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NATURE AND NURTURE IN ANIMAL PRODUCTION: A HERETICAL VIEW*

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THE PURPOSE OF an inaugural lecture is to give the newly appointed incumbent to a chair an opportunity to state in public what he actually professes to know of his subject. As the first Professor of Animal Science I do not pretend to know everything about the subject because of the publication explosion which has taken place over the last two or three decades. The Librarian of this University reported in 1976 that:

> the number of scientific journals doubled every 11 years;
> 30,000 of these were published in Western Europe alone and,
> over 1,000,000 scientific papers were published in that year.

Our library acquires over 4,000 periodicals a year which occupy a shelf space of 300m and a similar area is required for books!

If one takes into account time spent in the administration of a department, teaching undergraduates and guiding post-graduate students, there is not a great deal of time left for reading scientific journals and doing one's own research. I think you will understand now what I mean when I say, that of the total knowledge of Animal Science that is available, I profess to know very little. In fact I regard Animal Science as one of the tools by which the productivity of domesticated livestock may be enhanced. In my view this is the *raîson d'être* for the Animal Scientist's existence and, also, the reason why I shall profess more from the point of view of production than of science.

My outlook is conditioned by life in a developing country where 90 per cent of animal products are derived from cattle. About 55 per cent of the national herd is in the hands of large numbers of people who individually own small groups of cattle which are not very productive. The remaining cattle are owned by what are now called 'commercial farmers' who, in general, use up-to-date scientific methods and derive a comparatively high degree of production from their cattle. Yet, irrespective of the numbers of cattle they own, farmers have been misled or have misled themselves into the belief that the productivity of all domesticated animals is dependent on their choice of sire. We know that offspring of parents tend to be similar to each other in appearance and, consequently, it is obvious to assume they

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will be similar in productive characteristics. Unfortunately, many of these characters have very little relationship to parental productivity and this I intend to illustrate from the research I have carried out with my colleagues here and in the United Kingdom.

The productivity of animals has two foundations — nature and nurture. Nature has several definitions and for this purpose I use 'person's or animal's innate character'. This innate character, in scientific terms, is an animal's genotype or heredity potential and is created by fusion of male and female gametes at the moment of conception. This genotype, this blueprint for development cannot be changed in any way known to man at the present time. Its full expression can be limited, however, if the raw materials or nurture it requires are insufficient in quality or quantity or both.

Nurture means nourishment and this consists of the total environment in which an organism finds itself. Nurture in animal production is synonymous with environment and depends on a great many factors such as temperature, rainfall, soil type and so on. The main effect of interaction of these factors one with another represents the environment of the organism. Thus at last I have told you that I am going to speak about genotype and environment and make some heretical remarks about some aspects of currently held animal production dogma.

For many years animal geneticists have been revered, especially by farmers, because of a widely-held belief that if we can select and multiply those animals which are superior to the rest of the population for a number of productive traits, then the productivity of our herds and flocks will be greatly increased. For example, most dairy farmers believe that it is possible to purchase bulls whose daughters will produce substantially greater yields of milk than animals he already owns. Unless his cows are producing to their full genetical potential, then such an idea is patently absurd. In fact few dairy cows are ever given the chance to do so for lack of nurture.

There is not enough time to describe in full exactly how geneticists achieved such eminence. It was due in part to the work of Mendel, published in 1866 and ignored until 1900 when others rediscovered the principles of segregation and independent assortment of hereditary characters for traits of a simple kind. The modern science of genetics arose from these findings and since that time geneticists have sought to explain the nature of heredity in Mendelian terms. By about 1920 a great deal of knowledge had been accumulated in support of the Mendelian theory. From the predictions of geneticists and the hopes of farmers, the application of Mendelian genetics was expected by all to lead to vastly improved productivity in domestic livestock. Small wonder that geneticists were, and are still, held in the reverential awe I have already described.

