos taurus)* cattle. In 1942–1943 an additional group of cross-bred cattle was included. On each animal, 8 × 100 sq cm areas were marked off with

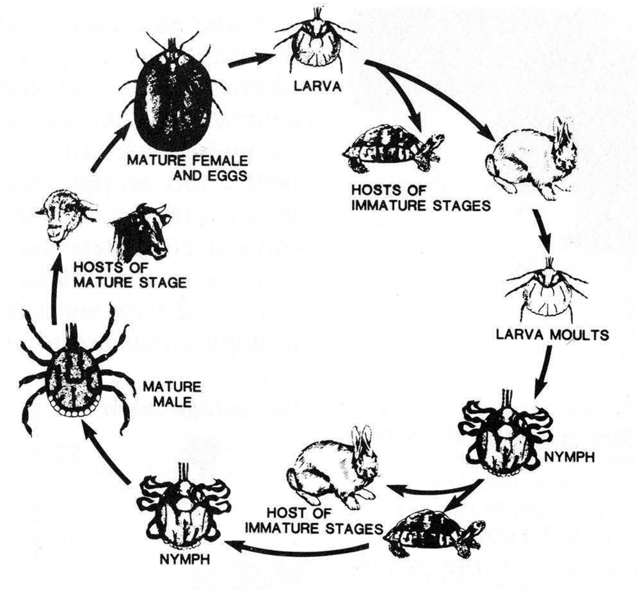


Fig. 1

Life cycle of the heartwater tick, *Amblyomma hebraeum* (18).

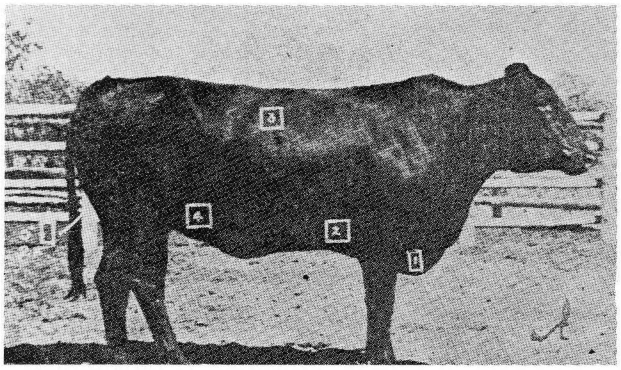


Fig. 2

For tick counts on cattle, 10 × 10 cm areas were marked out using a thick lime solution and all ticks within these areas counted.

a 10 × 10 cm wire frame dipped in a thick lime solution (Fig. 2). In addition, two areas were marked off on the escutcheon, and all ticks under the tail were also counted. Ticks were counted on both flanks because non-pregnant and early pregnant cows, bulls and steers have an 80 per cent preference for lying on their right side, while heavily pregnant cows have an approximately 70 per cent preference for lying on the left. I found a higher incidence of ticks on the side on which the cattle were lying.

All the cattle were run in the same paddock and were put through the plunge dip once per month immediately after the tick counts were made. All the ticks that were visible through a medical magnifying lens were removed and each area's ticks placed in separate bottles containing preservative. The dip was a 14 day arsenicum dip, and all the demarcated areas were erased after the animal had gone through the dip.

A monthly tick count was suitable because in heartwater ticks the larvae, nymphs and adults take 4–7 days, 4–20 days and 10–20 days respectively to engorge and to go through the various processes of metamorphosis. The different stages of development attach themselves to different host animals.

Female heartwater ticks on *Bos taurus* cattle usually engorge in about 10 days, and weigh about 3 g when they drop off in order to oviposit. Fully engorged females lay from 15 000 to 18 000 eggs (Fig. 3). Female ticks on *Bos indicus* take longer to engorge, approximately 20 days. They weigh about 1 g after engorgement and lay a third as many eggs as the ticks from *Bos taurus*. When making tick counts I found on every animal 3–5 times as many male ticks as female ticks. Although the sex ratio at hatching is 1 : 1, the males accumulate on cattle because they often remain attached for 60–90 days, while the engorged females drop off (Prof. G. B. Whitehead, personal communication, 1981).

During the period October 1941–September 1942 the total number of ticks counted on the 24 cattle was 14 867. Of this number 10 961 (74%) were on the exotic beef breeds, while 3 906 (26%) were on the Afrikaner cattle (Fig. 4). The proportion of ticks founds on the two types of cattle differed between summer and winter. During the summer months (January, February

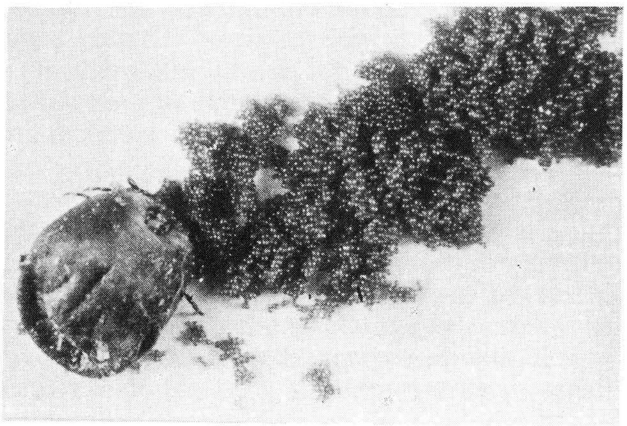


Fig. 3

Female heartwater ticks from *Bos taurus* cattle lay from 15 000 to 18 000 eggs.

and March) only 7,4% of the ticks counted were on Afrikaner cattle, while during the winter months (June, July and August) the proportion increased to 17%. The Afrikaner may be less susceptible to tick infestation in summer because its coat is shorter and smoother. The short hair and greasy coat afford little protection to the ticks which normally avoid exposure to direct solar radiation.

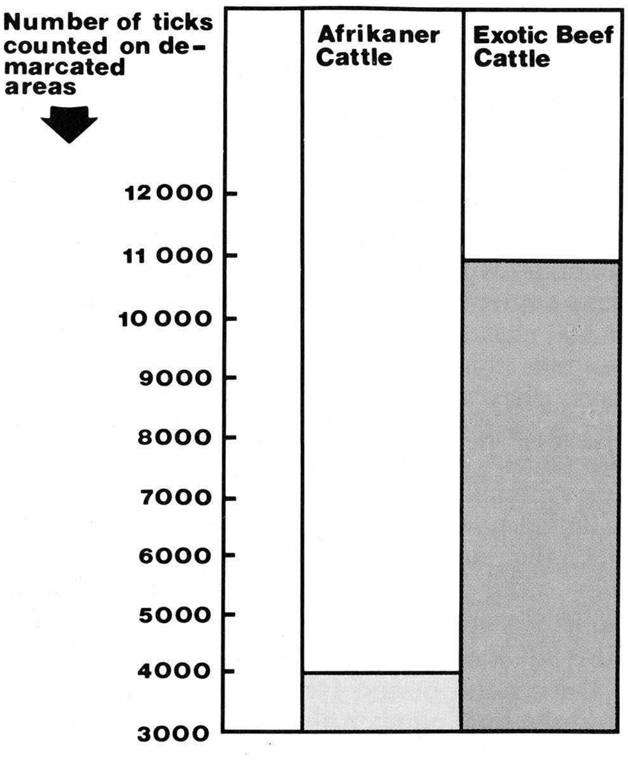


Fig. 4

Ratio between number of ticks on Afrikaner and exotic beef cattle. Tick counts were made on five demarcated areas of 200 sq. cm. each on 12 head of cattle of each of the different breeds for the period October 1941–September 1942: *Bos taurus* 10 961; *Bos indicus* 3 906.

