# Contents

**Defining Reproduction**
Definition and objectives of reproduction in beef cow herds

A. M. Nicol .......................................................... 3

**Physiology**
Physiology of reproduction in cattle

G. K. Barrell .......................................................... 13

**Factors Affecting Reproductive Performance**
Factors affecting reproductive performance in the cow

G. W. Mongomery ...................................................... 25

Breeding soundness in bulls

D. H. Mossman ......................................................... 33

Diseases causing cattle abortions

H. J. F. McAllum ...................................................... 39

Mineral metabolism and reproduction in cattle

A. R. Sykes and N. D. Grace ........................................ 45

The diagnosis of mineral deficiencies and methods of therapy

R. C. Gumbrell .......................................................... 61

**Improved Reproductive Performance**
Management of beef cows for optimum reproduction

D. H. Mossman .......................................................... 71

Management changes which have achieved concentrated calving

D. L. Munro .......................................................... 83

The effect of age at first mating on reproductive performance of beef cows

C. A. Morris .......................................................... 89

**Modified Reproduction**
Practice and place of oestrous synchronisation and induction of parturition in beef herds

A. M. Day ............................................................ 95

Super-ovulation and embryo transfer

A. S. Familton .......................................................... 111
INTRODUCTION

Obtaining optimal reproductive performance from a herd of cattle requires a knowledge of the basic principles of and factors affecting reproduction, an understanding of managerial strategies which can be employed to achieve such performance, and an awareness of existing and new technological advances which can be applied in the farm situation. All of these topics are put together in the series of papers included within this book, which were written to provide background material for a workshop on cattle reproduction held at Lincoln College, May 1984. The workshop participants include scientists, veterinarians, farm advisers and farmers. It is hoped that in addition this book will provide a useful text for a wider range of readers.

A summary is provided at the start of each section to assist any reader who does not wish to examine each topic in the detail provided in the individual papers.

G. K. Barrell
May, 1984.
DEFINING REPRODUCTION
SUMMARY OF THIS SECTION

For a beef cow reproductive performance can be gauged by two criteria. These are the number of calves weaned in her lifetime and their weaning weights. Invariably this means that once a cow enters the breeding herd she must produce one calf every year that she remains in the herd. Thus on a herd basis, the emphasis must be on attaining the highest possible number of calves weaned per cows joined to a bull (CW/CJ, usually expressed as a percentage). A high CW/CJ ratio requires a high percentage of cyclic cows, high conception rates and low neonatal mortality.

Some N.Z. herds are probably close to achieving the maximum CW/CJ but many within the same environments are performing well below the maximum.

Another important criterion for a herd's reproductive performance is the production of a narrow spread of calving dates. This is an indicator of good reproductive performance and produces many benefits for management of the herd.

It is fortunate that the management practices which increase weaning weights of calves, simultaneously increase weaning percentage. This association between reproductive performance and calf growth rate does not mean that there is a cause and effect relationship, but the fact that these important parameters are linked is of great value to the beef farmer.

The overall efficiency of beef production is influenced by the proportion of reproductive females in the herd. Thus a high number of heifers will represent a loss in efficiency and makes the mating of 'yearling' heifers an attractive possibility.
DEFINITION AND OBJECTIVES OF REPRODUCTION IN BEEF COW HERDS

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Introduction
Successful reproduction is the crux of high productivity from the beef cow herd.

With a dual product species such as sheep there is a chance of counterbalancing a reduction in income due to a decline in reproductive performance by an increase in wool production. There is only a single product from the beef cow; weight of calf weaned. Therefore a reproductive performance below maximum means lower output from the beef cow herd. The output of the herd is the sum of the production of individual cows.

Although the lifetime output of an individual breeding cow is the product of the number of calves weaned and their weaning weight it is number of calves weaned which has the greater impact on her lifetime output.

A reduction in total weight of calves weaned through fewer calves weaned cannot be compensated practically by an increase in calf weaning weight (Table 1).

<table>
<thead>
<tr>
<th>No. possible</th>
<th>No. calves weaned</th>
<th>Total lifetime output (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>calves in herd</td>
<td>Weaning weight (kg)</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>180 200 225 257 275</td>
<td>1800</td>
</tr>
<tr>
<td>7</td>
<td>180 210 252</td>
<td>1260</td>
</tr>
<tr>
<td>4</td>
<td>180 240</td>
<td>720</td>
</tr>
</tbody>
</table>

For example, if the average weaning weight of calves is 180 kg then a cow rearing 7 calves in her lifetime in the herd would rear a total of 1260 kg calf. If however she misses rearing a calf in one out of the 7 years then all six of her calves would need to weigh 210 kg for her to equal the lifetime output of 1260 kg.

It is critical to the output of the breeding cow herd and therefore its existence as a productive alternative livestock enterprise that management practices known to induce good reproductive performance are well understood and adopted.

Before considering these techniques, good reproductive performance in the beef cow herd must be defined.

Calving Percentage
The most common expression of the reproductive performance of beef cows is calving percentage. Calving percentage can be defined in a number of ways.

The number of calves born may be expressed;
- per cow calving (CB/CC),
- per cow wintered (CB/CW), or
- per cow joined (CB/CJ).
While CB/CW may be a useful management term, only CB/C accounts for cows which may have:
been sold not in calf (NIC),
died during winter, or
lost a calf during pregnancy
and is therefore an adequate definition. For example, culling 8 out of 12 non-pregnant cows prior to winter in a herd of 100 cows has the effect of increasing calving percentage from 88% expressed as CB/C to 95% when expressed as CB/CW. The higher figure does not satisfactorily indicate the success of the mating management. Every cow culled as NIC reduces the potential for culling cows rearing poor calves.

The word calving infers that calves are born but does not necessarily distinguish between calves born alive, dead or dying between birth and weaning. Neonatal mortality can vary widely between commercial herds in calves from both cows and heifers (Hanly and Mossman, 1977). Mortality rates can vary from 1% to 2% up to between 25 and 45%. Unlike the dairy industry where the fate of the calf is less critical, it is essential that a high proportion of beef calves are born alive and survive. Mothering-on of surplus dairy calves to beef cows which have lost a calf is not practical in most beef herds.

To account for calf death rate, weaning percentage or CW/C is a better definition of reproductive performance of the beef cow herd.

Weaning
Data on the reproductive performance of the N.Z. beef cow herd are regularly collected.

The Meat and Wool Boards' Economic Service (NZMWBES) records calves marked (CM) as a percentage cows joined but refers to calving percentage. Deaths from marking to weaning are considered to be low 1% to 2% so marking percentage is a good indication of weaning percentage.

National CM/C has shown some seasonal variation over the last 13 years but no systematic trend is detectable (Fig. 1). There are two

![Figure 1: Historical trend in marking percentage in beef cow herds.](image-url)
theoretical reasons for the constancy of this figure. First, the biological limits to reproductive performance of the beef cow under N.Z. conditions may have been reached. This is patently not the case (Fig. 2) since

![Graph showing distribution of calving percentages by farm class.](image)

*Figure 2: Distribution of calving percentages (1971 to 1982) by farm class.*

there is considerable variation between herds in CM/CJ within any one environment. Herds with the highest weaning percentage are close to the maximum but the majority could show considerable improvement.

Alternatively, the relatively poor average reproductive performance may represent an incomplete understanding of the factors limiting the reproductive performance of the beef cow herd. Furthermore, on-farm methods for overcoming limitations to reproductive performance may not be well known.

Factors affecting CW/CJ and the practical consideration of these factors will be discussed by other authors (Montgomery, Mossman; this publication).
Calving Spread or Length of Calving Period

The simple expression of reproductive performance as CW/CJ gives no indication of the variation between cows in calving date which determines the length of the calving period.

On theoretical grounds almost all cows in the beef herd should calve over a 63 day period and at least 80% should have calved in the first 42 days. Any departure from this pattern of calving reflects sub-optimal reproductive performance. While some commercial herds do show calving spreads of only 42 days others calve over periods as long as 105 days (Hanly and Mossman, 1977). The situation in bull producing herds is no better. Morris (1981) identified from Beefplan records that only 14% to 26% of recorded herds had a calving spread of shorter than than 80 days.

Such a departure in calving pattern from that theoretically possible will be of importance only if it has some significant effect on herd output or management. The effect of calving spread and calving pattern on reproductive performance is discussed later by Mossman (this publication). From a management point of view a condensed calving period is very desirable for the reasons which follow. It permits cows to be treated as one mob for changes in feeding level. Extended calving periods may require early and late calving cows to be separated for differential feeding. It produces calves at weaning with a small range in age and therefore weight which allows for the sale of large even-sized lines of calves. It permits efficient selection of replacement heifer calves without the need for age correction factors.

A definition of the reproductive performance of the beef cow herd must therefore include a statement about the length of the calving period and the pattern of calving.

Calves Weaned per Female in the Herd

In the majority of beef cow herds replacement heifers are retained to maintain cow numbers as cows are culled. These young replacement heifers must be considered as part of the total herd and the output of the herd (calves weaned) should really be expressed as a percentage of cows plus replacement heifers present at joining (females present, FP).

For example, if 30 heifer calves are retained for a 120 cow herd, with 25 ultimately entering the herd as 2-year-olds, and CW/CJ is 0.88 then CW/FP is 88/175 or 0.50. If only 20 heifer calves are retained of which 18 enter the herd at 2 years of age then with the same CW/CJ, CW/FP is increased to 88/158 or 0.56.

There may be good reasons for having a higher than average number of replacement heifers, e.g. expanding herd size or high culling rate, but it should be remembered that a cost of such a policy is a reduction in CW/FP.

Purchase of replacements as in-calf heifers will maximise CW/FP but age at first calving also will have a large effect (Table 2).
TABLE 2.
Example of age at first calving on calves weaned per females present at mating.

