Lethal and Other Inherited Factors Causing Abnormalities in New Zealand Stock

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THIS paper is a review of our present knowledge of the occurrence in New Zealand of inherited factors causing death of the unborn or newly born young, and of other factors which results in non-fatal abnormalities.

In general terms, there are two ways by which problems of this nature can be investigated. The most common way is what might be termed, the "pedigree" method. This simply involved the tracing of abnormal offspring through their pedigrees to common ancestors. First, however, it is necessary to discount possible pre-natal and, in some cases, even post-natal environmental factors. If a sufficiently great number of abnormal animals have been born, it is often possible to decide the mode of inheritance. For obvious reasons, it is only in exceptional cases that the inheritance can be established by direct experimental matings.

The other method of investigating inherited abnormalities is through identical twins. If both members of a set show the same anatomical defect it is logical to assume that the expression of this defect depends on inherited factors. While this method never can throw any light on the mode of inheritance, it has the advantage that it may establish the inherited nature of some infrequently occurring conditions. Occasionally identical twins may also provide the evidence to the effect that a cetrain trait is not inherited. This happens when only one member of a set shows the defect concerned. It is obvious that such negative information may be very useful in obviating long and costly research into the possible inheritance of characters that in the end would prove to be non-genetical. This point will be illustrated later.

The total number of well-established lethals in our domestic animals is not very great. In the latest check-list Lerner (1) enumerates 25 as occurring in cattle, but only 9 in pigs and 7 in sheep. This list includes only two from New Zealand—the "split ear" character in pigs and the "parrot jaw" in cattle—both recorded by Dr. Annett (2) (3). In recent years, however, a number of new factors have been discovered in this country. Some of them have already been fully investagated while others are in the process of investigation. In view of the likely spread of artificial insemination as a method of breeding, and its consequences on the population structure, it is time to take stock of the present position regarding lethals and inherited abnormalities. Such stocktaking must serve as a basis for a discussion on how the situation should be handled. The following is an outline of the extent of our present knowledge.

(a) CATTLE.

(1) Parrot Jaw (Lerner's A.14).—This condition was first recorded in New Zealand by Dr. H. E. Annett (3) and has recently been fully analysed by Mr. J. M. Ranstead, of Matangi (4). Ranstead actually was the culprit who, through his well-known pedigree Shorthorns, spread the factor widely through this breed in New Zealand—unwittingly, it may be added.

Fig. 1: Congenital Dropsy in Ayrshire Calf.

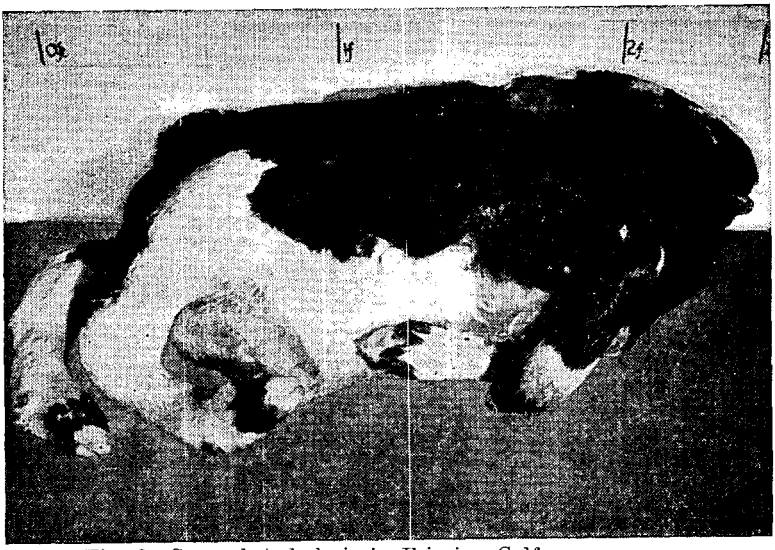

Fig. 2: General Ankylosis in Friesian Calf.

Fig. 3: A set of Monozygotic Twins showing poor but relatively unequal jaw development.

The condition is characterised by a lower jaw which is only half normal length. The molar teeth are impacted. The calves are often born alive, but as they cannot either suck or graze they are doomed to an early death. Ranstead has, in an admirable analysis, shown that the condition is due to a simple recessive factor. Lerner (1) lists this condition as a new lethal under the name of "Agnathia" (A.19). Ranstead (4), however, has shown that it is identical with "Impacted Molars" (A.14) first recorded by Heizer and Hervey (5).