It is interesting to compare the proportions of ticks on Afrikaner and exotic beef cattle (Fig. 4) with the rate of mortality due to heartwater in the same breeds, shown in Fig. 5. Moreover, when we look at the relative abundance of heartwater ticks on Afrikaner, cross-bred and exotic beef cattle (Fig. 6), it is apparent that the tick counts on the cross-bred cattle were smaller than on the British beef breeds. The histograms show a close relationship between the number of ticks on the different classes of cattle born at Mara and their mortality rate due to heartwater (compare Figs. 6 and 7).

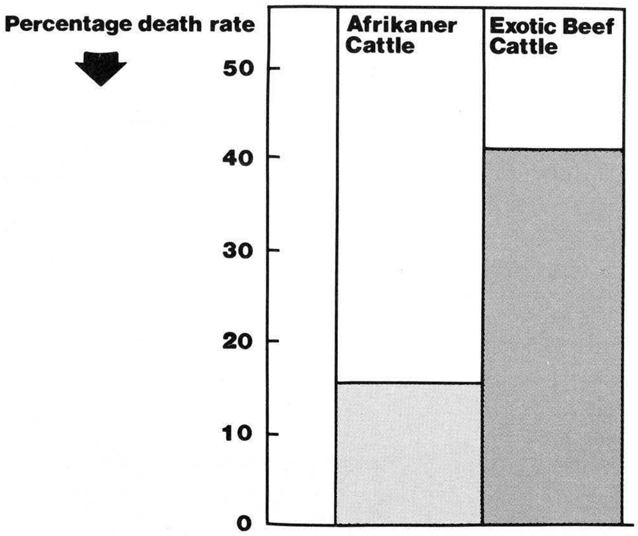


Fig. 5

Percentage death rate due to heartwater amongst cattle derived from non-heartwater areas.

For the total tick counts on the body, the proportions of the various kinds of ticks were as follows: 67 blue ticks to 3 heartwater ticks to 1 bont-legged tick. However, on the escutcheon the proportions were 6,4 blue ticks to 1,8 heartwater ticks to 1 bont-legged tick. The reason for this may be that heartwater ticks are less tolerant of exposure to sunlight, and also that they prefer to attach themselves to the host on areas where the skin is thinner. On the escutcheon where the skin is thin, 9,4 times as many blue ticks and 60 times as many heartwater ticks are found per unit of surface area as on other parts of the body where the average skin thickness is 40% greater. The relative proportions of ticks on Afrikaner, cross-bred and exotic beef cattle were the same for blue ticks (Fig. 8) as for heartwater ticks (Fig. 6). Bont-legged ticks were numerous only under the animals' tails, where they comprised 86% of the total count.

Skin characteristics

The correlation between mortality rates and tick counts brings us to the problem of the inheritance of characteristics in the external morphology of cattle which make them tick-repellent. In an effort to find out what makes cattle tick-repellent, tests were done on the hides of the cattle and also on the behaviour of the animals, and careful note was taken of the distribution of attached ticks on the body. Between 1937 and 1940 I took 14 body measurments every three months on all the cattle at Mara and Messina research stations, approximately 1 000 head, and thus came in very close contact with the cattle of all breeds and types within breeds. Hide thickness measurements, hair counts per square centimetere and felting tests on the hair gave a fair idea of how the hides and hair varied.

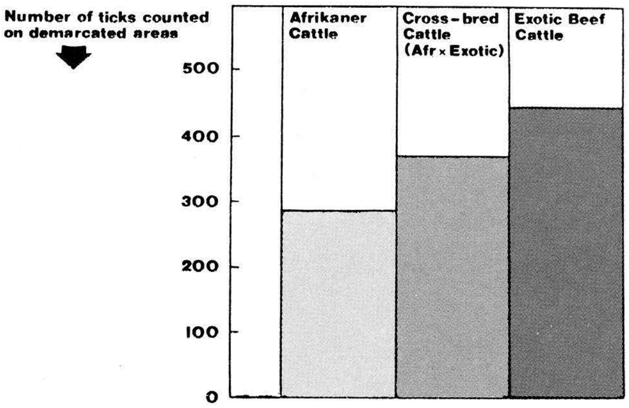


Fig. 6

Ratio between number of heartwater ticks (*Amblyomma hebraeum*) on Afrikaner, cross-bred and exotic beef cattle. Tick counts were made on eight demarcated areas of 200 cm^2 each on 12 head of cattle of the different groups for the period October 1942–September 1943.

The tick counts made during 1941–42 revealed that ticks prefer to attach themselves to those areas of the hide that are thin and not ex-

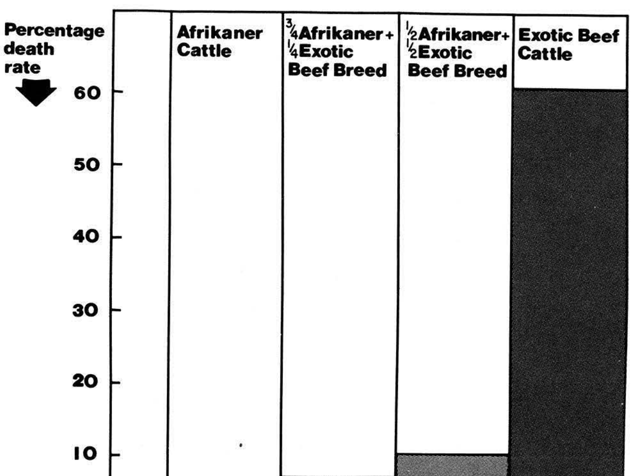


Fig. 7

Percentage death rate due to heartwater amongst cattle born at Mara.