Early experiments with cattle appeared to support genetical theory. Thus the inheritance was explained, in *Bos taurus* cattle, of coat colour in the Aberdeen Angus and the Shorthorn breeds, together with that of the

horned and hornless (polled) condition. These characters, dependant on a single pair of genes, have little or no importance in animal production. In simple terms, animals are bred to provide products which can be sold profitably by the farmer and used by consumers either within or without the national economy. Before this can be achieved female domestic mammals must be fertile and produce enough milk to enable their offspring to grow rapidly in early life and so be strong enough to fend for themselves once the dam is dry or, in other words, has ceased to lactate. The attempted application of early genetical theory to elucidate the pattern of inheritance of fertility and milk yield failed. This is due to the fact that the important productive characters in animals have a low heritability and their expression varies according to the total environment to which an animal is exposed.

At first sight it would appear to be logical to choose the offspring of high-yielding dairy cows as the parents of the next generation. Unfortunately, milk yield, like other productive characters, is an expression of an animal's phenotype or outward appearance and so is not necessarily hereditable. In fact only 7 to 15 per cent of a dairy herd's ability to produce milk can be accounted for by heredity while the rest is due to environment. The hereditable part of milk yield became generally recognized by geneticists to be the result of very many minor genes working together and for this phenomenon the term polygenetic inheritance was coined. This mode of inheritance can only be studied in large populations of animals and involves the use of that branch of mathematics referred to as Biometry. The pursuit of this kind of knowledge has had a variety of names but 'quantitative genetics' seems to be the most fashionable at the moment. It produces a voluminous literature, much of which follows a repetitive theme and uses a great deal of complicated mathematics to explain what has already occurred.

The development of quantitative genetics has not led to much discernable improvement of fertility and lactation yield. These are the two characteristics which are of fundamental importance to the productivity of beef cattle. My remarks are not intended to denigrate the valuable work which the study of quantitative genetics in general has produced. I do intend to indicate, however, that their contribution to the improvement of fertility and milk yield in cattle is meagre and that the methods they advocate are older than time. For example, geneticists give great importance to progeny testing, that is the assessment of merit in a sire by the performance of his offspring. The principle of the technique is implicit in the Biblical quotation 'By their fruits ye shall know them' (Matthew 7:20). It was described by Varro, the Roman writer on agriculture, about 2,000 years ago and was practised in the eighteenth century by the father of English animal husbandry, Robert Bakewell (1725 - 75), before Mendel was born. Bakewell's work was so successful that a host of imitators followed his example and livestock improvement became fashionable with wealthy landowners. Their farms and estates became centres from which new ideas spread through Western Europe. The advances in animal production in the eighteenth century are

Table I

CHANGES IN SLAUGHTER WEIGHTS (lbs) AT SMITHFIELD

	1710	*1795*
Beeves	370	800
Sheep	28	80
Lambs	18	50

Source: Pawson (1957).

shown by records from the Smithfield Meat Market (Table I), which is still one of the largest of its kind. It is interesting to note that all this was achieved before the so-called fathers of modern biological thought were born. There have been refinements in these ancient techniques which made these changes possible and they can be practised on a much wider scale today by the use of artifical insemination but there have been no new ideas from geneticists to improve fertility and lactation yield.

