WORTHAM LECTURES

IN ANIMAL SCIENCE

JAN C. BONSMA

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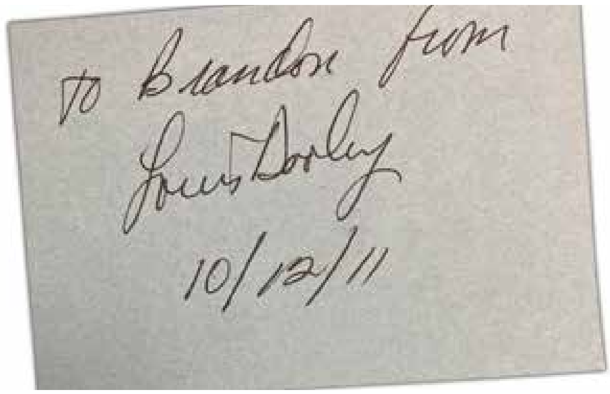
"Man Must Measure"

-Jan C. Bonsma



Nearly ten years ago, my husband Brandon Cutrer was in his early twenties, and a fellow Brahman breeder - Louis Dooley of Louisiana - recognized a spark in Brandon. A spark for breed improvement, and performance programs. Mr. Dooley mentioned to Brandon a rare book that he thought Brandon would really enjoy, but that the book was really hard to find. That book was The Wortham Lectures in Animal Science, published in 1965. Mr. Dooley cared so much about helping nurture this young breeder's passion that he went out and found a copy, and gave it to Brandon in 2011. Brandon and I both read it, and though the data is quite old, it truly opened our eyes about a lot of traits and philosophies in breeding and fertility. Dr. Bonsma's research helped us make huge improvements in our own cattle over a ten year period.

Through the years, we talk about Dr. Bonsma's work quite a lot, and I found many other breeders enjoy this old publication. So, in 2020, we began working on the reprint. We were able to speak with The Wortham Foundation to obtain approval, and they too were so happy that the work would continue to be published and continue to impact and help cattle producers more than 50 years since it was originally published. So, using my graphic design skills, I re-typed the booklet, and re-created the graphics from the original Xerox copy of the booklet we have. Now, this work can be fully preserved digitally for all others to enjoy. We are pleased to share this booklet with any breeders as a gift - because that's what Mr. Dooley did for us back in 2011 - and it changed our program.

Freely you have received; freely give. - Matthew 10:8

Best wishes for your success in the cattle business! -Rachel and Brandon Cutrer, B.R. Cutrer, Inc.

The Wortham Foundation

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2020 Reprint of he Wortham Lectures in Animal Science financed and produced by B.R. Cutrer, Inc., Brandon and Rachel Cutrer, Boling, Texas, 2020.

THE WORTHAM FOUNDATION

Mr. and Mrs. Gus Wortham established The Wortham Foundation in I960. The Foundation is authorized to carry on educational, experimental, research, religious and charitable activities. Several educational grants and gifts support the United Fund, the Houston Symphony Society and The Houston Museum of Fine Am have been made. Sterling C. Evans is trustee of the Foundation; Gus Wortham, Lyndall F. Wortham, £. R. Barrow and Allen H. Çarruth are advisory trustees.

Mr. Wortham's long-time interest in farming and ranching prompted The Foundation to sponsor The Wortham Research Laboratory which has projects underway studying beef cattle fertility. Dr. R O. Berry, one of the foremost scientists in this field, heads this project. Dr. Berry had a long and outstanding career at Texas A&M University and still serves as professor emeritus.

The facilities' of Nine Bar Ranch at Cypress, Texas, operated by Mr. Wortham and Mr. Evans, are available for the use of Dr. Berry's laboratory. The ranch has more than 600 breeding cows which are being used in the research programs. While the animals involved are of the Santa Gertrudís breed, Dr. Berry works on cattle, regardless of breed.

The Wortham Foundation, through The Wortham Research. Laboratory, sponsors a Fertility Symposium every September at the Nine Bar Ranch. The Symposium strives to bring together the most advanced ideas and the most learned individuals in the field of reproduction anywhere in the world. Internationally known speakers from England, the Republic of South Africa and Holland have been featured on these symposiums, which began in 1961.

The Wortham Foundation, with a grant in aid to the Department of Animal Science made it possible for Professor Jan C. Bonsma to spend ten months lecturing and writing at Texas A&M University as a visiting professor. The financial assistance needed to publish these lectures was furnished by the Foundation.

PREFACE

Professor Jan Bonsma is known internationally for his knowledge of livestock, ecology. During his recent year as a visiting professor on our staff he impressed cattlemen most with his visual appraisal of cattle for functional efficiency. In his many public appearances before a total audience of more than 12,000 cattlemen, he dared to estimate the previous, calving record of approximately 1,000 cows. His high degree of accuracy in making these estimates convinced most of the observers that animals with low fertility could be identified visually. Toward the close of his year here, it was necessary to restrict attendance at his demonstrations to prevent overcrowding available facilities. He certainly appealed to Texas cattlemen!

Professor Bonsma is a scholar and a philosopher. His under graduate training in South Africa was augmented by graduate training at Iowa State University under the close supervision of Dr. J. L· Lush. Professor Bonsma has traveled extensively throughout the world observing ecology and productivity of cattle. He was a guest lecturer at the King Ranch Centennial in I953.

The Texas Agricultural Extension Service through its county agricultural agents organized and conducted many of the demonstrations where Texas cattlemen were taught the principles of judging cattle for functional efficiency. Beef cattle producers who provided demonstration animals, breed associations, other organizations of cattlemen and all segments of the agricultural press helped to make Professor Bonsma's term as visiting professor a success.

College Station, Texas

October 1965

O. D Butler

LIST OF ILLUSTRATIONS

A Personal Approach to Student Training

"I do not know that I could make entirely clear to an outsider the pleasure I have in teaching. I had rather make my living by teaching than in any other way. In my mind teaching is not merely a life's work, a profession, an occupation and struggle: It is a passion. I love to teach, as a painter loves to paint, as a musician loves to play, as a singer loves to sing, as a strong man rejoices to run a race. Teaching is an art — an art so great and so difficult to master that a man or woman can spend a long life without realizing much more than its limitations and mistakes, and his distance from the ideal.

-Billy Phelps

Yale University

It is important for me as a guest professor at this institution to indicate to you how I feel about student training.

The teaching and educating of students have intrigued me since my earliest childhood, since I am the son of an educator and come from a family where for three generations one side of my family were university professors in the Republic of South Africa or in Holland. The other half of my pedigree stems from cattle farmers. It is clear that higher education and especially higher education in animal production, is something sacred to me.

When I was 10 years old, my father asked me to give a lesson to the sophomore class at the teachers training college in Heidelberg. I had to teach them what I knew about silkworms. I took my illustration material, worms, moths, eggs and cocoons to the class where I was to lecture. The lecture had to be prepared by reading a book on silkworms.

This lesson was given by a child, to adults, and I thought no more of this incident until many years later. Then I asked my father why I had to give that lesson to his students. His reply was: "I wanted to teach those budding teachers two things: first, you cannot bluff students even if they are children, many of the pupils may know more about a subject than you, the teacher, so never try to bluff them by pretending you know more than you actually do. Second, you must always prepare your lessons or lectures so that you know your facts about a chosen subject or area of study. You have to know your facts if you want to train students."

I learned at a young age to have a wholesome respect for young people and students. The great American, philosopher, Elbert Hubbard, put this so beautifully:

> I have a profound respect for boys; grimy, ragged, tousled boys in the street often attract me strangely. A boy is a man in the cocoon; you do not know what it is going to become, his life is big with many possibilities. He may make or unmake kings, change boundary lines between states, write books that will mold characters or invent machines that will revolutionize the commerce of the world. Every man was once a boy. I trust I shall not be contradicted; it is really so.
>
> Very distinctly and vividly I remember a slim, freckled boy who was born in the. 'Patch', and used to pick up coal along the rail-tracks in Buffalo. A few months ago I had a motion to make before the Supreme Court and that boy of the 'Patch' was the judge who wrote the opinion granting my petition.
>
> Yesterday I rode on horseback past a field where a boy was plowing. The lad's hair stuck out through the top of his hat, his form was bony and awkward, one suspender held his trousers in place, his bare legs and arms

were brown and sun-burnt and briar scarred. He swung his horses around just as I passed by and from under the flapping brim of his hat he cast a quick glance out of dark half bashful eyes, and modestly returned my salute. His back turned, I took off my hat and sent 'God bless you' down the furrow after him. Who knows I may go to that boy to borrow money yet, or to hear him preach, or to beg him to defend me in a lawsuit. Or he may stand with pulse unhastened, bare of arm in a white apron, ready to do his duty while the cone is placed over my face, and night and death come creeping into my veins.

Be patient with boys, you are dealing with soul stuff, destiny awaits just around the corner.

It is essential for teachers to have a wholesome respect for students. By encouraging them, by imbuing them with enthusiasm, we can get them to do so much more.

To be a successful teacher one must remain a student. It is so important to remain scholarly, read widely and discuss academic problems with people in our own area as well as with people in other academic fields.

As one philosopher put it, "He who learns from one who has learned all he has to teach, drinks from the green mantle of a stagnant pool, but he who learns from, one engaged in learning, drinks from the clear water of a running stream. To be a good teacher it is essential to be engaged in a research problem. That is the only way you can give something of yourself to the student. Then the student can drink from the clear water of a running stream. Your enthusiasm and devotion are infectious.

So often the professor finds it necessary to assume such a superior attitude that the students- will not take the liberty to openly discuss their problems with him. This superior attitude acts as a smoke screen. Fortunately, I may say that I have not come across much of this in America, but it is far too common in Continental and British universities.

The professor should not be afraid for his students to know him better and so discover his ignorance and inabilities. The greater the teacher the less he must use his status to impress his students. John Ruskin, great educator that he was, stressed the function of the teacher beautifully:

> Education does not mean teaching people what they do not know, it means teaching them to behave as they do not behave; it is not teaching the youth the shape of letters and the tricks of the numbers and then leaving them to turn their arithmetic to roguery and their literature to lust. It means on the contrary training them into the perfect exercise and kingly continence of their bodies and souls. It is a painful and a continual and difficult work to be done by watching, by warning, by precept and by praise, but above all, by example.

There can be no doubt that in the training of our students the setting of an example is one of the most important tools to be used.

As professors, we hold in bondage the idealism of so many students, so many really potentially great men. We are entrusted with their guardianship, and we have to set the example.

We have to do our teaching and research in such a way as to imbue the students with confidence. It is put so aptly in one of the hymns:

What ever way my days decline, I felt and feel though left alone, His being working in my own, The footsteps of His life in mine.

Another essential prerequisite for a good animal husbandry teacher besides being able to teach and do research work, is that he must also be a real cattleman. For instance, have 'a natural affinity for livestock. He must be able to appreciate the beauty of livestock and it must give him real enjoyment to be amongst his animals.

The famous surgeon and medical teacher, Sir William Osier, in his book *Aequanimitas and Other Addresses* put the function of the teacher so boldly. The teacher must be approachable; his students must have the confidence to come to him for counsel at all times. The most important attribute of the great teacher is equanimity. That means he is able to remain calm and dignified even under stress. It is essential to be able to think clearly and to pass fair judgment during periods of danger or difficulty. You are required to inspire the students entrusted, to your guardianship with confidence. No moody person can achieve real success in teaching students, because the student always is at a loss to know when he can discuss his problems with the teacher. The teacher's sense of humor is his greatest tonic.

To acquire equanimity—evenness of temper—it is essential not to expect too much from junior students. Knowledge comes fairly soon, but wisdom lingers. It comes with time, in our search for the truth, the absolute truth, we are aiming at the impossible. We have to be satisfied with each finding, a fraction of the whole truth. Each of us must endeavor to fit a few sections of the big jigsaw puzzle.

Scientists in movies and magazine advertisements are always shown examining test tubes as if on the brink of some great discovery, but I guess the outside world does not know how rarely one ever discovers anything. The road to the frontier is already long and undramatic, like someone who finds himself off the trail on a mountain at night with just a small flashlight and an average amount of nerve. The mountaineer only wants to find the trail again whereas the scientist — well, what does he want? Anyhow, if he gets even the smallest fragment of what he's searching for, then there comes a moment of sheer exhilaration comparable, I suppose, to what an artist feels when he has done something credible. Next comes the period of doubt, the check and counter cheek, and often as not the disappointment. It was not new after all or else it was not true.

The attitude of professors and research workers must be one of anxiety to make some contribution toward better agriculture. The greatest possession of any agricultural institution is the great name of those people who have given themselves to agriculture and the students — past and present. These men have walked the thorn-strewn paths. They climbed the steep incline to the top by determination, hard work, sacrifice and often at the cost of envy and jealousy of their colleagues. The reward obtained is not monetary. It is the appreciation, admiration and respect of students — a real sweet reward.

The influence of the teacher gives life to the institution — without it there is nothing. An academic system without the personal influence of the teacher or the professor is like a winter in the Arctic. It is cold, it petrifies everything; it becomes a cast-iron institute producing learned barbarians instead of educated and civilized citizens.

It is the duty of every university to endeavor to put men at the head of the departments who are enthusiastic, men who have a deep-rooted love for the subjects they have to teach. He must feel a constant urge to teach his students the subject to which he is devoted.

The teacher must have a thorough knowledge of his subject, obtained by study and research. He must share his experiences with his students.

If we have had the privilege of seeing foreign countries and the research work done by other workers in our field, it is our duty to convey this knowledge to our students. By doing so, we will imbue our students with enthusiasm. The students' self-confidence and enthusiasm must never be thwarted — it must be guided. The Physicians Bulletin commemorating the twenty-fifth anniversary of the discovery of insulin contains the following:

> In an attempt to sum up Banting's amazing accomplishments I should feel inclined to express the opinion that much of the success that he and Best met with was due to the fact that they did not allow themselves to be deterred by adverse reports and literature. Dr. Macleod was frankly skeptical about the whole enterprise, but fortunately was willing to waive his own opinions and to give Banting facilities to carry out the experiments which he outlined with the collaboration of Dr. Best. I think that this is most important. We should avoid undue regimentation of scientific research. In wartime it is obviously necessary. In peacetime the developmental stages of any program may, of course, be regimented; but in the initial stage the breaking open of a new fields,

such as the development of insulin or of penicillin, young investigators full of enthusiasm should be given the greatest possible free hand and should be allowed to carry out experiments as they see fit, in a manner that might not be approved in a thoroughly regimented system. Older men in charge of research laboratories should be extremely cautious about exerting a dominant position or dictating in any way to the younger men working with them. They should simply be advisers. I would venture to guess that had regimentation such as we have seen during the war been practiced at the time that Banting and Best were doing their epoch making work, the discovery and development of insulin might have been greatly delayed.

Since 1941, the memorials to Banting have grown and multiplied. The most important of these are not the' institutions and lectures- and buildings and foundations and ships and 'Other tangible memorials which bear his name. Of importance instead are the miracles that happen every day throughout the world the miracles of human beings brought back to health and hope by insulin.

My dislike for having agricultural economists at the head of Animal Science programs is dearly stated in the following quotation:

> The farm and the factory differ essentially at the point of freedom. If the economist makes a factory out of land for crop and animal production, introducing military control with large-scale units, piece work, specification, he destroys the peculiar character of the yeoman, the man who owns himself, directs himself, and has a judgment based upon independence. Therefore, I would say, let the economist of agriculture begin his plans with a thorough consideration of the human factor, its limitations and ideals, and lit his economic schemes to the character of the farmer.

Sir Solly Zukerman, eminent British Scientist, physiologist and the man holding the highest post in the British military world, defines academic freedom as follows;

> What first do we mean by academic freedom as It applies to the pure scientist? One means not only the freedom to investigate those problems which one seeks oneself, but also the fact that significant advances in scientific knowledge cannot be ordered by decree. Every act of creation requires its special freedom.

Hence the failure of the project system where projects are to be handed in a year or more la advance of the time at which the research worker can commence his research work- is there anything that thwarts the enthusiasm of the research worker more than this?

Dr. Filmer, retired director of animal husbandry research in New Zealand, concluded a farmer's day as follows:

> I will not embarrass my successors by expressing my news on the way agricultural research should be administered in the future, but I do want to emphasize that there is something infinitely more important than administration. Perhaps I can get my point across with three quotations. The first is from Punch of 23 years ago: "The greatest of all research problems is the people who do the research" - and I would like to add to this and to find the people who have a natural aptitude for research work. During the past 10 years the Department of Animal Husbandry at Pretoria University has produced over 200 graduates and I have grave doubts if there are ten real research workers amongst them.

The second quotation which Dr. Filmer used in his address came from Sir Henry Tizard's *Nature*, 4115,392: "The fact is that all really new developments of industry (and agriculture) are the product of the work of very few men." The third is from, an address by Sir Ben Lockspeiser, a former Secretary of the British Department of Scientific and Industrial Research, in a 1959 issue of '*Science*, "Let me therefore conclude by underlining the importance of good administration by reminding you also that administration in science will not of itself, produce a single new idea, and without new ideas science would cease to exist.

Research is based on the original ideas of few men. If these men can be encouraged to think, and if arrangements can be made to test the ideas that arise from their ‘thinking, yon will get all you expect from research.

At least 8 million people the world over owe gratitude to Best and Banting — but do they? The cattlemen of this- country owe much gratitude to this institution and the other universities where animal science is taught, and where important research is done. Who knows the financial benefit they derive from your work? They should show their appreciation by generously contributing toward research. The financial assistance given to research institutes is sound investment from which total mankind derives benefit

It is the duty of each professor of animal husbandry to have his finger on the pulse of the livestock industry. He must be aware of what is going on, on the cattle ranches, on the feeder farms, in the meat trade and in the feed trade. The goodwill between the professor or head of the department and the total livestock industry is measureless. It is that aspect of his work which helps raise funds for research and which enables him to place his graduates in better positions. The task of the professor and head of a department is a most difficult one and his task does not end with teaching and placement of the students. Long after the student has graduated the professor still guides his past student, for he has inspired the young man with so much confidence that he comes for counsel many years after graduation. The students who have been trained by you realize they have a responsibility to you and the institution. This responsibility prevents the past student from going off the rails and lends tradition to an institution.

An important responsibility rests with the student. He must have loyalty to his university, his professors, his fellow students and his parents. If a student is loyal to his university or teachers, he will tell them his feelings of their weakness or errors of judgment. He will, with the cooperation of the teachers, try to improve the status of his university. Loyalty to an institution means that the student after graduation will do his duty toward society in general and will endeavor at all times to uphold the good name of his university.

One aspect of the student-teacher-parent relationship which puzzles me greatly is the lack of interest parents have in their children.

For every ten parents who; come to discuss their animal husbandry problems with me, only one discusses his son’s problems.

It is moreover the duty of the parent to back a professor in disciplining the parent’s son. It is essential that the parent show loyalty to the teacher, but that loyalty is a mutual concept — teachers should try to know as many parents as possible.

Discipline is from the Latin word meaning “to learn.” I trust that each student might feel that when the university authorities have disciplined him, he would look upon it as part of his learning and not as punishment. Discipline and self discipline are part of our education.

The education of our students costs the state vast sums of money. It is expensive to build and equip laboratories, and it is the duty of the farmers and commerce and industries to make grants for that purpose.

Since the Russian revolution in 1917, we know little of what really happens behind the Iron Curtain and we know very little about the Russian educational system. What we do know, however, is that their technological education is of a high order. They were the first to successfully launch manned and unmanned satellites. So, obviously, Russian technological training is not poorer than that of the West.

How good their agricultural training is we do not know, but I doubt whether it equals that of the West, especially that of the United States. America had to feed many Russians during 1963. Had it not been for American wheat many Russians would not have had bread to eat. Scientific and technological leadership must be maintained in the West, and to do this we must devote much time to better teaching. In Russia the students are considered the most important fraction of the population, and they are certainly the best cared for group in Russia. In Russia all students in the basic sciences and technology are paid a minimum salary of 300 rubles, approximately $80 per month.

The outstanding undergraduate students receive a monthly salary of approximately $200 and special concessions are made to these men for their cultural development by allowing them to attend operas and concerts at reduced cost.

The problem of financing our student training is one which should receive much more attention from commerce and industries. It is the duty of the successful industrialist to contribute much more toward creating more and better facilities for student training and research — both for peace and war.

All I can hope for is a much closer cooperation in the future between professors, students, farmers and industrialists.

"On earth there is nothing great but Man,' said Sir William Hamilton. He also said, "When you invest in young people, you invest in eternity."

To live up to those two contentions, the professor must train his students with devotion. It is a persistent, intelligently directed effort to a better understanding of young men.

I wondered where my soul might be.

I searched for God but He eluded me.

I sought my brother out and found all three.

A Livestock Philosophy

After studying livestock, production in various parts of the world and after having had the good fortune of being a guest professor at Texas A&M University in America, I would like to describe some of my concepts of livestock philosophy.

During the past 3 decades I had the good fortune of seeing much agriculture and livestock production in various parts of the world. As a result of these observations, it became obvious to me that animal husbandry is influenced mainly by the cultural and religious background of the people who practice it. Throughout the world one finds that those races who are superstitious, ignorant and prejudiced are backward in their approach to livestock improvement and the betterment of agriculture in general. The Bantu tribes in Africa consider animals to be a token of wealth and a means of acquiring a wife. These people never have regarded livestock production as a means of benefiting mankind and a method of improving the nutritional standards of their people. They have never practiced systems of selection and improved breeding with the object of producing more and better food for their own people. Likewise, to the Hindu, whose outlook on the animal is holy. These people are not permitted to castrate useless bulls; hence, they carry out no system of herd improvement whatsoever. The people of the western civilization have a cultural and religious background which stimulates improvement in livestock production.

It is worthy to note that in the Bible in Psalms 8:5-8, David sang to the Lord,

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

On those people of the Western Civilization who practice livestock husbandry, these few verses place a tremendous responsibility as is illustrated in the words, 'they are put under man's feet' That implies that it is the duty of Westerners and Christians to improve that which has been given them. If they fail to do so they are failing in their responsibilities as husbandmen, and, in the case of university professors and lecturers, in their duty of teaching improved methods of livestock production.