(2) Congenital Dropsy (Lerner's A.12).—Although, as far as is known, only one case of this condition has been discovered in New Zealand, it is worth mentioning. A neighbouring farmer brought the monster to Ruakura for inspection and the photographs in Figs 1 were taken. The calf was swollen with fluid to twice its normal size. I have myself seen this type of monster in Finland, where it caused serious trouble in the Ayrshire breed (5). Once I was present at a delivery and it needed six men to remove the calf. The inheritance is very well established and a simple recessive gene is involved. It also occurs in Friesians in Sweden (6). The New Zealand specimen was the result of a half-brother sister mating and the sire was a pedigree Ayrshire, whose near ancestors were imported from Canada. It is interesting to note that the condition has been unearthed in Scotland, the home of the breed, where, according to Donald (9) it is fairly widespread.

(3) General Ankylosis.—This condition, which has been found in a herd of New Zealand Friesians, is probably the same as described by Stang (8) (Lerner's A.13). Miss E. J. Currie, of the New Zealand Dairy Board, has worked out the genetical situation and again it seems that a simple recessive factor fits the facts (9). Mr. M. D. Murray, of Wallaceville Animal Research Station, provided the photograph (Fig. 2) and a description of the abnormality. Thus, quoting his report (10): "The body of the monster consists of abdomen, neck and head, all of which are united in a solid mass with no visible line of demarkation. The back is usually a straight line. . . . The vertebrae are invariably completely ankylosed and the tail root small. . . . The tongue is usually protruding and swollen. . . . Most characteristic is the limb malformation. . . . The hind limbs are attached to the body as far as half-way down the tibia. The hock is ankylosed . . . and the digits are reversed in position. One fore limb is usually flexed at the knee and bent across the body, whereas the other is extended backwards lying under . . . the body. Anasarca of the head is also present."

(4) Inability to extend fore limbs.—As recently as last year a new genetically determined deformity was found in New Zealand. It occurred in a Jersey herd in North Auckland and was discovered by Mr. C. R. Ensor, Departmental Veterinarian in Whangarei (11). The affected animals were not able to extend their forelegs properly and thus could not stand up. They were born alive but could not suck because of their disability and would have starved to death under normal conditions. The calves traced back to a common ancestor on both their sire's and dam's sides and the number of affected animals actually born coincided almost perfectly with the expected number, assuming that a single recessive factor was responsible.

(5) Non-fatal Abnormalities.—All the previous factors are lethal or semi-lethals. That is, they either result in the young being stillborn or else in their dying soon after birth.

A few years ago, I discovered a condition which, although not fatal, causes great inconvenience to the affected animals (12). Two cows, mother and daughter, gave birth to four blind calves, when mated to the same bull. There was nothing apparently wrong with the eyes of the calves and not even a very meticulous post-mortem examination