The main contribution of modern genetics has been an endeavour to quantify the part of a characteristic attributable to heredity and that due to environment. Furthermore, our knowledge has been enriched by the concept of what is called the correlation between characters or, to use the technical term, traits. These data are by no means precise and although we speak of heritability estimates they only give some idea whether or not a trait has a high, medium or low heritability, and, conversely, whether or not environment is of major or minor importance. Correlation, or association between traits, is important because it gives an estimate of the effect of selection for one trait on the performance of another. Traits may be positively, negatively or independently correlated. One of the most important correlations in animal production is that between live mass gain and food conversion efficiency. Thus if we select animals for growth rate we automatically select for efficient food use. A useful negative correlation is that between length of body in pigs and backfat thickness. Thus selection for length is accompanied by decrease in backfat thickness which is important in determining the price a farmer receives for his pigs. This knowledge has an everyday practical application. As the pigs in a litter grow, some are shorter than others and the farmer knows they will be too fat if taken to bacon pig weight. Consequently he markets them as porkers and keeps the long pigs as baconers. The need for this practice does not indicate much progress in over fifty years of selection for length. In fact it went too far and hind legs became too long, leading to lameness in pigs with attendant loss of feeding efficiency while many boars were unable to mount. The point to be made here is that intense selection in one direction will be accompanied by change in another, often to the detriment of the total performance of the organism.

My doctoral research was concerned with the factors affecting udder health. The techniques to reduce udder infection developed during my stay at the National Institute for Research in Dairying were subsequently tested on a very large scale in commercial farms in the United Kingdom and in New York State. It took some years to get back into mastitis research when I came back to Rhodesia but much productive work has been done from our laboratory under the able control of Dr Maureen Milwid. It is not my intention to describe this work but it has confirmed and extended that of the National Institute for Research in Dairying.

So far as I am aware our laboratory is the only one in the world where research into the problems of mastitis reduction in hand-milked herds has been carried out (Milwid, Moore and Oliver, 1970). This appears to be very odd when one considers that most animals in the world which are kept to produce milk for human consumption are milked by hand. In this field the main contribution has been the introduction of an anti-bacterial teat lubricant at milking time and the important part which old cows play in keeping the mastitis pot on the boil. Figure 1 illustrates the main points of one trial carried out in collaboration with Mrs Marion Titterton.

Many productive characters in domestic livestock can be shown to be strongly influenced by environment. Arriving in Rhodesia in 1958, I noted that 90 per cent of all animal products came from beef cattle. These animals provide the main source of income to many people as well as having great social significance to them. Furthermore, the national calving rate was less

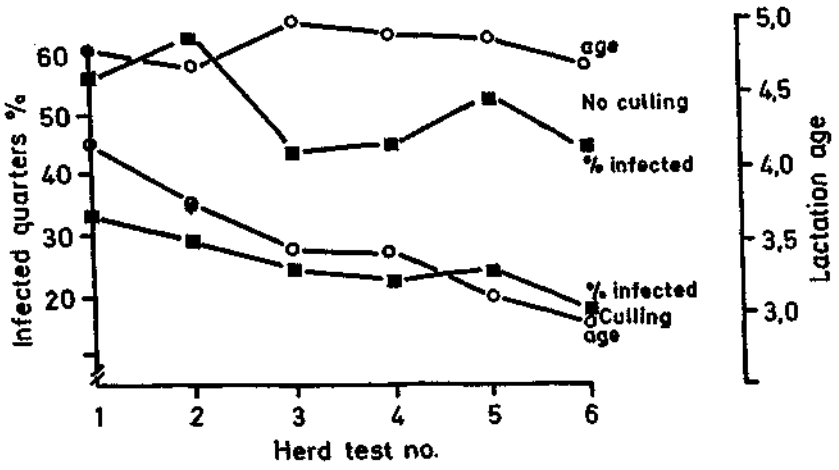

Figure 1: INFECTION IN RELATION TO AGE IN HERDS WHICH DID OR DID NOT CULL IN A TWO-YEAR MASTITIS CONTROL PROGRAMME (*Source:* Titterton and Oliver (1979a)).

than 50 per cent of cows mated, or more plainly, cows calved in alternative years. At that time the then University College had a farm and I was asked to set up those livestock enterprises which the farm could support. One of these was a herd of forty Mashona cows. Their breeding performance was studied and the results are shown in Table II.