A wheel drawn in three dimensions is used as the illustration of this livestock philosophy. In this diagram, Figure 1, man is considered the axle of the wheel, and the animal is the hub. The domesticated animal is in close symbiosis with man. In other words, the animal is to a great extent dependent for its existence on the management and husbandry of man. The domesticated animal is in close symbiosis with man because it has been modified and changed during the processes of domestication.

There are no fewer than 3,000 species of mammals in the world, of which man has domesticated approximately 30. Animals must have possessed certain characteristics and qualities to enable man to domesticate them. Some of the more important factors are tractability, docility and the ability of the animal to produce animal products useful to man, such as milk, meat, mohair, wool and hides.

Man has domesticated

1) Equidae — horses and asses;

2) Camelidae — camels, llamas and alpacas;

3) Bovidae — cattle, buffalo, yaks, gayals and bantengs;

4) Ovidae — sheep and goats;

5) Cervidae   reindeer; and

6) Suidae — swine.

It is my opinion that if human life is removed from this earth, the domestic animals, also within a relatively short period of time, will be extinct. Only animals which are really well developed from an adaptability point of view will be able to propagate and survive for a long time. Such exceptions are the few breeds of indigenous cattle, but the highly improved animals which are highly productive soon will become extinct.

In the symbiotic tie between man and his animals, the closer the tie, the stronger is their symbiotic relationship. In Holland, for instance, the Friesland dairy cattle and the cattlemen's families live under one roof. The cattle are the air-conditioning mechanism during the wintertime which keeps the homestead warm. Man looks after these cattle by making hay, which he stacks on top of the barn to keep the cattle at a comfortable temperature- during the cold winters. This chain relationship between man and his animals is closely linked, and where these links are closer than average, the cattle usually are very highly developed, and functionally more efficient than in those regions of the world where the symbiotic tie is not so strong.

In my livestock philosophy, man is the most important environmental factor. Man can, within limits, modify certain external environmental factors and by breeding, selection and modification of the environment, breed cattle which are highly productive and well adapted to a particular region.

If the approach of man changes due to certain economic factors and he loses his incentive to breeding better livestock, the livestock improvement program will degenerate. That is a facet of livestock production in America which perturbs me. So many cattlemen in this country have completely lost the incentive to produce better livestock because they need not show a profit on their livestock enterprises; they have made money in other fields of commerce and industry. These men have gone into livestock production as a token of social and financial status and as so many of these production sales, which started off as honest endeavors to, distribute and disseminate superior germ plasm, have degenerated, into a social event where, materialistic power is demonstrated and where status and friendship is traded. It has completely lost the incentive of selecting and buying improved genetic material to use in the betterment of herds.

From the point of view of man himself, the three greatest obstacles to improved livestock production are ignorance, superstition and prejudice. It is my opinion that the breed societies who have fixed ideas about what the ideal type of livestock is and who have made their breed standards so concrete that no modifications can take place have reached a point where they cannot select desirable variants; hence, they cannot improve their cattle. These fixed clay idols are nothing but prejudiced visions of men who really hero worship an image not measured in terms of functional efficiency. Prejudice is the main factor which in many instances prevents die improvement and progress of certain breeds.

Ignorance is another factor detrimental to the improvement and welfare :of breeds and breed societies. It is absolutely essential if breed societies have an inspection system of their cattle by livestock inspectors that these livestock inspectors are well acquainted with modern trends in animal research. They must be well read and must regularly associate with scientists in other fields of animal production to enable them to judge animals on a logical and functional basis. A livestock inspector or a cattleman who is ignorant will not make the necessary progress in livestock breeding which is essential in keeping abreast of time.

Superstition also plays a role in retarding the progress in livestock production, and it is for that reason that so many of the backward people cannot produce functionally efficient livestock. People who are disinterested in animals will never make a success of animal husbandry. The successful livestock

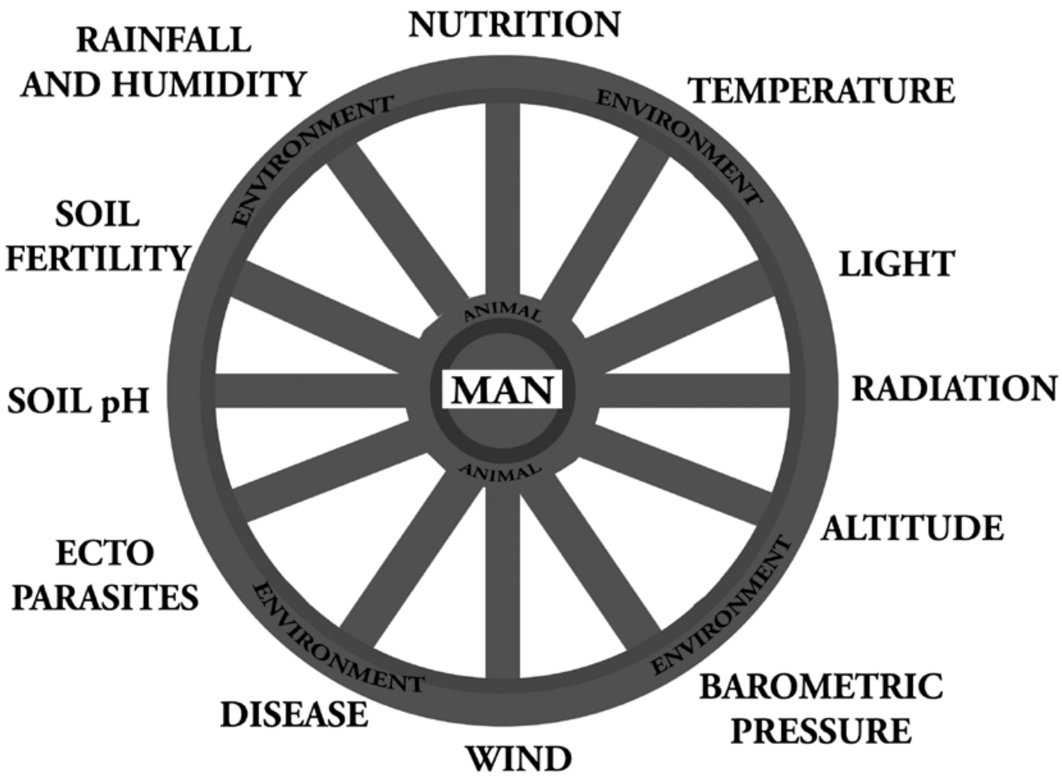

Figure 1. A schematic illustration of livestock philosophy.

producer is one who knows his animals and who treats them with care and love. Only then will the hub be lubricated and move with ease around the axle of the wheel.

In this livestock philosophy, the environment is the running surface of the wheel — a large concentric circle immediately around the hub which is attached to the hub by spokes, each of which has a direct action on the hub. 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 hub.

NUTRITION

Nutrition, together with metabolism which affects the transformation of food into products such as meat, milk and eggs is probably the mightiest spoke in the wheel. The nutrition of the animal and the interaction between the feed and the animal is a living chemical and physical, reaction between the animal and its total environment. The quantity and quality of feed produced is environmentally controlled; there are no two environmental regions which produce feed, of the same nutritional value, and no two animals interact exactly the same on the feed.

Animal metabolism is closely correlated with, and influenced by external environmental factors such as temperature, light, radiation, wind, etc, and their catalytic action on the chemical reactions taking place in the animal. The interaction between the animal and the total environment depends on its hide, hair and color.

An animal's color, coat cover, vascularity of hide and ability to maintain a normal thermal equilibrium in a specific environment greatly influences its metabolic rate and efficiency of food utilization. The animal's internal environment, namely its endocrine function and physiological reactions also determine what, the coefficient of digestibility of the feed will be.

The ability of man to assess the nutritional status of a particular region and to exploit the adaptability phenomena exhibited by animals has enabled man to produce livestock where previously it was absolutely impossible to maintain them.

We only have to consider the advances man has made in connection with the feeding of pelleted hay, concentrates or rations with a low heat increment in areas where thermal, stress was too high for dairy cows to produce milk, In Israel, it was impossible as recently as 20 years ago to produce enough milk to supply public demands. Now, by feeding dairy cattle concentrated rations with a low heat increment, it is possible to produce an abundance of milk — in fact, the Israeli dairy cattle are highest milk-producing cattle per capita in the world.

It is, however, not possible for man to overcome the hazards of climate from a reproductive point of view by nutrition. It is probable that this hazard will also be overcome but at this date it is very definite that the cattle in Israel require more inseminations per conception than in most other countries of the world.

Energy for maintenance can be compared to a cooling ball used at Messina Research Station, Northern Transvaal, Republic of South Africa, to measure the energy input and energy loss from a bail painted the color of human skin. Electric energy was transferred from electric storage batteries to an electric coil in the ball. By controlling the flow of electric energy into the ball, it was possible to maintain an average temperature of 98:7° F. The slightest change in daylight hours or the passing of a cloud in front of the sun would immediately cause the cooling ball to radiate more energy; hence, more energy had to be put into the cooling ball to maintain a temperature of 98.7° F.

The energy input into the cooling ball was recorded by a galvanometer in gram calories per minute, and it became very obvious that weather fluctuations such as wind, rain, clouds or a sudden cold spell would immediately change the amount of energy dissipated by the cooling ball. From this concept it became clear that there is no such thing as a maintenance ration for an animal. The amount of feed or energy put into the animal is dictated by weather and climate and by the internal and external function of the animal. That is, the internal function, the endocrinology and the physiology have a marked influence on the efficiency of food utilization.

The surface which forms the contact between the animal and its external environment is the hide and hair. The vascularity of hide and the nature of the hair determine the rate of radiant energy dissipated from the animal's body, and it is very obvious that animals which differ in coat color and cover and hide thickness definitely vary in their nutritional requirements in a particular environment. This also clearly illustrates that there is no universal breed regarding efficiency of food utilization in a particular environment. The object of the performance testing of animals and the determination of the efficiency of food utilization is based upon this interaction between the total environment and the animal. If we performance test animals, we try to measure which animals give the greatest return on the amount of energy put into the animal. Performance testing is a method to measure the relationship between energy input and output and to select the animals which are most efficient. It is a basic concept to breeding better livestock.

TEMPERATURE

High temperatures are a serious problem to livestock production. Low temperatures do not constitute the same problem if the animal is supplied with sufficient food. The inflow of electric energy will maintain the temperature of the cooling ball despite cold wins or rain. If the radiating surface of the cooling ball is covered by material there will be less energy radiated. The nature of the external radiating surface of the animal such as coat color, coat cover, vascularity of hide and relationship of surface area per unit weight has a marked influence on the amount of radiant energy lost and on the animal's adaptability.

At the University of Missouri, some experiments were carried out in which Zebu, Jersey and Holstein cattle were kept in rooms where the temperature varied from 5° to 105°F. The sleek-coated Zebu cattle, which have a relatively large surface area per unit weight, can withstand high temperatures very well. Low temperatures are less well tolerated as a result of greater radiating surface. These animals could not overcome cold as readily as cattle of the European, breeds. In a series of experiments: the animals were kept in psychometric chambers at a temperature of 65° F, and the food intake was measured. When the temperature was raised to 105c F, the animals showed acute symptoms of distress. When the temperature was lowered, to 5° the cattle showed no sign of real distress. The result of this experiment showed that at 5° F. the Holsteins consumed 8 percent more food, the Jerseys 26 percent more and the Zebus 36 percent more than what they respectively consumed at 65° F. Although Zebu types (*Bos Indicus*) could withstand the cold and were not uncomfortable, they had to consume appreciably more food than did the British breeds (*Bos taurus*) in order to maintain their heat balance at 5° F. Extra energy had to be given the animals which had a more effective radiating surface to enable them to maintain their thermal equilibrium.

The coefficient of digestibility of feed is greatly reduced by high atmospheric temperatures. In preliminary tests on rats kept on a constant well-balanced ration, it was found that the coefficient of digestibility of the ration was 72 percent at 85° F and that it was reduced to 59 percent at 85° F. At 105° F. the appetites of all the animals were greatly reduced and all showed symptoms of distress.

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 Research Station, Northern Transvaal, Republic of South Africa. Animals should be bred in such a way as to promote their adaptability to high temperatures. For this reason, all cattle which are to be adapted to a high environmental temperature must have certain characteristics which enable them to maintain thermal equilibrium on hot days. Here again the basis of selection should be determined by research. In an endeavor to determine which animals are more adaptable, man must measure, correlate, interpret, select and breed. It was found from research work done on tropical and subtropical adaptation of cattle that certain morphological characteristics are closely associated with the ability of the animal to maintain a thermal equilibrium in hot environments. The most important factors to select for are the following: The animal must be sleek coated and must have hair that is medullated — only one hair must come out of each primary hair follicle. The animal must have a thick, pigmented hide having a high degree of vascularity. Those animals with movable hides that exhibit downward skin folds have a high vascularity of hide. The amount of dewlap and development and naval fold is not significant where adaptability is concerned. Animals should be able to move freely to obtain nutrients from areas where the climate is semiarid and where vegetation is sparse. Only animals which move with ease and which can maintain a thermal equilibrium are able to sustain themselves under such conditions.

Also, if it is possible, the hemoglobin index should be measured. Animals that are tropically adapted usually have a high hemoglobin index.

Beef cattle such as the Brahman (*Bos Indicus*) and the Afrikaner (*Bos Indicus*) are well adapted to the high temperatures in subtropical areas. However, these animals are slow maturing and often are sub-fertile. By crossing cattle of the *Bos Indicus* breeds with the British breeds of livestock such as Shorthorn, Hereford, Aberdeen Angus or Sussex, desirable genetic traits from both species of livestock can be combined and new breeds can be created, such as the Santa Gertrudis, the first “man made” American breed of livestock, and the “Bonsmara” in South Africa.

LIGHT

Light is the most constant of all weather and climatic conditions. At the same location, the atmospheric temperature on a particular day may vary greatly from year to year, and light intensity may vary slightly, but light duration remains constant at comparative dates of different years. Light rays cause an impulse or stimulus on the pituitary gland and hence, a reaction by which the animal sheds its hair. As the days become shorter and the nights longer, cattle begin growing longer hair and develop winter coats. Conversely, as the nights shorten and the days lengthen, they shed their winter coats and become smooth coated.

In Britain the difference between the longest days in summer and the shortest days in winter is at least 12 hours; in countries in the Southern Hemisphere such as South Africa this difference is approximately 2 hours; and on the equator there is a difference of 2 minutes between the longest and shortest days.

Those animals which shed their winter coats and become smooth coated early in spring can adapt themselves, and breed regularly in a subtropical environment. In research work done in the photo-period rooms at the University of Pretoria, Republic of South Africa, it was shown that animals with smooth coats and which sleek off readily with changing light stimuli have a higher gonadotropic content in the blood than those that maintain their woolly coats,

A smooth-coated Hereford herd was bred at Mara in the Northern Transvaal by using only animals that reacted to a stimulus of only 3 hours difference in daylight between the longest and shortest clays of the year. By selecting those early hair shedders in spring, it was possible, in approximately 15 years, to build, up a smooth-coated, thick-hided herd of Hereford cattle. Four smooth-coated, Hereford heifers were transferred from Mara Research Station to Mpapwa Research Station in Tanganyika approximately 250 miles south of the equator. As a result of the slight difference between daylight length during summer and winter, these heifers did not shed their hair at Mpapwa. It is very definite that light acts as a catalyzing agent with regard to the metabolism of food in the animal. In the photo-period rooms at the University of Pretoria, it was possible to change the rate of hair shedding by changing the photo-period in the rooms, and it also was possible to change the gamma globulin content of the blood. Animals maintained in the dark had superior marbling to those maintained in the light.

Light has a very marked influence on the metabolic rate of animals. For this reason extra light is used in chicken houses to facilitate rapid feathering and earlier egg production. It also is used in broiler production, and rapid alterations of dark and light stimulate the amount of food consumed and hence increase growth rate. The marked influence light has on animals has been clearly demonstrated by German scientists who placed pigeons in light bell jars and others in dark bell jars. All the pigeons were deprived of food. The pigeons in the light bell jars died after 12 days while the ones in the dark bell jars survived, for 24 days.

It is my opinion that more research should be done in connection with the influence of the photo-period on various physiological reactions of animals. It is one of the most important factors influencing the sexual activity of animals. In the research work on the sexual activity of cattle in the subtropics and tropics, it was found that the cattle showed higher sexual activity when the daylight and night hours were equal. The influence of light on sexual activity and how this will affect animals which are transferred through several degrees of latitude is most important where cattle are shipped from one hemisphere to another.

During the war years, cattle were transferred from the Southern Cape area in South Africa to Messina Research Station in Northern Transvaal. This change of environment through 100 of latitude caused the animals which cycled normally in the southern part of South Africa to stop cycling. In the group, 16 Shorthorn heifers never cycled for approximately 1 year. The 16 Afrikaner heifers in this group did not come in heat or show estrus for approximately 10 months. After more than a year, 12 of the 16 Afrikaner heifers were in calf, but only 4 of the Shorthorn were settled.

If animals are transferred from one environment to another and are brought through 10 or more degrees of latitude, the normal periods of estrus are upset and animals will not come in heat in; many instances for as long as a year. If cattle are transferred from the Northern Hemisphere to the Southern Hemisphere, for instance, from the United States to the Argentine, it would be best to transfer young animals which are pregnant for the first time. The transfer should be made when these animals are approximately 3 months pregnant. Results obtained in transferring cattle from one hemisphere to another indicate that the normal reproductive processes are impaired. Many animals will become completely sterile, and many will not exhibit estrus for as long as a year.

Animals taken from the northern part of the United States and transferred to the Argentine will take appreciably longer to adapt themselves than those transferred from Southern states such as Florida, Louisiana or Texas. It also is necessary to transfer the cattle from the United States to the Southern Hemisphere during the American autumn so that those animals arrive in the Southern Hemisphere during spring. That is when the daylight is on the increase.

Cattle transferred during the winter from Colorado, Kentucky or states further north will have long outer protective coats, woolly inner heat retaining coats (winter coats) and such animals will not readily shed their hair during the summer in southern United States. It is absolutely essential, if transfer of cattle is made, to select sleek coated animals.

The woolly coated animals transferred from the Northern Hemisphere to the Southern Hemisphere will never become absolutely sleek coated because the difference between summer and winter daylight length in the Northern Hemisphere is much greater than the difference between summer and winter daylight length in the cattle producing regions of the Southern Hemisphere. In the Northern Hemisphere there are approximately 12-14 hours difference between summer and winter daylight, and this large difference stimulates these animals to shed their hair and become smooth coated. The woolly coated animals of the Northern Hemisphere will not react to the stimulus of approximately 2-5 hours difference in the summer and winter daylight as is usually experienced in the cattle regions of the Southern Hemisphere.

It also is advisable to transfer cattle through degrees of latitude, that is from North to South or vice-versa, during early spring. In the research work done in the photo-period room at the University of Pretoria, Republic of South Africa, it was shown that the gamma globulin content of the blood increased during increasing daylight, and it probably would be advisable to immunize cattle during the spring. If cattle are transferred from America to Latin America, it would be easier to immunize them during the South American spring.

In the work done in the photo-period room at the University of Pretoria, animals that sleek off readily as a result of the changing photo-period have a higher gonadotropin content than those which do not become smooth coated. It always is advisable to select animals which are early hair shedders in spring. If exports of cattle are to be made from Britain to the Republic of South Africa or from the United States to the Latin Americas, it will be advisable always to select sleek-coated animals.

Various colors in animals will react differently to light intensity. Where light intensity is low, dark colored cattle will have a higher metabolic rate than light colored ones; hence, in thickly forested regions I would prefer dark colored cattle. Light cannot be separated from radiation because light is composed of the various spectra, namely red, orange, yellow, blue, indigo and violet, and the infrared rays are heat rays and the ultraviolet rays are the chemical rays, hence light intensity is in many ways correlated with the effects of radiation.

RADIATION

Sunlight comprises a series of rays differing in wave length, composition and action. If sunlight is split into the spectrum and thermometers are placed in the various segments, temperatures will become progressively higher from violet to red. The hottest spot of the spectrum is the invisible section just beyond the red, namely the infrared. The 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, 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 infrared radiation.

In open Savannah country where the infrared radiation is intense, it is considered that red cattle with pigmented hides or white cattle with pigmented hides will be better able to radiate energy and utilize the nutriment of that particular environment more efficiently than other cattle. 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. Effects of the ultraviolet beam are demonstrated when animals are exposed to high altitudes, it is very obvious that animals which do not have pigment in or around the eyes suffer from eye cancers. If an animal is predominantly white or with areas lacking pigment in the hide, as in the case in some British breeds, ultraviolet rays cause hyperkeratosis of the hide and the animal suffers severely. 'White pigmentation in an animal is a great hazard in areas where ultraviolet impingement is intense, as at high altitudes or in regions where the sky is often slightly overcast. The hair color and the hide and its functioning are most important in those climatic zones where ultraviolet radiation is intense. The hide is a temperature regulating organ containing a thermostat which efficiently can control the body temperature of the animal, and it also supplies sebum which will enable the animal to overcome the ill effects of ultraviolet radiations such as hyperkeratosis.

Much research work needs to be done on how an animal's color influences its adaptability to overcome hazards of ultraviolet radiation and infrared impingement. In those areas where ultraviolet impingement is intense, a white color or even white areas in which there is no pigment in the hide constitute a definite hazard to the animal. The white animal with strongly pigmented hide well supplied with sebaceous glands can overcome the hazards. Zebum has a screening or filtering effect upon the ultraviolet radiation. The combined effects of light and radiation may cause animals to become photosensitized when they consume certain plants; for instance, in the case of sheep, goathead, *Tribules terestis*, will cause disease. It also will cause the sloughing of the white areas of the hide in cattle. Cattle which consume lantana will become severely photosensitized, the mucous membranes of the body will become terribly irritated and such animals usually die. Sandburn in horses also is a condition where photosensitization is caused by the eating of a plant.

ALTITUDE

Altitude has a direct influence on man and animals; for every 1,000 feet increase in altitude there is an average decline of 3° F. At high altitudes, the temperature usually is lower than that of lower lying surrounding areas on the same degree of latitude.