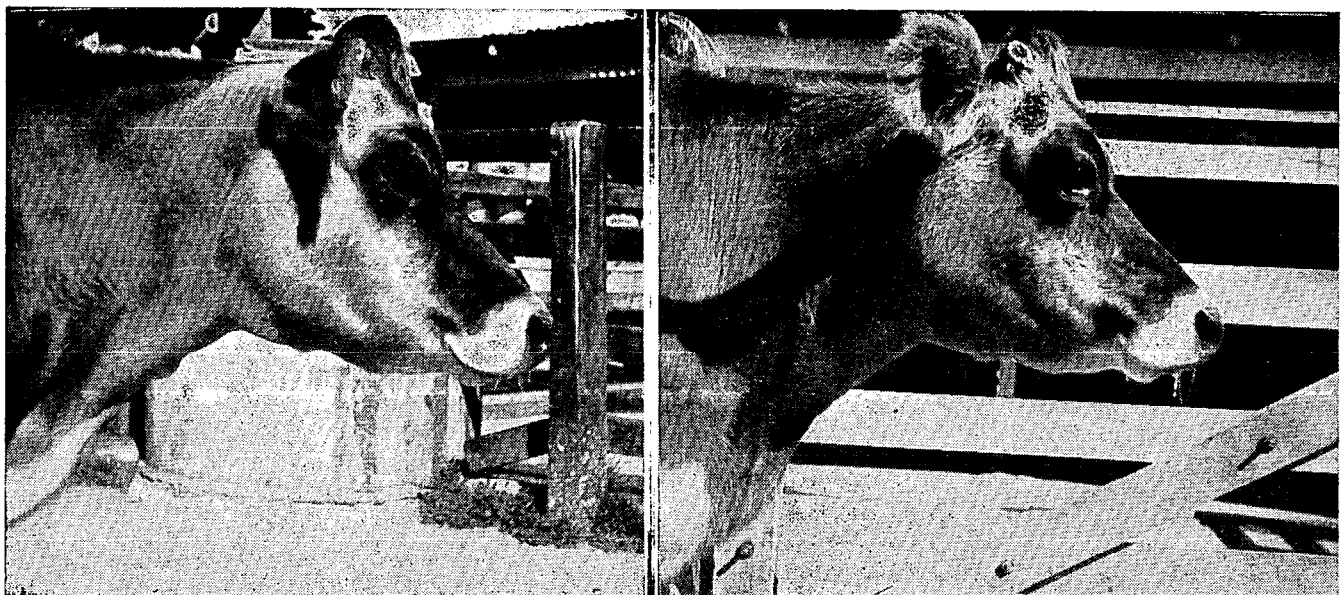

Fig. 4: A set of Monozygotic Twins showing strong and equal jaw development.

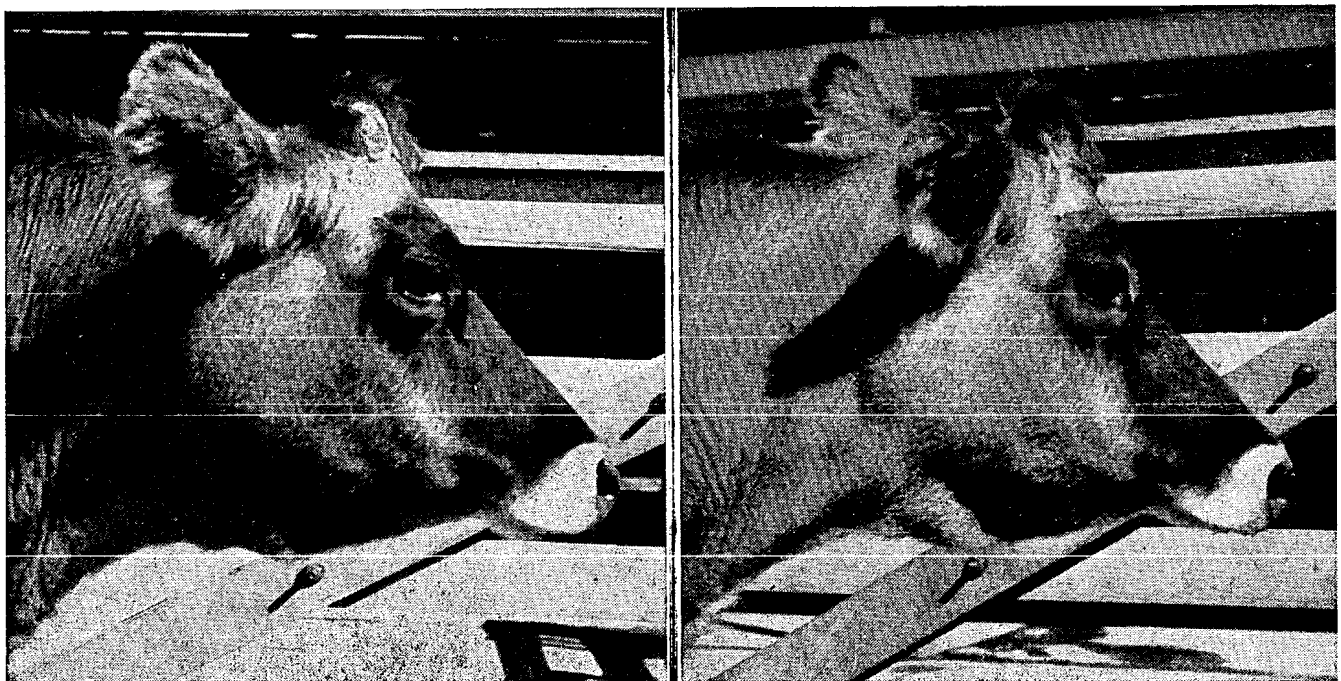

Fig. 5: A set of Monozygotic Twins showing poor and equal jaw development.

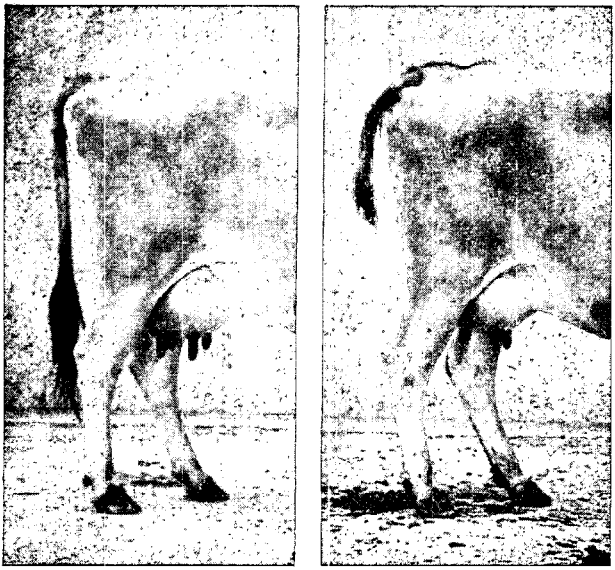

Fig. 6: A set of Monozygotic Twins in which one shows tail deformity while the other twin is normal.