<table>
<thead>
<tr>
<th>Age at first joining</th>
<th>14 months</th>
<th>21/4 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>CW/CJ*</td>
</tr>
<tr>
<td>14-month heifers</td>
<td>25</td>
<td>80</td>
</tr>
<tr>
<td>21/4-year heifers</td>
<td>20</td>
<td>85</td>
</tr>
<tr>
<td>Mixed-age cows</td>
<td>120</td>
<td>90</td>
</tr>
<tr>
<td>Number of calves weaned</td>
<td>145</td>
<td>126</td>
</tr>
<tr>
<td>Number of females present</td>
<td>165</td>
<td>165</td>
</tr>
<tr>
<td><strong>CW/FP</strong></td>
<td>0.88</td>
<td>0.76</td>
</tr>
</tbody>
</table>

*calves weaned per cows joined.
**calves weaned per females present at mating.

If replacement rate is independent of age of first calving then calving at 2 years will increase CW/FP to 0.88 compared to 0.76 when first calving is delayed until to 3 years of age. This represents a substantial improvement in the overall efficiency of beef cow production. Morris discusses further details of age of first calving later (in this publication).

**Synergy of Reproduction and Growth**

As discussed earlier, output from the breeding cow herd is the product of weaning percentage and weaning weight. In some species an increase in reproductive rate is due to an increase in the proportion of multiple births (e.g. sheep). In these case, an increase in reproductive rate is associated with a reduction in growth rate of individual offspring, although an increase in total weight weaned is achieved.

However, in beef cattle a higher weaning percentage simply reflects a greater proportion of females rearing an offspring. In this case, an increase in average weaning weight is generally observed when weaning percentage increases. This consistent positive relationship has been shown within a herd subjected to different nutritional treatments, between differently managed herds and between farm classes.

Hight's (1966, 1968) nutritional experiments showed that weaning weights of 140 and 160 kg were associated with weaning percentage of 75% and 92% respectively. Properties which showed a marked reduction in spread of calving from 105 days to 42 days also recorded an increase in average weaning weight from 137 kg to 182 kg (Hanly and Mossman, 1977).

A five year average of marking percentage and value of weaners sold show that the higher marking percentage achieved in the North Island Hill Country compared with the North Island Hard Hill Country is associated with a higher average weaner sale price (NZMWBES, 1977—1982). This positive association between increasing weaning percentage and increased weaning weight is because management factors which improve weaning percentage are also those which increase growth rate. This potential for combined improvement in weaning percentage and weaning weight makes efforts to improve the...
reproductive performance of the national beef cow herd all the more worthwhile.

Summary
Reproductive performance is of central importance to the output of the beef cow herd.

It is not sufficient to define the reproductive performance of the herd as CW/CJ.

Knowledge of the distribution of calving date and the proportion of reproductive females to total females in the herd is also required.

An increase in average weaning weight is likely to accompany an increase in weaning percentage.

References
SUMMARY OF THIS SECTION

Reproduction in cattle involves more than just the organs of the reproductive tract. The general health, body condition and mobility of cows and bulls are essential requirements for successful reproduction. In addition the hypothalamus in the brain and the pituitary gland just under the brain have an important influence over the reproductive organs and also provide a means by which environmental factors such as daylight or social stress can modify the whole process.

The regulatory links between the gonads (ovaries, testes) and the other glands are provided by hormones and an understanding of the role of hormones has been instrumental for the development of techniques to manipulate cattle reproduction.

In spite of the advances which have been made in the elucidation of reproductive physiology there are still important events which are not understood. These include the question of how some ovarian follicles mature and ovulate (release an egg from the ovary) instead of merely regressing which is the ultimate fate of most follicles. Whilst it is known that the functioning of the corpus luteum (which is formed from an ovulated follicle) can be terminated by a prostaglandin released from the uterus, and this event can be mimicked artificially, it is still a mystery why this is prevented if the egg becomes fertilised. The reasons for the loss of many embryos (about one-third) during the early stage of pregnancy also are not known. Clearly if some of these unexplained issues become better understood then there could be considerable scope for increasing the productivity of breeding cattle.

The paper in the section provides a summary of the current state of knowledge of the processes that regulate the production of egg cells and spermatozoa and culminate in the delivery of a live calf.
PHYSIOLOGY OF REPRODUCTION IN CATTLE

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Introduction

Reproduction in animals is a process which determines the continued existence of a species. Consequently it justifies the involvement of much of the physiological resources of an individual. Whilst specific sections of an animal may be responsible for producing gametes or nurturing foetuses, it is probably more realistic to view reproduction as the combined function of many internal body systems, some of which are influenced by factors originating from external social and physical environments. Because the process is so complex, any simplification will be an over-simplification and any component singled out for scrutiny will gain inappropriate attention in relation to its importance in the whole scheme.

One of the functions of the gonads is to produce gametes (egg cells, spermatozoa) and this is regulated primarily by hormones, called gonadotrophins, which are secreted by the pituitary gland. This gland is stimulated to release the gonadotrophins by gonadotrophin-releasing hormone (GnRH) which is secreted by the hypothalamus. Both the pituitary gland and the hypothalamus are influenced by hormones produced in the gonads. As a result these links between hormones and target organs are arranged in the form of a loop, the final link, in this case between gonadal hormones and the structures associated with the brain, being an example of feedback. Other reproductive functions are regulated by similar convoluted interactions between different hormones. The endocrinology of reproduction therefore must be a central issue in any discourse on reproductive physiology.

Testicular Function

The major products of the testes (male gonads) of adult bulls are spermatozoa and hormones. Spermatozoa are formed from precursor cells (spermatogonia) in walled-off tubes called seminiferous tubules. In conjunction with nutritive support from specialised tubular cells (Sertoli cells) spermatogonia progress through a series of developmental steps within a sequestered environment, somewhat analogous to that provided for oocytes in ovarian follicles. Fluid produced in the tubules carries newly formed spermatozoa into a central duct through which they are conveyed out of the testes. An important accessory structure, also housed within the scrotum, is the epididymis. It is in this latter organ that spermatozoa are stored, gain their ability to move (although they do not actually become motile until ejaculation), and acquire some of the biochemical properties needed for fertilization of ovulated oocytes (ova). Spermatozoa develop their full potential to fertilise ova after they have spent several hours in the female tract.

The secondary sexual glands associated with the male reproductive tract provide additional components of the seminal fluid during ejaculation.
Regulation of Reproduction in Bulls

Both of the pituitary gonadotrophins, follicle-stimulating hormone (FSH) and luteinizing hormone (LH), are required for the successful production of spermatozoa. FSH has target receptors on the Sertoli cells and is instrumental in providing the correct tubular environment for spermatogenesis. On the other hand LH stimulates testosterone production by testicular cells located outside the seminiferous tubules (Leydig cells). From here testosterone diffuses into the tubules where it is needed for satisfactory completion of spermatogenesis. Testosterone also reaches the general circulation and is the main hormone responsible for male sexual characteristics such as libido.

The whole process in bulls is controlled in a similar manner to that described below for cows. Stimulatory signals are transmitted by GnRH and the gonadotrophins, with testosterone producing an inhibitory 'negative feedback' influence over hypothalamic and pituitary function. The gonads of both sexes produce a hormone called inhibin which specifically inhibits the secretion of FSH and which probably provides the fine tuning for the control of gamete production.

Ovarian Function

Reproductive activity in the cow hinges on the state of the ovaries, which produce both egg cells (called oocytes) and hormones. The oocytes are not just scattered about the ovaries in isolation but are each present within a surrounding membrane in association with a cluster of specialised cells (granulosa cells). Another layer of specialised cells (theca cells) appears outside this membrane when these structures become further developed. These structures are called follicles and approximately 40 000 are present in each ovary of a calf at birth. Only a minute fraction of them will eventually ovulate and release an oocyte from the ovary. Follicular death, or atresia, commences before birth and is the fate of about one-third of the remaining follicles each year. Therefore ovulation is a most unlikely fate for a follicle. At any time during adulthood there are always a few follicles either growing or undergoing atresia.

Growth consists of multiplication of the granulosa and theca cells and the accumulation of fluid within follicles so that they take on the appearance of small blisters under the surface of the ovary. Just prior to the start of an oestrous cycle one of the larger follicles in each ovary is rescued from the otherwise inevitable fate of atresia and undergoes marked and rapid increases in size. At this stage follicular cells, especially the granulosa cells, produce large quantities of oestrogens. Recruitment of a follicle into this latter phase of maturation is partly dependent on the provision of a suitable hormonal environment. The number of follicles which ovulate at each ovulation seems to be related to the supply of the gonadotrophin, aptly named FSH. Provision of supplementary FSH, or of FSH-like drugs such as PMSG (pregnant mare serum gonadotrophin), can lead to increased numbers of ovulating follicles, i.e. 'super-ovulation.' This phenomenon has been usefully
exploited for embryo transfer procedures.

After ovulation the successful follicle takes on a new appearance. Blood vessels from surrounding ovarian tissue penetrate through the outer membrane, granulosa cells increase in size and the previously fluid-filled follicle is transformed into a solid cell mass — the corpus luteum or yellow body. There is a concurrent change in the hormonal product of the granulosa cells, as the major hormone secreted from the corpus luteum is progesterone. Meanwhile the development and regression of small follicles continues largely unaltered. The ovarian events which characterize oestrous cycles are; the final maturation of a follicle so that it eventually ovulates — (the 'follicular phase'), and the subsequent development and functioning of the corpus luteum — (the 'luteal phase'). If a discharged oocyte is not fertilised, the corpus luteum finally regresses after 16 to 18 days and the whole process is repeated.