High altitude also has an influence on the oxygen tension of the atmosphere. In the Andes Mountains, many European organizations attempted to settle at altitudes of 11,000 feet and higher. However, they found that men could work there for a while but the women could not work at all as they could not stand the rarified atmosphere. The Inca Indians live in this region. The men weigh an average of 114 pounds. These people have tremendous chest capacity; hence, they can utilize the oxygen in the rarified air better than other people who are not so well adapted. In breathing they must inhale a tremendous volume of air to obtain sufficient oxygen to feed their tissues. At those high altitudes where the soils are usually acid, potatoes grow well although they are of low nutritional value. In general, crops grown at high altitudes are very low in calcium, hence the small stature of the people.

Soil pH usually is low at high altitudes, usually resulting in the development of animals of small stature. An exception is the high soil pH in the valleys of the Swiss Alps where large Brown Swiss cattle are produced. Some animals can live at high altitudes better than others. One of the most important is the llama, which has a red blood cell count twice that of man, and the affinity of the blood for absorbing oxygen also is twice as efficient as that of human blood. What has this to do with animal breeding? The Swiss worker, Duerst, and his associates many years ago found that cattle in regions of high altitudes, such as the Brown Swiss cattle, have the highest blood counts of all breeds. The tropical adaptability of the Brown Swiss centers around this point, since at high altitudes and in areas of high temperature the animals contend with the problem of rarified air. Further mutual similarities between high altitudes and subtropic conditions are that at high altitudes ultraviolet impingement is great, such as in the tropical regions. Infrared radiation also is intense, and the dark colored animal is preferable at the higher altitude where infrared radiation is required as a source of energy. In the tropics, however, infrared radiation is not required as a source of energy and therefore is a problem. Because of the occurrence of intense ultraviolet and infrared radiation at high altitudes and in the subtropics, similarities between animals of the two environments are apparent. In most high altitude regions where indigenous cattle are encountered, these cattle usually are dark brown or black in color. There is no doubt that, at high altitudes, light hair color and hides which lack pigmentation are definite hazards to animals. At high altitudes the incidence of eye cancer in cattle such as the Hereford also is very intense. Windy days are more frequent at high altitudes and wind acts as a cooling agent to these animals. The problem of wind is not nearly so severe in South Africa as it is in New Zealand or in the north of Scotland.

On the eastern seaboard of New Zealand where wind blows continuously, cattle are inclined to have appreciably longer hair-than in regions where wind is less often encountered. It also is a well-established fact that in an endeavor to grow long curly hair on Hereford cattle for show purposes it is only necessary to use atomized water and blow it over the animals with a strong fan. Moist wind will stimulate hair growth in animals. At high altitudes and in regions where cattle have to endure moist cold winds, they usually grow very long hair. A typical example is the Scots Highlander. The animals grow two types of hair: an inner heat retaining coat, and an outer protective coat. These two coats have different electrical charges, and when wind blows over the animal the hair packs tightly as a result of the increase in the difference between the charges. The coat becomes impermeable to moisture and wind, and the loss of energy is reduced.

In high altitude areas such as the High Veldt of the Transvaal in South Africa, where the average altitude above sea level is over 4,500 feet, animals lose weight rapidly during cold spells. If animals are to overcome the cold, they must be provided with more heat, ie., extra feed. It also is certain that in areas where animals are adapted to the subtropics and which have sleek coats die in greater numbers during a cold spell because of the rapid energy loss, regardless of stored fat. Shelter also is considered very important at very high altitudes.

DISEASE AND PARASITES

The problem of disease in livestock production often can be relegated into the background if the animals are well adapted to the environmental conditions in which they are maintained and if they are well nourished. It is certain that by proper management and good nutrition the disease factor will become less important. In a series of experiments done at the Onderstepoort Veterinary Laboratories in South Africa on badly worm-infested sheep, one-half of this group was properly fed while the other half was poorly nourished but treated with wormacides. Results showed that the properly nourished sheep were free from internal parasites long before the others. The malnourished animals became prey to internal and external parasites.

During 1940-42, a study to determine tick repellency on different animals showed that adaptable animals with slick smooth coats, thick movable hides, and a sensitive pilometer nervous system were relatively free from ticks and were in good condition. Cattle which lacked adaptability had thin hides and were woolly coated, were infested with ticks.

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 the environment.

The problem of parasites in livestock production also has been greatly overcome in many instances. An example is the almost complete eradication of the screw worm problem in Texas and other southern states. When such a vast ecological change such as the complete eradication of screw worm has been brought about in a particular environment it will become essential to do new ecological research work to reorient the whole livestock production situation in these environments. As a result of the screw worm fly eradication, the deer population in vast ranching areas has greatly increased and new ranch management programs will have to be worked out. It also will be necessary to reorient certain management practices for instance, the dehorning of cattle and the castration of bulls can take place at other seasons than previously, and the methods adopted, for these operations can be changed because there is no longer the problem of fly strike.

During seasons of higher rainfall and humidity the incidence of internal and external parasitic infestation is high, and provision should be made for livestock to be protected against those hazards. Animals which lack adaptability become prey to parasites and also become more susceptible to diseases carried by insects such as ticks. Internal and external parasites can be partially overcome in two ways: the first method - which is preferable - is to breed cattle to be adapted animals with short hair, smooth coats and thick movable hides which are tick repellent. It would, however, be foolish not to use the protective measures science has provided in the form of various dips. De-worming remedies and therapeutic treatment of internal and external parasites can contribute greatly to overcoming those problems. If there are successful methods of combating disease by immunization 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 marked role in cattle production. In the hot humid areas of high rainfall, the soil pH usually is low as a result of the leaching out of soluble calcium, phosphorus and trace elements'. In such areas, small cattle usually are encountered. In humid, subtropical areas such as Southern Africa, India and Australia, the cattle are small because of the problem of maintaining thermal equilibrium. The problem of heat dissipation through evaporation of moisture from the lungs and the hide in a hot humid climate, becomes an acute problem. Animals maintained under these conditions usually have a relatively large skin area per unit weight. It is my opinion that in all regions where the relative humidity and temperature is high in those climatic zones where the average annual isotherm is about 65° F and the relative humidity is above 85 percent, the animals will be small. In many of those regions there is a very profuse plant growth and dense formation. In such areas it is desirable to maintain black cattle, as they are considered better adapted to dull and subdued light. In most areas where the humidity and temperature is high, the nutritive value of the pastures is very low as a result of fast pasture growth, the lignin content and hence the crude fiber content of such pastures is high and the protein content is low. In areas with a muggy climate the soil pH is low and nitrification cannot take place readily, hence, such areas must be fertilized with lime and if the soil. pH can be raised certain leguminous crops which will improve the protein content of the pastures can be grown. It must be realized, however, that under natural muggy conditions, livestock will be small. Soil fertility has an indirect effect on the welfare of livestock. As a result of the increased crop production on fertile soils, it is possible to improve the nutritional conditions of livestock; hence, better cattle can be produced on fertile land by virtue of greater yield crop which provides feed, of higher nutritional value.

SOIL PH

No large cattle have been bred in acid soil country. This explains why the indigenous cattle of the high Himalayan Mountains are very small, the black cattle of the higher regions of Wales, the cattle on the higher slopes of the Drakenberg in South Africa and the indigenous cattle of Mashonaland are all small. Mashonaland is a highly fertile area but lacks lime, and as a result of the low pH in that region the cattle have small skeletal development. In areas where the soil pH is low, nitrification cannot take place successfully and hence the grasses grown in those areas have a very low protein value and do not form a natural curing hay on the land during winter. It is very interesting from an ecological point of view to have a thorough knowledge of the indigenous trees that grow in an area. The trees which grow in an area are indicative of the soil pH value and are correlated with nutritional value of the natural pasture.

In work done at the Mara Research Station in South Africa, cattle were kept on the same ranch in paddocks 3 miles apart under the same managerial conditions. The only difference in these pastures was that the one section had high soil pH as indicated by the Acacia tiortulis trees, and the other section had a low soil pH as indicated by the *Combretum apiculatum* trees growing there. Steers maintained in the two pastures differed 300 pounds in live weight between pastures at 3 years of age in favor of those on the high pH (6.5) pasture. In the low pH pasture the soil pH was approximately 4.5 to 5.

TOTAL ENVIRONMENT

Every spoke of the wheel as drawn in the diagram has been discussed and it is very definite that if there is complete harmony between the animal and its total environment that the wheel will be round — the spokes will be equidistant from the hub and will not throw the wheel out of balance. If there is complete harmony between the animal and its total environment the animal will flourish and be an efficient producer. The wheel will move forward smoothly and progress will be made in the breeding of better livestock. A thorough knowledge of how each environmental factor influences the animal will enable us to select animals adapted to a particular environment. In successful livestock production it is essential that the breeder be well acquainted with the climatic conditions of the environment in which he intends to breed cattle. It is essential that a thorough knowledge of the interactions between plants and total environment, trees and pastures and pastures, and the livestock be understood. If we understand the particular hazards of an environment it will be possible to select those animals in that environment which are more adaptable and which will propagate adapted animals.

In livestock production, much stress is put on performance testing of the livestock. Hence, those animals which respond best to certain nutritional conditions are selected for further breeding purposes, but, if in a particular environment the nutritional conditions are fairly good but temperature becomes a hazard, more emphasis should be placed on the selection of cattle able to withstand high atmospheric temperatures. In mountainous areas radiation becomes a problem and more stress should be placed on selecting cattle which can overcome the hazards of ultraviolet radiation. By carefully evaluating the total environment production records and being aware of the limiting factors in the environment, it will be possible to breed well adapted cattle. Selection is our mightiest tool and the time has come that we must regionalize our livestock production on ecological grounds.

Red cattle and light-colored cattle with pigmented hides should be stocked in the open Savannah country, and in forested humid and muggy climates, cattle should be black. At high altitudes animals should have brown or black hides, A white colored hide lacking pigmentation is a great hazard to animals in high altitudes. In livestock breeding, it is essential to carefully observe animal behavior and to determine which factors in the total environment cause stress on the animal. By changing certain environmental conditions and by selecting cattle which are in harmony with their environment, livestock production can become efficient.

An important factor to be remembered in livestock production is that reproduction is the most sensitive index of the total adaptability of the animal. Any environmental factor which causes a stress on the animal will reduce its fertility. In the selection of cattle to be fed under artificial conditions, it will be necessary to select on the basis of performance testing in feed lots. To breed cattle that must be able to overcome high atmospheric temperatures, it will be necessary to select smooth coated cattle which become smooth coated early in spring. An animal with a poor nutritional status which comes through the winter with difficulty and has only a small reserve of vitamin A in the liver will not readily shed its coat. Even when daylight lengthens, it will not possess the vitamin A required to assist in shedding its winter coat. Furthermore, the animal which sheds its winter coat early is sexually more active and more fertile. Every heifer that sheds its hair the first spring after birth and becomes sleek coated will be a good one. No degenerate animal is able to do this and if one is not able to carry out all the adaptability tests, it is best to select the early hair shedders since they are the ones possessing nutritional reserves and hormonal balances enabling them to become smooth coated early in spring.

If intense light is a problem, as it often is in coastal regions and in open savannah country, it will be necessary to select animals which have light coat color and dark pigmentation in the hide. Animals exposed to intense ultraviolet radiation should preferably be dark colored, and if Hereford cattle are maintained at high altitude every effort should be made to breed these cattle to have pigment around the eyes. The problems of disease in any well managed herd should be overcome by preventive inoculation.

The third dimension or depth to the wheel is indicative of my approach to judging livestock for functional efficiency. I felt that it was necessary that one should judge cattle with an object of seeing more than the superficial. We should not only see the animal from the outside — it's external appearance - but we must endeavor to interpret what we see in terms of the animal's internal environment — in terms of its endocrinologic and physiological functions.

Successful livestock production and ranching depend on calving and weaning percentages. The aim in livestock production is to produce the maximum amount of beef per unit area. Every rancher can breed better cattle than he does at the present time and it is essential that this responsibility is appreciated. The rancher must realize that selection is his best tool. The institutions of higher education must devote much more attention to the teaching of livestock ecology. The relationship between the animal and its total environment should be more clearly understood. It is only through complete adaptability and selecting for functional efficiency, that is, regular reproduction and efficient food utilization, that a success can be made of livestock production.

Livestock Ecology

Animal ecology is the science which explains the interaction between the animal and its total environment. In livestock production it is essential to have a clear concept of how each environmental factor influences the animal and how we can breed animals to be better adapted to any environment. Livestock ecology is explained by the diagram of a wheel (Figure 1). The axle of the wheel is man, the most important single environmental factor in the interaction between heredity and environment. The animal is the hub and is in close symbiosis with man who domesticated the animal. Of 3,000 species of mammals, only 30 different types of animals have been domesticated.

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

The world is divided into four major climatic zones (Figure 2). The first is KEEN, the regions where the atmospheric temperature never reaches a monthly average temperature of above 65° F and where relative humidity is usually lower than 65 percent. An area which is cold and dry is classified as keen. Cold and dry conditions are antagonistic to promoting plant and animal life, hence, in keen climates we have very little vegetation to nourish animals. Highly productive animals cannot be maintained in a keen climate. In the slightly milder regions of the keen climate, it is possible to keep animals such as reindeer which live on mosses and lichens. In the keen climate we usually find certain fur-bearing animals which live on fish and other nutriments obtained from the ocean or from the sparse vegetation found in those areas.

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

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

The next climatic zone is MUGGY. Those regions which have high atmospheric temperatures of 65° F. and higher, and where the humidity is 65 percent and higher are called muggy.

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

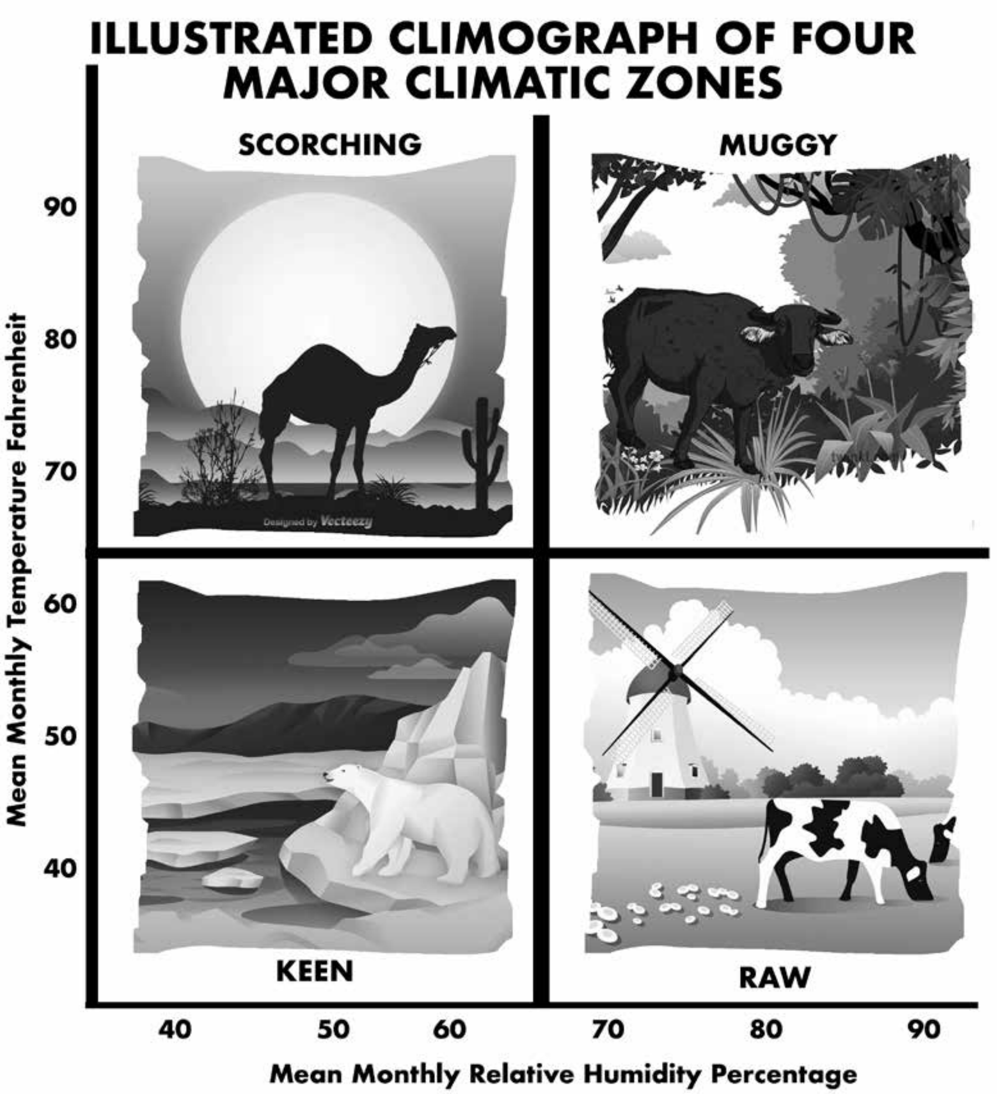

Figure 2. Diagram of the four main ecological regions.

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

The Alpine pastures in Switzerland are in a high altitude raw environment. High altitude raw environments also are found in various parts of Europe, South America, North America and the European Continent where we have altitudes above 4,500 feet. There the rainfall usually is approximately 2 inches per month, and the average annual isotherm does not exceed 60° F. In such areas the pasture growth is very slow, the pastures are very succulent, are low in crude fiber and are high in protein. It is an environment which is very favorable to livestock production. In the high altitude pastoral regions o! Switzerland with its raw climate, grazing often is communal. The pastures are harvested for hay production and the communal cattle owners live in their huts high in the Alps. These herdsmen live there to be near their animals when storms come tip rapidly. These storms are real hazards to the cattle, and human endeavor is essential to prevent heavy stock losses.

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

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

Another type of environment is the high altitude, semiarid climate of parts of Southwest Africa, at altitudes of 6000 feet and higher. These semiarid high altitude pastures do not get very cold or very hot. The limiting factor in these areas is the unreliable, fairly low seasonal rainfall and low vegetation density with the accompanying low carrying capacity.

Low altitude, scorching climates are found in most of the semiarid regions of the world such as Africa, Australia and parts of South America. In the low altitude, scorching climates, the altitude of the ranching areas is usually is less than 2,000 feet above sea level. The average annual isotherm is above 70° F. Rainfall is sparse; it usually varies from approximately 1.2 to 16 inches per annum and often is seasonable and unreliable. The Bushveldt and Middleveldt pastoral regions of the South African savannah country have an altitude of approximately 3,500 feet above sea level. The average annual temperature varies from approximately 63° to 70° F. In these regions the pastures usually are of a natural curing hay type. The soil pH determines whether or not the pastures are high in protein.

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

Areas of the southern United States like parts of Louisiana, Florida and Texas have a muggy climate. High temperature and humidity give the soil a low pH; the minerals in the pastures are leached out and in some of those areas the water table is near the surface. Such areas are very deficient in both macro and microelements. In a muggy climate the problem of heat dissipation always is more difficult than it is in a semiarid climate.

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

The polar bear is a most beautifully adapted animal to a keen climate; its most obvious adaptability phenomenon is the white coat made up of an inner heat retaining coat and outer protective hair. This forms a formidable insulating coat. In this way radiation of energy from the body surface is reduced and maintaining body temperature is no problem. The polar bear also has a layer of fat approximately 1 inch thick over the body which also insulates. The animal conforms to Bergman's and Allen's Laws, that in a cold climate the animal is squarely built, has a small surface area per unit weight and its extremities are relatively short and thick. In the case of the polar bear, its legs are exceedingly thick. If given a diet of fish, this animal will always select those fish which have the highest liver oil content to provide the most readily available abundant source of energy.

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

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

The Rocky Mountain goat has adaptability phenomena, especially for climbing steep ledges and mountains. It also has a color which makes it adaptable to the environment.

The dromedary camel of the Asian deserts is adapted to the scorching climate of the desert. Its nostrils close when dust storms come up. Its lips and tongue are very poorly supplied with nerve fibers and these animals can consume fibrous and thorny desert plants without injuring the mucous membranes of the lips, tongue and mouth. The animal has false eyelids which cover the eyes when harassed by dust storms. The areas of the body in close contact with the hot desert sand have calloused pads. The camel can drink tremendous amounts of water and by an adaptability mechanism in the digestive system, can maintain itself for several days without drinking water. The feet are especially adapted to desert travel. It has a well protected outer and inner heat-retaining coat during winter which it sheds rapidly during the summer.

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

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

The zebra is really adapted to Savannah country because of mimicry, namely dark and light areas on the body. They are most difficult to see in forested areas and it is difficult for predators to see and get these animals.

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

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

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

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

The black-faced Scotch Mountain sheep are well adapted to the tremendously hard climates found in north Scotland. Interestingly, these sheep have a very short breeding season. Those lambs born out of the 6-weeks lambing season will succumb. The ewes come in heat for a short period and are anoestrus the rest of the year.

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

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

In 1953, an advertisement by a company which produces animal feeds intrigued me. They indicated that, in 1910, 500 pounds of their pig rations were required to cause a 100 pound gain in weight, and the pigs reached 100 pounds in 5 months. By 1930, improved rations could cause the pig to gain 100 pounds on 364 pounds of feed. In 1953, the pigs could gain 100 pounds on 300 pounds of feed and they could top the 200 pound mark in 5 months. These people concluded that the great improvement made in balancing their rations by adding antibiotics, minerals, vitamins and balancing the amino acids in the proper portions could produce rations that could make pigs gain 100 pounds on 300 pounds of feed. This advertisement is a half-truth. From 1910 to 1953, livestock breeders changed the body conformation and function of these animals and the improved rations were only partly responsible for the increased and more efficient weight gains.