Fig. 7: A set of Monozygotic Twins, one member showing ear deformity while the other twin is normal.

could reveal any abnormality. Nevertheless the calves were almost stone blind, as judged by their behaviour in the paddock. One of them was a bull. When he was mated to 15 normal cows, he produced all normal progeny. Mated to his blind full-sister, he sired a blind calf. It seems therefore that this condition depends on a single recessive factor.

All previously related factors were investigated through the pedigree method. Some results obtained by the twin method will now be illustrated.

A lower jaw, which is too short, is probably one of the worst impediments a grazing animal can possess. Especially under hard grazing conditions, a short jaw becomes a great embarrassment. To illustrate: One member of a set of short-jawed identical twins was subjected to a system of grazing which resulted in sward, which was always short, while her mate was full-fed on plenty of grass and a daily ration of concentrates. The full-fed animal produced as a two-year-old 360lb. of butterfat, while her mate only yielded just over 100lb. The length and shape of jaw are mainly determined by inherited factors, although uterine environment must have some effect. This contention is evidenced by the fact that the dimension of the jaws of identical twins are, by and large, very similar, although they sometimes show perceptible differences. Figures 3 to 6 illustrate this point.

The practical usefulness of identical twins in investigations of problems of this type is perhaps best illustrated by the following case. A well-known breeder discovered that he had sold a bull calf out of a cow which possessed only two functioning quarters—the back quarters. Thinking that the condition might be inherited, he quickly re-purchased the bull and kindly donated the animal, together with the dam, to Ruakura for further investigations. Anybody acquainted with the time and expense involved in finding an answer, positive or negative, to a problem of this nature, would be correct in guessing that we would still be labouring had it not been for the fact that I, fortunately, discovered a set of identical twins, of which both members showed the characteristic in question. Its inherited nature can now be assumed.

Epileptic fits in calves of the Brown Swiss breed have been described in the United States as being due to a simple dominant factor (13). A similar condition but occurring later in life has been observed in New Zealand by Mr. James in a set of identical bull twins (14).

It was indicated previously that evidence showing that a certain abnormality is not inherited is often as useful as positive evidence. The identical twins at Ruakura have furnished many instances of this type. Dr. L. R. Wallace of this Station has found that in two sets of twins one member in each set lacked a mammary gland, while their mates were quite normal.

The following figures will illustrate other cases:

Fig. 6 .... Tail deformity.
Fig. 7 .... Ear deformity.
Fig. 8 .... Skew face.
Fig. 9 .... Dewclaws missing.

For the benefit of the doubters, it may be added that Dr. C. Stormont, formerly of Wisconsin, has recently perfected a blood test which makes it possible to distinguish between identical and fraternal twins with virtual certainty and that he has applied this test to the last three sets of twins and found that they were monozygotic on all counts (15).

Fig. 8: A set of Monozygotic Twins, one showing "skew face" condition while the other twin is normal.

Fig 9: Fore feet of a set of Monozygotic Twins, one member of which lacks inner dewclaws, while the other twin is normal.

(b) SHEEP.

(1) Congenital Photosensitivity in Southdowns is an inherited condition peculiar to New Zealand (16) and is really so well-known that it needs only a short reference. Affected animals show the first symptoms at approximately 4-6 weeks of age. They consist of an intense skin irritation, oedema and necrosis of the portion of the skin not covered by wool (Fig. 10). Blindness, sloughing of ears and secondary infections soon appear as consequence, followed by death through starvation or exhaustion. The photosensitizing agency is phylloerythrin, a break-down product of chlorophyll. Its presence in the skin tissue must be due to the inability of the liver to excrete the substance at sufficiently rapid rate. Experimental matings at Ruakura have clearly shown that the expression of this disease depends on a simple recessive factor.