Table II

THE BREEDING PERFORMANCE OF COWS AT UNIVERSITY COLLEGE FARM 1960-3

Number of	*1960*	*1961*	*1962*	*1963*
Cows mated	36	36	40†	40‡
Calves born	28	26	33	37
Per cent	77.7	72.2	82.5	92.5

† 4 heifers added
‡ 8 cows culled, 8 heifers added

Source: Oliver (1966b).

The data indicate the ease with which it was possible to increase the calving rate of the herd by improving their diet in winter and by culling barren cows. Some authors claim that it is possible to select for fertility. From the evidence available to me fertility can be improved in an unselected population by culling infertile females. This is selection against infertility and should never be confused with selection for fertility, in which as I have said, genetic improvement has been meagre. Similar remarks apply to selection against low milk yield. Although the heritability of fertility is low it must not be neglected. Unfortunately, the pedigree breeder buys and sells bulls on body shape. That may be good business but it is not livestock improvement. If I had to buy a bull I would be looking for an animal from a cow that had produced at least eight heavy weaners in consecutive years and not one so fat that he could hardly walk or mount.

A report by Coop (1962) described a classical analysis of the relationship between liveweight at mating and lambs weaned per 100 ewes mated. Results over four years for 11,258 sheep at various sites in New Zealand showed that, within the Corriedale breed, as the liveweight of the ewes increased the percentage of lambs weaned increased substantially. Corriedale sheep are a mutton breed which have a valuable fleece and a high proportion of twin births from ewes is common. Coop's work showed the over-riding importance of size within a breed on lambing percentage.

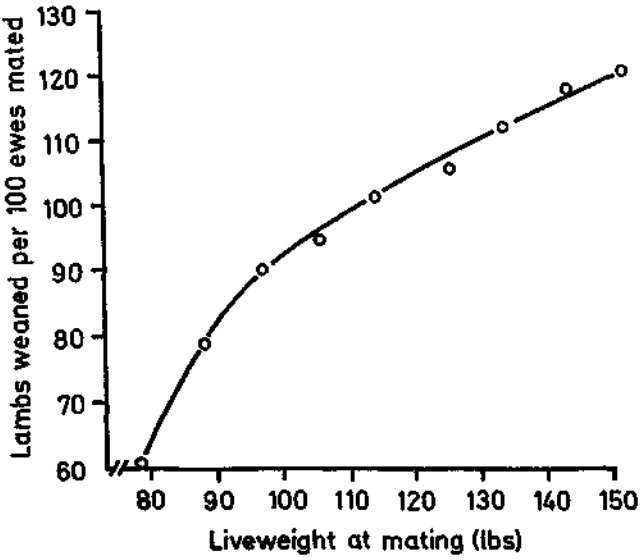

Figure 2: THE RELATION BETWEEN LAMBS WEANED PER 100 EWES MATED AND LIVEWEIGHT AT MATING (*Source:* Coop (1962)).

Research workers in other parts of the world began to mention that cow size (within a breed) seemed to have an effect on fertility. Lamond (1970) in Australia stated that there was a target weight for each breed of cattle below which conception would not take place. In 1968 Ward at Makoholi showed that few Mashona cows conceived at weights less than 550 lb. and none when body weight fell below 500 lb. At this stage research workers placed a great deal of importance on fertility expressed as calves born per 100 cows mated. Much useful knowledge became available in this way. However, I have always looked at the problem differently and am interested in the weight of weaned calf per 100 cows mated. This criterion not only takes into account female fertility but, in addition, ability to produce milk and, in consequence, weight of weaner produced. This production of big weaners is synonymous with strong and healthy calves and that is what cow productivity on veld is all about. Most experiments with cows had investigated one or more factors affecting productivity but usually they were short term trials.

Dr F. D. Richardson and I planned a long-term experiment in which many of the interacting factors affecting weaner production could be examined. Mlezu Rural Technical Institute was the ideal site because there was a large number of students who could provide the substantial technical assistance required. The trial would provide more rewarding instruction to them through handling groups of cattle treated in different

ways than would be possible where a single herd was managed in a conventional way.

