I had intended to start my address by thanking you for the honour you have bestowed on me to deliver the Theiler Memorial Lecture. Then I encountered this remark made by Theiler in 1935 in Gutsche's biography\textsuperscript{2}, which brought me down to earth, but did not diminish my gratitude:

"Honours kept coming - "a sure sign of advancing senility", he told Alfred."

As theme for this lecture I have selected what I regard as 3 cardinal interrelated developments which will have a profound effect on animal production-orientated research requirements and the future education requirements for such research. I shall try to motivate this theme by means of facts, figures and my own thoughts, some of which are speculative, but will hopefully be convincing. Since this occasion commemorates Sir Arnold Theiler, particular attention will be paid to veterinary aspects of the theme.

The Future Home of Animal Production-Orientated and Other Agricultural Research

The correct home for agricultural research, which includes veterinary and other animal production-orientated research, in a country which has occupied the minds of men, from the researcher at the bench, middle and top management levels, to politicians, in the past as well as in recent years. The so-called "Kaib Report" is the most recent and, at the moment, most tangible addition to the published line of thought.

I shall confine myself today to thoughts on and recent developments with regard to the home for research being done by the Department of Agriculture and Water Supply, which includes the Veterinary Research Institute, Onderstepoort and other animal production-orientated research being done by the Department.

It is clear from Gutsche\textsuperscript{2} that Theiler felt strongly that the Onderstepoort Research Institute should be unburdened from the bureaucratic system applying to the Department at large.

Theiler was not prepared to accept these restrictions and proposed "a very strong protest demanding the right of Onderstepoort to be put outside general arrangements by reason of the nature of its work, by its traditions, by its standing in the scientific world and its outstanding success... It has the right to have its own way - the psychology of scientific workers should not give way to the general machine-like way of working of the Treasury, the Auditor-General and the Agricultural Department".

Many have shared that view. It must, however, be realised that the account for Onderstepoort's research budget and those of other research institutions within the Department is being paid by the taxpayer. In pure government service, bureaucracy is a given fact. The Treasury, Commission for Administration and Auditor-General are essential for orderly government administration. These institutions are like the Rock of Gibraltar. There may be room for improvement in their modus operandi, but they cannot be wished away. Any move away from the "hated" bureaucracy will mean having to find funds, to a greater or lesser extent, elsewhere.

This is particularly relevant now in view of the Government's avowed policy of privatisation and deregulation. This can be interpreted to the end of state-funded agricultural research to move out of the government service per se. Such developments and the anticipated advantages that will accrue, can also be construed as being a contribution to the State's declared policy to "restructure and rebuild agriculture" in order to achieve a better agricultural dispensation for the farmers and thus for the country as a whole.

A move towards a semi-state, also known as parastatal institution, which will probably be known as an Agricultural Research Council (ARC), is on the cards for research being conducted by the Department of Agriculture and Water Supply. The Onderstepoort Veterinary Research Institute, being its largest single component, will be implicated.

The Department of Agriculture and Water Supply has been instructed by the Minister of Agriculture to investigate the possibility of establishing an ARC and to report back before the end of 1988 on its likely structure, probable personnel requirements and estimated financial implications. Sources of possible funding must also be provisionally explored. This is of course excellent news to me since I have been propagating this move for the Onderstepoort Institute by written word and verbally ever since I was in a position to do so.

It must be clearly appreciated that a parastatal body such as an ARC will of necessity obtain a considerable proportion of its funds from the State. The amount is, however, most unlikely to be increased annually, particularly in respect of running expenses. This means that it will be eroded by inflation, and an annual escalation in private funding will have to be sought by the ARC in order to compensate for this loss, not to mention providing for growth.

The most important message is that the products of research will have to be marketed in future in a format sought by the consumer.

In this case I am referring to the marketing of technology generated by research in a format that the market seeks. In the case of veterinary and other animal production-orientated research, the potential market extends from "conception to consumption", in other words from the producer to the consumer. Into this reasoning can also be read that research will not stop at the farm gate, as has been the policy hitherto, although exceptions were made. This means that the farmer is not the only client for the products of agricultural and veterinary research, but that all the farming-orientated industries are also potential clients.