(2) Congenital Dropsy.—Another interesting condition which has not previously been suspected as due to inheritance has recently turned up in the Southdown breed in New Zealand. The well-known animal obstetrician, W. L. Williams, has described it as "total anasarca" (17), but it may as well be called "congenital dropsy" to conform with the name given to the similar condition in cattle. Fig. 15 shows a typical sample of an affected animal. Lambs of this kind, naturally, cannot survive. In fact, they are never born except through a ceasarean section. They are alive up to full term providing that the dam's uterus has not ruptured previously. As the ewe is a very poor operative risk even under skilled professional hands, the condition is not only fatal to the young but also the dam. Genetically the condition is still puzzling. The farmer who owned the pedigree Southdown flock in which the first known cases occurred stated the story along the following lines. He mated two unrelated rams to a flock of a hundred largely unrelated ewes, and in the following spring 23 of the ewes died because they carried hydrops lambs. It seemed to me that the following working theory fitted the facts. Assuming that each ram tupped 50 ewes and that one of the rams carried a dominant factor in a single dose, one would expect that approximately 25% affected lambs would be born. This hypothesis naturally still left the question open of how an animal carrying a dominant lethal could be alive. However, that was only a minor blemish which a geneticist can account for in many ingenious ways. The next year, the farmer mated each ram separately to 50 ewes. On my suggestion he employed Romney ewes in order to save his expensive stud Southdowns. These matings did not result in any affected offspring. On the new theory, which had to be constructed hastily, the Romneys possessed a high frequency of inherited factors which inhibited the expression of the hydrops gene. In the third year each ram was allowed to tup 10 Southdown ewes and 40 Romneys and last spring it appeared that one of them produced 5 affected lambs out of the Southdowns and also 21 hydrops lambs out of the Romneys; near enough to a 1:1 ratio in both breeds. And that is as far as we have gone.

There are other more or less well-established lethals in New Zealand sheep stock. One of these is amputated limbs (Lerner's D.5) which occurs in Southdowns. Another to which Mr. D. MacFarlane (19) of Wallaceville has drawn attention is polycystic kidneys.

Of non-fatal abnormalities a short lower jaw is perhaps the most important one as it seems to appear to some extent in most Romney flocks. The inherited nature of this condition is well established by American work (20). The mode of inheritance, however, is not quite certain, although it appears that interactions of several pairs of genes probably are involved.

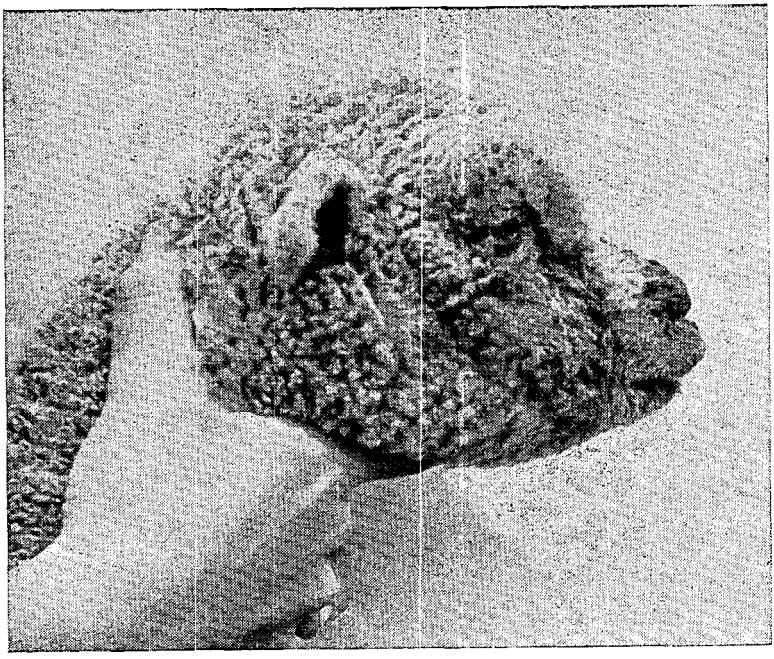

Fig. 10: Congenital Photosensitivity in Southdown lamb.

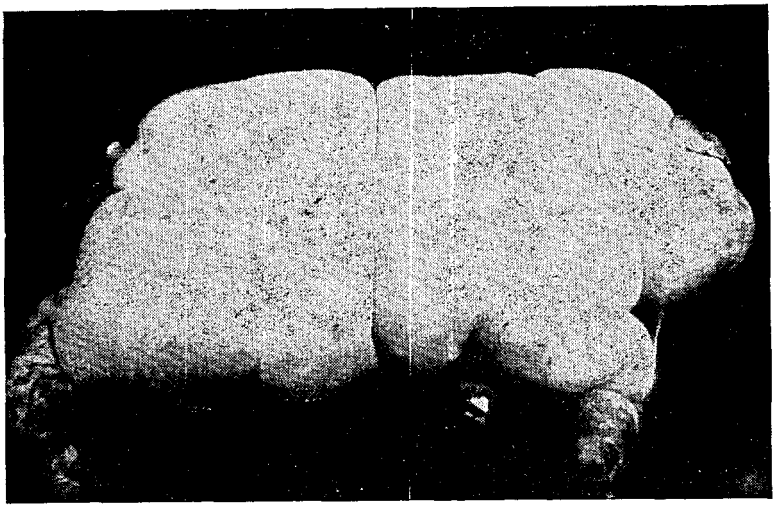

Fig: 11: Congenital Dropsy in Southdown foetus.