The reason for the low calving rate in Rhodesia in many herds was mainly due to loss of weight in winter. From May to the onset of the rains veld grasses have a low energy content and no digestible protein. In consequence cattle mobilize body tissue in order to maintain essential metabolic functions of the body and so lose weight. Basically, weight loss can be prevented by offering cattle a small quantity of protein-rich concentrate daily. The effect of the protein dietary supplement not only removes the need for the mobilization of body tissue but leads to an increase in appetite and, consequently, of energy. This is a simplified account of what takes place and must suffice for my purpose.

At Mlezu we induced wide ranges of weight and of weight change in cows on veld by offering different amounts of concentrates in winter and by weaning their calves at either 150 (early) or 240 (late) days of age. Early weaned calves were given concentrates each day until other calves were weaned at 240 days. The feeding programme is shown in Table III. The high plane of nutrition was designed to ensure that cows in that group did not lose weight in winter.

Table III

FEEDING AT MLEZU (g/day)

Plane	*Feed*	*15 May - 30 June*	*July*	*Aug.*	*1 Sept - 8 wks Post Partum*
High	Cottonseed	450	450	450	450
	Maize Meal	—	450	900	1350
Medium	Cottonseed	225	225	225	225
	Maize Meal	—	225	450	675

Source: Richardson, Oliver and Clarke (1975).

A great deal of valuable information was amassed from the experiment which confirmed and extended existing knowledge. There is not time to describe all our findings but I shall give you some of the main results. We established the association between size of cow and calving rate and in addition were able to calculate the proportions of probable calvings for cows which have lost a given percentage of body weight (Fig. 3). Knowledge of these weight and calving-rate changes enables the cattle farmer to adjust the amount of food given to cows in order to achieve a given calving rate. Obviously we found that cows receiving the most food were heaviest at

calving, produced most calves and these were heavier than others. Similarly the heavier the cow, the greater her milk yield and, consequently, the heavier the weaner produced. The effect of plane of nutrition and time of weaning on production of weaned calf per cow can be seen in the Table IV.

Table IV

PRODUCTION OF 240 d WEANER (kg) per COW/YEAR AND USE OF CONCENTRATES BY COW AND CALF AS A UNIT

Age at Weaning (Days)	*Plane of Nutrition*			
	High	*Medium*	*Low*	*Mean*
WEANER PRODUCTION				
150	146	140	116	134
240	180	145	107	144
Mean	163	143	112	
CONCENTRATES USED				
150	426	284	106	268
240	304	148	Nil	150
Mean	365	213	55	

Source: Richardson, Oliver and Clarke (1979).

All of these associations were highly significant in biometrical terms and indicate the overwhelming effect of environment on the productivity of beef cattle. At the same time there are differences in calf growth rate which are partly due to heredity and efforts are made to try to estimate this component of productivity by what is called performance testing. Robert Bakewell made extensive use of this technique. Briefly, bull calves are put on a standard diet designed to allow them to grow at their full genetical potential. Those which exhibit the highest growth rate are selected as future sires because growth rate is said to be strongly inherited, i.e. about 50 per cent. In view of the findings at Mlezu, particularly the fact that calf birth weight accounts for over 56 per cent of the dam's lactation yield and the latter accounts for 72 per cent of the variation in calf growth to 98 days and that these differences persist to weaning and later in life, we must seriously reconsider the value of performance testing. May this be merely a reflection of a farmer's choice of calf to put on test? Must we now question the relatively high heritability of growth rate? Substantial further research must be carried out before a much more accurate test can be made than those in vogue today. However, this is a task for the animal production man and not the geneticist.