**Regulation of Oestrous Cycles**

The survival of large follicles beyond the atresia barrier depends on pituitary gonadotrophin secretion, which in turn relies on pulses of GnRH released by the hypothalamus. Hypothalamic activity itself can be altered by nervous stimuli arising from sources such as temperature, light and social stress. Other factors to consider are level of nutrition, body condition, stage of body growth, stage of lactation, time since the last calf was born and state of health. These have considerable influence on the release of gonadotrophins, the response of target cells to their specific hormones, and the metabolism and biological half-life of hormones generally. Consequently the mechanisms by which these factors can modify initiation of the crucial, final stages of follicular maturation are not well defined.

Once maturation is initiated the reprieved follicle produces large amounts of oestrogens, mainly oestradiol. At this stage of the cycle oestrogens have a 'positive feedback' effect on the hypothalamus and pituitary because they stimulate secretion of LH (*Fig. 1*). Two major events occur over the next few days. First the elevated gonadotrophin levels increase oestrogen secretion by the follicular cells and the high concentration of oestrogens may be sufficient to cause behavioural oestrus (heat) — although admittedly oestrus does not usually occur at the first pubertal or post-partum cycle. Secondly the enlarged, mature follicle ovulates, gently releasing its oocyte from the ovary, and then undergoes conversion into a corpus luteum. Ovulation requires a surge of LH secretion which must amount to something like the pituitary equivalent of an explosion - an event which only female hypothalamic-pituitary systems are pre-programmed to carry out.

Over the ensuing sixteen days the cow is dominated, reproductively speaking, by the secretion of progesterone. This hormone inhibits hypothalamic function via a 'negative feedback' signal (*Fig. 1*) and consequently impedes any further follicular maturation during the life span of the corpus luteum.

When these events occur without any overt display of oestrus — a
so-called 'silent ovulation', or if for some other reason fertilisation does not occur, then the cow faces a crucial reproductive situation. In order for follicular maturation to recommence the inhibitory influence of progesterone must be eliminated. This is achieved by destroying the corpus luteum, an event which depends upon the timely arrival from the adjacent uterus of a hormone known as prostaglandin $F_2\alpha$ (PGF). Once this occurs, and the corpus luteum has been destroyed, another normal ovulation can be expected within a few days. Destruction of the corpus luteum, or 'luteolysis', is probably the key event for control of ovulation and therefore provides the basis for synchronisation techniques.
Fertilisation
Successful fertilisation of mature oocytes (or ova) is largely a matter
of correct timing. Some adventitious spermatozoa reach the innermost
regions of the female reproductive tract within a few minutes after
ejaculation. However their haste is fruitless since spermatozoa must
spend at least an hour in the uterus acquiring the final attributes needed
for egg penetration. Reservoirs of spermatozoa are stored within folds of
the cervix and the progression of spermatozoa from these stores to the
site of fertilisation in the oviducts is a continuous and carefully regu-
lated process. Exposure of the female tract to the various hormonal
changes leading up to ovulation appears to be an essential prerequisite
for this critical but poorly understood process of spermatozoal trans-
port.
An ovulated oocyte reaches the oviduct, usually within 40 minutes of
ovulation. It must encounter competent spermatozoa waiting in the
upper reaches of this channel if fertilisation is to occur at about six
hours after ovulation. With natural mating spermatozoa should be
present in the female tract before ovulation, and fertilisation must occur
within 24 hours from ovulation.
This integration is achieved in natural mating by the high levels of
oestrogens causing standing oestrus to commence about 30 hours
before the maturing follicle ovulates. The peak of oestrous behaviour
should thus coincide with the optimal time for mating.
Pregnancy
The newly fertilised embryo reaches the uterus three to four days
after ovulation, by which time the uterus is under the influence of
progesterone secreted from the corpus luteum. This hormone stimu-
lates uterine secretions which nourish the developing embryo until it is
implanted. Implantation does not commence for 5 to 6 weeks yet
during this time the corpus luteum fails to undergo luteolysis. The
embryo apparently produces a signal which prevents the uterus from
releasing a luteolytic dose of PGF. The precise nature of this 'pregnancy
signal' has yet to be elucidated.
Most of the embryonic and foetal mortality (about one-third of all
fertilised eggs) occurs during the first six weeks of pregnancy and for a
variety of reasons. For instance, the 'pregnancy signal' may have been
inadequate, the uterine environment may be nutritionally or endoc-
rinologically imbalanced, the corpus luteum may fail to maintain an
adequate supply of progesterone, or the embryo itself may lack compe-
tence for survival. Unfortunately this is another topic where precise
information is lacking yet where there is much scope for possible future
intervention.
Pregnancy is maintained by progesterone secreted from the corpus
luteum. In addition placental tissue provides an extra source of this and
other essential hormones during the gestation period. The hormones
associated with the pregnancy are instrumental also in developing
mammary tissue for the impending lactation.
In the early stages of pregnancy there is a differentiation of parts of the embryo into membranes which develop into an inner amniotic membrane and the outer allanto-chorionic membranes. Cells of the chorion progressively invade the caruncles of the uterus and form the cotyledo-

nary placenta which is unique to the ruminants. Although the blood circulations of mother and foetus are quite separate the placental attachment provides a site of intimate association of blood vessels which allows ready movement of most small molecules between the two organisms. Growth of the placenta is a dominant feature of the first two-thirds of pregnancy whereupon it is overshadowed by foetal growth during the latter third. Throughout pregnancy free development of the foetus is permitted by the cushioning action of the amniotic fluid which surrounds the foetus.

Parturition

Pregnancy ceases when the sources of progesterone are shut off by the action of PGE. This situation arises when corticosteroids from the adrenal cortex of the foetus reach the placenta, causing the release of prostaglandin and the formation of oestrogens. The foetus is thus responsible for triggering its own birth. This chain of hormonal events causes relaxation and softening of connective tissue at various sites in the birth canal and pelvis, stimulates uterine contractions, and also switches on lactation.

Uterine contractions during the preparatory stage of labour force the foetal membranes into and through the cervix. Usually the allanto-chorionic membrane bursts at this stage, releasing a copious volume of allantoic fluid. The amnion usually ruptures during the second stage of parturition when the forefeet of the calf pass through the vulva. As a result the calf is expelled free of the placental membranes. The maternal and foetal components of the placenta separate after calf delivery so that expulsion of the foetal membranes occurs half an hour to 8 hours later, although most cows complete this process in 4 to 5 hours.

In conclusion, the presence of the newborn calf plus its ready source of nourishment represents a successful outcome for the whole reproductive process and an assurance of continued survival for both the bovine species and the cattle industry.

Bibliography
FACTORS AFFECTING REPRODUCTIVE PERFORMANCE
SUMMARY OF THIS SECTION

The cow.

Reproductive performance in N.Z. beef herds falls short of that which should be attainable. In cows a major source of the impaired level of performance is the long delay from calving to the onset of oestrus — the post-partum anoestrous interval (PPAI). The factors influencing PPAI are; season of calving (late winter calvers are slower at recommencing cycling than cows which calve in late spring), level of nutrition and age of cows. In 2-year-old cows nutrition is a critical factor in PPAI. Other factors which are important in the beef cow herd are calf mortality and nutrition during the latter part of pregnancy. There is a conflict here, however, because the major cause of calf mortality is difficult birth (dystocia) yet in younger cows increased nutrition in late pregnancy will predispose them to calving difficulties. A possible source of increased productivity from a breeding herd lies in the production of twins. Techniques to achieve this may become available in the future.

The bull.

The paper describing important factors for bull performance introduces the concept of examining bulls for reproductive soundness. Whereas bulls previously were simply classified as sound or unsound, it is now possible to allocate an individual score for mating ability to each bull. Older bulls can be ranked for their usefulness as existing herd sires and younger bulls for their potential contribution to the herd. Examination of bulls for breeding soundness involves a physical examination of the testes (including firmness and scrotal circumference), feet and limbs, eyes and jaw, followed by a test of serving ability. This modified serving capacity test (M.S.C.T.) detects breeding unsoundness in many bulls which would previously have been declared as sound on the basis of the physical examination alone. The whole procedure needs to be carried out by an experienced veterinarian.

Causes of abortion.

The third paper in this section describes the causes of abortion, which represents a source of reproductive loss occurring between a mating programme and the expected calvings. Causes of abortion can be classified under inherited defects, congenital defects (mainly due to some viruses or to toxic chemical agents) and infectious agents. Most diagnosed abortions in N.Z. cattle arise from the latter cause, the major diseases involved being; leptospirosis, campylobacteriosis (previously known as vibriosis) and mycotic (fungal) abortion. Leptospirosis is the most commonly recorded cause of abortion (25—30½ of all cattle abortions) and is significant also because of its transmission to humans. Brucellosis, listeriosis and pasteurellosis are now uncommon as causes of abortion in cattle but when outbreaks do occur, they can involve many members of a herd. Emphasis is placed on the importance of providing well-preserved specimens for submission to Animal Health Laboratories so that diagnosis and correct remedial procedures can be carried out.
Minerals.

The remainder of this section deals with minerals.

In terms of direct effects on reproductive performance in cattle, there is little clearly demonstrated effect attributable to any of the minerals. Mineral deficiencies may be sub-clinical and interfere with nutrition, causing poor growth rates. As a result such deficiencies may manifest their effects on reproduction indirectly.

Nevertheless for a few minerals direct affects on reproduction are suspected and the metabolism of such minerals is discussed in some detail. Such minerals include calcium because the symptoms of milk fever (caused by a lowering of blood calcium levels) may mask signs of oestrus. A range of minerals have potential to impair reproduction but need to be investigated specifically to determine this. These include; phosphorus, magnesium, copper (molybdenum and sulphur interfere with copper absorption), selenium, iodine, zinc, and possibly; manganese, sodium and cobalt.

The main mineral deficiencies which have been reported in N.Z. cattle are of copper, selenium and to a lesser extent, magnesium.

Diagnosis of mineral deficiencies is often a difficult task and involves an understanding of the background to the problem, a definition of the cause and the development of a suitable test. The latter may involve analyses of samples of soils, herbage or animal specimens and will be influenced by whether the undertaking is to investigate an existing clinical problem or to prevent one from occurring in future. Animal Health Laboratories of M.A.F Animal Health Division carry out such tests and maintain reference ranges for the various minerals in animal specimens. Veterinarians are kept informed of any updating of reference ranges.