(3) PIGS.

Pigs in New Zealand possess a fair share of lethals and other inherited abnormalities. When I say "pigs in New Zealand" I mean more specifically the pigs at Ruakura Animal Research Station. As far as I know there is only one factor of all those known to occur in this country, which has not been demonstated in the Ruakura herd. The exception is the split ear deformity, described by Dr. Annett in the Tamworth Breed (2) (Lerner's C.7). This condition which is lethal and inherited as a recessive, is often associated with deformed hindquarters and sometimes cleft palate. Otherwise our pigs have turned up with such factors as atresia ani (Lerner's C.3), cryptorchidism, scrotal hernia, intersexuality, kinky tail and polydactyly. All these factors, except the last one, seem to depend on recessive genes, (21), (22), (23), (24) (25) and (26) but the analyses of the mode of inheritance are generally well-hedged with such terms as "poor penetrance," inhibiting or modifying genes also present" and "pre-disposing uterine environment." In other words, the frequency of affected animals is generally lower than expected on the basis of a single recessive factor.

A factor new to the literature has recently caused a lot of trouble in the Ruakura herd (27). For several years we have been plagued with a high frequency of deaths due to peritonitis. Seventy per cent. of the total mortality has actually been due to this condition. As hygiene and housing conditions generally have always been of a high standard in the Ruakura piggery, high peritonitis incidence remained a mystery for a long time. It was not until Mr. D. MacFarlane (19) demonstrated in some of these pigs a condition now called "diverticulosis" that Mr. D. M. Smith of this Station began to investigate the problem from a genetic angle. The abnormality in Fig. 12 appears as a series of pockets formed by the mucus membrane of the gut, usually arranged along the mesenteric edge of the last foot of the ileum. The pockets or diverticuli range in size from very small up to 1½ inches in diameter. The condition is invariably associated with a thickening of the gut. As a result of the irritation caused by the diverticulo, inflammation of the mesentery sets in and local peritoneal adhesions frequently occur. The pockets often burst when the pig is 3-4 months of age, resulting in general peritonitis and death. However, sometimes the damage may be sealed off and the pig goes on living. On slaughter the peritoneal cavity of such an animal frequently presents a horrid mess. In a few cases the diverticuli cause little inconvenience and the pigs may reach the bacon stage or even, as in the case of a sow at Ruakura, live long enough to produce several litters. The incidence of diverticuli in the Ruakura Berkshire herd is very high—approximately one-third of all pigs examined in the last three farrowings showed this condition, and there is not a single sow or boar used over this time which has not produced at least one affected offspring. No cases have occurred in Ruakura pigs of the Large White Breed. As pigs are kept at Ruakura in order to provide experimental animals for various investigations on feeding, management, and breeding, it is easy to understand that a condition such as diverticulosis, which causes the sudden death of a pig during an experiment, is likely to be very bothersome. The mode of inheritance is by no means clear. All the animals concerned are fairly strongly inbred and closely related to each other. This, together with the fact that some affected animals may live long enough to reproduce, makes it just possible that the condition is due to a recessive gene in spite of the very high incidence of cases.

DISCUSSION:

The importance of lethal factors and other inherited abnormalities may be considered from two points of view: (1) The individual farmer;