Corollaries of this reasoning are that:

- more personnel may be appointed if the necessary funds can be found
- the ARC will in a best position to compete for high-quality personnel
- there will be a shift away from the "publish or perish" concept to "publish and perish"

It will consequently be more important to tie a patent than to publish a paper

- there will inevitably be a shift away from fundamental to more applied research
- evaluation of the progress of research will feature much more strongly
- the consumer of research results will have much more say - researchers have hitherto enjoyed a remarkable degree of freedom from external or even internal pressures

It must be clearly understood, however that a parastatal body is no Utopia. Probably the most important potential problem which will have to be firmly addressed is the fact that "he who pays the piper calls the tune". Special care will have to be taken that fundamental research, which is the backbone of long-term scientific progress, is not an eventual casualty of this system. Many of the big scientific breakthroughs come from "fortuitous observations" made during fundamental scientific research. For this reason, state funding can, in my opinion, never be entirely dispensed with.

Future Research Requirements for Progress in Animal Production

I think it can be positively stated that Theiler was aware of the fact that animal production and animal health cannot be divorced from one other. In other words, the ultimate objective of any research on diseases or animals must be to keep animals healthy so that they can produce optimally. In 1928 Theiler said:

"The Institute of Onderstepoort, South Africa which was founded and organised by me, did not deal with the aspects of animal health as I propose should be done in Australia. It dealt almost exclusively with disease. Animal health... is national wealth..."

The food requirements for a self-sufficient South Africa, a situation that would...
be expedient for strategic and economic reasons. For the coming century will be determined by its population growth. The latter can only be described as astronomical. It has been predicted that the total human population will number about 47 million people by the year 2000, most of whom will have adopted a Western food consumption pattern. In the average Western diet animal products provide 70% of the protein, 35% of the energy and most of the required minerals.

The expert has estimated that the increase in the requirement for beef will be 50%, for mutton 30%, and for dairy products 60% by the turn of the century, to name but a few products. Another predictor has forecast a 70% increase for beef and 75% for mutton. Irrespective of which of these predictions is correct, it is clear that these goals can only be attained by a considerable increase in animal productivity. Théler's2 view on South Africa's potential for beef production is clearly overoptimistic:

"The last hindrance to cattle farming in South Africa has been cleared up and this country will now become one of the biggest producers of meat2". It is obvious that we cannot increase our cattle, sheep, goat and game numbers dramatically. We are already trading a full house under exceptional conditions. The potential for increase by greater intensification is, with the exception of poultry and pigs, also limited. A dramatic increase in the productivity of our pastoral livestock is the only alternative left to reach the abovementioned production goals. To reach a goal of 70% mortality rate are required. A higher turnover of animals being slaughtered is increasing, thereby increasing from 44% in the A category in 1987 to 53.5% in 1987 (R.T. Naude, AD S RI, S. Afr. vet. Ve r. (1989)60(3) : 126 - 129)

3. Gene transfer technology must be made freely available on a country-wide scale. This technology includes all the technologies associated with embryo transfer such as multiple ovulation, recovery and freezing of embryos obtained thus or from ova fertilised in vitro, embryo splitting, embryo freezing, sexing of embryos and gene transfer. England is already offering beef embryos salvaged as ova from abortors and fertilised in vitro as "super bulls" to those interested. Austra­lia and New Zealand are importing Angora embryos, against our wishes, from South Africa for the benefit of their countries. Is this technology being exploited to multiply genetically superior small stock in South Africa to any significant extent?