A useful technique for investigating mineral deficiencies, if properly planned and executed, is a production response test where a group of supplemented animals is studied in comparison with unsupplemented herd mates.

Treatment of mineral deficiencies usually takes the form of administration of short acting preparations of the mineral whereas prevention often involves long-term supplementation such as inclusion of minerals in topdressing mixtures.
FACTORS INFLUENCING REPRODUCTIVE PERFORMANCE IN THE COW

G.W. Montgomery
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Introduction
Reproductive performance in many N.Z. beef herds is well below standards acceptable to sheep farmers. A high proportion (20% to 25%) of cows mated fail to rear calves (Montgomery, 1978) due to both barren cows and calf mortality. Comparisons between the performance of a typical beef herd and sheep flock (Table 1) show that the major differences are the proportion of barren animals and litter size.

TABLE 1. Reproductive performance in a typical beef herd and sheep flock.

<table>
<thead>
<tr>
<th></th>
<th>Beef herd*</th>
<th>Sheep flock**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young weaned per 100 females joined</td>
<td>78</td>
<td>120</td>
</tr>
<tr>
<td>Barren animals (%)</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>Cow or ewe mortality (%) (joining to parturition)</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Calf or lamb*** mortality (%)</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Litter size</td>
<td>1</td>
<td>1.41</td>
</tr>
</tbody>
</table>

*Data summarised from Montgomery (1978)
*Data from Kelly (1982)
**Data for lambs born as singles

In addition to the high proportion of barren cows, there is a problem of calving taking place over several months. For example, Morris (1981) analysed three years' data from Beefplan records and found that only 26 percent of Angus herds and 14 percent of Hereford herds had calving spreads of less than 80 days. Therefore the proportion of barren cows in herds would be higher if mating was restricted to three cycles (i.e. 63 days).

Post-partum Anoestrus
The major reasons for poor reproductive performance is a period of anoestrus in all cows after calving, known as the post-partum anoestrous interval (PPAI). Once a cow becomes pregnant she does not have regular oestrous cycles. During pregnancy, factors such as high concentrations of steroid hormones cause disturbances in the system controlling reproduction and as a result there is a long delay after calving before beef cows re-establish regular oestrous cycles. Until regular oestrous cycles recommence and the cow shows oestrus, ovulates, and has a functional corpus luteum capable of supporting pregnancy, she will not get back in calf.

Because the gestation length in cows is about 280 days they must get back in calf within 85 days of calving to calve at the same time each year (i.e. within 365 days of previous calving). Under many situations in N.Z. the period of post-partum anoestrus is longer than 80 days (Knight and Nicoll, 1978; Morris et al., 1978; Montgomery et al., 1980).

In spring calving cows at Invermay A.R.C. (Montgomery et al., 1980), mean PPAI ranged from 65 to 90 days between years resulting in a protracted calving pattern (Fig. 1). In contrast, mean PPAI in an autumn
calving herd ranged from 31 to 51 days. As a consequence, all cows were cycling regularly when bulls were introduced and the calving pattern was highly concentrated (Fig. 1).

Factors affecting post-partum anoestrus interval.

Major factors influencing PPAI that are under management control are season (calving date), nutrition, and cow age. In spring calving beef herds there is an important relationship between calving date and PPAI (Fig. 2), that over a 60 day calving period from August to October, mean

![Graph showing the relationship between calving date and PPAI for spring and autumn seasons.](image)

*Figure 1: Percentage of Angus cows calving during successive 21 day periods in autumn and spring at Invermay A.R.C.*

*Figure 2: The relationship between post-partum anoestrous interval (PPAI) and calving date for Angus cows at Invermay A.R.C. (Data from 3 years' observations.)*
PPAI would decrease by 36 days from 90 to 54 days. Furthermore, the slope of the regression line varies between years (Knight and Nicoll, 1978) and can be as high as $-1.05$ days per day (Morris et al., 1978). Under these circumstances, early calving cows do not return to oestrus before late calving cows.

In spring, length of daylight is changing rapidly, temperatures are rising and with increased grass growth the amount of feed available to the herd is increasing. A trial has been conducted recently to look at the relationship between season and nutrition in controlling PPAI (Montgomery, 1981). There was an effect of season because despite a controlled high level of feeding both before and after calving, early calving cows (August) took longer to return to oestrus than did late calving cows (October: slope of the regression $-0.3$ days per day, S.E. = 0.06). Furthermore, under-nutrition has a much greater effect on early calving cows than on late calving cows (Table 2). Compared with a high

<table>
<thead>
<tr>
<th>Calving Date</th>
<th>Nutration HIGH</th>
<th>MEDIUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 21 — Sept 15</td>
<td>66.7* **</td>
<td>82.7</td>
</tr>
<tr>
<td>Sept 9 — Oct 30</td>
<td>56.7</td>
<td>62.3</td>
</tr>
</tbody>
</table>

* Data are the mean of 3 years' results
** S.E.D. of treatment differences = 2.35

plane of nutrition, a moderate plane of nutrition increased PPAI by 5 to 6 days in late calving cows (56.7 vs 62.3 days, S.E.D. = 2.3), but by 16 days in early calving cows (66.7 vs 82.7 days, S.E.D. = 2.3). A similar interaction between calving date and nutrition has been reported recently in 2-year-old cows (Nicoll et al., 1984). There is little effect of cow age on PPAI in mature cows. However, PPAI is 20 to 30 days longer in 2-year-old cows (Tervit et al., 1977; Knight and Nicoll, 1978). From the relationship between post-calving liveweight, calving date and PPAI obtained in that study, it is likely that the interaction between season and nutrition is more important in 2-year-old cows.

**Calf Mortality**

Calf mortality represents a major loss to the beef industry. Based on N.Z. survey data, about 9% of calves are born dead or die between birth and weaning (for a review see Montgomery, 1978). At Invermay A.R.C. calf mortality from 3-year-old cows was 11% and of the 37 recorded calf deaths, 76% occurred in the first 3 days after calving (G.W. Montgomery and I.C. Scott, unpublished observations). From these data and observations at Tara Hills (Montgomery, 1978), the pattern of calf deaths
appears to be similar to overseas results (Wiltbank et al., 1961; Koger et al., 1967; Young and Blair, 1974) suggesting similar causes of calf mortality. However there have been no detailed investigations of causes of calf death in N.Z.

In a detailed study, Young and Blair (1974) showed that slow or difficult birth (64%), enteritis (13%), and starvation (10%) together accounted for 87% of calf deaths. Slow and difficult birth was most important and factors affecting difficult birth, or dystocia, are likely to have the biggest effect on calf mortality. These factors include dam age and parity, calf birth weight, calf sex, breed, and sire within breed.

Dam age and parity is the most important factor. The incidence of dystocia is 3 to 4 times higher in first calving cows than in 5 and 6 year old cows despite lighter birth weights (Brinks et al., 1973; Laster and Gregory, 1973; Laster et al., 1973; Philipsson, 1976). In addition, other factors affecting dystocia have more pronounced effects in first calving cows (Laster et al., 1973). For example, sire breed had little effect on dystocia in 4- and 5-year-old cows, but major effects in 2-year-old cows.

Nutrition of the dam in late pregnancy.

Severe dietary restriction in late pregnancy reduces calf birth weights and increases calf mortality (Hight, 1966; Corah et al., 1975). Mechanisms by which under-feeding can increase mortality are failure of pelvic structures to relax or general weakness (Hodge et al., 1976; Marsh et al., 1968; Young, 1968). At moderate planes of nutrition calf birth weights increase there is little change in the incidence of dystocia (Rice and Wiltbank, 1972; Price and Wiltbank, 1978).

In contrast to this situation in older cows, recent evidence from 2-year-old cows suggests that in younger cows calf mortality may increase markedly with increasing plane of nutrition in late pregnancy (Nicoll et al., 1984). If such increases in calf mortality do occur, appropriate feeding in late pregnancy is critical. Requirements for calf viability and subsequent cow production may be conflicting.

Twinning in Cattle

Marked increases in beef cattle production could be achieved through a higher incidence of twinning. Increased twinning frequencies could be achieved in one of several ways. Intensive selection to increase the natural twinning frequency is being undertaken in at least four locations; in Australia, France, U.S.A. and N.Z. (Piper and Bindon, 1979; C.A. Morris, pers. comm.). A further technique is the implantation of a second fertilised egg resulting from super-ovulation (see Hamilton, this publication) or from in vitro fertilisation of recovered oocytes. The most promising method is the use of immunisation techniques similar to the product 'Fecundin' (Glaxo Laboratories Ltd) recently released for general use in sheep. In a recent report 3/14 immunised cows had twin calves following one such immunisation treatment (Wise and Schambacher, 1983).
Practical Implications

Herds calving in late winter will have long intervals to first oestrus, and consequently depressed reproductive performance compared with herds calving in late spring. Poor nutrition will have a much greater effect in herds calving in late winter and these are the herds where nutrition is most likely to be restricted. This seasonal effect is of major importance and will mean that rebreeding of first calving heifers is also much more difficult in herds calving in late winter. All the data on reproductive performance suggest that calving date should be later than it is in many herds at present. At Invermay A.R.C., beginning calving in early September rather than late July shortened mean post-partum intervals by 30 days and greatly reduced problems of poor reproductive performance.