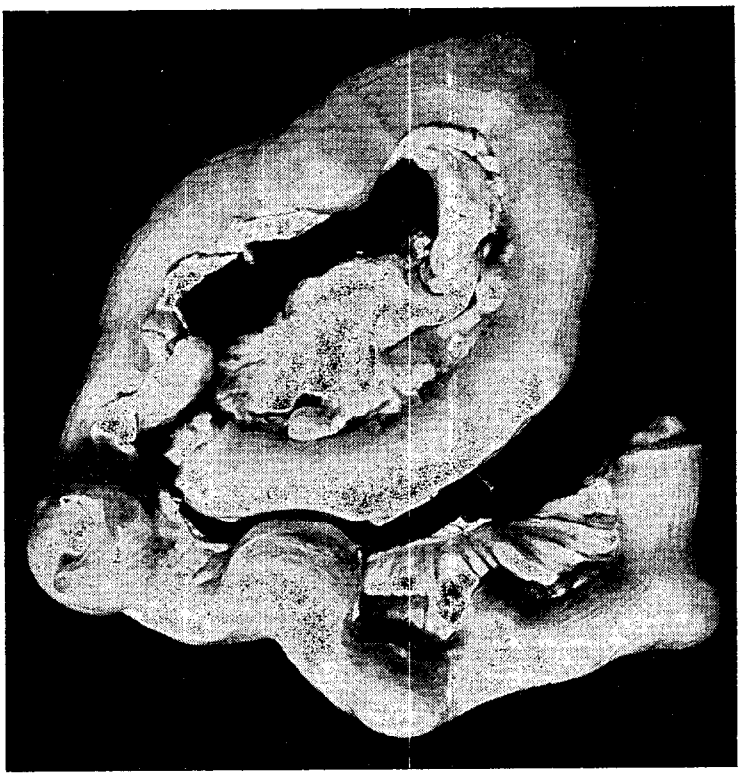

Fig. 12: Diverticulosis in Berkshire pig.

(2) National breeding policy.

It has been a trend in animal research to bother but little about problems which are not of national significance. Before the coming of artificial insemination the occurrence of inherited defects was mainly a concern of the individual farmer, who, however, may be very hard hit economically by the appearance of non-viable or otherwise abnormal animals in his flock. His distress in the face of mysteriously occurring monsters born by healthy parents results in numerous enquiries for advice to places such as Ruakura. For this reason alone, it seems necessary that research into problems of this nature should continue.

The possibility of using artificial insemination as a method of breeding and thus spreading the genes possessed by a few animals very widely and the consequent risk of inbreeding have given the geneticist new food for thought.

Many recommendations have already been made from authoritative sources to the effect that all bulls, before they are used for artificial insemination should be test mated to their daughters in order to discover whether they carry any undesirable factors. In New Zealand, where we are using only old proven sires for artificial insemination, such a stipulation is practically impossible. A test mating scheme would make it necessary to breed a new crop of daughters and then wait for three years before the result of the back mating to their sire becomes available. By that time the animal would be at least 9-10 years old and practically useless for breeding. Another point which is often forgotten by the advocate of test mating schemes is the very great number of matings necessary for a relatively reliable result. It has been calculated that 63 sire-daughter matings are needed. Mr. Ranstead has admirably illustrated in his paper on "parrot jaw" (4) how easily a recessive factor may be missed even after a prolonged system of inbreeding has been followed.

However, even if a test mating policy is impracticable it is highly desirable that the position regarding inherited abnormalities should be watched closely and that animals transmitting undesirable genes should be culled ruthlessly, no matter how superior they are in other respects. In this connection it seems worthwhile to point out that lethals have in the past received more than their fair share of attention in comparison with other inherited but non-fatal abnormalities. The lethal genes tend to be self-limiting and are thus in the long run not very important while the frequency of the other abnormalities may increase and cause a widespread deterioration in a breed if no conscious effort is made to check the trouble.

From New Zealand's point of view, it is suggested that factors influencing fertility may become the most important ones. Swedish (28) and American (29) (30) work have unearthed many different inherited factors influencing the breeding efficiency both in the male and female, and the Swedish work, particularly, has shown how this type of trouble can become almost a breed calamity. However, it is consoling to know that the near calamity was later rectified by the introduction of proper methods of breeding.

The Large White pigs which McMeekan (31) imported from Cambridge provide an interesting example of the complete extinction of a valuable strain through genetic factors causing sterility.

And this brings me to one of the worst aspects of the problem of inherited faults in livestock, and that is the secrecy by which breeders surround the birth of malformed animals in their herds and flocks. In this they are often abetted by the breed societies, whose first duty it should be to investigate and make public occurrences of this type. Full knowledge of the frequency and the mode of inheritance of detri-

mental genes is naturally a prerequisite to intelligent counteraction. It would have been impossible, for instance, to eradicate the factors causing sterility in the Swedish Mountain breed (28) if the breeders and breed societies, instead of letting all facts be known, had been content with piling up skeletons in their cupboards.

In this connection, I would like to recommend two pieces of work as models worth emulating: 1 Ranstead's paper (4) on "parrot jaw" in his own cherished Shorthorns, in which he names every animal known to have produced defective offspring; 2 Korkman's paper (5) on Congenital Hydrops in Finnish Ayrshire cattle, which contains a very detailed herd analysis giving the names and owners of all carrier animals. This frankness was so much more commendable as the work was done under the auspices of the Ayrshire Cattle Breed Society, of which Korkman was the Chief Geneticist.