As a result of this advertisement, I bought unimproved native pigs in the Bantu territories of South Africa and brought them to the University of Pretoria. There we maintained a number of Bantu sows and a number of Swedish Landrace sows. Young pigs of the unimproved Bantu type and highly improved Swedish Landrace pigs were divided into two groups, one group was put on a 1913 unimproved ration composed of com meal and a little tankage, and the other group was placed on a very well balanced 1957 commercial ration. The most amazing results were obtained. The Bantu pigs fed on the 1957 commercial balanced ration suffered badly. They grew slowly, scoured regularly and made very poor gains. The Bantu pigs on the 1913 ration flourished and weighed 135 pounds when those on the 1957 ration only weighed 85 pounds. This was a difference of 50 pounds in 8 months.

Improved Swedish Landrace pigs on the 1857 ration weighed over 200 pounds at 6 months, while those on the 1913 ration weighed only 180 pounds. There is no doubt that the two types of pigs differed markedly in their ability to use various types of rations. Sows of the Bantu and Swedish Landrace breeds were mated to Bantu and Swedish Landrace boars. Both breeds of sows gave birth to purebred and crossbred litters. Hence, we succeeded in producing purebred and crossbred litters which had the same prenatal environment. The crossbred pigs on the good rations did well, while the Bantu pigs on the good rations made very poor growth. The Bantu, pigs on the 1913 rations produced a tremendous layer of fat which had a low iodine value, that is a firm fat, contrary to all expectations. The Swedish

Landrace pigs on the 1913 ration produced an oily fat. The .1957 ration, which gave a firm fat in the Swedish Landrace pigs, gave an oily fat with high iodine value in the Bantu pigs. The crossbred pigs produced by the Bantu sow and the Swedish Landrace boar weighed 200 pounds on the 1957 ration, while their littermates which were pure Bantu pigs only weighed 100 pounds.

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

It is essential in evaluating the nutritional and mineral deficiencies of an area that the cattleman should know the indigenous trees of an environment. Those areas in which *Tarconanthus camphoratus*, a shrub indigenous to South Africa, grows naturally are usually deficient in phosphorus. In all phosphorus-deficient areas, cattle breeders suffer severe financial losses if they do not feed phosphate supplements. Phosphorus deficiency causes much lower fertility and much slower growth rate. Steers which received 2 1/2 ounces of bone meal under phosphorus-deficient conditions had carcasses weighing approximately 750 pounds at the age of 4 years, while the control steers which did not receive the ounces of bone meal daily had carcasses weighing 350 pounds.

The rainfall and temperature of any particular region determines the protein value and the crude, fiber content of pastures. In all regions of Britain where domestic breeds of livestock, such as the Hereford, Shorthorn, Sussex and Aberdeen Angus have been evolved, the average monthly rainfall is approximately 2 inches per month and the atmospheric temperature varies from, an average monthly temperature of approximately 40° F. during the winter to approximately 80° to 65° F during the hottest summer month. In those areas with a temperate climate and a steady rainfall, pasture growth is slow, crude fiber is low and crude protein is high. Those are the areas having very succulent pastures.

New Zealand, has an average monthly rainfall of approximately 2 ½ to 3 inches per month and an average monthly temperature seldom exceeding 85° F. In that country probably are found some of the lushest, mainly artificial pastures in the world with a high carrying capacity.

In most semiarid countries the rainfall is seasonal; there are dry seasons with no rain or practically no rain and short seasons with very heavy downpours. In. South Africa, the average rainfall in some of the semiarid regions is approximately 16 inches; approximately half falls from the beginning of December to the latter part of February. The average monthly temperature varies from approximately 60° to 80° with an average annual isotherm of 65° to 76° F. In those areas pastures grow very rapidly; hence are very high in lignin content, that is the crude fiber content is very high and the protein value is low. In semiarid regions, livestock often suffer from nutritional deficiencies of energy and protein for a fairly long period during the year.

Temperature is most important in determining which type of animal can be maintained in a particular region. In areas where the atmospheric temperature is high and where the average annual isotherm (the average temperature for the year) is high, unadapted cattle will degenerate. Few British breeds of livestock can thrive in areas where the average annual isotherm is above 65° F. If it exceeds 700 all British breeds of livestock will suffer from tropical degeneration. Tropical degeneration is not only characterized by stunted growth but also by a marked reduction in fertility. Animals not tropically adapted, which cannot withstand high temperatures, become hyperthermic and often show a rise in body temperature as high as 104° to 106° F. Young animals from birth to 1 year suffer appreciably more than older animals. The young animal's thermo-regulation mechanism is not functioning properly and only after the animal is approximately 1 year old can the unadapted animal maintain a body temperature a few degrees lower than what they would have had if they were younger. The tropically adapted animal will show little if any rise in body temperature at atmospheric temperatures of 85° F. and higher. Animals which show symptoms of hyperthermy are tremendously retarded in growth and Shorthorn, Hereford and Aberdeen Angus cattle at the Messina Research Station in Northern Transvaal often weighed as little as 700 pounds at 3 years of age, while the adapted animals that are heat tolerant weighed 1,100 pounds or more.

The tropically adapted animal is smooth coated and has a thick movable hide of high vascularity. Animals of the British breeds, although they are often born beautiful, have an outer protective coat and an inner heat-retaining coat. Animals not born with a sleek or smooth coat will suffer severely when young. A calf which is born beautiful may weigh as little as 280 pounds at 8 months weaning. These animals have heavy coats, and as a result of hyperthermy on hot days may suffer pituitary damage. Such animals are very retarded in shedding their hair; often it is delayed until the age of 3 to 4 years. These animals are usually sterile; they have very small pituitaries — 1.4 to 2.5 grams. Postmortem examination shows they have infantile ovaries in most instances.

Some of these tropical degenerates have the typical body conformation of the sterile animal. In one instance a typical tropically degenerated cow was removed from the Messina Research Station (average annual isotherm 70° F) to the Experimental farm, Pretoria University with an average isotherm of 68° F. At the age of 11 years she had had no calves at the Messina Research Station, but when removed to the Pretoria University Research Station this cow gave birth to her first calf at the age of almost 12 years. Although sub-fertile, the change to a temperate environment and a better nutritional level caused her to ovulate and to get in calf.

Hair and hide play a tremendous role in the adaptability of animals. A mutant woolly coated purebred Afrikaner bull, whose sire was a show-winning bull and whose mother was an outstanding Afrikaner cow, was obtained for tropical research work. This woolly coated bull was brought to the Messina Research Station and mated to sleek coated Afrikaner cows. Approximately half of his progeny were woolly coated and half sleek coated. In every instance, the sleek-coated cattle outweighed the woolly coated ones. The woolly coated progeny became tropically degenerated. The woolly coats acted as an insulating layer which did not facilitate the radiation of energy from the body. The smooth-coated heifer calves by this bull weighed an average of 400 pounds at 8 months and the woolly coated heifers, 300 pounds. The. woolly coated Afrikaner bull was mated to Aberdeen Angus, Shorthorn, and Hereford cows. One Aberdeen Angus cow-produced two bull calves by the woolly Afrikaner bull. The first bull calf was woolly coated and the second bull calf was smooth coated. At the age of 7 years, the woolly coated steer weighed 870 pounds and the sleek coated steer weighed 1,360 pounds. It is obvious that hybrid vigor had no value whatsoever in the animal that was not adapted.

Several of the woolly coated Afrikaner bull's purebred female progeny were mated to sleek coated Shorthorn bulls. The Afrikaner cows which were the progeny of the woolly coated Afrikaner bull by sleek coated Afrikaner cows produced some smooth and some woolly coated calves. When the Afrikaner- cows which were heterozygous in coat cover were bred to smooth coated Shorthorn bulls, they produced smooth and woolly coated calves. The calves that were bora sleek coated could overcome the hazards of the subtropics; they did not show a rise in body temperature or hyperthermy not even when they were young. Those born woolly coated could not overcome the hazards of high temperatures. At the age of 8 years the steers born sleek coated weighed an average of 1,080 pounds, while those born woolly coated weighed only 800 pounds.

The animal with a sleek, thick hide with high vascularity will bleed profusely if the hide is punctured but injuries will heal rapidly. Such animals are well adapted to high atmospheric temperatures. Wounds inflicted in the animal with a thick, movable, vascular hide heal within a week to 10 days. Wounds in the animal with a woolly, thin coat with low vascularity often take 3 weeks or longer to heal.

Miniature calves could be produced when low heat-tolerant cows were mated in early spring and were pregnant throughout summer. Calves as small as 19 to 40 pounds were produced from low heat-tolerant cows pregnant during the summer. In every instance the bull calf weighed lighter than the heifer calf. These results because the male fetus has a higher metabolic rate than the female fetus, and the cow which suffers from hyperthermy suffers appreciably more when pregnant with a male calf. In normal calves, the male always is heavier than the female. These calves often are so small that they can barely reach the udder of the cow. Miniature calves are often caused by the lack of adaptability of the mother. Heat tolerant Afrikaner cows mated to Hereford bulls produced heavy calves at birth while Hereford cows with a low heat tolerance mated to Afrikaner bulls produced miniature calves. The difference in weight between the two reciprocal crosses was approximately 75 pounds as compared to 40 pounds.

In Australia, small miniature lambs in areas such as Queensland were found, and none knew what caused miniature lamb production. In 1949, when the results on the cattle were discussed in Australia it was mentioned that the miniature lambs might be caused by ewes pregnant during midsummer. Perhaps some ewes were more heat tolerant than others and those ewes which lack heat tolerance would produce small lambs. Drs. George Moule and Neal Yeates mated a number of ewes and placed half the pregnant ewes in cold rooms and half in hot rooms. Those placed in an environment of 85° F produced lambs weighing 4 pounds. Those placed in an environment with an average temperature of 65° F produced lambs weighing on an average 8 pounds.

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

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

When other animals such as horses and mules eat plants which make them photosensitive, such as goathead, they will develop many photosensitivity symptoms. A white mule consumed Tribulus terrestris and his hide looked as if it were corrugated. The unpigmented areas were swollen while the pigmented areas were normal. Animals which consume plants like lantana suffer severe photosensitivity. if a cow or horse eats lantana, it becomes photosensitive and will die if exposed to light. A Friesland cow which consumed lantana exhibited severe photosensitivity symptoms, all the white areas of her body were badly inflamed; it became one large sore and lost all white hair. The animal was placed in a dark stable and recovered. All mucous membranes were also severely inflamed. Horses which consume plants which make them photosensitive develop vast sores on their bodies called sand bum in Texas. As early as 1909, the veterinarians of the Department of Agriculture in the United States tried to solve this problem and as yet have not found an answer. It is advisable to put animals which suffer so severely from sandburn in a dark stable.

Radiation also has a marked influence on the animal. Animals which have no pigment in their eye suffer severely. The most important rays which impinge on animals and cause damage are ultraviolet. Daylight is composed of a spectrum of colored rays: red, orange, yellow, green, blue, indigo and violet. The rays just beyond the red spectrum are infrared rays, and they are heat rays. Beyond the violet spectrum are ultraviolet: rays. These rays are chemical rays and when they impinge on an animal that has no color in the hide or has a dry hide from a lack of sebum secretion, these animals will suffer severely. The white animal will develop cancer or hyperkeratosis of the hide where the hide hardens and becomes very sensitive. White faced animals like the Hereford will develop cancer on the eyelid from moisture forming on the eyelid due to dust, or other matter which irritates the eye. Constant radiation of ultraviolet light may cause cancer on the eyelid or on the eye itself. The white-faced animal which lacks pigment in the sclera of the eye develops a cancer in the eye. Many ranchers have these cancers removed by surgical operation, but this is not very successful. We can, by selective breeding, breed Herefords with pigment around the eyes. The incidence of cancer in eyes of animals which have pigmented eyelids is negligible. By strict selection for pigment around the eye, the amount of pigmentation can be increased and such eyes will never suffer from eye cancer. A survey on Hereford cattle in South Africa showed that in young animals, the proportion of animals with pigment around the eye is relatively low. In the older age group, of 6 years and older, the proportion of animals with pigment around the eyes was much greater. Therefore, the mortality rate of the animals without figment around the eye is appreciably higher up to the age of 6 years than it is in those that have pigment around the eyes.

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

In a group of 'N Guni cattle, those with pigment in the hide show a dark number when branded, while those devoid of pigment in the hide show a white number. Those animals which are white suffer severely from ultraviolet impingement and usually are sterile.

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

High altitude is a problem to most animals. In high altitudes, cattle must have a higher hemoglobin index than at low altitudes. In the early work done by Duerst, a Swiss animal scientist, it was proved that the high altitude cattle of Switzerland, the Brown Swiss and the Simmental had a higher hemoglobin index than any of the other breeds of cattle in Europe. We must evaluate the adaptability phenomena of animals adapted to high altitudes to understand the adaptability phenomena required by cattle at those altitudes. The llama, an animal well adapted to the high altitudes of the Andes Mountains, has a red blood count of more than twice that of the human being. The llama on average has 14 million red blood cells per cubic centimeter; man has approximately 5 million. The affinity of llama blood to oxygen also is twice as high as that of the human being; hence the llama is four times as efficient in utilizing the oxygen in the rarefied air at high altitudes as is man. At high altitudes, we find various breeds of cattle which show certain adaptability phenomena. In Switzerland are found the Simmental and the Brown Swiss, and from a color point of view, the Brown Swiss with its dark pigmented hide is appreciably better adapted to the high altitudes than the Simmental. The Simmental white areas become hyperkeratinized and the animals often suffer. In high altitude, semiarid regions like southwest Africa, the white areas of the Simmental are a real hazard.

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

Another environmental factor which requires certain adaptability phenomena in the animal is wind. In the northern parts of Scotland and the eastern seaboard of New Zealand, cold and moist wind blows continuously. The most beautiful adaptability phenomenon in animals adapted to cold moist winds is their two types of hair, the inner heat retaining coat and outer protective coat, and these coats are charged electrically opposite. The inner heat retaining coat is positively charged and the outer protective coat is negatively charged. If wind blows over these animals, the charge, becomes stronger and the hair packs closer and the animal becomes waterproof and coldproof and the insulating coat is functioning efficiently.

Pigs constantly exposed to severe cold and wind develop long, woolly hair. In the forests of Yugoslavia, Mangalitsa pigs exist on nuts and are exposed at all times to the climate; these pigs are woolly coated, almost as woolly as a sheep. In 1770, Captain Cook on his exploratory travels in the Antarctic dropped a number of pigs of the type maintained in England at that time, on the Campbell and Cook Islands in the Arctic Zone south of New Zealand. In 1943, a few research workers of the Ruakura Research Station in New Zealand stationed on the islands to do radar work during World War II encountered long haired pigs having an inner heat retaining coat and an outer protective coat. Only those pigs which had the genetic potential to develop an outer protective coat and an inner heat retaining coat could survive. After almost 200 years, there were large numbers of pigs well adapted to the Arctic regions.

An environmental factor which has received very little attention in the literature on ecology is soil pH. Where the soil pH is high, nitrification of bacteria in the roots of leguminous plants can take place, and if nitrogen can become available to pastures, the pastures are higher in protein value. Leguminous trees like some of the Acacia species are indicative of a high soil pH. A soil pH of approximately 6.5 will produce pastures relatively high in protein. The calcium in such pastures usually is readily available to the cattle and they have good skeletal development.

The type of plant growth may be indicative of the pH of the soil and the skeletal development of animals. At the Mara Research Station pasture having a high pH, where the predominant tree is *Tribules terestis* we grew large cattle. In a pasture not 8 miles away we had *Combretum apiculatum* grazing where there was a low soil pH, and animals kept in these pastures were appreciably smaller.

Steers indicative of the average of two groups kept in the *Tribules terestis* pastures, and steers in Combretum pastures differed 300 pounds in weight at 3½ years. The steers in the Acacia pastures averaged 1,250 pounds when those in the Combretum pastures weighed only 950 pounds. So many Texas cattlemen do not appreciate why cattle from East Texas grow bigger if moved to West Texas. Most pastures in East Texas grow in areas with a low soil pH and adding lime would add tremendously to the nutritional value of these pastures.

The Afrikaner breed, indigenous to the semiarid subtropical areas of southern Africa, are beautifully adapted to the Savannah country where Acacia trees predominate and mature cows weigh approximately 1,200 pounds.

The 'N Guni cattle are best suited to the low pH pastures of the coastal regions and to the higher rainfall, lower pH areas of Swaziland. The mature cows weigh approximately 750 pounds. Afrikaner cows maintained on pastures with a soil pH of approximately 6.2, averaged 300 pounds more than Afrikaner cows maintained on pastures with a soil pH of 5.4. The problem of varying soil pH values had a marked influence on the skeletal development of cattle in Holland. This was known 100 years ago. It was known in Holland that cattle maintained in areas where forests and sandy soil with low pH existed had small body conformation and were light boned. Animals kept where soil had a high pH were large framed and heavy.

Animals adapted to low soil pH and high humidity are most often shade lovers. The 'N Guni cattle in Swaziland, where the humidity is high and the soil pH is low, are shade lovers because of the hazard to the animal to radiate energy in a humid climate when not in the shade. Hence, these animals are forest dwellers. Animals in coastal and humid areas often are very light colored, ash grey or almost, white and must have pigmented hides.

A hazard to many animals in their natural environment is insects, ticks, mosquitoes and flies. Tick-borne diseases are a serious hazard to most areas of Africa, and in research work done by Baque in Cuba many years ago it was found that ticks remove as much as 96 kilograms of blood from one animal per annum. We can overcome this hazard of ticks by proper management and breeding. Animals can be bred to be tick repellent. Those animals which have thick movable hides, well developed panniculus muscles and a sensitive pilomotor nervous system will move their hides very rapidly upon the slightest irritation and will be much more tick repellent than those animals with woolly hair and thin hides. The tick-repellent animal has well developed panniculus muscles; those not tick repellent have poor panniculus muscle development. The hide of the animal where tick borne diseases are a hazard is one of the most beautiful immunizing organs. Those animals with thick hides become immune much more readily and succumb much less to tick-borne diseases than those with thin hides and woolly hair.

Conquering the screwworm hazard in Texas and in the southern United States will completely change our approach to livestock production. By eradicating the screwworm fly, the screwworm problem has almost become a thing of the past, and the increase in the deer population in many of our natural grazing areas has caused us to realize that the livestock carrying capacity of these pastures has changed. Since the screwworm is eradicated, we can now probably produce calves in other seasons of the year than we did in the past. I believe that by conquering this plague the livestock industry will have to do new research on cattle pasture management, breeding seasons of cattle and carrying capacity.

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

Internal parasites often become a hazard to animals. Where rainfall is periodic and intense in the summer, animals often drink stagnant water in muddy tanks and suffer from internal parasites such as liver fluke and various types of worms. Animals on artificial pastures with a very high stocking rate often are infested with internal parasites. Animals on artificially irrigated pastures are more parasite infested in pastures irrigated by overhead spraying, than those flood irrigated. The problem of maintaining large numbers of cattle on intensive artificial pastures is largely one of internal parasites. Animals susceptible to external parasites also are more susceptible to internal parasites. The less adapted animal with a lower nutritional status in a particular environment usually has a high incidence of external parasites and is often infested with internal parasites of one kind or another.

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

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

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

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

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

There probably is no country in the world where the symbiosis between man and his animals is closer than in Holland. The stable and the homestead in Holland are often under one roof. In winter the animals are the air-conditioning mechanism of the Dutch homestead; the heat given off by the stabled animals keeps the house warm. The stable and the living room are separated by a single door. Above the animals in the stable is the barn containing hay. The animals are under continuous supervision by the owner and many of these cattlemen say their cattle have a soothing and calming effect upon them. The tranquility of the cows chewing their cuds in a comfortably warm stable has a favorable psychological effect on the husbandman; if they are worried the first thing they do is to go into the stable with the tranquil cattle.

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

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

In a country like New Zealand where no concentrate feeding takes place and ail the production of milk is off green pastures, cattlemen select those Jersey cattle with tremendous stomach capacity to enable them to produce enough milk. Only those animals which consume enough green pasture to produce enough energy and nutriment on, die total digestible nutrient and dry matter basis are maintained in the herds. Ninety percent of the dairy cattle in New Zealand are Jerseys with tremendous stomach capacity. New Zealand has lush pastures and no concentrates are fed to cows there. Most cows calve in early spring and the incidence of twinning in New Zealand is appreciably higher than other parts of the world. At the Ruakura Research Station in New Zealand there were 222 pairs of identical twins in. experimental work.

The standard of livestock production in a country depends largely on the cultural and religious background of the people. In Africa, India and other parts of the world where the people are ignorant, superstitious and prejudiced, the cattle are poor. In Ovamboland, the cattle are kept overnight in corrals and the cows are milked by women in pails cut out of wood that are never washed.

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

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

A thorough knowledge of livestock ecology is essential if we want to select and breed tropically adapted cattle. In cattle of the British beef breeds enough variation in the coat cover is observed to enable us to select the variants which exhibit adaptability phenomena. If sleek coated, thick hided animals are selected, they will be much more heat tolerant than those which are woolly coated. The undesirable woolly coated calves can be recognized at a very early age, as early as 3 days, by a felting test on their hair. A small sample of hair is taken from the animal's coat with a pair of small scissors, spit upon and rubbed intensely. If the small sample of hair felts into a tight, mass, the animal will never become sleek coated in a subtropical environment. A sample of hair of those animals with smooth, straight hair which is medullated will not felt when moistened and rubbed. The hair of the woolly coated animal is of two types, an inner heat retaining coat, not medullated, and an outer protective, coat which has medullated hair. There are primary and secondary hair follicles in the hide. The smooth coated animal has medullated hair only. A hair comes out of each primary hair follicle, and in most instances, there is a sebaceous gland attached to each hair follicle. Hence the secretion of sebum in the smooth coated animal is appreciably higher than in the woolly coated animal.

The complete coat cover of animals of the British breeds have been closely clipped and pet through a felting machine. The hair of the woolly coated animals felted into a tight mass required a pull of 26 pounds to pull it apart. In the sleek coated animals, a pull of 4 pounds will separate any sample of semi-felted hair. Animals with hair without felting properties are the tropically adapted.