One major reason advanced for early calving is to have large calves by the time of weaner sales. Monetary returns are clearly determined by the number of calves sold and the average price, not the price for the top 10% of calves. Delaying calving until later in spring will reduce the age of first born calves at sale time, but will not change average calf age by the same amount. Shorter intervals to oestrus will result in a more concentrated calving pattern. For example, a month's delay in calving should result in a change in mean calving date of 20 days or less, depending on the length of the joining period. Remaining differences in calf age, and hence weaning weight, could be compensated for by increased calf growth rate. The use of Friesian and Jersey crosses as dams in beef herds can substantially increase weights of calves weaned (Baker et al., 1981). Systems of cross-breeding to allow the use of a terminal sire breed would also increase calf growth rate. In addition, a sire breed with a known low incidence of dystocia should be used over first calving cows as one of the practical methods of controlling dystocia and resulting calf deaths.

An alternative method for increasing the total weight of calves weaned is an increase in twinning frequency. Improved reproductive performance through later calving would be an advantage in a twinning programme. The challenge for the beef industry is to develop management systems so that recent knowledge and new techniques can be utilised to improve production and financial returns.

References

BREEDING SOUNDNESS IN BULLS

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Introduction

In this paper all discussion relates to *Bos taurus* bulls. Under natural mating conditions many of the techniques used in the past for examination of bulls for breeding soundness are valueless. The emphasis has been on the wrong criteria, if in fact any were actually used. Generally an 'all or none' approach has been used. The bull had semen or it did not, the bull could serve or it could not, the bull had large testes or it did not. Not only in many cases have the wrong criteria been used, but much of the information was wrongly interpreted (e.g. seminal vesiculitis — is it really important?) and the value of many examinations or tests have been placed in the wrong order. For example — experience in the cattle industry under natural mating conditions shows that semen evaluation is not very useful, even though veterinarians receive comprehensive training on this. Is a bull sound if it serves a cow on heat in a paddock once and gets that cow in calf? How good is good semen? If a bull has large testes, does it mean that he can serve many cows? What about the high growth rate bull with good semen but with 'low fertility' in the paddock and causing a spread out calving pattern? All the above are instances of the wrong emphasis being placed on selection criteria for reproduction.

The objective of beef reproduction is to get as many cows in calf over as short a period as possible with a repeatability of one calf per cow per year. Thus examination of bulls must extend beyond the all-or-none concept — from the unsound versus the sound bull, as traditionally recognised (although even this has been severely limited in the past) to the evaluation of how you can decide which is the better of two sound bulls.

The examination of bulls for breeding soundness has been comprehensively dealt with by Blockey (1984).

Definitions.

**Serving capacity** (S.C.) is the number of services a bull achieves in a 3 week paddock mating period. It is predicted with a 90% accuracy by the serving capacity test.

**Serving capacity test** (S.C.T.) is the yard test of serving capacity and is number of services the bull completes in a standardised 40 minute yard test.

**Modified serving capacity test** (M.S.C.T.) is the yard test to ensure that bulls achieve a minimum of medium serving capacity by performing three successful services which must be completed in 40 minutes — it does not identify high serving capacity bulls. It is an all or none approach.

**Scrotal circumference** is obtained by measurement of the largest diameter of the scrotal sac around both testes when they are pulled to the lowest part of the sac.

**Mating potential** (M.P.) is an index of the number of cows which a bull can mate successfully in a three week period. It will differentiate between two sound bulls. The two pieces of information required to calculate M.P. are S.C. and the scrotal circumference. For example the scrotal size minimum in a bull for 40, 60, 80 cows are 30, 32, 34 cm. The
S.C.T. minimum for 40, 60, 80 cows is 3, 9 and 12. The restriction on the number of cows a bull can handle is based on the minimum measurement of either scrotal size or serving capacity. If a bull has a S.C. of 12 but a scrotal circumference of 30 cm, it can only serve 40 cows; with a SC of 3 and scrotal circumference of 34 cm it can only serve 40 cows even though it has enough semen for 80 cows. However with a S.C. of 12 and scrotal circumference of 34 cm it can serve 80 cows.

**Breeding Soundness Examination (B.S.E.)**

Examination and collection of data of bulls' clinical and physical performance is considered in two categories. First, 3 years and older bulls (existing breeding bulls) and second, 3 years and younger bulls for their potential performance plus an evaluation of their suitability for breeding (new breeding bulls).

Three questions need answering —
(a) Whether the bull is suitable for use?
(b) Whether the bull can be used successfully at say 1:40 cows?
(c) Whether the bull is superior in getting a greater number of cows in calf over as short a period as possible when used in a ratio of 1:60 to 1:80 cows?

The examination should be split into two sections; breeding soundness for commercial herds, and breeding soundness for sale bulls and stud sires.

The existing situation in many areas of N.Z. is disastrous in many commercial herds and is not much better in many stud herds. Of over 2000 commercial bulls examined for breeding soundness, more than 23% were unsound (see Table 1). These were bulls farmers would normally use. The incidence of unsound bulls at the first examination on a property is often high, but many conditions associated with poor bull ability to serve are progressive, so annual re-examinations should

| Reference          | Number of bulls examined | Incidence of unsoundness % | Proportion detected by:
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>(a) Physical test %</th>
<th>(b) Serving capacity test %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blockey (1984)</td>
<td>494</td>
<td>28.3</td>
<td>54</td>
<td>46</td>
</tr>
<tr>
<td>Blockey (1984)</td>
<td>548</td>
<td>20.7</td>
<td>57.5</td>
<td>42.5</td>
</tr>
<tr>
<td>Blockey (1984)</td>
<td>464</td>
<td>27</td>
<td>31</td>
<td>69</td>
</tr>
<tr>
<td>McDiarmid (1981)</td>
<td>278</td>
<td>19</td>
<td>27</td>
<td>73</td>
</tr>
<tr>
<td>D.H. Mossman**</td>
<td>over 2000*</td>
<td>23</td>
<td>22</td>
<td>78</td>
</tr>
<tr>
<td>D. McColl**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>J.B. Peters***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Unpublished data—**Wairoa Veterinary Services
***Gisborne Veterinary Club

TABLE 1.
Comparison between different methods for detecting breeding unsoundness in bulls.
be practised. At one stage 4 years ago, 33% of bulls examined for the first time were unsound for breeding.

Identification of unsound bulls in commercial herds.

Breeding soundness examination consist of a general physical examination including, first general condition, then (a) testes (palpate for consistency and measure scrotal circumference), (b) feet, legs and muscles, (c) eyes, (d) jaws; followed by (e) M.S.C.T. This procedure will detect all bulls with abnormalities of penis, leg, hips and back and detect bulls with a low serving capacity.

(a) Testis.
Consistency score; 1 to 4 (firm and springy to soft and spongy) — semen test spongy only.
Scrotal circumference — if below 30 cm cull (all or none). Above 30 cm depends on results of S.C.T. related to M.P.
(b) Legs and muscle.
Stand in front of bull to examine its knees. Compare joint sizes, claw overgrowth and look for interdigital granulomata (corns). Any abnormal wearing of claws should be noted.
Conditions such as arthritis in the hips are indicated by the outside claw corkscrewing across the back feet.
Note wasting of muscles.
Walk and run bulls for any signs of lameness. Many instances of lameness may now show up until the S.C.T., but this general examination will reveal potentially unsound bulls with arthritis.
(c) Eyes.
Inspect for cancer eye and general eye conditions.
(d) Jaws.
Check for under- or over-shot, fractures or woody tongue.
(e) M.S.C.T.
This is used to detect unsound bulls (refer back to the definition) and also low serving capacity bulls. If the above clinical and physical examinations are carried out the results could be like those described in Table 1.

The important point for farmers, advisers and veterinarians is that in N.Z. right now, in excess of 20% of beef bulls in commercial use are totally unsound for breeding purposes. This could be overcome by use of the M.S.C.T. since all medium S.C. bulls are capable of handling 40 cows (Blockey, 1984; Mossman, unpublished).

When the farmer is on a Planned Management Production Scheme then the S.C.T. test is required and the major benefits derived from concentrated calving become more obvious.

Breeding soundness for sale bulls.

As commercial farmers become more aware of breeding soundness examinations there will be pressure to have young bulls tested prior to sale to evaluate their mating potential. Already this information should
form an integral part of a sale catalogue. Why? The incidence of unsoundness in 2-year-old bulls and the importance of S.C. test in detecting unsound bulls was shown after the examination of 1255 2-year Hereford and Angus bulls. Of the Hereford bulls, 9.4% were unsound for breeding compared with 22% for Angus. In Hereford bulls 82% of unsoundness was detected by use of the S.C.T. and the corresponding figure for Hereford bulls was 95% (Blockey, 1984).

The following diagram contrasts the current situation with that which should be possible in future.

**At present** — Buying untested bulls

- 10% poorly fertile
- 40% medium fertile
- 50% highly fertile

moderate herd productivity
cull old bulls or broken-down bulls

**In the future** — Buying tested bulls

many highly fertile and fewer bulls

high herd productivity
bulls tested annually and unsound bulls culled
Breeding Soundness in General

The reasons for classifying bulls as unsound, based on data recorded in N.Z., are shown in Table 2.

**TABLE 2.**
Defects causing breeding unsoundness in 350 Angus and Hereford bulls (80% of the bulls were Angus) detected by the Modified Serving Capacity Test (D.H. Mossman and D. McCall, 1981; unpublished data).

<table>
<thead>
<tr>
<th>Defect</th>
<th>%</th>
<th>Defect</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>No libido (no mounts)</td>
<td>4</td>
<td>Low libido (S.C.T. less than 3)</td>
<td>5</td>
</tr>
<tr>
<td>Total spiral deviation of penis</td>
<td>6</td>
<td>Partial spiral deviation of penis</td>
<td>3</td>
</tr>
<tr>
<td>No penis</td>
<td>1</td>
<td>Arthritis*</td>
<td>1</td>
</tr>
<tr>
<td>Injured penis</td>
<td>3</td>
<td>Small testes</td>
<td>1</td>
</tr>
<tr>
<td>Old age (no libido)</td>
<td>3</td>
<td>Poor condition</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bad feet</td>
<td>4</td>
</tr>
</tbody>
</table>

Total unsoundness 34%

*Probably lbw. Arthritis suspects are now given a full 40 minutes S.C.T. In 1983/84 incidence of arthritis exceeded 6%. N.B. Culling for unsoundness has reduced the incidence of low libido and spiral deviation of the penis.