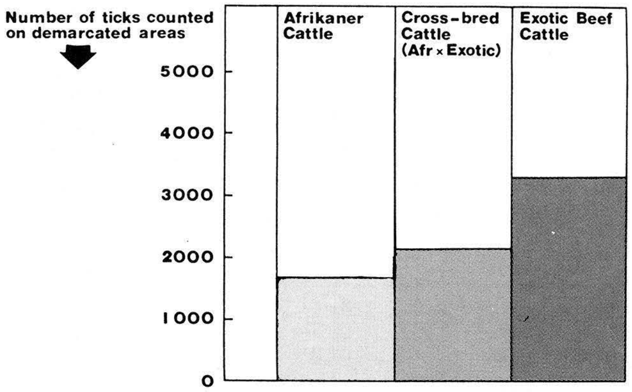


Fig. 8

Ratio between number of blue ticks (*Boophilus decoloratus*) on Afrikaner, cross-bred and exotic beef cattle. Tick counts were made on eight demarcated areas of 200 cm^2 each on 12 head of cattle of each of the different groups for the period October 1942–September 1943.

posed to direct radiation. The intensity of infestation by both blue ticks and heartwater ticks was greater on the escutcheon, where the hide is thin, than on the rest of the body (Fig. 9). Also, tick numbers on the general body surface were 7,5 times higher in the British beef breeds than in Afrikaner cattle, but on the escutcheon the ratio was more even, with the count on the exotic breeds being 2,9 times higher.

The ticks also preferred to attach themselves where the skin movement was less vigorous. Very few were attached to those areas of the body where the subcutaneous muscles are well-developed and flickering is intense at the slightest stimulus. In order to determine the sensitivity of the hide, I tickled the cattle with a culm of grass from which the seeds had been stripped. The thin point of the culm lightly touching the hide caused a very strong flickering of the hide in a tick-repellent animal.

This type of reaction is always found in cattle with thick hides, short, smooth coats and good subcutaneous muscle development. Figure 10 shows the prominent subcutaneous muscles in a tick-repellent animal. The panniculus carnosas is a large muscle extending from the neck to the buttock region. It is supplied by a nerve derived from the branchial plexus with motor fibres, and its sensory nerve supply is from the intercostal and interlumbar nerves. In the case of cattle which are not sensitive to tickling, it may be that those nerves are incompletely myelinated, with the result that the subcutaneous muscle contraction is diminished (Trevor-Jones, Dept. Anatomy, Witwatersrand Univ., pers. comm. 1981).

Another observation relevant to arthropod-repellency in cattle is the way some cattle stamp their feet at the slightest stimulus to the leg. For this reason I was unable to use a pedometer to

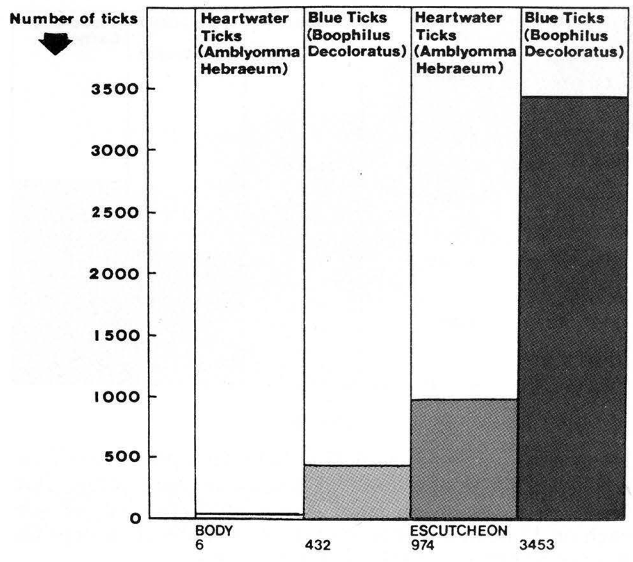


Fig. 9(a)

Relative intensity of tick infestation per unit area (200 cm^2) on the body and escutcheon (total of all three groups of cattle).

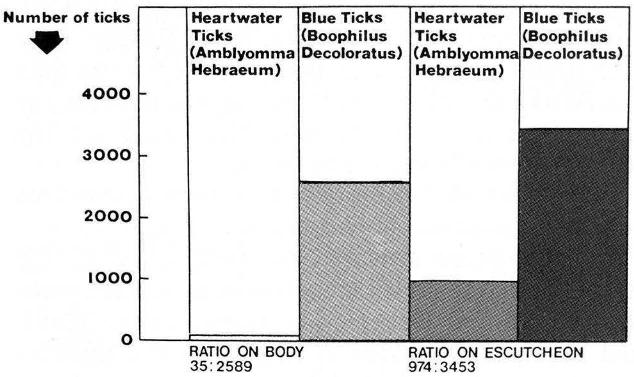


Fig. 9(b)

Ratio of heartwater ticks to blue ticks on the demarcated areas on the body and the escutcheon (total of all three groups of cattle).

measure the distance walked daily by N'guni and some Afrikaner cattle. The energetic stamping of their feet recorded extra steps on the pedometer attached to their front legs.

It is easy to select for hide thickness in cattle, even in young calves. When an animal is approached from the side and looks around, the slight bending of the body will show prominent skin folds, as in Figure 11. In some animals the vertical skin folds extend from behind the shoulder to the flank. A correlation coefficient of r = 0,866 was found between the number of vertical folds and skin thickness. Hide thickness has a direct effect on attachment by ticks. The average double skin thickness was measured for the cattle on which tick counts were made. Measurements were made on the same demarcated areas of the body, by means of a caliper slipping at a constant pressure. The average results for

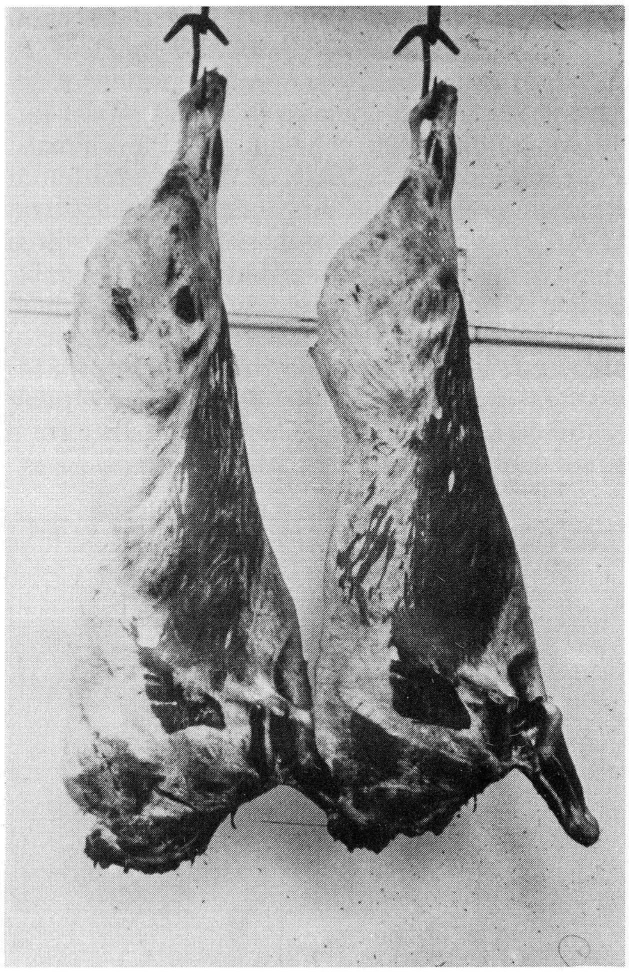


Fig. 10

The carcasses of two animals, one of an animal which is not tick-repellent (left), and one of a tick-repellent animal (right), showing muscles on the subcutaneous fat.

the 12 animals of each group are shown in Table 4. It is clear that the hides of the Afrikaner cattle were significantly thicker than those of the other groups.