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

Out of a tropically degenerate Hereford herd, it was possible to breed by strict selection for adaptability a herd of Hereford, very well adapted to the subtropics. Selection was based on sleek coats, thick hides and pigmentation around the eyes. At the Mara Research Station in Northern Transvaal, a Hereford herd bred for tropical adaptation was established. In a period of approximately 15 years, it was possible to breed a completely adapted Hereford herd with all the adaptability phenomena required for tropical adaptation. The only factor which could not be overcome was the susceptibility of these animals to tick-borne diseases, although, the incidence was reduced. The Hereford bulls selected in this program were all thick hided as indicated by downward skinfolds; they had pigment around the eyes, and the color of the hair on. the neck, upper flank, lower rib regions and lower thighs was appreciably darker than the other hair.

A survey made on the Hereford cattle in three ecological regions of South Africa found that Hereford cattle with sleek hair in the subtropics were 200 pounds heavier at maturity than those that were woolly coated. In the region of the Mara Research Station the average mature weight of woolly coated Hereford cows was 990 pounds. Medium coated animals weighed 1,090 pounds, while those that were sleek coated weighed 1,187 pounds. In a temperate region the difference was l,030 pounds for woolly coated cattle, 1,044 for medium coated cattle and 1,071 for sleek coated ones, a difference of only 41 pounds between the sleek coated and woolly coated cattle in the temperate region. It became very clear from this survey that adaptability phenomena such as a smooth hair coat is of much greater importance in a subtropical region than in a temperate region.

All animals can overcome cold if they are well fed. The major livestock problem in all tropical and subtropical regions where the average annual isotherm is above 65 degrees is tropical degeneration. When the adaptability work at the Mara and Messina Research Stations was started in 1937, those areas had thousands of cattle of the British breeds — Shorthorn, Hereford, Angus and Sussex — which were typical tropical degenerates. After careful research on the factors which bring about adaptability, in the subtropics, it was possible by selection, breeding and crossbreeding to replace these animals by adaptable types. At Mara Research Station by crossbreeding and inbreeding, a new breed of cattle has been evolved, the Bonsmara. The Bonsmara was bred on fairly similar lines as that adopted in the breeding of the Santa Gertrudis in the United States, but we adapted a few different methods in our selection program. Very little was left to empirical standards; animals were tested for climatic adaptation by taking their body temperatures, respiration rates and pulse rates. It was decided to breed cattle 5/8 Afrikaner, 3/16 Hereford and 3/16 Shorthorn. After obtaining 5/8 Afrikaner-3/8 Hereford cattle, and 5/8 Afrikaner--3/8 Shorthorn cattle, these two types were interbred to get the 3/8 Afrikaner, 3/16 Hereford and 3/16 Shorthorn. It was found that animals with more than half the blood of the British breed could not withstand the subtropical conditions.

Hereford were brought in because they are better grazers than the Shorthorn, more heat tolerant and have a more even fat distribution than the Shorthorn. The Shorthorns were brought in because they are faster maturing than the Hereford, have better milk production and are a uniform red color. By crossing the 5/8 Afrikaner 3/8 Shorthorn with the 5/8 Afrikaner 3/8 Hereford it was possible to develop a red animal with no white on it. I am opposed to white on any animal. I consider it a hazard to any animal in the tropics and subtropics.

Some of these Bonsmara cows were selected for longevity, fertility and functional efficiency, and in some instances, we have cows that are 17 years old now that have had 15 calves. The heavier ones weighed over 600 pounds at 8 months and the lightest weighed 450 at 8 months. Any animal which shows hereditary weakness or a point of lower resistance is culled. The bulls used in the selection and breeding work at the Mara Research Station to establish the Bonsmara breed have to be functionally efficient. They must be able to serve 50 or more cows in a 2½-months breeding season. They are sexually active and highly fertile.

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

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

At the moment of conception the complete genetic potential of the animal is fixed. What this animal is ultimately going to be, depends on these pathways (Figure 3). The first pathway is from the complete genetic potential to the morphology or phenotype of the animal. That is, breed characteristics, such as skeletal size, muscling, fat deposits and hair color are all genetically predetermined. These characteristics may further be modified by the interaction between heredity and the total environment. The total environment includes the environment in which the fetus develops. Certain factors act on this potential genetic makeup to ultimately determine what that animal will be like. What the animal will be like, therefore, depends on the interaction between environment and genetics. It is this interaction that will determine what the effector organs are like — what will be the length of the legs or how long or tall will the animal grow. What is its hair coloring going to be, what will its skeletal development he like, its muscling, its fat deposits. So, pathway 1 determines to a large extent how the animal's body conformation will be expressed, but in addition the genes will help determine how these endocrine glands are going to function to modify the expression of body conformation.

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

If the animal is stimulated through the central nervous system, the hypothalamus has a pathway to the endocrine glands, especially the pituitary. The pituitary then feeds back an impulse to the brain that has a pathway to the central nervous system causing certain 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 the animal's genotype in its phenotype (its total morphology being the product of the interaction of the external environment such as nutrition and temperature, as well as the internal environment) is the result of the action of the endocrines on the gene complex laid down at fertilization.

The interaction of the endocrines upon one another must also be considered. The pituitary secretes gonadatropim, which are hormones which stimulate the sex glands. These hormones have a direct influence on the gonads, that is, the testes or ovaries. The pituitary gonadatropin, the lutenizing hormone, has a direct influence on the interstitial cells of the testes, which in turn produce testosterone, the male sex hormone. Testosterone has a marked influence on the male secondary sex characteristics of the bull. If there is a breakdown anywhere in the chain reactions between hormones, this will be reflected In the morphology or the body conformation of the animal concerned. The same holds true for the female. Another pathway of a pituitary trophic hormone is through the corticotropìn, and its effect on the adrenal cortex is reflected by hair growth, carbohydrate metabolism and male and female sex characteristics. The thyroid gland has a marked influence on the metabolism of the animal. If any one of the hormone functions is severely interrupted, this will be reflected in the external morphology (body conformation) of the animal.

Figure 4 is a diagrammatic drawing of a cow showing where the various endocrine glands are located and how these glands interact with one another, (their interaction is reflected in a diagramatic illustration.) The

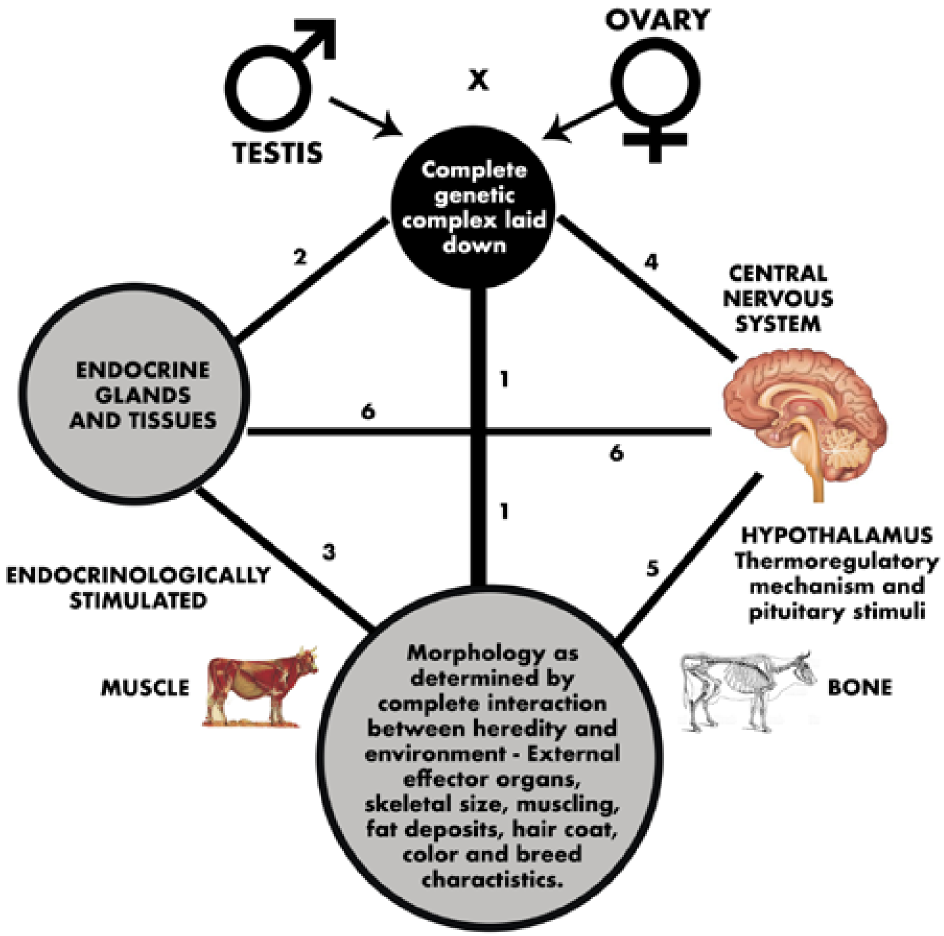

Figure 3. The interaction between genes and the phenotype.

interrelationship of the endocrine glands is reflected visually in the external morphology of the animal much as is the case in a jigsaw puzzle.

Figure 5 shows the interaction of the pituitary gland on the gonads. The hormones secreted by the gonads have a marked influence on the complete secondary sexual characteristics of the bovine, depending on whether that bovine is male or female.

For example, the male sex hormones have a direct influence on the masculinity of the head. In the human it is a beard, receding in the hairline and baldness; in the bull, it is coarser hair on the head, neck and a special pattern of hair on the neck, upper shank region, lower midrib region and on the lower thigh. It has a direct influence on the sound the animal makes. When an animal bellows, a really experienced cattleman will tell you that is a bull, a steer or cow bellowing.

The male sex hormones have a direct influence on muscle growth. All the data that has accumulated so far on feeding steer calves, bull calves and heifer calves clearly illustrate this. The male calf's rib eye muscle is appreciably larger than that of the female or the steer. This phenomenon is controlled by hormone action. 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 the appearance of a normal male. The

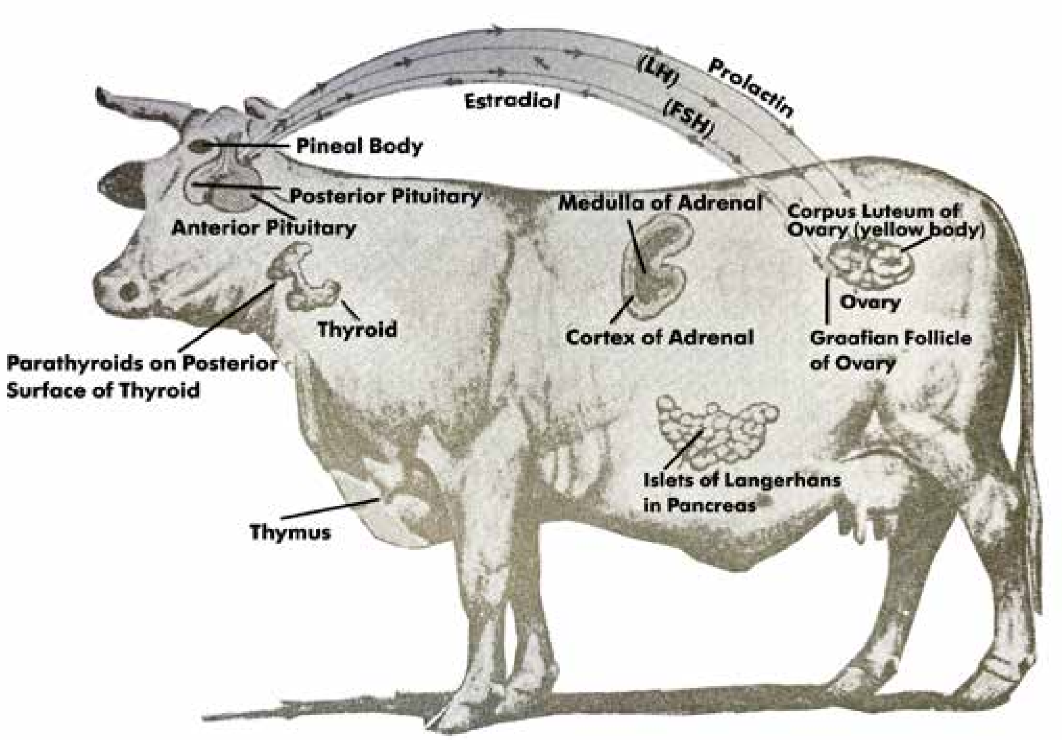

Figure 4. Location of the various endocrine glands.

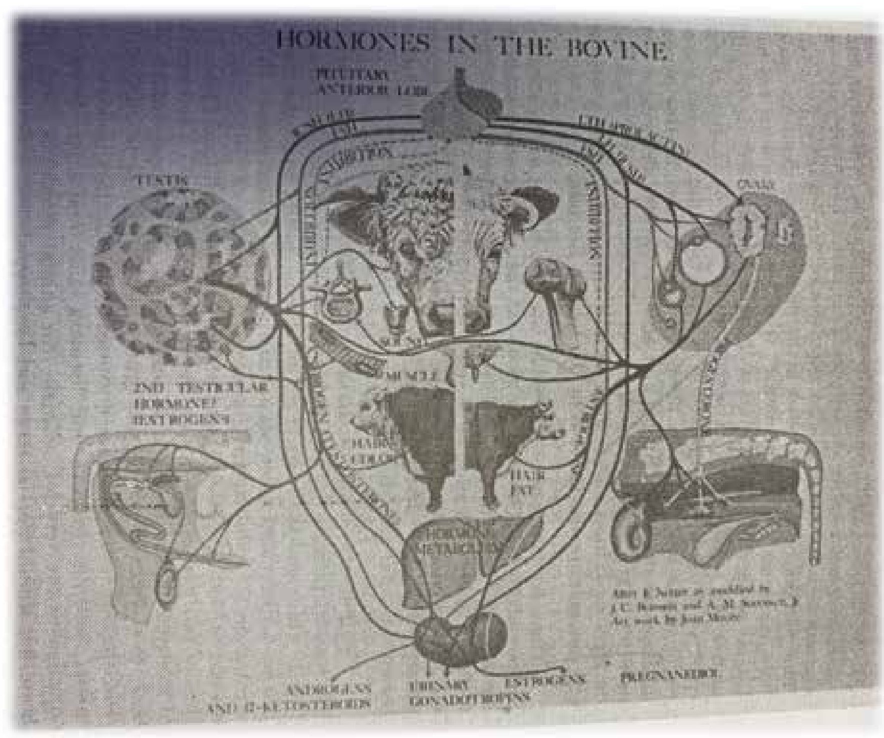

Figure 5. Response to hormone in the bovine.

ossification of the epiphysis depends on the secretion of estrogen of the cow and testosterone of the bull. The sex hormones have a direct bearing on the development of the sex organs and also on whether the animal will have sex urge. The end products of the hormones are given off through the kidneys and I think we now have enough proof that the end products are also secreted by the liver in the bile.

These sex hormones are steroids; steroids belong to the chemical compounds, fats. The steroids (fats) of the sex hormones probably are absorbed or diluted by the fat of an overfat animal. Such hormones have been found to be secreted in the bile of fat animals. The sex hormones are absorbed in the adipose tissues and are excreted through the liver. The male and female sex hormones have a direct bearing on total growth.

Figure 6 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 length, ossifies when the animal reaches puberty and when sexual maturity has taken place. 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 the hormone balance. The secretion of estrogen in the female and testosterone in the male causes the bone to ossify, and the overall growth of the animal is stopped because the bone growth has discontinued. If ossification is delayed, the animal continues to grow and becomes taller and taller, hence the objection to the very tall animal. An animal should be large lying down, but should not be large and long-legged and indicative of an animal with an imbalanced hormone control.

The ovarian hormones have a direct bearing on the udder formation of the heifer. All the stages of development in the animal take place in a very orderly fashion. When the heifer reaches puberty, udder development takes place. That is the way we judge that the animal is functioning normally. In the cow the sex hormones also determine when the long bones are ossified. The relationship of the various bones to the body and towards one another influences the total expression of masculinity or femininity which in turn is an expression of gonadal function.

The pituitary gland which is situated on top of the palate below the brain secretes certain hormones which have a direct influence on the various organs of the body. It has a marked influence on the thyroid and on the total metabolism of the animal. It also has a marked influence on the adrenal gland, especially the adrenal cortex. The adrenal cortex gives off a sex hormone androgen, which stimulates the animal's sex activity. The adrenal cortex produces the hormone which causes melanization (darkening) and probably the thickening of the bull's hair producing a pronounced masculine appearance. The pituitary secretes hormones which have a direct influence on the testes, on the ovaries and on the growth of the long bones. Somatotropin is the hormone which stimulates total growth.

The basis of judging livestock for functional efficiency is illustrated by the work of Zawadowski. If a cock is castrated, its whole endocrine system is thrown out of balance and it becomes a capon, but if the ovary of a hen is grafted in the neck of the capon, it develops all the secondary sexual characteristics of a hen. If a hen is ovariectomized, it is a capon that looks like the caponized cock, and if the testes of a cock are grafted in the neck of the ovariectomized hen-capon, an animal is produced with the secondary sexual characteristics of a cock. In other words, sex reversal can be experimentally produced as far as the secondary sexual characteristics are concerned.

The basis of the approach to livestock judging by functional efficiency is, 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 March 4, 1965 at the Livestock and Forage Research Center in McGregor, Texas. These same changes brought about experimentally in cattle often take place in animals under natural conditions.

Why have we not judged cattle on a functional efficiency basis earlier? One reason is that every textbook on endocrinology mentions that the 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 the 2-year-old ox for both the male and the female. If show animals are studied carefully for functional anatomy, it is very obvious that the show bulls have fewer male sex

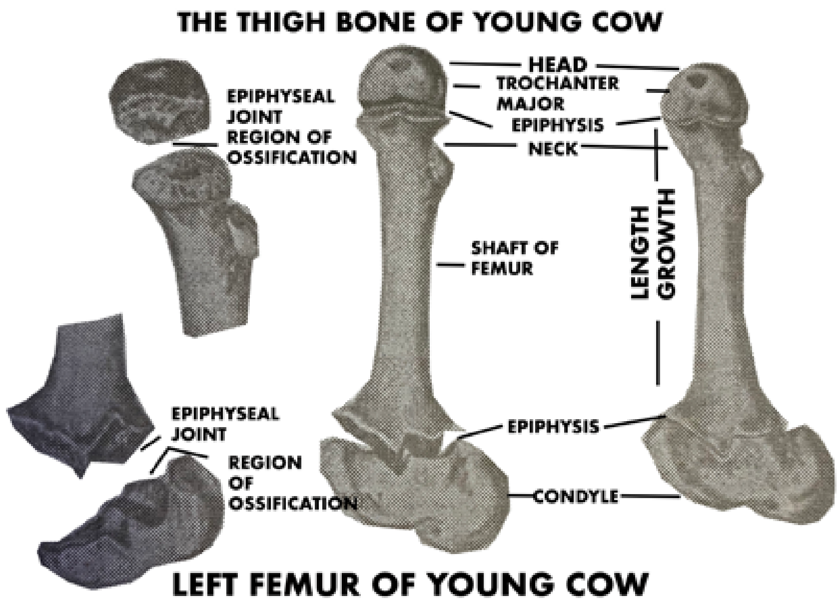

Figure 6. Ossification of long bones in the bovine.

characteristics. The Aberdeen Angus bull sold in Britain in 1963 for $200,000 or 60,000 pounds, the highest price ever paid for a bull, was completely sterile and one could clearly see that he was not masculine; his muscling was not clearly defined, and he had fine feminine hair over his body.

It is my opinion that the three illustrations of the 12-year-old bull, the steer castrated at 2 years and the steer castrated at 6 months dramatically illustrate how male hormones or lack of them change the body conformation (Figure 7).