4. For the coming century will be determined by the replacement of species of African ticks. We have already determined that an in­creased rate of occurrence of tick-borne diseases such as trypanosomiasis and tick-borne diseases. Perhaps even more important is the difference in the plights and circumstances in which a disease is being investigated. To predict that ticks will find a way to circumvent the immunity thus induced. Their ability to manifest resistance to antigens which are relevant to disease is small and there will be individuals in a population endowed with the ability to avoid an immune response directed at specific antigens. The more far-sighted ones recommend an im­mune approach of developing cattle with transgenically induced tick-resistance should therefore not be neglected. In the use of tick-resistant breeds of cattle in the appropriate environment should be

1. A dramatic breakthrough in respect of ruminant digestion which will enable ruminants to utilise the millions of tons of available low grade roughage such as veld grass and crop residues more efficiently. This should enable us, for example, to market younger animals off the veld or other roughage, in a finished condition and to eliminate winter nutritional stress. Develop­ment by recombinant DNA techno­logy of ruminal micro-organisms (super bugs) that can effect this miracle is, for example, no longer such a far-fetched idea.

2. Embryo transfer technology must be made freely available on a country-wide scale. This technology includes all the technologies associated with embryo transfer such as multiple ovulation, recovery and freezing of embryos obtained thus or from ova fertilised in vitro, embryo splitting, embryo freezing, sexing of embryos and gene transfer.
exploited much more fully.

The ultimate aim regarding warm and blowfly control in sheep should be to get a better predetermined resistance. Resistance to chemical control by the parasites concerned, and the increasing pressure against pesticide residues in animal products and agro-industry will make this approach inevitable. Transgenic animals, and their multiplication by embryo transfer technology, again come into the picture as a means of breeding resistance genes into a breed more quickly than by classical selection for resistant animals.

Mice, equipped by gene transfer with a human growth hormone gene, grew more than twice as fast as litter mates. This has opened up the way for similar research in other species. I doubt, however, whether elephantine cattle or sheep will be an advantage production-wise under extensive South African conditions.

Transgenic fodder plants and grasses can also make an important contribution to increased animal production. A sulphur-containing lucerne cultivar which increases wool production has, for example, been developed in Australia. More digestible nitrogenous grasses, which are already drought resistant, or the introduction of drought-resistance genes into more nutritious grasses would be most useful as improved artificial pastures. For example, under the crop withdrawal scheme, or even natural pastures, which would amount to radical pasture improvement.

4. Recombinant-DNA technology has made it possible to produce vast quantities of growth hormone in vitro, which has been shown to substantially increase growth in pigs and sheep and to induce considerably higher milk yields in cattle. It still remains to be seen whether the product will eventually be released for general use. Public pressure against its use seems to be triumphing in Europe, and the USFDA appears to be dragging its feet too.

5. Genetically engineered vaccines against local diseases must feature strongly in any research programme aimed at increasing animal production. Particularly relevant are those diseases against which it has not been possible to develop vaccines, such as snotsiekte, jaagsiekte and oestrosis of cattle, or instances where existing vaccines are either not very effective, or for various reasons, impractical to use or dangerous to produce. Important examples of the latter are vaccines against heartwater, redwater, anaplasmosis (current vaccines consist of infected blood, with obvious disadvantages), bluetongue (which is a live attenuated vaccine consisting of 15 serotypes, also with obvious disadvantages) and FMD (which consists of inactivated virulent viruses).

6. Recombinant-DNA technology will also provide a series of diagnostic probes for a variety of diseases and parasites which could revolutionise the diagnosis of diseases and carrier states. The detection of measles in live cattle, coccidiosis, bovine mastitis and even sheep diseases such as heartwater, redwater, and anaplasmosis; detection of the carrier states of Theileria lawrencei in buffalo, jaagsiekte in sheep, bluetongue in cattle and sheep, and vaccines for export, equine viral arteritis and various other viral diseases in imported stock, biliary fever and hoesickness in horses destined for export, and heartwater infection in ticks, are a few examples which come to mind.

Biotechnology therefore has much potential for making a significant contribution towards increasing the productivity of our extensively-farmed livestock. It is, however, longterm research and consequently unlikely to have a dramatic effect before the year 2000. Therefore our imports of the commodities referred to initially, are likely to increase. It may well be necessary to fill in the balance with pork and chicken.