Coat characteristics

Coat characteristics are inherited in cattle as dominant, hence *Bos indicus* × *Bos taurus* cross-bred cattle have thick hides with short,

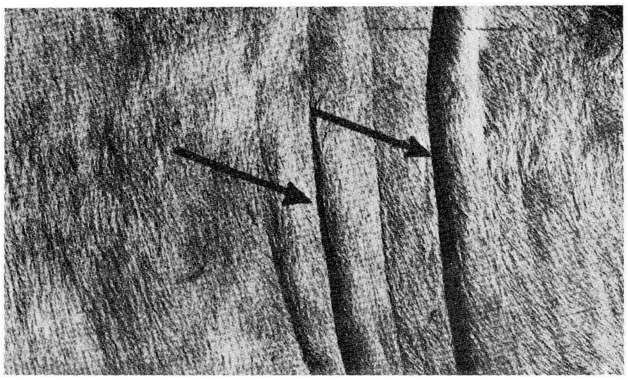


Fig. 11

The vertical skin folds of a calf with a very thick hide.

Table 4. Double skin thickness of cattle selected for tick counts

Breed of cattle	Double-skin thickness in millimetres on various parts							
							Averages	
	Brisket mm	Front rib below mm	Front rib upper mm	13th rib mm	Flank mm	Escutcheon mm	Thick-skinned areas mm	Thin-skinned areas mm
Afrikaner	6,87	6,76	11,00	12,30	12,80	7,81	12,03	7,15
Cross	5,21	6,07	11,50	10,70	10,60	6,99	10,93	6,09
Exotic	5,82	5,84	10,25	9,67	9,76	6,99	9,89	6,22
Averages	6,00	6,20	11,00	11,00	11,00	7,25	10,95	6,49

The differences in skin thicknesses between Afrikaners and exotic beef breeds and between the various areas, viz., thick skin and thin skin, are statistically significant, P being <0,01. The other differences are not.

glossy hair and well-developed subcutaneous muscles. These animals also have superior pilomotor activity facilitating erection of the hair over large areas of the body. The more greasy hair of adaptable cattle develops less static electricity when stroked and does not mat, so that penetration by parasites to the skin surface is more difficult. Far fewer ticks attach themselves on the hides of such adapted cattle, and those that do are seldom as fully engorged as those on woolly-coated cattle.

The type of coat of the various cattle breeds affects the quantity of dip which animals remove from the dipping tank. In the Mara experiment the cattle were put through the dipping tank after all visible ticks had been removed. In summer the Afrikaner cattle removed an average of 3,41 litres of dipping material per head from the tank, while the average quantity removed by the exotic beef breeds was 5,69 litres. In winter the figures for Afrikaners and exotic beef breeds were 3,78 and 6,83 litres respectively. The average weight of the animals was approximately the same, about 544 kg per animal. As discussed above, blue ticks are less discriminating than heartwater ticks in terms of skin thickness, a fair percentage of the blue ticks occurring where the hide is thick and the dipping material drains off rapidly. These ticks, therefore, may not be destroyed as easily as others attached to parts of the skin from which the dipping material drains more slowly, such as the escutcheon.

At the beginning of the tick-counting experiment I selected six Hereford cows and divided them into two groups, three that I thought would be low tick carriers and three that I thought would carry high numbers. The division was based primarily on skin and coat type, as these were thought to play an important part in the susceptibility to tick infestation. After selection according to external characteristics, detailed skin measurements were made on the six animals, and the results are given in Table 5.

Table 5. Skin thicknesses of six Hereford cows

A. High tick carriers (3 Hereford cows)

	Brisket mm	Front rib below mm	Front rib above mm	13th rib mm	Flank mm	Escutchoen mm
	4,50	5,20	7,55	7,45	9,00	6,70
	4,50	5,10	10,30	9,90	8,70	6,60
	5,90	5,35	10,70	8,15	9,15	6,40
Total	14,90	15,65	28,55	26,50	26,85	19,70
Averages	4,96	5,22	9,51	8,83	8,95	6,60

B. Low tick carriers (3 Hereford cows)

	mm	mm	mm	mm	mm	mm
	6,85	6,55	11,05	10,45	8,95	8,00
	8,75	7,55	12,65	10,35	12,10	8,90
	7,35	8,05	12,50	8,70	10,50	7,25
Total	22,95	22,15	36,20	29,50	31,55	24,15
Averages	7,65	7,38	12,06	9,83	10,52	8,05
Differences in averages between A and B	7,65	7,38	12,06	9,83	10,52	8,05
	4,96	5,22	9,51	8,83	8,95	6,60
	2,69	2,16	2,55	1,00	1,57	1,45

All differences greater than 0,65 are statistically highly significant, P<0,01.

In only two out of 18 skin measurements did animals in group A (high carriers) have a thicker skin than animals in group B (low carriers), and these two differences were not statistically significant. Those animals with thick, loose skins covered with a short, glossy coat were considered to be low tick carriers. At the end of the test period the average number of ticks on these animals was only 36 per cent of that on the high carriers. It is therefore possible, even in the case of exotic beef breeds, to select individual animals which will not be attacked readily by ticks. By selective breeding the proportion of such animals in a breed could be increased considerably.

The total tick population in the bushveld is smaller in winter than in summer, yet Afrikaner and cross-bred cattle carry more ticks in winter. The reason for this is that the animals' coats become much longer during winter and consequently offer more protection for ticks (Fig. 12). This finding makes one doubt the wisdom of the customary method of moving Afrikaner cattle from the Highveld to the bushveld during the winter months.

Even in summer the British breeds have longer coats than the winter coats of *Bos indicus* and cross-bred cattle. However, even within the

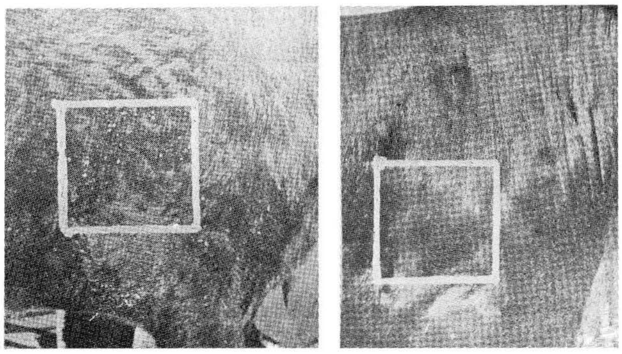


Fig. 12

Longer coats offer more protection for ticks. On the woolly-coated animal (left) 203 ticks were counted in the demarcated area, while on the smooth-coated animal (right) there were only 14 small ticks in the same area. Both photographs were taken in winter.