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 bulls color is not uniform and any breed society that puts down in its breed standards that bulls should be uniform in color is treading on dangerous ground. The adrenal cortex of the animal gives off the male sex hormone, testosterone, which influences the sex libido of the animal. Research tends to show that androgen, the secretion of the testes and adrenal cortex have an indirect influence on the darkening of the color of the hair on the animal. A bull should not be uniformly colored because he has to have masculine hair in all the regions mentioned. Figure 7 is an illustration of the bull's half brother, also 12 years old, castrated at 2 years of age. Since castration, his color turned uniform, 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 completely taken place. 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 reaches sufficient sexual maturity for the sex hormones to cause bone growth cessation. 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 region of the rump and loin is the last part of the body that reaches maturity. Actually it is the last part of the body that reaches

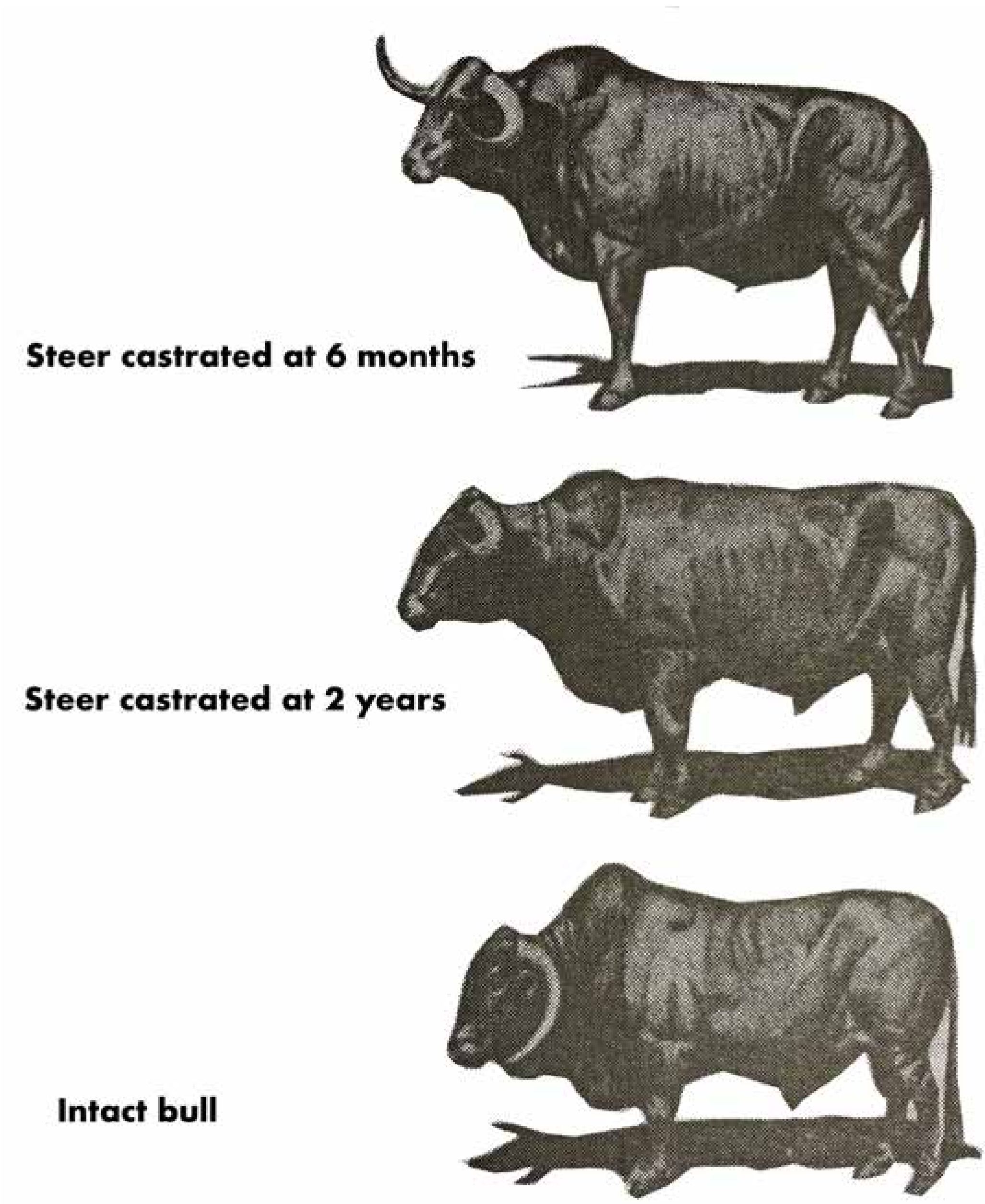

Figure 7. Influence of sex hormones on hair, muscular development and skeletal growth. All three animals are 12 years old.

maturity in the fertile animal, in the animal that is a castrated, or in the infertile female, the front ribs, thorax, chine, brisket and head are the last parts of the body to reach maturity, that is, 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 (Figure 7) is 17 years old now and he still shows a certain amount of growth in the length of ribs, head and horns. The bull's size, limited by the ossification of the long bones, was genetically and endocrinologically determined. The steer castrated at 6 months had delayed ossification of all the long bones in which occurs an epiphyseal line and hence, his tremendous size. He is exceedingly tall and flat, overdeveloped anteriorly and underdeveloped posteriorly. This is the typical shape of any breed of steer. The stag or late castrated bull has a much more muscular upper shank than a steer. The steer's horns continue to grow. The anterior part of the mandible continues to grow because the body of the mandible is made up of epiphyseal cartilage which in the bovine never completely ossifies. The region of the rump is relatively small.

It is short from the hip to the pin bones and it is relatively shallow from the hip to the patella or stifle joint.

The concept of what happens to the bone growth in the fertile animal as compared to the subfertile is illustrated in Figure 8. The scapulae or shoulder blades were taken from two 12-year-old cows that had eight calves and two that had no calves. Note how much larger and heavier the shoulder blades of the subfertile cows are as 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 Mara Research Station in South Africa were measured from tip to tip every year from his fifth year until his death at 9 years. Every year his overall horn length increased approximately 3 inches. He had an overall horn length of 109 inches when he died. The horn growth of the cow that has produced calves regularly and the horn growth of the bull will be appreciably slower than that of the steer.

Every bull castrated at the age of 6 months or earlier will develop a well-developed, lower muzzle or jaw. The jaw bones are long bones and the body of the mandible contains epiphyseal cartilage. That cartilage 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 look like steers. They often are very tall, with small or hypoplastic testes, are very broad over the hips, have muscles not well-defined and fat disposition distributed like that on a female. Bulls with primary hypogonadism (small or infantile testes) possess potentiality for growing in height over a longer period of time than sexually active normal bulls because the deficiency of androgens causes a delayed ossification of the epiphyseal cartilages of the long bones, especially the front limbs and long ribs. The activity of the growth-promoting glands, such as the pituitary, and thyroid which is hereditary determined continue to produce hormones which determine whether or not excessive growth of the extremities will take place. The body proportions of the anterior development as compared to the posterior development can be used for distinguishing between various endocrine types.

The heifers from eunuchoidal bulls often are tall and bellow like steers, and very often 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 low-fertile animals, cycling irregularly with infantile udder development. The udder of a heifer that comes in heat 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 special endocrine patterns. It is known that, in human beings, certain kinds of growth disorders such as gigantism, partial gigantism, dwarfísm, etc. are found in members of the same families. 1 have seen gigantism in several members of the same family of cattle and we are still very painfully aware of what happened to dwarfism in cattle in this country.

The body of the highly fertile cow is in beautiful proportion; she looks feminine or broody. 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 pan of the body, not the thurls or hipbones. When the region of the thurls and thighs (mainly the regions through the rump from the one thurl to the other) is wider than the rest of the body a bull has eunuchoid proportions and often is low fertile, and a cow with such body proportions is also often of low fertility.

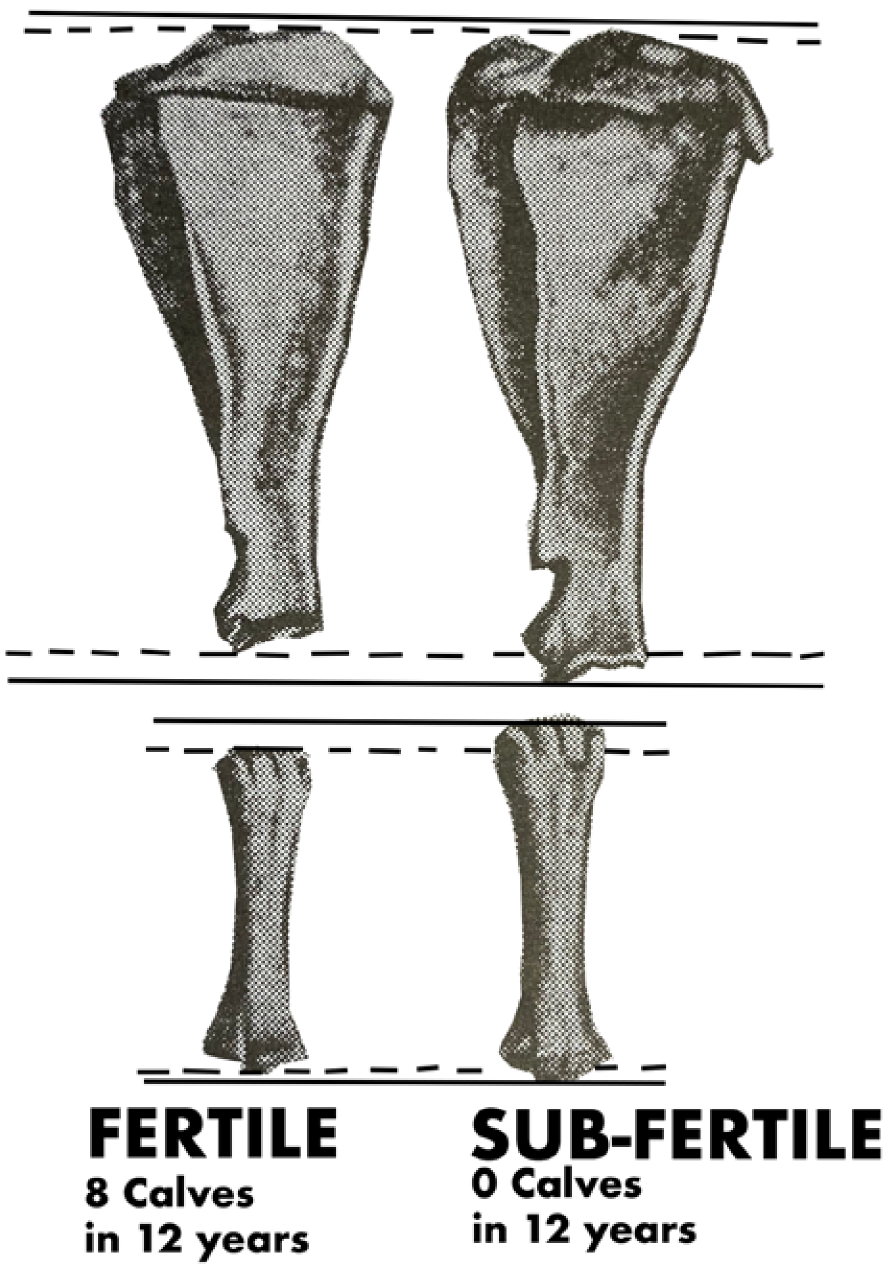

Figure 8. Scapula (upper) and metacarpus (lower) of fertil and subfertile cows.

Figure 9 shows the shape of the highly fertile animal. She has a good girth of chest. The floor of the chest is relatively near the ground. On the rump, the area from the hip bones to the pin bones is large and from the pin bone to the stifle joint is deep. The depth of chest in a subfertile cow that has had three or four calves is appreciably greater than that of the cow that has had nine or ten calves in the same time. The udder of the subfertile cow is functionally less efficient. It is interesting how coarse the hair of the subfertile cow is. It is a much coarser hair than that of the fertile cow, especially from the middle of the back region to the crown of the head. Really 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 subfertile animal. The shape and skeletal proportions of the front limb are clearly illustrated by Figures 10, 11 and 12. The dorsal edge

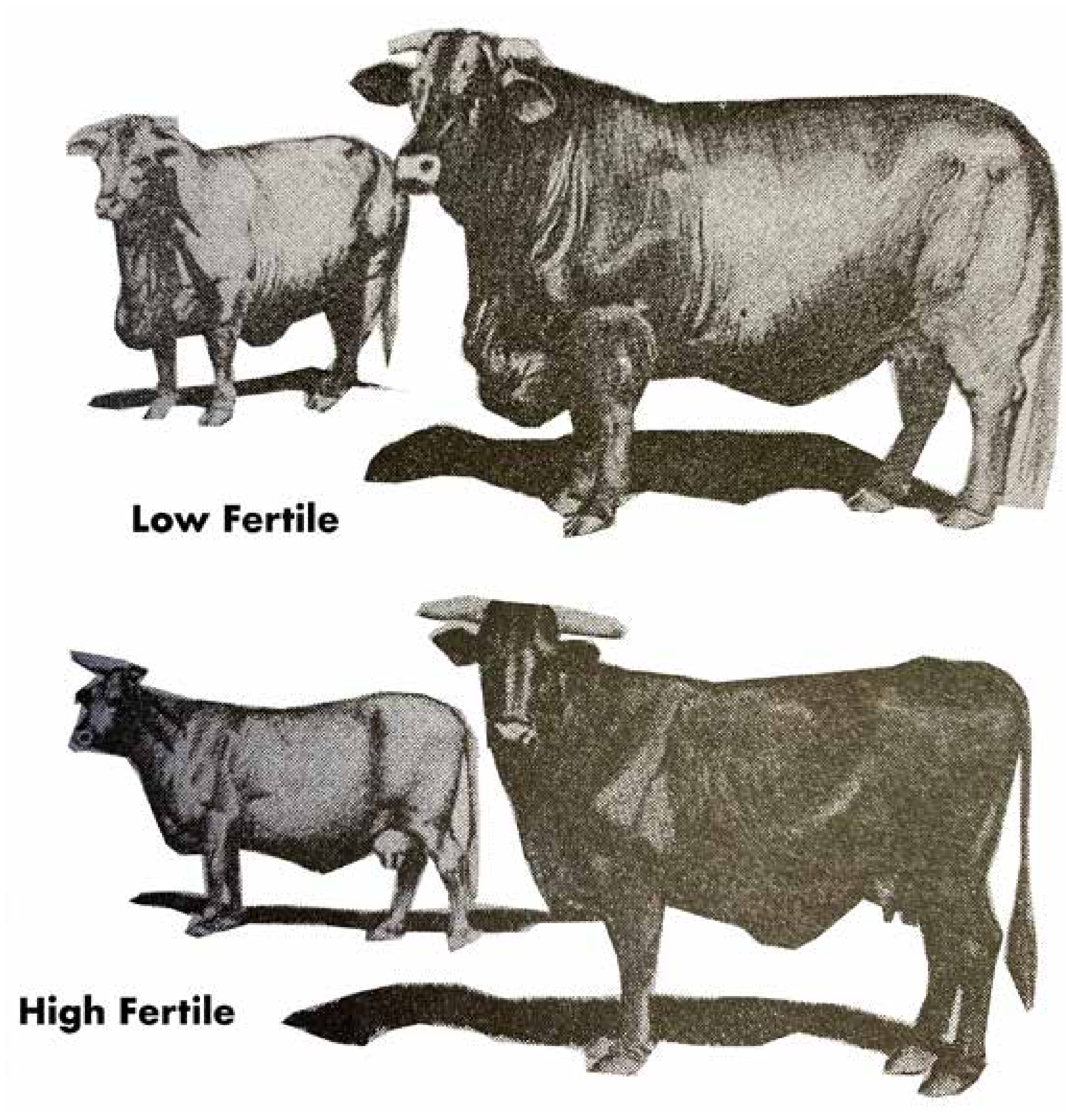

Figure 9. Santa Gertrudis cows. UPPER: Low fertile; LOWER, high fertile.

of the scapula is appreciably lower than the dorsal processes of the front vertebrae in the subfertile animal, and the scapula slants backward. The sternum is pushed down and slopes downward. The hair on the neck is masculine, coarse and heavy as compared with the hair of a fertile cow. The subfertile cow is relatively short from the hip to the pin and from the hip to the stifle joint.

The completely sterile cow again differs from the highly fertile and subfertile cow. Such cows have a tremendous depth through the chest, the brisket is very full and the immediate effect is that it slopes forward and downward. The sterile cow has tremendous fleshing on the cheeks. The distance from the eye to the corner of the mandible is large and the lower jaw is relatively heavy. She has bristly hair on her body. The distance from the hip bone to the pin bone and from the hip ío the patella is relatively small. The sterile cow has a tremendously well-developed buffalo hump. It is well fleshed and fat. The subfertile cow has flesh and fat on the

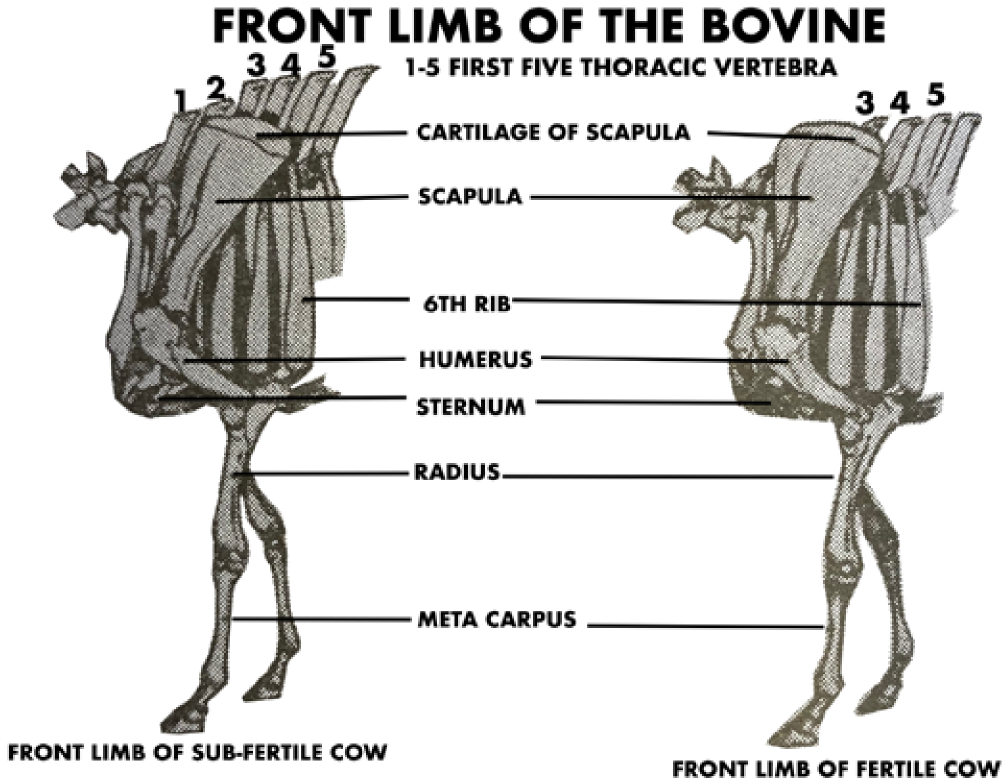

Figure 10. Skeletons of the forequarters of cows with (left to right) low and high fertility.

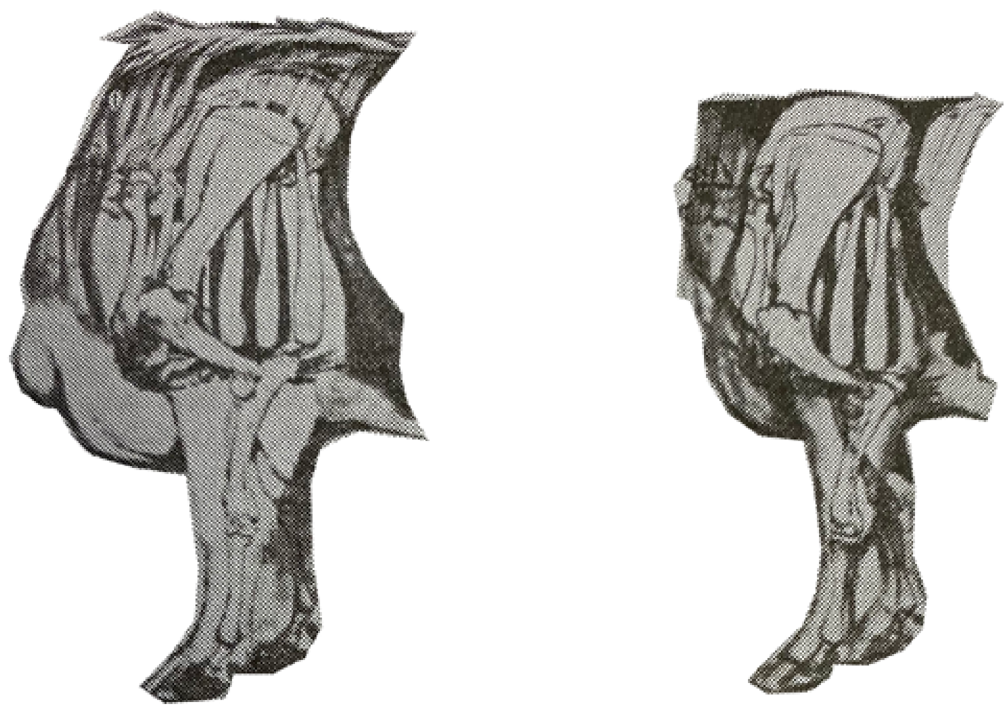

Figure 11. Front quarters and skeletons of Hereford cows with (left to right) low and high fertility.

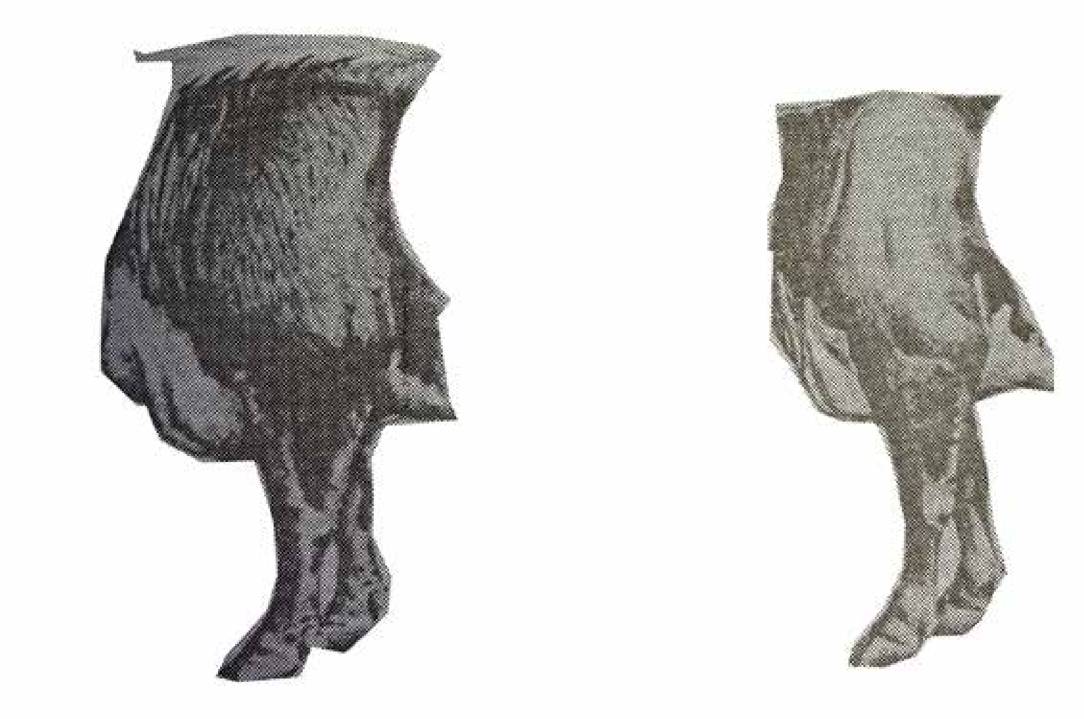

Figure 12. Front quarters and skeletons of Hereford cows with (left to right) low and high fertility.

shoulders, and a very full brisket. The floor of her chest is high off the ground. The accurate scale drawings of the fertile and the sterile cow differ markedly. The sterile cow is appreciably taller than the highly fertile cow. The sterile cow is big in front; all the body parts in the anterior half of the body are much bigger in the sterile cow than in the fertile one. If you compare the hindquarters, the pelvic region and rump of the fertile cow, they are appreciably larger than those of the subfertile cow. The distance between the hip and the stifle joint is appreciably larger in the fertile cow than it is in the subfertile cow. The overall size of a low-fertile animal is larger than that of the highly fertile one of the same breed, but the fertile one is much better developed and relatively much larger in the hindquarter than the subfertile cow.