FUTURE EDUCATIONAL REQUIREMENTS FOR PROGRESS IN ANIMAL PRODUCTION

I am convinced that much of the progress required in animal production will, in the medium and longer term, depend on research in which biotechnology in its various guises, will feature strongly. Suitably-trained manpower will have to be found for this purpose.

From the above exposition it is also clear that a veterinary qualification is not a prerequisite for most of the research work required. Whereas experienced veterinarians should be in their element with the required improvement in the management of livestock, and likewise those with appropriate postgraduate training with embryo transfer technology and all its permutations, the work can also be done by non-veterinarians. Much of the basic research on embryo transfer technology in this country is already in the hands of non-veterinarians who have been trained in a variety of biologically-orientated natural sciences.

Applicable research approaches for which there is currently the greatest need and which offer the greatest chances of success are:

- Biotechnology, which includes embryo transfer technology and all its ramifications, gene transfer, molecular biology, r-DNA technology, microbiology and immunology.
- Genetically-determined resistance to disease and parasites, which can be achieved relatively slowly by conventional methods or probably faster by means of gene transfer.
- Physiology, particularly that of ruminal nutrition and digestion.
- Chemical and molecular pathology, and pathogenesis of disease.
- Ecology, under which umbrella I include studies on the epidemiology of disease, ecosystems, pastoral sciences and plant poisonings, livestock and game management, and pollution-oriented sciences, which would include the use of industrial byproducts to produce food and energy.

These research approaches all require a sound background knowledge of the basic, biologically-orientated sciences such as biochemistry and molecular biology, microbiology, physiology, biology, genetics and ecology.

Throughout his career, even before his association with the brilliant biochemist, Harry Green, Theiler had what can be described as a yearning for the "pure sciences." It is once again illustrated by this quotation from Gutsche:

"Theiler concluded his address with a virtual expression of his own philosophy: Foster by all means the pure sciences. They are, in the hands of experts, the medium of solving the many economic problems of South Africa.

Veterinarians receive some training in the abovementioned subjects at the undergraduate level. But is it sufficiently sufficient to equip them for a research career in which the abovementioned scientific approaches feature strongly. I have a problem with the concept of providing for their đồduong and postgraduate level because it is like placing the cart before the horse. Moreover, it will be necessary to rope in expertise from all possible institutions, irrespective of whether the required knowledge is at undergraduate or postgraduate level.

In my opinion veterinarians would be wise to take note of recent developments in a sister profession. Members of this profession can be likened to dinosaurs. Like the dinosaurs, they excelled in every respect. They eventually filled every niche and every cavity. They became so specialised that they could not adapt and, to and behol, eventually virtually worked themselves out of a job. Now they have gone back to the drawing board to try to find a way out of their predicament.

If the basic sciences are neglected in favor of clinically-orientated veterinarians will at best be at a disadvantage and at worst be unable to contribute towards the advanced research required to increase animal production. This will not only curtail the job opportunities for veterinarians, but will also lower the high status that they have always enjoyed as researchers in this country. The technological revolution currently on our doorstep may even further increase the demand for veterinary services in the farm animal industry, because scientists with a more basic training would be in a better position to provide for the whole spectrum of sophisticated biotechnological techniques required to improve animal production.

Thus the veterinarian's slice of the animal production market is bound to shrink even further. Let us hope the market containing the currently fairly lucrative companion animal market may be virtually the only one left. May I remind you that the saying goes: Don't put all your eggs into one basket.

CONCLUSION

In conclusion I wish to say that the purpose of my talk was not to show that Theiler was propitious. I used Theilerian quotations to give perspective, colour and spice to my views and arguments. I have, however, noted, that Theiler was remarkably far-sighted, as was aptly diagnosed by Smuts (Gutsche\textsuperscript{2}) when he unveiled the statue of him in 1939:

"Theiler had had a great capacity for
application but in addition he had insight into the nature of things which was given to very few people. Rutherford, Einstein and others like them had had that insight into the significance of the situation before them. It is the grace of God, genius - something you get in some unaccountable way”.

Let those of us who, quite naturally, sometimes have doubts about the revolutionary developments envisaged, take heart. Theiler would undoubtedly have given these changes his blessing.

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