British breeds it is easy to select livestock for smooth coats. Calves born with long, straight, medullated hair containing a low percentage of non-medullated inner coat will become smooth-coated in the first spring after birth (Fig. 13). These cattle are usually early hair shedders in spring. Using these principles I was able to breed a smooth-coated Hereford herd at Mara, and as a result the mortality rate of the Herefords from all causes was reduced from 34 per cent in the late 1940s to 14 per cent in the late 1950s.

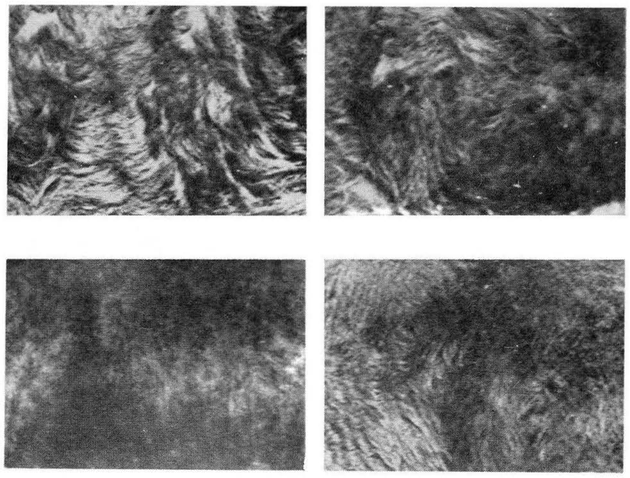


Fig. 13

Upper left: long straight hair of a 3-day-old Hereford calf. This hair does not possess felting qualities. *Lower left:* the hide and hair of the same animal at maturity. She is smooth-coated.

Upper right: another 3-day-old Hereford calf with fairly short hair that is non-medullated and felts. *Lower right:* the woolly coat of the same animal when full-grown.

During the period 1938–1949 a large amount of data were collected on the climatological reactions of cattle of different breeds and types within breeds. It became apparent that smooth-coated cattle succeeded much better than woolly-coated cattle within the same breed in maintaining body temperature. The data on the mortality rates of these large herds at the research stations also revealed that the highest mortality rates were among the woolly-coated cattle and among the *Bos taurus* breeds.

Those woolly-coated animals which were unable to dissipate excess metabolic heat on very hot days (> 29 °C) became hyperthermic and were often in a state of stress. Their body temperatures rose to as high as 40,0 °–41,1 °C, and they salivated profusely. Stressed animals are prone to stand or lie in the shade of trees, where the grass is usually tall and the ground moist, resulting in a much higher incidence of ticks than in the open. The fact that Afrikaner and cross-bred cattle are less likely to lie in the shade of trees reduces their susceptibility to tick infestation.

Criteria used in breeding tick-repellent cattle

Since the tick-count work at the Mara Research Station in 1940–43, all cattle breeding, which ultimately resulted in the Bonsmara breed, included selecting for tick-repellent cattle. For example, all the bulls of the British beef breeds used in the stages to breed Bonsmaras were selected for their smooth coats and thick hides. By selecting tick-repellent cattle, we were also selecting animals with a high degree of hardiness to tropical and subtropical conditions, and the mortality rate under ranching conditions was greatly lowered.

The following criteria were adopted in the breeding of tick-repellent cattle:

1. Breed for adaptability with regard to tropical and subtropical climates where heat tolerance is important. The adaptable animal is not in a state of stress on hot days and will not spend much time in the shade. Cattle heavily infested with ticks are under additional stress and may die as a result of tick toxicosis.

2. Select cattle with thick hides and smooth coats. The reasons for this have been discussed fully above. Smooth-coated animals with thick hides also have more vascular hides which freely admit exudation and clotting at the site of insect and tick bites. This reduces the ability of parasites to attack the skin effectively, and few of these cattle develop tick-bite abscesses, for which treatment is costly. It also costs less to dip smooth-coated cattle, because of the smaller volume of dip carried on the hair.

3. Coat colour is also important in breeding livestock to be tick- and fly-repellent. Black coloration in cattle is a distinct disadvantage in areas of the humid subtropics where ura-flies (*Hypoderma* spp.) prevail. These flies are very similar to the warble flies of cold temperate zones, but

much more ferocious. The females lay their eggs singly on hairs, chiefly about the mid-rib region, and the larvae hatch in 4–5 days. *Hypoderma* infestations in cattle cause occasional deaths due to anaphylactic shock, damage to the central nervous system, and the migrating larvae cause severe damage to the most valuable portion of the hides. In the case of Friesland cattle, ticks also prefer to attach themselves to the black portion of the hide (see Fig. 14). Ticks and stinging flies are probably attracted to black cattle because the hide temperature is higher and perhaps because of differences in light reflection.

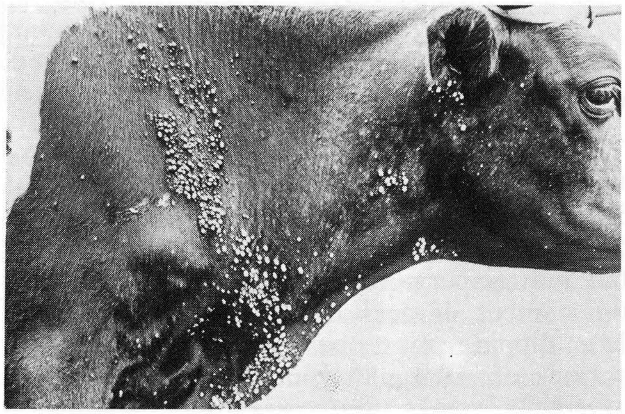


Fig. 14

Large numbers of ticks attached to the black part of the hide of a Friesland cow.

4. Tail flicking is an additional factor which became apparent from taking 14 body measurements on approximately 1 000 head of cattle every three months. It was found that the *Bos indicus* types of cattle flick their tails faster and with more force, and at a lower threshold stimulus, than do the *Bos taurus* types of cattle. The tip of the tail switch hair is also much sharper in *Bos indicus* cattle, so that while measuring cattle it hurts to be struck by a fast flick of the tail, especially that of an N'guni. The terminal 20–25 cm of the tail in *Bos indicus* cattle, particularly the lighter-coloured ones, is devoid of the small, thin caudal vertebrae. The resulting increased flexibility of the tail is important in flicking off insects in the region of the thigh. The tail's reaction in cattle is a very complex process and a speculative assumption is that certain animals lack myelination of the lower caudal nerves. The myelin sheath around nerves results in a swift response of the innervated muscles upon stimulus. Much research work remains to be done on the function of the tails of cattle. For example, a thermoregulatory function has been suggested (P. Wright, Department of General Physiology, University of the Witwatersrand, pers. comm.).