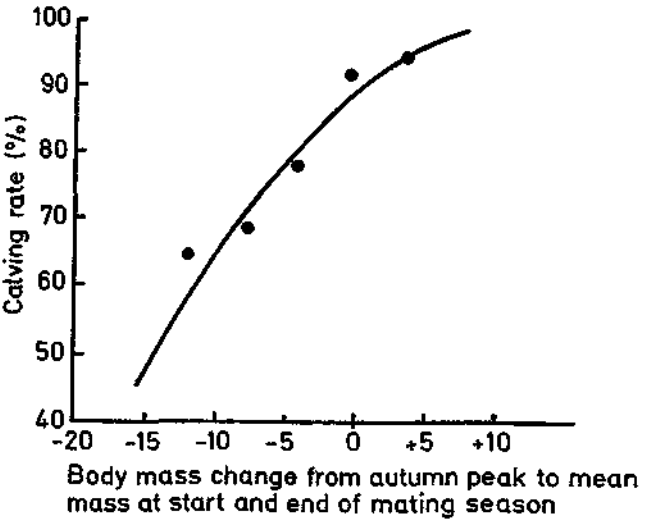

Figure 3: RELATION BETWEEN MASS CHANGE FROM AUTUMN PEAK TO MID-MATING AND SUBSEQUENT CALVING RATE (*Source:* Richardson, Oliver and Clarke (1975)).

Earlier I said that time does not permit a full account of all the complex facets of genotype and environment and their interaction. For that reason I have confined myself to an outline of the factors which affect fertility and milk yield in beef cattle. I have stressed the importance of cattle in the lives of people in this country and we know that they make a substantial contribution to the gross national product. What I have not said, and do so with whatever scientific reputation I may have, is the need for the application of statutory veterinary regulations throughout Africa. Without compulsory dipping against tick-borne disease, preventive innoculation and the power to control cattle movement to limit the spread of disease, all my previous remarks might well be cast into limbo. Animal production can only begin where a viable state veterinary service exists.

We must not forget the tribulations of the great pandemics which decimated the cattle population in 1896 and 1901. They were caused by the Rinderpest and East Coast Fever which killed off 90 per cent of all cattle in Rhodesia (Oliver, 1966a). In an age where rapid transport is the norm and the journey of 10,000 km is an overnight trip, it is difficult to visualize an era when the trek ox was the only source of motive power. A good day's trek was only 25 to 30 km, and although this was not far, disease spread through the country with great rapidity. Eventually compulsory innoculation and control of cattle movement brought the Rinderpest under control while compulsory dipping checked East Coast Fever. These diseases enabled the Government veterinarians to develop a system by which major cattle losses through disease could be prevented.

Over the past three years many people have been prevented from dipping and innoculating their cattle with the result that about one million head, or one third of African-owned cattle, have died of disease. Even were it possible to re-impose tomorrow statutory regulations governing cattle health, it will take many years to restore the national herd to what it was three years ago.

This will be due to a general shortage of veterinarians on the one hand and a growing tendency for them to specialize in the lucrative cat and dog trade in the towns. Future veterinary control of cattle disease is in even greater jeopardy because few, if any, young people from this country are undergoing veterinary training at the present time. This is not due to lack of interest — in fact interest is very great — but the unpalatable fact is there is nowhere to send them. South Africa will admit only four foreign students a year, while the United Kingdom does not want any, and entry requirements there are three 'A's at the A-level examinations in Chemistry, Physics and Mathematics, and for every place available there are two candidates with such qualifications. The British Veterinary Schools prefer to take their own people whose qualifications they understand rather than outsiders whose qualifications and motivation they often have reason to doubt. Once this country is at peace we shall probably have to recruit veterinarians on contract. In the long term, however, we must produce our own veterinarians but, at the same time, we must make a careful re-appraisal of the kind of veterinary structure which can grow in a developing country.

This veterinary base of which I have spoken is a prime example of the over-riding importance of nurture over nature. In discussing it I have not strayed outside my self-imposed brief which is to talk about bovine fertility and productivity. Implicit in the evidence I have given is the assumption that cows are free from reproductive diseases which cause abortion and which can be controlled by preventive innoculation. Now that I have established my case I have one last brick to throw. That is against the animal physiologists who are not sure whether or not they should undergo a metamorphasis to forsake their lawful business and join the latest bandwagon called genetic engineering.