The difference in functional efficiency in cows is beautifully illustrated in dairy cows. 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, they are going to dual purpose cattle for the production of milk and meat. It is not necessary to go into dual purpose cattle — just select beef cattle that do not have too much fat on the shoulder, balanced, bone growth between the shoulder blades, secondary sex characteristics and hair. Then we will have functionally efficient beef cattle.

The second cow in Figure 13 is an 8½ year-old Jersey cow that has had seven calves with only seven inseminations. The first cow in Figure 13 is 8½ years old 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 center 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. The hair on the sterile cow often is darker than that of a fertile cow. The adrenal cortex of the sterile cow probably gives off androgen hormone which is responsible for the darkening effect of the hair of the sterile animal.

The sex hormones have a very marked influence on the quality and texture of the hair and hair shedding. At the University of Pretoria it was found that Friesland bulls and steers (bulls castrated at 8 months) differed

Figure 13. Jersey cows; Upper: Low fertile; Lower, high fertile.

markedly 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 masculine crest development and clearly defined muscles. A male should have clearly defined muscles; the smooth animal is so often eunuchoidal. The steer has very little masculine hair on the opening of the penis, his neck is thinner and there is no round and muscular crest development.   If a 14-months~old bull is compared with a I4-months-old steer, it is obvious 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 dead and dull. The relative positions of the shoulder blades also differ in these animals. The scapula of the steer is in a slanting backward position. The legs of the steer are appreciably thinner than those of the bull. At 14 months, the bulls weigh, on an average, 80 pounds more than the steers.

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 subfertile 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 stilbestrol 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 had been rubbed with an oil rag. The sleeking off also takes place in the steer or open heifer when they are in good health, have good nutritional status, and the climate is getting warmer, but the sleeking off 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. There often is no real sleeking off and there is no darkening of the hair on the spine on top of the back.

The color and texture of the horns of fertile and subfertile or sterile animals differ very much. The horn of the fertile animal is uniformly colored and often looks waxy. The horn of the sub-fertile or sterile animal is hard and flinty and often has ossified white rings or patches which are very smooth, porcelain-like and very hard.

The cow that has aborted often develops the extremely smooth, hard white spots or rings on the horns. The brisket often is full with lumpy patches of fat. A buffalo hump develops and the hair becomes darker and bristly. The hair on the head, neck, shoulders and lower thigh regions is coarse, dull and dry. Fat in front of the udder and a longitudinal lump below the vulva are typical characteristics of the subfertile cow, and the aborter shows irregular lumps of fat which are probably harder and encapsulated.

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

Any animal that has become subfertile, sterile or calves irregularly, having intercalving dates of 18 months and more, develops certain characteristics which indicate that the cow's endocrines are inbalanced and her normal metabolism has been upset. The cow develops certain characteristic fat deposits on the body. The first is on the lower cheek. The second develops on the brisket; the brisket becomes full and the whole dewlap disappears and there is no skinfold around the brisket. The cow develops a buffalo hump on the chine, 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. An oval fat deposit develops on the lower ribs. A very heavy fat deposit develops on the hip bone; this fat is a very solid type. It is a sort of immobile fat which becomes almost as hard as cartilage when the animal becomes thin — but it is not absorbed or used as a source of energy when the cow becomes thin. It feels like a hard piece of cartilage and will remain. If this stage is reached, it is almost certain that it will be almost 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 6 inches 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 discontinued to calve also shows characteristic changes in her morphology. The brisket drops forward and downward and it loses the skin fold off the dewlap around it. The cow that has been fertile and then gone sterile develops a peculiar body conformation in the hindquarters. She is completely round in every direction, from directly behind and from the side view. Such an animal's vulva often becomes infantile. As a result of discontinuing the reproductive function, hypoplasia of the genitalia takes place. A. definite oval lump of fat develops in the region below the vulva and as previously indicated, she is round in every direction of the hindquarter. Her hindquarters resemble a big ball cut in half and put at her rear end. If an animal becomes so rounded in the hindquarter that it resembles a horse's buttock, it becomes doubtful that she will settle readily. Many typical show heifers have tremendously developed hindquarters 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. If a cow or heifer's tail cannot hang down perpendicularly, it is doubtful whether she will settle readily. 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 the overfat, subfertile cows for 100 years or more. An illustration of a show champion cow in South Holland shows an absolutely low-fertile cow. She has tremendous development in the front region, is small in the rear, has a heavy crest, a rounded neck and a full face. It is a problem with which we have been faced for generations as a result of show standards. Those animals that are regular show winners are those that have fertility problems.

An illustration of a show winning Shorthorn cow is typically that of a low-fertile cow with a full brisket with 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 low or subfertile cow often has a dark line of bristly hair on the top of the neck and crest and a full, brisket. The animal that has aborted often has patchy lumps of fat on the brisket. The brisket is not smooth and the teats very often show that the udder has developed to a certain extent and then receded, indicative that the cow has aborted. The cow that loses a calf before suckling it for a few months or the cow that aborts develops a real white porcelain-like mark on the horns. If too much stress is placed on growth in an animal, an imbalance between the somatotropins {the growth hormones) and the gonadotrophins, (the sex hormones) is struck and fertility is lowered.

At the livestock and Forage Research Center at McGregor, Texas, a Hereford bull was treated with a female sex hormone, stilbestrol, by implantation in the neck. The bull started sleeking off in 8 weeks time; the hair color became lighter and his head became completely feminine. He showed the typical syndrome of gynecomastia, the development of female teats on a male, and his hair was completely different from that of the control bulls.

The vulva of a cow that has been treated with male sex hormones develops a very large clitoris. If a heifers vulva points downward and protrudes posteriorly and is very large, it indicates an imbalance of the female sex hormones and that her clitoris is very large. Such females often come in heat irregularly. 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 subfertile heifer usually is very large, 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 protuding brisket. She does not cycle normally. In an old cow that calves regularly, the horns usually are an even, grayish color with no hard-smooth patches. The regular calver has a lean face, an absolutely lean neck, a skin fold 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 tremendous stomach capacity and a well-developed udder that is functionally efficient. The animal that is really functionally efficient has small, sleek and very shiny teats. Her tail hangs down perpendicularly. When a cow gets very heavy in the brisket and shoulder regions, she does not calve regularly and is a poor milk producer if she calves.

Figure 14 shows two Brahman cows drawn to scale. The first cow has had 11 calves in 13 years, the second has had two 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. She has developed fat on the shoulders, ribs and hipbones, the typical conformation of the low or subfertile animal.

In a functionally efficient bull, there is a darkening of the hair. Even in an Aberdeen Angus bull, masculine black hair is desired on the neck and crest. A bull must have a well-muscled, masculine crest with well-defined muscles in the neck. 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. A too loose, extensive sheath development is most

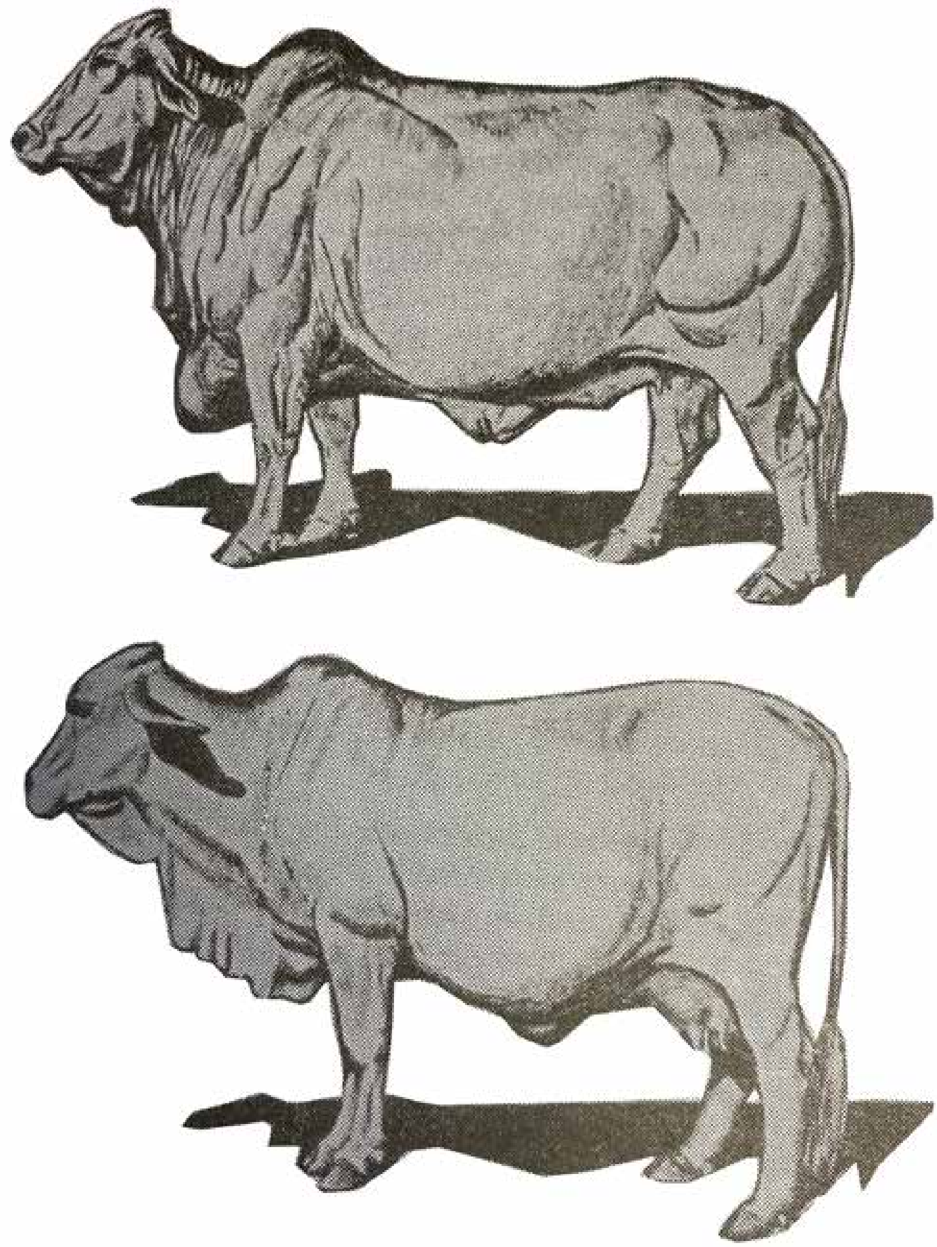

Figure 14. Brahman cows; Upper: Low fertile; Lower, high fertile.

undesirable. Viewed from behind, the fertile bull has well sprung ribs, and the lower rib region is the widest part of the body.

Figure 15 is a Brahman bull that has a good pair of testes. In most lectures on the sex physiology of bulls, it unfortunately is customary to start with the internal anatomy of the sex organs by showing cross-sections of the various organs. 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. 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 scrotum is a most delicately arranged thermo-regulatory mechanism; it has the function of keeping the

Figure 15. A pair of well developed testes and a good sheath of a Brahman bull.

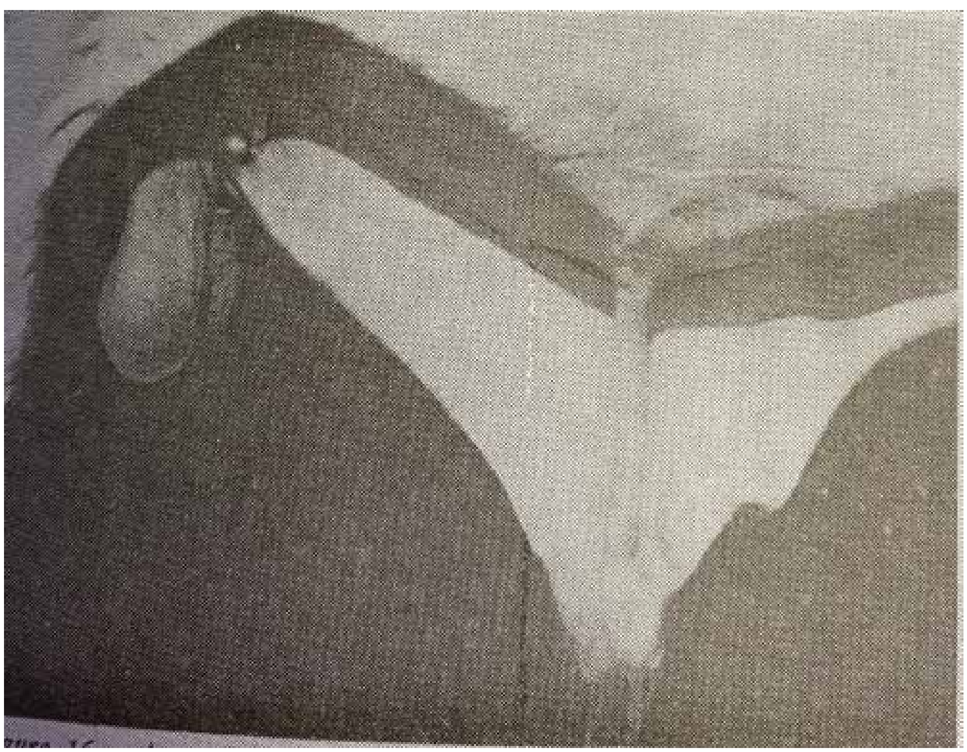

Figure 16. A good pair of testes but the sheath is far too loose and pendulous and the opening of the sheath is too large.

testes cool when hot, and if it is cold to keep them warm. The scrotum can pucker up when it gets cold, that is, the skin of the scrotum can withdraw and form skin folds which makes the skin an appreciably better heat retaining organ by reducing the surface area and entrapping air in the skinfolds. It also draws the testes almost into the abdominal cavity of the bull.

Dr. Harrison of Liverpool University and I did quite a bit of work on the thermo-regulatory mechanism of the scrotum and vascular system of the reproductive organs of bulls. The spermatic arteries and veins have a thermo-regulatory function. By putting Chlor-bismuth, a radio opaque substance, in the spermatic vein and taking X-rays of the testes, it was obvious that the vascularity of the testes of bulls adapted to temperate zones differed markedly from those of bulls adapted to tropical and subtropical regions. The animal whose scrotum and testes has a really good thermo-regulatory mechanism has tremendously tortuous spermatic vein development which enables the animal to maintain the temperature of the testes. If the testes become too large and pendulous and swing about, they get injured, a varicocele develops that blocks the vein and the whole thermo-regulatory function is impaired and the animal becomes sterile.

Figure 16 illustrates a less desirable type of male reproductive tract. The testes are good, the scrotum shows puckering; there is, however, no fullness of epididymis. The bull has got real gyneco-mastia, female-like mammary development next to the scrotum attachment where the rudimentary teats develop on bulls. This is the result of female sex hormones indicating hormonal imbalances in that bull; such bulls lack sex drive. A bull with such tremendous sheath development in which the opening in the sheath is large lacks sex drive, and the quality of the semen usually is poor. Too much sheath development is a serious objection as is a large opening in the sheath.

Figure 17 shows the testes and sex organs of a bull with severe hypoplasia of one testicle and another testicle that is overdeveloped. The penis shows prolapse of the prepuce, far too much sheath development and a large opening in the sheath. These defects are hereditary. In the Polled Swedish Mountain breed, two show winning bulls with one hypoplastic testicle and one normal testicle almost ruined the whole breed of cattle, by producing subfertile female progeny.

Figure 18 illustrates the difference between the development of the hindquarters 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 completely hypoplastic testicles. It cannot be doubted that this syndrome is hereditary.

Recently I encountered hypoplastic bulls on one ranch and all these were sons of a hypoplastic bull. The sire had produced only seven offspring in 1964, and his three sons had produced no progeny in 1964. At a Brahman ranch, a very tall bull produced many tall subfertile heifers. In Sweden, two bulls that were regular show-winners were used extensively; they were half-brothers and both were hypoplastic. Thirty years later this breed was found to be subfertile. In an endeavor to overcome this problem, 8,000 heifers were slaughtered and no fewer than 1,070 were found to be subfertile and had abnormalities of the genitalia; either one or both ovaries were abnormal.

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, resulting in a very straight rump. That is what so often happens in the Friesland breed in Holland, England and South Africa. The hip bone (femur) is more upright than is desirable and that changes the position of the opening of the pelvis. Hence, in cattle with straight hocks and very square or level rumps like the Friesland in Holland, England and South Africa, 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 as illustrated in Figure 19.

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 sperm testing of bulls is no index of their ability to settle cows, unless we are certain they have no defects which will interfere with their serving ability. Semen quality and a semen test is not the answer to

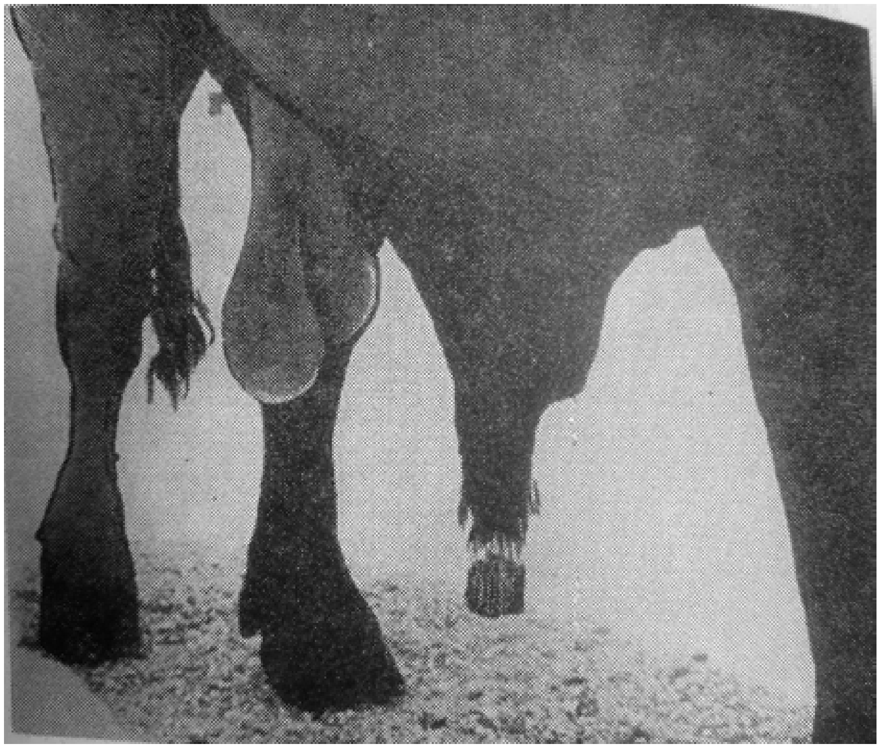

Figure 17. Very undesirable male sex organs. Hypoplasia of a testis, a very large sheath and a protruding prepuce.

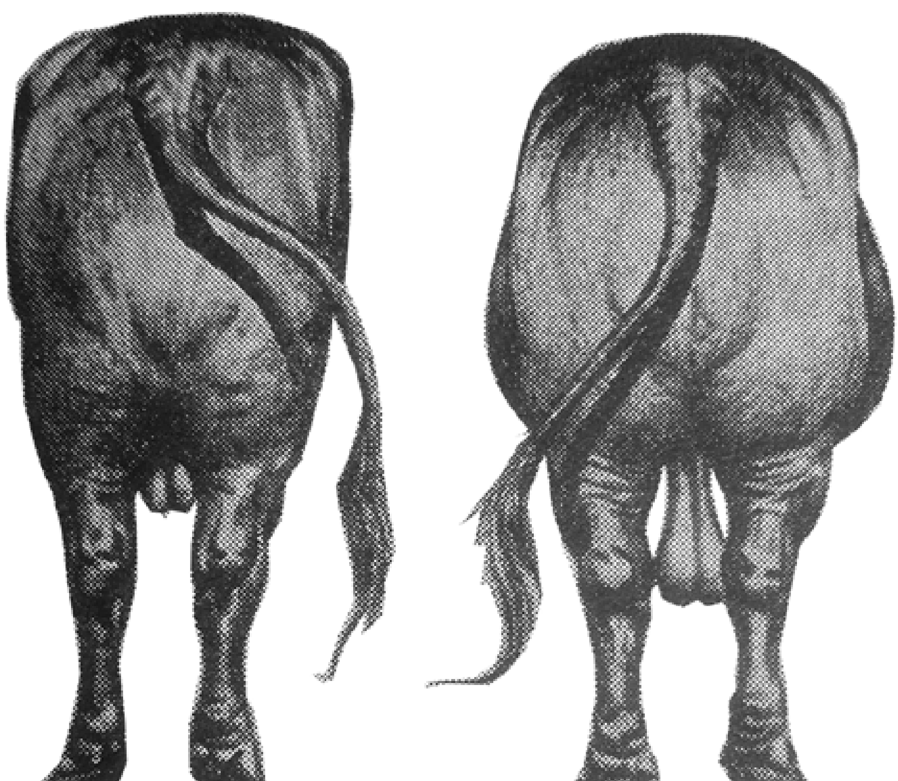

Figure 18. Rear view of bulls with (left to right) low and high fertility.

whether the bull is fertile and whether he will have many calves. The sperm test and the sperm evaluation of a bull's semen is important, but the bull must be inspected and observed to determine whether he has certain physical disabilities and to deter-mine whether he has sex drive. The electro-ejaculator can get semen out of a bull, but it is no index of his ability to serve.

A physical defect such as corns between the hooves is a serious handicap to the bulls ability to walk and also to serve. Corns between the rear hooves are especially undesirable. The moment a bull with corns jumps a cow, the corns hurt and the bull withdraws before mating is completed.

Arthritis is another heritable defect; it is caused by a disturbance in the steroid metabolism. It is closely correlated with reproductive impairment. The sex hormones and fluids are products of steroid metabolism and any animal that has arthritis should not be used in a breeding program. Several herds in this country have badly arthritic bulls. Some badly affected arthritic bulls are kept at bull hotels were the semen is obtained by the electro-ejaculator and semen banks are built up for future use. What a disservice is done to the breed by propagating these arthritis inclined livestock. In the case of one arthritic bull in this country, I saw 13 of his heifers. Eleven had to be culled for being low fertile and arthritic.