Comparison with other research

My 1944 paper, "Hereditary heartwater-resistant characters in cattle"[19] was severely criticised by Neitz and Alexander, Section of Protozoology and Virus Diseases, Onderstepoort, in a paper called "Immunisation of cattle against heartwater and the control of the tick-borne diseases redwater, gallsickness and heartwater"[20] who wrote:

> "Had the work and the article been confined to an investigation of the tick-repellent characteristics of either breeds of cattle or individuals of different breeds, adequate recognition could have been accorded a valuable contribution. Unfortunately the author digressed to a dissertation on immunity unsupported by adequate data or based upon incomplete observation. But it is quite certain that relative insusceptibility to tick infestation is correlated in no way with immunity to disease, and it must be fully appreciated that if a single tick sets up infection in a susceptible animal the resulting disease may be no less severe than that produced by the simultaneous feeding of ticks."

With regard to infection set up by a single tick, a knowledge of statistics made me aware that the probability of infection by heartwater ticks is much greater if 100 ticks are attached to an animal instead of 10. The following statement in the paper by Neitz and Alexander demonstrates that all their conclusions with regard to heartwater susceptibility were obtained in the laboratory by the injection of heartwater blood in cattle: "Immunisation of a mixed group of purebred Afrikaner cattle showed that the Afrikaner is no more resistant to heartwater than the Aberdeen Angus or Hereford." Table 6 shows that this is quite untrue under natural conditions. When the calf crop and mortality figures for Ranch B (Roodekuil Estates) and Mara are compared, we see a much higher percentage calf crop and a much lower mortality among the adapted cattle types at Mara.

Unfortunately not one of the South African or Australian papers written from 1944 until 1980 has added a single selection criterion on how to breed tick-repellent cattle. In connection with the chemical control of ticks, in a recent Australian paper[22] it is claimed that cattle of *Bos indicus* origin have a greater natural resistance against tick infestation than cattle of *Bos taurus* origin, and that selection on these grounds could bring about a tremendous saving in dipping costs. The concept of breeding cattle to be tick-repellent did not originate in Australia, but very definitely in South Africa. The first Austra-

Table 6. Calving percentages and mortality rates on cattle ranches in the Northern Transvaal and Zimbabwe

Ranch	Locality	Altitude metres	Average annual temperature °C	Average rainfall mm	Breed of cattle	Average no. of breeding cows	Average % calf crop	Average mortality %
A	Long. E 26°53′ Lat. S 24°21′	853	21,0	648	Herefords	1 477 for 22 yrs	39	18
B	Long. E 28°21′	1 110	19,0	964	Aberdeen Angus	3 143 for 5 yrs	56	23
C	Long. E 29°45′ Lat. S 20°45′	1 345	18,3	984	Sussex	17 400 for 20 yrs	55	14
Mara	Long. E 29°34′ Lat. S 23°09′	914	19,5	642	Adaptable types	416 for 6 yrs	83,5	10,6

Data from Bonsma *et al.*[21]

lian to do research on breeding livestock to be tick-repellent was G. W. Seifert, who was a student in my classes at the University of Pretoria during the late fifties and early sixties.

The Australian method of measuring tick-repellency is to put a collar containing 20 000 tick larvae around the neck of an animal, then to count the number of ticks remaining on the animal after a certain period. I do not believe this to be an accurate index of an animal's tick-repellency under natural conditions. At the start of their life cycles ticks do not attach themselves to the necks of cattle. Moreoever, the subcutaneous muscles on the neck are not well developed, and hence very little flickering takes place upon irritation. More importantly, the technique puts the tick-repellent animal at a disadvantage relative to other animals, because the resistant animal is seldom stressed by high temperatures and does not lie in the shade where tick numbers are high. Furthermore, the efficient flickering of the thick vascular hide, fast flicking of the tail and stamping of the legs make it so much more difficult for ticks to attach themselves to the highly adaptable, tick-repellent animal.

In spite of these factors, the tick-repellency work in Australia indicates that there are substantial differences in the number of ticks that become attached to cattle after they have been infected with 20 000 larvae. The less resistant animals have 15 per cent of the original number of ticks, i.e. 3 000 ticks, while the tick-repellent cattle have only 2 per cent of the original number, i.e. 400 ticks. If one assumes that approximately 20 per cent of these ticks are females, there will be 600 fully-engorged females on the non-repellent animal, and these ticks are capable of laying 10 million eggs.[18] This is a far greater quantity than the eggs laid by the 80 relatively small female ticks on the tick-repellent animal.

Conclusions

There is only one efficient way to reduce the tick populations in the tick-infested areas of South Africa. That is to breed tick-repellent cattle and to dip these cattle regularly. As rainfall and temperature have a direct influence on the number of ticks in the environment (Fig. 15), dipping must be done weekly during periods of intense tick infestations, which are usually 2–3 weeks after good rains in summer.

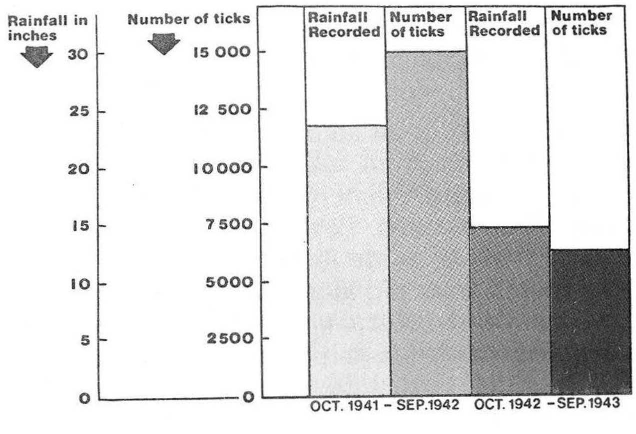


Fig. 15

The ratio between the amount of rainfall recorded and the number of ticks counted on 24 head of cattle (12 Afrikaner and 12 exotic beef cattle).

Every aspect of the breeding of Bonsmara cattle[23] was based on the concept "Man must measure". The measurement of adaptability was based on all the available data recorded on the foundation animals: body temperatures, respiration and pulse rates, tick counts, hide thickness, hair counts and the most composite measurement for adaptability, namely Average Daily Gain (A.D.G.), fertility, milk production, low mortality and ultimately longevity. This breeding policy has been adopted since the early forties.

To this day every Bonsmara breeder is encouraged to do tick counts on his stud bulls. Unfortunately many feel it is too time-consuming to do tick counts on 2×100 cm^2 areas, one on the escutcheon and one on the dewlap. If breeders do not do tick counts on their cattle, my advice to them is to inspect their cattle carefully on dipping days and cull the 10 per cent of animals carrying the most ticks. These cattle usually carry more than half the total number of ticks in the herd. By adopting this selection method it will be possible for breeders in South Africa's ranching areas to greatly reduce the numbers of ticks on their adaptable cattle. It is the only logical method of reducing the tick population cheaply and effectively in time to come, especially the three-host ticks like the heartwater tick.