REFERENCES:

(1) Lerner, I. Michael (1944): J. Heredity, **35**, 219-224.
(2) Annett, H. E. (1938): J. Heredity, Vol. **29**, (12), 469-470.
(3) Annett, H. E. (1939): J. of Genetics, **37**, 301-2.
(4) Ranstead, J. M. (1946): N.Z.J. Sci. Tech., **28**, (3), 206-16.
(5) Reizer, E. E., and Hervey, M. C. (1937): J. of Heredity, **28**, 123-8.
(6) Korkman, Nils. (1940): Nordisk Jord-brugsforksming Hefte, 7-8, 225-43.
(7) Larsson, Erik, L. (1935): Lantbruksvechans Handeinger, 1-22.
(8) Stang, L. (1940: Z. Zucht, **46**, 280.
(9) Donald, H. P. Personal Communication.
(10) Currie, E. J., Personal Communication.
(11) Murray, M. D., Personal Communication.
(12) Ensor, C. R., Personal Communication.
(13) Hancock, John, Unpublished.
(14) Atkeson, T. W., Ibsen, Heman L., and Eldridge, Franklin, (1944): J. Heredity, **35**, (2), 45-48.
(15) James, J. P., Personal Communication.
(16) Stormont, C., Personal Communication.
(17) Hancock ,John, N.Z.J. Sci. Tech. (In Press).
(18) Williams, W. L., (1931): Veterinary Obstetrics, Second Edition Ithaca, N.Y.
(19) McFarlane, D., Personal Communication.
(20) Nordby, Julius, E., Terrill, Clair, E., Hazel Lanoy N., and Stoehr, John A. (1942): Anat. Rec. **92**, (3), 235-254.
(31) Kinzelbach, Werner, (1932): Zeit Ind. Abst. Vererb. **60**, 84-124.
(22) McKenzie, F. F. (1931): Missouri Agric. Exp. Sta. Bull. 300.
(23) Warwick, B. L. (1926): Wisconsin Agric. Exp. Sta., Res., Bull, **69**, 1-27.
(24) Crew, F. A. E. (1923): Vet. J. **79**, 306-311.
(25) Donald, H. P. (1949): J. Agr. Sc. **39**, (2), 164-173.
(26) Kalugin, T. T. (1925): State Trust of White Russia Bull., 11, 111, IV and V. cit Buchanan Smith, A. D., Robison, E. J., and Bryant, D. M. (1936): The Genetics of the Pig, Bibl. Genetica XII. The Hague.
(27) Smith, D. M., Personal Communication.
(28) Lagerlof, Nils (1949): Factors of Sterility Bulletin Primo Congresso Internazionale di Fisiapatologia della Riproduzione Animale e di Fecundazione Artificiale.
(29) Gregory, P. W., Regan, W. M., and Mead, S. W., (1945): Genetics **30**, (6), 506-517.
(31) Pfau, K. O., Bartlett, J. W., and Stuart, C. E., (1948): J. Dairy Sci., **31**, 241-254.
(31) McMeekan, C. P., Personal Communication.

Discussion on Mr. Hancock's Paper

Mr. LAMBOURNE: Atresia ani and bowed forelegs are fairly common in sheep. Are these characteristics known to be inherited?

Mr. HANCOCK: While Atresia ani has been shown to be an inherited condition in pigs and cattle it has not been reported in sheep. Its mode of inheritance in pigs is not well understood.

Mr. FLUX: Are there any lethals that affect the foetus at an early stage?

Mr. HANCOCK: No such lethals have been seen in New Zealand. In other countries they have been reported in sheep and horses. In fowls most lethals are of that type.

Dr. DRY: I have seen a bulldog calf from a sire-daughter mating, the heterozygote showing no abnormality. Further observations would have been useful but the sire had been slaughtered. I feel that such animals should be purchased for purposes of study. I would like to ask whether it has been shown in any known lethal conditions that the heterozygotes are inferior in any way to the homozygous normal.

Mr. HANCOCK: The only condition I have studied from this aspect is congenital photosensitivity in southdowns. No difference could be detected between heterozygotes and normal homozygotes.

Mr. MacFARLANE: In diverticulosis in pigs the organs require very careful dissection to demonstrate the true nature of the condition. The openings of the diverticuli may be so small as to be visible only when the gut wall is stretched. The thickening described is due to a hypertrophy of the muscle layer. At Wallaceville we have also seen cases of extreme fragility of the skin, when large pieces of skin may lift away if the lamb is handled by the wool. This appears to be inherited, and with care affected animals can be reared.

Mr. HANCOCK: The rarity of conditions such as this make their study very difficult.