Over 30 years ago at Cambridge, multiple ovulation was induced in sheep by means of hormones. The eggs were fertilized, implanted in a rabbit, flown to Pietermaritzburg, then transferred into ewes which carried them to full term. The technique has been extended to pigs using tissue culture and to cattle using surgery for ova collection and subsequent implantation. More recently the technique has been applied in humans under the sensational title of test-tube babies. What nonsense!

In theory, of course, we can now create a breed of genetically superior animals but superior in what way? Certainly not for fertility and milk yield. Transplant the ova from the super cow into a beef cow on veld, neglect the cow and the result is an unnecessary and expensive waste of time. Even under optimal conditions the technique is uncertain because of the difficulty of arranging for the embryo and the uterine wall to be at a compatible

physiological state so that implantation can take place. No doubt the ingenuity of man will overcome the difficulties of so-called genetic engineering.

A more appropriate term would be genetic contrivance for the physiologist and genetic connivance for the geneticist. Implicit in heat synchronization and mass insemination is the mistaken belief that high production is synonymous with high conception rate, that high conception rate is synonymous with high calving rate and that this is synonymous with high production of weaned calf. These concepts are only true if the dam is kept up to weight and size for her age and breed during her working life. The badly nurtured cow may abort, or she may have a difficult calving and die, or she may be so weak she abandons her calf and, at best, she lives to rear a miserable calf whose chances of survival are remote.

By this time many of you will be wondering what this heretic recommends. First, we must accept that, within a given environment, mass of weaned calf per 100 cows mated is the criterion by which productivity of beef cattle must be judged under our extensive conditions. This can be achieved by strategic hand feeding in winter, adjusting stocking rates so that veld productivity is maintained, by adopting rotational grazing and by planting tropical legumes so that veld productivity is enhanced.

Second, we must promote the traditional skills which have been proven to be essential to successful animal husbandry. This must be carried out throughout the country and applied to the majority of cattle owners whether they have large or small groups of cattle. This concept applies to our own agricultural students who will provide the future hierarchy of scientists and extension officers. Why is it that former Chibero and Gwebi College students are in great demand while our own have difficulty in finding jobs? There are two reasons. Firstly, many students today refuse to take jobs outside the main cities. Second, and of much greater importance, the diploma holders have mastered traditional husbandry skills. These give a man self-confidence, help him to make maximum use of agricultural teaching and make him of immediate use to his employers. Most universities in the world insist on approved practical farm experience either before entry to the course or during a practical year after the first year at University. How can anyone expect to take a responsible position in agriculture if he has not mastered the traditional skills on which the industry is based?

You can imagine my astonishment over twenty years ago when I discovered that practical experience was not a qualification for entry to our degree in Agriculture. Our degrees are second to none in the opinion of external examiners from the United Kingdom and South Africa. Many of our graduates have made highly successful careers in research, teaching and in many branches of the commercial sector. In the main these were people with practical farming experience. Now that the majority of our students lack these skills we must provide facilities for them to be acquired. Third, we must find ways to persuade the small farmer in particular to adopt the relatively simple techniques which lead to increased cattle production. This

will involve a substantial injection of capital into the developing farming sector but, of greater importance, is the need to expand our agricultural extension of knowledge services at different levels.

Many people outside this country agree that we have the finest animal research, extension and veterinary services in Africa. They have enabled us to create a highly productive cattle industry which is capable of substantial expansion once our political problems are sufficiently resolved to permit the rehabilitation of cattle production. However, I, whose life has been devoted to research in animal production, offer my final heresy. Have we not reached a stage in this country when the basic problems of cattle productivity have been solved and should we now give more attention to extension and less to research?

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