In my opinion, the heartwater immunisation work and the tremendous publicity it was given retarded a proper breeding policy for the semi-arid subtropical ranching areas by many years. It must be remembered that immunisation of cattle may make them immune to heartwater, but does not make them adaptable to the subtropical and tropical ranching areas of South Africa. The result of the immunisation campaign was that many ranchers persisted in breeding *Bos taurus* cattle in areas to which they were not adapted. Immunisation also does not prevent cattle from dying as a result of tick toxicosis.[24] Nor does immunisation or therapeutic treatment of an unadapted animal make such an animal productive and functionally efficient in the tropics and subtropics.

It is also a great pity that the extension service of the Department of Agriculture never propagated the concept of breeding tick-repellent cattle. The only breeders who really endeavoured to breed adaptable tick-repellent cattle under my guidance were the Bonsmara breeders. As a result the mortality rate of Bonsmara cattle in the ranching areas has steadily decreased and is now even lower than that of the pure-bred Afrikaners.

Adaptable, tick-repellent cattle will not only reduce the tick population in an area, but are also a much better economic proposition than heartwater-immunised cattle. They grow better, have a higher calving percentage, are bred for functional efficiency and finally they carry much less dip out of the dipping tank. Unfortunately all the climatological, ecological and breeding for adaptability research work done by my associates and myself during the period 1937–1960 was abandoned when I left the Mara and Messina research stations in 1960.

Literature cited

1. Lambert, W. V. 1932. *J. Immunol.* 23: 229–260
2. Hutt, F. B., Cole, R. K. & Bruckner, J. H. 1941. *Poultry Sci.* 20: 463
3. Gowen, J. W. & Schott, R. 1933. *Am. J. Hyg.* 18: 688–694
4. Cameron, H. S. *et al.* 1942. *Oklahoma Expt Sta. Bull.* 255: 1–30
5. Lambert, W. V. *et al.* 1939. *J. Hered.* 30: 349
6. Cameron, W. J. M. 1935. *Proc. Int. Vet. Congr.* N.Y. 3: 44
7. Otto, J. 1935. *Parasitol.* 21: 443
8. Boyed, M. F. & South, M. J. 1934. *J. Immunol.* 277: 155
9. Yakimoff, W. L. 1937. *Berl. Tierӓztl. Wochr.* 37: 563–566
10. Kelly, R. B. 1932. *Prog. Rep. Coun. Sci. Indust. Res. Aust.* No. 1, pp. 33
11. Zuravok, J. S. 1939. *Dokl. Akad. Seljskohoz Nauk.* 20: 30–35
12. Curson, H. H. 1936. *Fmg S. Afr.* 11: 467
13. Ehrlich, P. 1892. *Z. Hyg. Infektionkrank.* 12: 183
14. Hochfeld, M. 1907. *Arch. Kinderheik.* 46: 161–227
15. Famulener, L. W. J. 1912. *Infect. Dis.* 10: 332–368
16. Little, R. B. & Orcutt, M. L. 1922. *J. exp. Med.* 35: 160–171
17. Smith, T. & Little, R. B. 1924. *J. exp. Med.* 39: 303
18. Norval, R. A. I. 1974. *J. Ent. Soc. S. Afr.* 37: 357–367
19. Bonsma, J. C. 1944. *Fmg S. Afr.* 19: 71–92
20. Neitz, W. O. & Alexander, R. A. 1945. *Onderstepoort J. Vet. Sci. Anim. Ind.* 20: 137
21. Bonsma, J. C., van Marle, J. & Hofmeyr, J. 1953. *Empire J. Exp. Agric.* 21: 154–175
22. Utech, K. B. W., Whatron, R. H. & Kerr, J. D. 1978. *Aust. J. Agric. Res.* 29: 885
23. Bonsma, Jan 1980. *Livestock Production: A Global Approach.* Cape Town, Tafelberg Publishers pp. 201
24. Thomas, A. D. & Neitz, W. O. 1958. *Jl S. Afr. vet. Med. Ass.* 29: 39

J. C. Bonsma, J. F. G. Badenhorst and J. D. Skinner

The Incidence of foetal Dwarfism in Shorthorn Cattle in the Subtropics

South African Journal of Animal Science, 2

The phenomenon of offspring of reduced birthweight has been referred to previously in British beef breeds in the subtropics (Bonsma, 1949), and has been reported in Angora goats in the subtropics (Skinner, Van Rensburg & Badenhorst, 1971) and in sheep following heat stress (Yeates, 1958; Shelton, 1964). The object of the present note is to report on the incidence of foetal dwarfism in a Shorthorn herd imported from the temperate regions of Southern Africa to a subtropical region.

Procedure

The data presented are from the routine records kept at the Messina Research Station in the subtropical bushveld of the Northern Transvaal. Complete details of the climate are given by Bonsma, Van Marle & Hofmeyr (1953).

In 1949 a herd of 30 two-year-old Shorthorn heifers was imported from the Eastern Cape Province which is a temperate region where the breed thrives. During their active lifetime at Messina, 15 of these 30 cows produced a total of 41 calves. The other 15 cows did not produce any calves. The overall calving percentage was 43,6 per cent.

Results

At Messina normal ranching procedure involves the practice of two mating seasons per year, viz. an autumn mating season (March to April), followed by winter pregnancy and summer calving season (December to January), and a spring mating season (August to September), followed by summer pregnancy and winter calving season (June to July). The birthweights for 30 calves are given in Table 1 together with some gestation periods, i.e. where mating was observed. Comparative figures are supplied from Dohne Research Station in the temperate Eastern Cape Province. Over a period of 15 years seven abnormally small Shorthorn calves have been recorded at Dohne with a mean weight of 17,3 kg (range 13,6–20,4 kg); this is an incidence of 3,7 per cent.

In the Messina herd all calves with a birthweight lower than 18 kg, of which there were six, were classified as dwarfs; an incidence of 33,3 per cent. Of these only one was born following a winter gestation period; incidentally the heaviest dwarf weighed 16,4 kg. Five of the 15 calves born following summer gestation periods were miniatures. The incidence of calves under 22,75 kg, the figure given by Bonsma (1949) as indicating reduced birthweight as a result of climatic stress, was 50 per cent. Again, only one such calf (that of 16,4 kg) was born following a winter gestation period. No cross-bred calves fell within this category, but there were too few calves born following a summer gestation period to draw definite conclusions.

Six calves less than 19 kg were born following a gestation period which extended from September 1953 to June 1954. Temperatures during this period are illustrated in Table 2. This is typical of the temperature pattern at Messina and, as it is an arid area, it is improbable in this instance that relative humidity played a significant role. Temperatures at Dohne are much lower and, although not available for the dwarf gestations, the means only exceed 28 °C in January (28,5) and February (28,7).