Unsound bulls can occur in any breed although it appears that certain conditions are more common in some breeds than in others. For example there is a prevalence of penile deviation in mature bulls of polled breeds (about 10%) and arthritis in the hips of large breeds, especially in 4-year-olds and above (6%).

Between 1981 and 1984 many other conditions that lead to unsoundness have been recorded. Abnormalities that directly affect the penis included; penile haematoma, persistent penile frenulum, split penis, scar tissue (with adhesions) from old penile injuries, or no penis at all. Lameness from poor conformation giving rise to bad feet and claw wear also has been a cause of unsoundness. Other defects included small scrotal circumference, epididymitis and, least of all, poor quality semen (0.5%). Culling bulls on the basis of scrotal measurement and palpation has eliminated semen quality as a factor of importance. Often the most aggressive bulls exhibiting high libido are found to be unsound when subjected to a S.C.T.

Bull examination for breeding soundness (B.S.E.) is an integral part of Planned Management Production and should only be carried out by an experienced veterinarian. The technical details are now comprehensively covered in the literature (Blockey, 1984).

This paper serves as an introduction to one of the most powerful tools in beef breeding — the examination for breeding soundness in the bull.

References
DISEASES CAUSING CATTLE ABORTIONS

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Introduction
A practical definition of abortion is 'the death and expulsion of the foetus at any time during pregnancy or the expulsion of a living foetus before it reaches a viable age.'

Causes of abortion will be discussed under the following headings; inherited defects, congenital defects, and infectious agents.

This paper is concerned primarily with the infectious agents as these are the major abortifacients (abortion producing agents). For completeness, examples of the other categories will be mentioned.

Pathogenesis
The physiological pathways leading to abortion differ according to the type of agent. Viral infections such as bovine viral diarrhoea (B.V.D.) and rinderpest cause lymphatic tissue depression and therefore reduce the immunoresponsiveness of the host. Reggiardo and Kaeberle (1981) showed that the pathogenesis of the immunodeficiency caused by B.V.D. involved impaired function of polymorphonuclear cells (a certain type of white blood cell).

The effects of stress, whether psychological, physical, environmental or nutritional in the form of protein-calorie malnutrition, are identified as means of suppressing immunological responsiveness.

Immunosuppression is also caused by; toxins from bracken fern, tetrachloroethylene, irradiation, 2,4,5-T residues, D.D.T., aflatoxins and heavy metals.

Inherited Defects
Genetic defects exert an influence in several ways. Usually it is a structural defect, leading to congenital deformity or premature degeneration. These inherited defects may increase foetal susceptibility to relatively mild pathogens.

Inherited diseases generally are difficult to diagnose and because of this it is important to gain as much information as possible to establish whether the disease is inherited or acquired. The clinical picture and history, cytogenetic markers, specific biochemical reactions and epidemiological data can all contribute.

In bulls, Klinefelter's syndrome, i.e. where more than one X chromosome is present in the somatic cells, leads to foetal deformation, death and absorption.

Inherited goitre is due to a defect in the synthesis of thyroid stimulating hormone (TSH), giving rise to thyroid hyperplasia (goitre).

Congenital Defects
Congenital defects are commonly caused by a teratogenic agent (an agent producing physical defects in the foetus). This may be a chemical, a viral infection, a nutritional deficiency, a toxic product from bacteria, or hypoxia (lowering of oxygen level). Congenital defects may not cause abortion but they can bring about calf death due to the inability to survive after the umbilical cord is severed or causes obstruction during
parturition, with subsequent foetal retention and death.
Examples of the more important teratogenic agents are given below.

(a) Viral teratogens.
The BVD virus can cause cerebellar hypoplasia (defective brain development) in calves, optical defects, brachygnathia (abnormally short lower jaw), abortion, still birth and foetal mummification.

The akabane virus which may cause arthrogryposis (permanent flexure of a joint) and/or hydroencephaly (abnormal fluid within the brain - 'water on the brain').

(b) Toxic agents.
Irradiation with $\beta$ or $\delta$ rays can cause foetal malformations and death.
Nitrate/nitrite poisoning brings about the conversion of haemoglobin to methaemoglobin, thus reducing the oxygen carrying capacity of the blood. Because of the hypoxia the foetus may die and abort. High levels of nitrate are present in mangels, kale regrowth, turnip tops and some rye-grasses, e.g. Tama and Ariki — at certain times of the year (Clarke and Clarke, 1967).

Ergot from the fungus \textit{Claviceps purpurea} acts as a vasoconstrictor (constricts blood vessels) which causes hypoxia followed by foetal death and expulsion.

Abortion due to wilted macrocarpa (\textit{Cupressus macrocarpa}) is a well-recognised clinical entity (MacDonald, 1956). The lesions of cerebral leucomalacia (softening of certain areas of the brain) in the foetus, associated with macrocarpa abortion in cattle, have been described by Mason (1974).

Pine needles also have been incriminated as causes of abortion (Knowles and Dewes, 1980) but the toxic agent has not been identified.

(c) Nutritional deficiencies.
Iodine. Lack of iodine or a high intake of brassica crops containing goitrogenic compounds can cause an enlargement of the thyroid gland — goitre.
Magnesium. Magnesium deficiency leads to limb deformities in calves.
Malnutrition. Simple inanition (lack of any foodstuff or water) or a deficiency of protein can lead to abortion or still birth.
Vitamin A. Vitamin A deficiency has many untoward effects. One of these is impairment of endometrial function which produces infertility or resorption of the foetus as clinical findings. Other effects are blindness and structural deformities occurring in the calves. In N.Z. cattle, vitamin A deficiency is unlikely to be of significance.

Infectious Agents
Infectious agents are by far the most important abortifacients. Most are well-recognised agents and relatively easy to identify. However if specimens of aborted material are of poor quality, laboratories have a
difficult task isolating the causal agent(s).

**TABLE 1.**
Diseases and disease agents causing abortion in N.Z. cattle.

<table>
<thead>
<tr>
<th>Disease</th>
<th>OF MAJOR IMPORTANCE</th>
<th>Stage of gestation</th>
</tr>
</thead>
<tbody>
<tr>
<td>leptospirosis</td>
<td>25 - 30%</td>
<td>after 6 months</td>
</tr>
<tr>
<td>campylobacteriosis (previously called vibriosis)</td>
<td>less than 5%</td>
<td>5 - 6 months</td>
</tr>
<tr>
<td>mycotic abortion</td>
<td>5 - 7%</td>
<td>3 - 7 months</td>
</tr>
</tbody>
</table>

**OF MINOR IMPORTANCE**

- bovine viral diarrhoea (B.V.D.)
- infectious bovine rhinotracheitis/infectious pustular vaginitis (I.B.R./I.P.V.)
- brucellosis
- *Pasteurella multocida*
- sarcocystis
- rotavirus
- severe debilitating disease
- listeriosis
- *Corynebacterium pyogenes*
- salmonellosis
- trichomoniasis

As a result of the brucella eradication scheme, artificial insemination (A.I.) and better hygiene, the previous order of importance has changed. For example, brucella abortions were probably the most important but as at January 1984 there were no recorded infected herds in the South Island and only 78 in the North Island. Leptospiral abortions are now probably the most common of all abortions in N.Z. cattle. Table 1 lists infectious agents isolated in specimens submitted from cases of abortion in N.Z. cattle. Leptospirosis, campylobacteriosis (previously called vibriosis) and mycotic (fungal) abortion are, in my view, the most common of these diseases. Brucellosis, listeriosis and pasteurellosis are more likely to be involved in abortion storms, so when an outbreak of one of these occurs on a farm a large number of pregnant animals may be involved. Nevertheless, as causes of abortions in this country, these diseases are of lesser significance than leptospirosis, campylobacteriosis or the mycoses.

**Leptospirosis.**

Of the *Leptospira interrogans* serotypes, *pomona* and *hardjo* are the two most important as causes of abortion in N.Z. cattle.

Abortions caused by *L. pomona* usually occur in the latter half of pregnancy. The normal host for *L. pomona* is the pig (Blood et al., 1983) but it can affect many animal species. In cattle the disease caused by this agent occurs in three forms; acute, sub acute and chronic. In the acute form icterus (jaundice), a swollen yellowish liver and petechiation (very small haemorrhages) are the principal gross findings. Haemolytic anaemia accounts for the haemoglobinuria (red water) and partially contributes to the icterus and hepatic lesions. The abortion is not
associated with specific lesions in the placenta or foetus, but is due to the systemic responses to hypoxia. In the sub acute form abortion may occur in 3 to 4 weeks post infection and the clinical signs are less severe than in the acute form. The chronic form of the disease is manifested by abortion. Severe abortion storms can occur when animals of the same age are all infected at the same time.

Cattle are the normal hosts for *L. bardjo* (Blood *et al.*, 1983) and it occurs only in pregnant or lactating cows. This is because growth of the organism is restricted to the pregnant uterus and the lactating mammary gland. There is a sudden onset of fever, anorexia, immobility and agalactia (failure to secrete milk). The udder may become flabby but with no heat or pain detectable. Abortion may occur several weeks after infection. Where the disease is endemic only the heifers become newly infected (Hellstrom, 1982) and may abort. Towards the end of 1983 a serological survey was conducted by the N.Z. Ministry of Agriculture and Fisheries (C.J. Boland, pers. comm.) to determine the prevalence of *L. bardjo* in dairy cattle in Canterbury, Otago and Southland. It was found that 61%, 95% and 78% of herds, respectively, were infected according to the criteria used.