Double muscling in cattle is a serious problem; not only are double muscled cattle lower fertile, but calves by double muscled bulls cause calving difficulty. I am not interested in any bull which has abnormal muscle development anywhere. 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.

The sex hormones have a direct influence on the coat color, the sleekness and the darkening of the hair in the bull. Bulls with sleek hair and darkening of the hair on the neck, upper shanks and thighs usually have greater sex libido than bulls with dull, evenly colored coats. The darkening of the hair and the coarsening of the hair on the neck, a definite masculine secondary sexual characteristic is caused by the androgens given off by the testes and adrenal cortex. If a bull's color on the darker regions of his hide fades, the bull will become less sexually active. A highly fertile bull with much 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. Bulls that are dark in those areas usually have tremendous sex activity. Illustration of high and low fertile bulls are shown in Figures 20 and 21.

Why does it help you to know how to judge cattle for functional efficiency? If you know whether a heifer is going to be highly fertile when you select her, and you know that a heifer will settle with one service 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 percent 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. 349 cows out of 2,689 were butchered. The owner was perturbed about having to cull 349 at this stage; he thought he would never have a large calf crop again. The calf crop jumped to 87 percent; then 85, 87 87, 90, 92, 93 and 93 percent. The year after the culling, this ranch had produced 170 calves more than they had ever produced and the overall income increased by $40,000.

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.

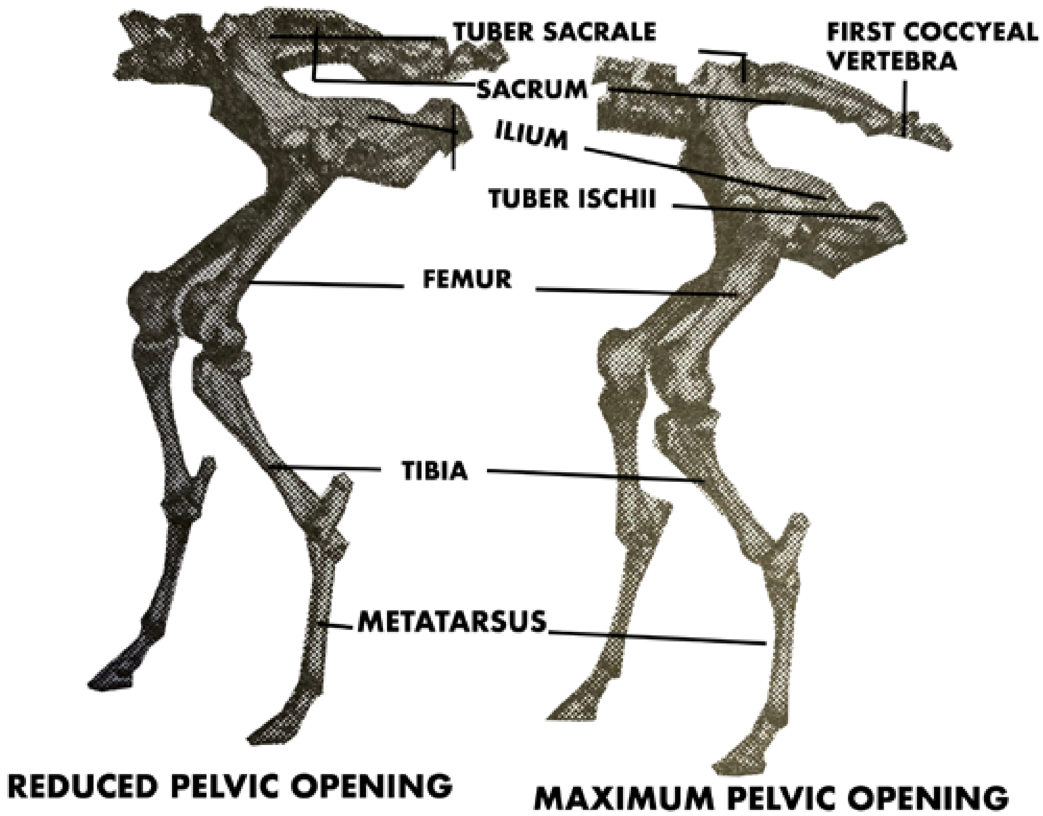

Figure 19. Skeletal structure that affects size of pelvic opening.

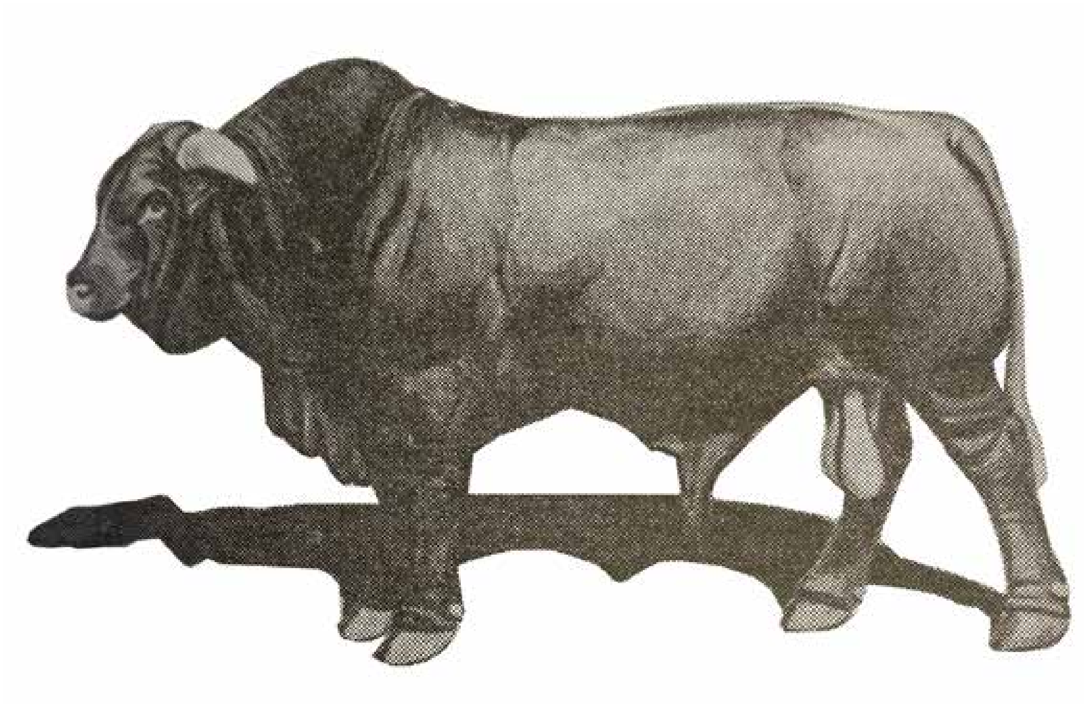

Figure 20. Bull with high fertility.

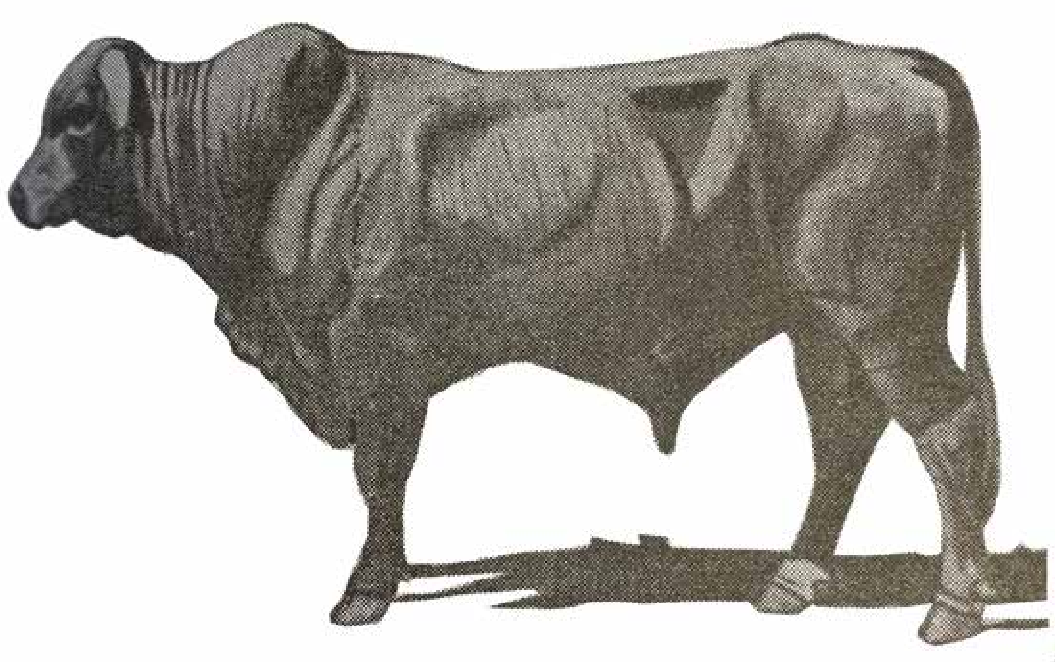

Figure 21. Bull with low fertility.

Breeding Cattle for Functional Efficiency

In the Santa Gertrudis Recorded Herds Book Volume 1, 1953, Robert J. Kleberg, Jr., of whose life's work the Santa Gertrudis breed is a product, says "While the art of Breeding requires intense application to detail, endless study, observation and application of a keen artistic sense, the rewards are great and I know of no task of such consuming and lasting interest."

The great Friesland cattle breeder, the late John Wassenaar, once said, "to create gives great satisfaction and by carefully selecting and mating your cattle you create better animals and this gives you a feeling of everlasting satisfaction — you are a creator." The endless study, keen observation and application of animal science to animal breeding enables the livestock breeder to produce better cattle. By "breeding for functional efficiency*' is meant to produce as much good red meat per unit area as possible.

The late Richard J. Kleberg wrote to Dr. John R. Mohr, then Chief of the Bureau of Animal Industry, USDA, summarizing briefly this article on the problems of the animal industry, its main statement amounts to this: Breed descriptions or standards on which breed improvement are mainly based are not primarily founded on biological values; they are part artificial devices lacking scientific basis. As a result, improvement is delayed or checked. If pedigrees contain little beyond the names and identification numbers of ancestors or if items entered in the pedigree records for each ancestor are only those of a more favorable character they are a "meaningless genealogical jumble' and produce merely a false sense of security. If two or more breeds are developed for the same purpose they are simply arbitrary division fences. These ideas are shaking modern animal breeding to its foundations, but they are only the logical consequence of this natural but nevertheless neglected question: What is the purpose pursued by men in breeding domestic animals; and the only reply thereto: His purpose: is to produce animals which, at the lowest possible cost and expenditure of labor, give the highest possible' and longest lasting returns. The main, purpose of animal breeding, as thus defined, often has been obscured, it is in fact, only through quite recent developments that breeding for performance has found its way into the animal industry, i.e., the wish to realize an increase and improvement in production performance of stock by selecting high yielding animals for breeding purposes.

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

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

The low fertility of cows is the most important single factor which brings about culling of young cows for slaughter purposes. In some regions of Poland, 20 percent of the female cattle are culled because of low fertility. Berge, 1949, reported that in Norway 57 percent of the female stock were slaughtered because of low fertility. Hoekstra (Netherlands) reported that 22 percent of the dairy cows are annually butchered because of low fertility. No mention was made of the causes of the infertility of the cows. It is certain, however, that disease played a very minor role, because in those countries contagious absorption has been controlled for many years and Vibrio fetus and Trichmonas fetus have rarely occurred since 1945.

It is generally accepted among population geneticists that the heritability of reproductive efficiency in beef cows is very low (Warwick, 1958) and any progress made by selection for improved fertility will be slow. The low heritability estimates of cow fertility are partly artifacts since this trait is very complex physiologically, and genetic differences in individual fertility are obscured by many factors such as disease, the libido of the bulls to which the cows are mated and the fertilizing capacity of their spermatozoa. Also confusing the issue is that selection has all too often favored those animals which axe morphologically of a subfertile type for future breeding purposes. We only have to look at pictures of famous cattle 100 years ago to realize that the show-winning, subfertile types of cattle were the ones that were selected for breeding.

In view of the role artificial insemination plays in bovine reproduction and the emphasis placed on milk, production in selecting sires for artificial insemination to the exclusion of constitutional defects and /or inadequacies, heritable lethal and sublethal defects warrant more than just passing attention. The Central Control Council for artificial insemination in the Netherlands (1953) obtained all the available information on hereditary defects in bovine and published a report which lists no fewer than nine lethal and 35 sublethal hereditary defects in cattle. Of the 36 sublethal hereditary defects no less than 14 affect reproduction.

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

Hypoplasia of the testes of the bull can cause serious breeding problems in the future. Gonadal hypoplasia (underdeveloped sex organs) in both males and females of the Swedish Mountain Cattle is a case in point. Lagerìof (1950) has described this defect in bulls of the Swedish Highland breed. In these bulls, about 100 cases were studied and the degree of hypoplasia noted. In 81.9 percent of the cases only the left testicle was involved; in 3.6 percent, the right testicle and in 14.6 percent, both testicles. Eriksson (1950) proved that the hypoplasia of Swedish Highland cattle is caused by a recessive autosomal gene. The incidence of hypoplasia was reduced by strict selection front 16 percent in 1937 to 7*9 percent in 1942.

Blom and Christensen (1956) reported observations in 5,382 slaughtered bull calves; they found that abnormalities of the genital organs had almost doubled in comparison with results obtained 10 years earlier. In examining the pedigrees of calves with aplastic Wolffian ducts, it was found that one bull had sired seven such calves, another, four and a third, two. These research workers state that aplasia is undoubtedly a hereditary defect.

In work done with Ayrshire cattle in Britain it was found that all the Ayrshire bulls with hypoplasia of the testes were descended from one bull reported to be hypoplastic. The defect in bulls is carried over to their female progeny. As a result, the fertility of the Swedish Mountain Cattle became disparagingly low. Detailed studies were made over a period of 20 years on the sexual organs of 8,145 slaughtered cows. Lagerlof (1950) found that 13.1 percent of 1,070 cows had abnormalities of the reproductive organs. Of the animals affected, 87.1 percent had hypoplasia of the left ovary, 4.3 percent of the right ovary and 8.6 percent of both ovaries. Fincher (1946) observed that three daughters of one cow, each sired by a different bull, had a virtual absence of ovaries, together with an infantile genital tract and absence of estrus activity.

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

Rendel (1952) studied this condition in British Shorthorn bulls. One bull sired nine affected white heifers out of 23, four affected roans out of 115 and one affected red among 94. Apparently, homozygosity for white greatly enhances the manifestation of this phenomenon. This condition also is found among the N'guli (*Bos Indicus*) breed

TABLE 1: Differences in the percentage pregnant and the average number of inseminations required to settle the cow.

Name of the bull, abbreviated	Number of daughters	Percent pregnant total	Percent pregnant after insemination	Average number of inseminations per successful pregnancy
A	389	93.6	75.8	1.47
LT 8	784	93.9	67.9	1.54
Jetze	318	94.3	67.9	1.58
WA 1	1415	92.4	62.9	1.70
K	239	92.5	62.8	1.71
JJ 2	338	92.6	61.8	1.75
TH	903	90.5	58.2	1.89
JHR	538	89.2	57.8	1.92

of cattle in South Africa. Nordlund (1956) at the International Congress of Animal Reproduction at Cambridge described 12 cases of the above-mentioned defect, all of which were the daughters of the same bull used in artificial insemination. The bull was not related to the dams nor were the dams interrelated to one another.

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

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

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

Table 1 shows that the daughters of the two bulls L, T. 8 and A are much easier to settle than those of J. H. R. and T, H. It was also found that in bull J. H. R. it was not possible to settle 10.8 percent of his daughters, while in the case of the bulls L·. T. 8 and JETZE, only 6.1 percent and 5.4 percent respectively did not settle.

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

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

Research work done by van Dieten in the Netherlands established very significant differences in the frequency of stillbirths between paternal half-sister groups (influence of sire of the dams) as shown in Table 2 and he concluded that this phenomenon is influenced by heredity. There can be no doubt that the sire has a marked influence on the number of calves born dead and on the number of instances where dystocia (difficult calving) occurs.

Both bulls and cows may be responsible for causing dystocia. In the cross-breeding work done by the Milk

Marketing Board in Great Britain, the Charolais bulls are more responsible for dystocia than any other breed of bulls used. But it is also amazing that the percentage incidence of dystocia is much higher among Friesian cows than among Jersey cows where Charolais bulls were used in both instances.

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

Several sons of this bull gave similar difficulty in their female progeny. It is considered a serious hereditary defect, and the Dutch research workers consider the cause to be the inheritance of an infantile type pelvis.

Friesland cattle in England, Holland and South Africa are very susceptible to dystocia.

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

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

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

Several countries report that lack of ability to mate is a common cause for culling among bulls. Lagerîof, studying the records of some 13,000 insured bulls of the Swedish dairy breeds, found that compensation had been paid out on approximately 20 percent of the bulls, and the most common cause was reproductive failures, especially among young bulls from I to 2 years of age. Table 3 indicates that the indemnities were distributed on the three groups of sexual disturbances which were distinguished in the case histories of the bulls.

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

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

After having read Julius Bauer's book on "Constitution and Disease*', I think that many reproductive disturbances are apparently due to endocrine imbalance and run in families, hence they may be hereditary in their origin. Ericksson (1950) comes to the conclusion that sires with low copulatory efficiency were over represented as ancestors of bulls with copulatory disturbances. He concludes that hereditary factors contribute to these disturbances and those of a psychic-hormonal nature.

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

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

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

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

Garm found a high frequency of nymphomania among dams of cows with nymphomania, and he assumed that the predisposition for the disturbance was hereditary.

At a field day at the Mara Research Station in the Republic of South Africa in 1958, the author selected four nymphomaniac cows for a demonstration and found that all four were sired by the same bull.

Casida and Chapman (1951) studied the incidence of cystic ovaries in a herd of Holstein cattle and concluded that 31 percent of the daughters of cystic cows were cystic in the different service periods and 9.4 percent of the daughters of noncystic cows were cystic. Twice, the difference between these two values., 48.2 percent,- is the estimated heritability of the occurrence of cystic ovaries in this particular herd when the dams and daughters had the same number of service periods.

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

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

TABLE 2: Stillbirths of calves of different sires, red and white (Rein-Mass-Ysel) breed. (Table abbreviated)

Sire number	First calf heifers				Dam with more than one calf			
	Male calves		Female calves		Male calves		Female calves	
	Number	Percent stillborn	Number	Percent stillborn	Number	Percent stillborn	Number	Percent stillborn
04	1266	22.7	1243	14.0	2096	5.4	2110	4.0
11	410	18.8	439	5.5	1010	2.8	982	3.9
28	691	18.6	581	9.5	2551	4.4	2446	3.9
33	780	10.9	756	4.8	1559	3.3	1347	2.4
45	468	6.2	481	3.3	897	3.0	882	2.5
24								
Bulls average		16.0		8.9		4.6		3.3

TABLE 3: Reproductive problem of bulls of three Swedish dairy breeds.

Breed	Inability to copulate	Inability to fertilize	Combination of both causes
		------Percent-------	
Sweedish red and white cattle	37.2	21.5	6.4
Swedish friesians	37.4	15.1	9.6
Polled Swedish cattle (Highland)	68.0	4.8	4.3

inconspicuous heat is a characteristic found among some animals in a herd.

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

A publication by two South African research workers, van Kensburg and de Vos (1962) throws some interesting light on ovulatory failure in Afrikaner and Friesland cows. Using 161 Afrikaner and 118. Friesland cows they found that of the 536 estrus periods observed in the course of the investigation, normal ovulation occurred in 396 cases, and failure to ovulate occurred in 140 instances or 26.1 percent of the periods. They report that ovulatory failures were of two types, either delayed ovulation or anovulation. The former occurred in 86 percent of the failures, the latter in .84 percent. The possibility of ovulation terminating in foliicuîar regression and atresia or cystic degeneration also is mentioned.

TABLE 4: Frequency of traits associated with reproduction among Holstein dam-daughter pairs.

Traits	"Positive dams"	"Negative dams"	Difference
		------Percent-------	
Twin births	17.4	12.0	5.4
Retained placenta	33.2	25.0	8.2
Ovarian cysts	16.5	13.9	2.6
Cystic tendency	53.6	45.8	7.8
Twinning and retained placenta and cystic tendency	68.4	48.4	20.0

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

Another problem of the livestock breeder is the "repeat breeder." It is often possible to distinguish the repeat breeder in a herd on the basis of morphological deviations, but to the inseminator or physiologist she is symptomless. The repeat breeder has been defined by Casida (1951) as a cow which manifests no clinical signs of infectious genital disease and rectal examination shows no signs of anatomical abnormalities of hyper- or hypo-ovarîan activity. The animal does exhibit reduced fertility and although it is customary to choose repeat breeders for experimental purposes on a basis of four or more unsuccessful services, Casida maintains that if insemination conditions are optimal, a single return from service is sufficient for a cow to qualify as a repeat breeder. Casida (1961) has reviewed the theoretical causes of repeat breeding and says that both fertilization failure and embryonic loss are major causes of repeat breeding. Poorly developed corpora lutea has been associated with high embryonic loss, but apparently progesterone therapy on repeat breeding is not convincing.

Van Remburg and de Vos (1951) differ from Casida (1961) in their interpretation of a repeat breeder. Much depends on the significance which Gasida attaches to the terms hyper- and hypo-ovarian activity. It must be mentioned that van Rensburg and de Vos consider ovulatory failure' the most common, causal factor in the production of the repeat breeder or "problem" cow.

A fairly comprehensive review has been given of various endocrine and other abnormalities which cause lowered fertility in cattle. Many of these abnormalities and endocrine imbalances have a genetic origin. To breed functionally better livestock, it is essential to select for further breeding animals which have no morphological abnormalities and which do not show clinical symptoms of endocrinological imbalance.

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

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