No data were collected on embryo resorption or foetal wastage. In the pregnancies recorded the foetus was carried to term and it would seem that after implantation between day 11 to 40 (McLean, 1962), the foetus was affected by the high environmental temperature from October to March. It is also of interest that gestation length was 12 days longer in the subtropics than in the temperate region, as demonstrated by the data in Table 1.

In the case of winter calves, monthly weight records are available for one calf with a birthweight of 9,5 kg which had an average daily gain (ADG) to 200 days of 0,2 kg, for two calves with a birthweight of 22,3 kg ADG to 200 days of 0,2 kg and for four calves of birthweight 27,3 kg ADG to 200 days of 0,3 kg. Unfortunately when they were weaned and deprived of maternal care and nutrition the calves soon died. In contrast, the seven dwarfs in the Eastern Cape had an ADG of 0,6 kg (range 0,5 to 0,9 kg) to 200 days and none died.

Discussion

There are a number of interesting facts arising from this study. Maximum temperatures were apparently not sufficient to cause embryonic loss

Table 1. Comparison of birthweights and gestation lengths of Shorthorn and Shorthorn × Afrikaner calves at Messina Research Station in the subtropics and Dohne Research Station in a temperate region

Breed	Born in	Sex	No.	Birthweight ± ± S.E. (kg)	Range (kg)	No.	Gestation length ± S.E. (days)	Range (days)
Shorthorns at Messina	Winter	Male	9	18,4 ± 2,9	9,5–27,3	6	289,6 ± 1,9	286 – 199
		Female	6	20,3 ± 10,8	9,5–27,3	2	295,5	281 & 301
	Summer	Male	1	22,7		—	—	—
		Female	4	22,8 ± 2,7	16,4–25,0	—	—	—
Messina All Shorthorns			20	20,1 ± 3,2	9,5–27,3	8	290,0 ± 1,9	281–301
Shorthorns at Dohne*	Autumn	Male	23	31,9 ± 0,7				
		Female	22	30,4 ± 0,7				
	Spring	Male	66	30,6 ± 0,5				
		Female	74	29,4 ± 0,4				
All Dohne Shorthorns			185	30,0 ± 0,4	—	121	278,9 ± 1,0	277–286
$\frac{1}{2}$-Shorthorn $\frac{1}{2}$-Afrikaner at Messina	Winter	Male	1	20,4	20,4	—	—	—
		Female	3	28,8 ± 3,1	22,7 – 31,8	2	297	293 & 301
	Summer	Male	2	29,5	25,0 & 34,1	—	—	—
		Female	2	27,3	25,0 & 29,5	2	292	283 & 301
$\frac{3}{4}$-Shorthorn: $\frac{1}{4}$-Afrikaner	Summer	Female	2	26,1	25,0 & 27,3	1	288	288
Messina All crosses			10	27,3 ± 2,6	20,4–34,1	5	293,2 ± 2,5	283–301

* Data provided by E.J.B. Bishop

Table 2. Mean maximum temperature °C and highest maximum temperature recorded during gestation at Messina from September 1953 to June 1954

	Month											
	VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII
Mean maximum	26,6	27,3	31,8	31,4	31,8	30,7	31,8	31,1	29,5	28,9	23,5	23,0
Absolute maximum	34,5	39,5	37,2	38,2	37,8	37,4	37,7	37,7	34,8	29,6	29,6	29,8

after implantation had taken place. The Shorthorn cow, unadapted to a tropical environment, was markedly influenced by temperatures above 31,0 °C. It is difficult in retrospect to decide precisely when foetal development is affected or the reasons for this effect. In the ewe the effects of high temperature seem to be quantitative (Shelton & Huston, 1968). Under normal conditions, as is also illustrated in the weights from the Dohne calves, males are heavier at birth than females. In the Messina Shorthorns, however, bull calves were lighter than heifers at birth. The reason for this may be due to a higher metabolic rate of the male foetus, although this has never been demonstrated experimentally, which in turn may impose a greater temperature stress on the cow with a low heat tolerance when she is pregnant in summer.

There is a strong possibility that the adrenal is also implicated although no weights were recorded or adrenal hormone levels measured in this study. It has been shown, for example, that the foetal adrenal is strongly implicated in terminating gestation (Van Rensburg, 1967; Liggins 1968, 1969). Gestation length was, moreover, considerably longer in the Messina calves suggesting the possibility of some form of adrenal malfunction. Yeates (1958), found that the adrenals from heat-stressed lambs were heavier than controls and also suspected they may be implicated. On the other hand, Shelton & Huston (1968) found that in the heat-stressed ewe, gestation length is reduced considerably. This may indicate a difference in the reaction of different species to heat stress. Moreover, in the sheep the nutritional level did not appear to be of any importance. The Shorthorn in the present study were grazing in paddocks and estimates of their nutrient intake were not made, but they have been found to exhibit a marked voluntary anorexia (Bonsma & Louw, 1966). Reference has been made on occasion in the popular farming press to the results reported here, and in a review (Bonsma & Louw, 1966). A detailed report however, was considered necessary because of the increasing interest in the effects of climate on animal production. Not only do these results emphasise how unwise it can be to introduce unadapted farm animals into areas for which they are unsuited, but also that we are still unaware of the fundamental reasons for foetal dwarfing. In this regard there is a need for more detailed research into the mechanisms involved.

Acknowledgement

We would like to thank Mr. E. J. B. Bishop of the Department of Animal Science, University of Fort Hare, Cape Province for kindly supplying the data on the Shorthorn from Dohne Research Station.

References

Bonsma, J. C., 1949. *J. agric. Sci.* Camb. 39, 204

Bonsma, J. C. & Louw, G. N., 1966. *Proc. IIIrd int. Biomet. Congr.* Pau, France. pp. 371–382

Bonsma, J. C., van Marle, J. & Hofmeyr, J. H., 1953. *Empire J. exp. Agric.* 21, 154

Liggins, G. C., 1968. *J. Endocr.* 42, 323

Liggins, G. C., 1969. *J. Endocr.* 45, 513

McLaren, A., 1962. Fertilisation, cleavage and implantation, Ch. 7 in *Reproduction in Farm Animals* ed. E. S. E. Hafez Lea & Febiger: Philadelphia

Shelton, M., 1964. *J. Anim. Sci.* 23, 360

Shelton, M. & Huston, J. E., 1968. *J. Anim. Sci.* 27, 153

Skinner, J. D., van Rensburg, S. J. & Badenhorst, J. F. G., 1971. *S. Afr. J. Anim. Sci.* 1, 69

Van Rensburg, S. J., 1967. *J. Endocr.* 38, 83

Yeates, N. T. M., 1958. *J. agric. Sci.* Camb. 51, 84