**Campylobacteriosis** (previously called vibriosis).

Abortions from campylobacteriosis (*Campylobacter fetus*) are usually of low incidence (up to 5%) but on occasions the incidence may rise to 20% (Blood *et al.*, 1983). Abortions occur in the 5th to 6th month of gestation.

*C. fetus* causes petechiation, localised avascularity (reduction in blood) and oedema (swelling) of the placenta. The infection and its products kill the foetus which is then expelled. This may occur as quickly as two days after infection. The foetal liver has foci of necrosis (death of tissue) a few millimetres in diameter and perivascular cuffing with neutrophils and eosinophils (types of white blood cells).

Campylobacteriosis is most unusual in dairy cattle but occurs more commonly in beef cattle.

**Mycoses.**

In N.Z. two species of fungi are the main causes of mycotic abortion. These are *Aspergillus fumigatus* and *Mortierella wolfii*. The latter fungus is not found in the South Island to my knowledge but occurs in the North Island, mainly in the Waikato area.

When mycotic placentitis occurs, it is usually as a result of feeding cattle mouldy hay. It is considered that the fungal spores are disseminated via the circulation and many of them lodge in the placentomes (attachment points between dam and foetus). Incubation period for this infection is thought to be one to two months. The hyphae grow in the vascularised areas and their growth may eventually lead to hypoxia. Although fungi can be isolated from foetal organs it is unusual for lesions to occur in foetuses.
Specimens Required for a Diagnosis

Diagnosis of abortion in dairy cattle is usually easier than for beef cattle. In both, the dead foetus is rarely expelled from the uterus immediately and thus degeneration of the tissues occurs. The autolysis may affect the causative organism so that when tissue specimens are sent to the laboratories for a diagnosis it can be very difficult to grow the organisms.

The specimens required for diagnostic examination vary a little according to which organism is suspected. Foetal lung and liver samples (formalin-fixed and fresh) and foetal stomach contents are the most useful samples. Placental fluid, fixed and fresh cotyledons and serum from the dam are also desirable.

Conclusion

In summary, it can be seen that leptospirosis is the most common disease diagnosed as a cause of abortion in N.Z. cattle. However, many abortions are undiagnosed and it is important that both the farmer and the veterinarian make certain that the fullest range of specimens is submitted, in the best state of preservation possible, to the Animal Health Laboratories.

The major role of infectious agents in bovine abortions means that careful consideration should be given to control measures and the development of prevention programmes. Both control and prevention will depend on accurate diagnoses being made.

The development of vaccines against the leptospiral serovars has provided an effective tool in the management of this condition. Not only will the use of these vaccines reduce the incidence in cattle but it will also reduce the danger of transmission to humans.

Finally it is essential for the cattle industry that close liaison with the veterinary profession is established by the farmer and maintained for successful elucidation and control of this problem.

References


MINERAL METABOLISM AND REPRODUCTION IN CATTLE

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Introduction
Reproductive problems are complex and may result from poor husbandry, disease and in some cases mineral deficiencies. The potential significance of mineral status in impaired cow fertility requires an understanding and acceptance of the concept that the effects of mineral deficiency may operate through a number of mechanisms.

(a) The first signs of a mineral deficiency are generally non-specific and are manifested sub-clinically in poor growth. Specific signs of deficiency become apparent only when animals are severely deficient. Young animals are particularly sensitive to mineral deficiencies. Such affected animals tend to be mated at the lower range of weight-for-age and remain sub-optimal in weight throughout their lifetime. They may be particularly susceptible to low weight-induced problems during breeding and in early lactation.

(b) Secondly, marginal deficiencies may depress dry matter intake. If this occurs during lactation body weight loss is exacerbated and, as an indirect consequence, re-breeding problems may increase.

(c) Thirdly, biochemical reactions concerned with specific physiological processes in reproduction may be dependent upon specific mineral nutrients and a direct effect of mineral deficiency may occur; for example dopamine β-hydroxylase is a copper-dependent enzyme involved in the synthesis of hypothalamic transmitter substances important in the control of ovulation.

(d) Finally, disease agents could reduce the animal’s ability to absorb its requirement and thus contribute to mineral disorders. These changes are often suspected to occur in gastrointestinal parasitism, because of the ubiquitous nature of nematode parasites and their inevitable association with ill-thrift syndromes in which a mineral deficiency is suspected; but there is surprisingly little incontrovertable evidence that this is, in fact, the case. There is strong evidence for impairment of phosphorus absorption and for low phosphorus status in parasitism of the small intestine in sheep (Sykes, 1983) and for reduction in copper status in cattle infested with the large intestinal parasite *Bunostomum phlebotomum* (Bremner, 1959). The latter species of parasite is not, however, of major importance in N.Z.

The current recommendations, expressed on a dietary basis, for the major and trace mineral requirements of growing and lactating cattle are given in Table 1.
**TABLE 1.**
Minimum dietary mineral concentrations for maintenance of nutrient balance in growing and lactating dairy cattle (after A.R.C., 1980).

<table>
<thead>
<tr>
<th>Element</th>
<th>Growing cattle</th>
<th>Lactating cattle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>200kg; gaining</td>
<td>300kg; gaining</td>
</tr>
<tr>
<td></td>
<td>1.0kg/day</td>
<td>0.8kg/day</td>
</tr>
<tr>
<td></td>
<td>20 — 30 1 milk/day</td>
<td></td>
</tr>
<tr>
<td>calcium (Ca)</td>
<td>4.4 g/kg DM</td>
<td>3.0 g/kg DM</td>
</tr>
<tr>
<td>magnesium (Mg)</td>
<td>1.2 g/kg DM</td>
<td>1.2 g/kg OM</td>
</tr>
<tr>
<td>phosphorus (P)</td>
<td>2.3 g/kg DM</td>
<td>2.3 g/kg OM</td>
</tr>
<tr>
<td>sodium* (Na)</td>
<td>0.6 mg/kg DM</td>
<td>0.5 mg/kg DM</td>
</tr>
<tr>
<td>potassium* (K)</td>
<td>4.4 mg/kg DM</td>
<td>4.4 mg/kg DM</td>
</tr>
<tr>
<td>sulphur (S)</td>
<td>1.8 mg/kg DM</td>
<td>1.8 mg/kg DM</td>
</tr>
<tr>
<td>copper** (Cu)</td>
<td>8 mg/kg DM</td>
<td>8 mg/kg DM</td>
</tr>
<tr>
<td>iron (Fe)</td>
<td>30 mg/kg DM</td>
<td>30 mg/kg DM</td>
</tr>
<tr>
<td>cobalt (Co)</td>
<td>0.08 mg/kg DM</td>
<td>0.08 mg/kg DM</td>
</tr>
<tr>
<td>selenium (Se)</td>
<td>0.03 mg/kg DM</td>
<td>0.03 mg/kg DM</td>
</tr>
<tr>
<td>selenium*** (I)</td>
<td>0.5 mg/kg DM</td>
<td>0.5 mg/kg DM</td>
</tr>
<tr>
<td>zinc* (Zn)</td>
<td>25 mg/kg DM</td>
<td>25 mg/kg DM</td>
</tr>
<tr>
<td>manganese* (Mn)</td>
<td>25 mg/kg DM</td>
<td>25 mg/kg DM</td>
</tr>
</tbody>
</table>

*Limited ability for storage in animal body — see text.
**Coefficient of absorption may change this value markedly — see text.
*** 2mg/kg DM in the presence of goitrogens.

These have been calculated from the daily losses of the nutrient from the body, including milk, or deposition in the body, and knowledge of the fraction of dietary mineral likely to be absorbed. For many trace elements, however, requirement is that concentration found in practical feeding trials to be consistent with normal performance. These are only guidelines as many factors can influence the proportion absorbed (e.g. see Fig. 2). Pastures containing a greater mineral concentration than those given in Table 1 are unlikely, however, to be deficient.

The mineral content of pasture varies according to season, pasture species, soil type and previous fertilizer treatment. A true picture of the pasture mineral status therefore requires direct measurement of the area under investigation perhaps several times a year. Further the animal has body stores of some minerals, e.g. calcium, phosphorus and copper and these can be used without loss of production and mask a deficiency for considerable periods of time. Some minerals such as sodium and zinc, however, cannot be stored and continuous dietary supply is essential.
**TABLE 2.**
Conditions of greatest risk for trace element deficiencies (low Cu, Co, Se and I; high Mo) (from Cornforth, 1982).

<table>
<thead>
<tr>
<th></th>
<th>Cu deficiency</th>
<th>Co deficiency</th>
<th>Se deficiency</th>
<th>I deficiency</th>
<th>High Mo (induced Cu deficiency)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Season</strong></td>
<td>Spring</td>
<td>Spring/summer</td>
<td>Late spring/autumn</td>
<td>Summer</td>
<td>Late winter/spring</td>
</tr>
<tr>
<td><strong>Pasture maturity</strong></td>
<td>Old</td>
<td>Old</td>
<td>—</td>
<td>—</td>
<td>Young</td>
</tr>
<tr>
<td><strong>Pasture growth rate</strong></td>
<td>Rapid</td>
<td>Rapid</td>
<td>—</td>
<td>—</td>
<td>Slow</td>
</tr>
<tr>
<td><strong>Pasture species</strong></td>
<td>Grass dominance, Fescues</td>
<td>Fescues, cocksfoot, Timothy, Phalaris</td>
<td>White clover, paspalum, kikuyu</td>
<td>White clover, Cruciferae</td>
<td>Clover dominance or Yorkshire Fog, cocksfoot</td>
</tr>
<tr>
<td><strong>Soil pH</strong></td>
<td>High</td>
<td>High</td>
<td>—</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td><strong>Soil organic matter</strong></td>
<td>High</td>
<td>High</td>
<td>—</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td><strong>Soil water</strong></td>
<td>Dry</td>
<td>Dry</td>
<td>Wet</td>
<td>—</td>
<td>Wet</td>
</tr>
<tr>
<td><strong>Animal species</strong></td>
<td>Calves</td>
<td>Lambs</td>
<td>Young stock</td>
<td>Newborn lambs</td>
<td>Cattle</td>
</tr>
<tr>
<td><strong>Soil contamination</strong></td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td><strong>Soil types or parent rocks (PR)</strong></td>
<td>Peats, sands, podzols, shallow rendzinas, upland YB earths</td>
<td>—</td>
<td>Taupo and Kaharoa pumice, peats, N podzols, gleys, S.I. YG earths, Manawatu sands, coarse acidic PR</td>
<td>—</td>
<td>S.I. areas, sedimentary PR</td>
</tr>
<tr>
<td><strong>Dietary interactions</strong></td>
<td>High S, Fe and Mo</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Goitrogens</td>
</tr>
</tbody>
</table>
The diagnosis of mineral deficiencies is complex (Clark, 1983) and is discussed by Gumbrell (this publication). It is impossible in a paper such as this to deal in detail with the metabolism of each mineral. For further comprehensive information consult A.R.C. (1980), Underwood (1981) or Grace (1983).

**Calcium (Ca)**

Calcium is predominantly (98%) found in the skeleton. However, ionized Ca in body fluids also has a major role in nerve conduction and muscle contraction and despite the large skeletal stores short-term problems with mobilization of Ca, coupled with low Ca absorption, can lead to nervous disorders. These are seen clinically as milk fever or hypocalcaemia which is associated with a decrease in plasma Ca levels and characterised by restlessness, inappetance, muscle tremors and collapse. While this is usually a problem of the cow just before calving there are numerous cases of hypocalcaemia recorded coincident with oestrous activity (Bach & Messervy, 1969). Such cows are less likely to be detected in heat and will tend to have long calving intervals (CI).

![Figure 1: The mechanism of regulation of calcium absorption from the digestive tract and skeletal reserves to maintain plasma ionic calcium (Ca) concentrations. Dashed lines indicate reactions which diminish and solid lines those which enhance plasma Ca concentration. (PTH is parathyroid hormone.)](image-url)
Calcium metabolism is under strict hormonal control in ruminants as demonstrated in Figure 1. Lowering of Ca in blood plasma through demand, for example, for milk production ordinarily sets in a train a series of events involving parathyroid hormone (PTH) which promote Ca absorption from the intestine and Ca resorption from the skeleton under the action of 1,25 dihydroxy cholecalciferol (1,25(OH)₂D₃), thus restoring plasma Ca content. The counter reaction, to prevent excessive rise of plasma Ca, is the secretion of calcitonin from the thyroid gland; this has the action of promoting the deposition of Ca in bone and inhibiting the production of 1,25(OH)₂D₃. Ostrogens produced by the ovary at oestrus have been shown to interfere with this control and to reduce the ionized Ca content of serum, thus predisposing the animal to hypocalcaemia. This effect is not a disorder of Ca intake since it is caused hormonally. Prophylactic treatment is difficult. Culling is probably the most effective solution because it is likely to occur in the same animal again.

Phosphorus (P)

Given the dependence of pasture production in N.Z. on superphosphate application it would seem unlikely that P deficiency will present major problems for cow fertility, either for adequate growth of young stock or fertility of adult stock. Pasture content is usually between 2.0 and 4.0 g P/kg DM. Comparison with estimates of requirement (Table 1) suggests, however, that in some cases animals might not meet requirements for lactation from pasture and may use their body P reserves, particularly during early lactation. As with Ca large stores of P exist in the skeleton and production penalties do not appear to be incurred if these reserves are utilized; indeed there is evidence that these reserves are used rather well.

Littlejohn and Lewis (1960) offered heifers a diet containing only 1.05 g P/kg DM, less than half that generally recorded on pasture in N.Z., for two months prior to insemination and considerable reduction in blood P concentration was induced compared with animals supplemented to a dietary concentration of 2.1 g P/kg DM. No difference in fertility was observed. Further, Call et al. (1978) fed Hereford heifers a diet containing only 1.4 g P/kg DM for two years and found no effect on growth rate or fertility.

On the other hand Hunter (1977) observed that animals with declining serum P concentrations during the mating period had non-return rates of 46% compared with 80% in herd mates with rising P concentrations. Moreover, Scharp (1979) showed a major response of first service pregnancy rate from 36.5% to 63.2% with supplementary superphosphate in drinking water, in cows with blood P concentrations of about 40 mg P/l. The feeds concerned, however had high P content (3.9 — 5.4 g P/kg DM). Moreover, it was difficult to determine whether the response reflected a true response to P as the super-phosphate used contained considerable quantities of other essential elements including copper.
The relevance of these latter studies to N.Z., situations is difficult to assess since in some cases, pasture analyses were not reported. It would appear, however, that only if herbage P concentrations are below 2 g/kg DM would supplementation trials be worthwhile.

**Magnesium (Mg)**

The symptoms of Mg deficiency — nervousness, pricked ears, head held high and staring eyes, with stiff or stilted gait — are symptomatic of acute disease and the animal usually rapidly passes into convulsions, coma then death or is treated and recovers. However, a chronic form of Mg insufficiency has been found in dairy cows and is characterised by plasma Mg levels below 15 mg/l (normal range 18 — 24 mg/l). These animals are very prone to hypomagnesaemic grass tetany and may respond, in terms of production, to daily Mg supplements (Young and Rys, 1977). While there are no reports which clearly link subclinical hypomagnesaemia with infertility, it seems reasonable that this possibility should be examined more thoroughly. An indirect effect through low intake and body condition, as a result of low Mg status, may operate. The estimates of requirement given in Table 1, when compared with the normal Mg content of pastures in N.Z. (Grace, 1983), suggest that Mg deficiency is unlikely. However, we know little about absorbability of Mg in fresh herbage other than that it is generally rather low, possibly due to interference to Mg absorption by dietary factors such as high concentrations of potassium and possibly from the high protein content of pastures. In some situations the absorbability may be lower than that on which estimates in Table 1 have been based. The estimates of minimum dietary Mg concentration could then be a serious underestimate. Responses to Mg supplementation will provide the best assessment of the Mg status of the cow.

**Sodium (Na)**

Sodium is an important extracellular cation and is involved in maintenance of the osmotic relationships between body cells and extracellular fluids. The animal can not store Na and a continuous, adequate supply is required. Lactation poses a particularly heavy demand for Na which may be exaggerated in those cows with mastitis infections where Na secretion has been suggested to increase 5-fold (Towers and Smith, 1983).

Certain pasture plants, notably lucerne, red clover, timothy and brown-top assimilate Na only poorly compared with rye-grass, prairie grass, white clover and brassicas (Table 3) and therefore the Na concentration in the former may range from 0.1 to 0.4 g Na/kg DM, while that of the latter would be 0.8 to 3.1 g Na/kg DM on the same soil type.
TABLE 3.
Sodium content of pasture and crop plants (from Towers and Smith, 1983).

<table>
<thead>
<tr>
<th>Natrophilic</th>
<th>g Na/kg DM</th>
<th>Natrophobic</th>
<th>g Na/Kg DM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perennial rye grass</td>
<td>3.1</td>
<td>Brown top</td>
<td>1.0</td>
</tr>
<tr>
<td>Cockspoot</td>
<td>3.2</td>
<td>Meadow grass</td>
<td>1.7</td>
</tr>
<tr>
<td>Phalaris</td>
<td>4.4</td>
<td>Tall Fescue</td>
<td>2.4</td>
</tr>
<tr>
<td>Prairie grass</td>
<td>3.4</td>
<td>Timothy</td>
<td>0.3-0.4</td>
</tr>
<tr>
<td>Yorkshire fog</td>
<td>1.4-4.0</td>
<td>Kikuyu</td>
<td>0.4-0.5</td>
</tr>
<tr>
<td>Yorkshire fog</td>
<td>1.4-4.0</td>
<td>Paspalum</td>
<td>0.4-0.6</td>
</tr>
<tr>
<td>Lotus</td>
<td>3.2</td>
<td>Lucerne</td>
<td>0.1-0.5</td>
</tr>
<tr>
<td>White clover</td>
<td>3.3</td>
<td>Red clover</td>
<td>0.4</td>
</tr>
<tr>
<td>Subterranean clover</td>
<td>3.5</td>
<td>Lupin</td>
<td>0.3</td>
</tr>
<tr>
<td>Choumoellier</td>
<td>4.1</td>
<td>Maize</td>
<td>0.1</td>
</tr>
<tr>
<td>Kale</td>
<td>3.7</td>
<td>Sudax</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Other conditions predisposing to low herbage Na content, other than plant species, include free draining soils derived from pumice material. Silage making is a process notorious for Na losses which exaggerate deficiency in plant material; lucerne silage being particularly low in Na.

The requirement for the lactating dairy cow is considered to be about 1.2 g Na/kg DM and for growing stock 0.5 g Na/kg DM. Sodium supplementation would seem inevitable where stock have sole access to the natrophobic group of herbages. A specific requirement for Na for reproduction does not appear to have been established but indirect effects may be expected through reduced feed intake and body condition.

**Sulphur (S)**

It is unlikely that, where soil deficiency of sulphur for optimum herbage growth has been corrected, a deficiency of sulphur in livestock will exist.

**Copper (Cu)**

Copper metabolism in ruminants is a complicated topic. The estimate of requirement in Table 1 is based on an assumption that about 4% of dietary Cu is absorbed. We know, however, from studies of Suttle and McLaughlin (1976) with semi-purified diets, that molybdenum (Mo) and sulphur interfere with absorbability of Cu by forming insoluble copper-thiomolydate complexes in the rumen, thus reducing Cu availability. The general relationships between these three minerals and their effect on absorbability of Cu are given in Figure 2. These serve only as a guide. Caution should be exercised in extrapolating these data to herbages because there is evidence that the estimates may be in error by a factor of 2 when applied to fresh or conserved herbages (Suttle, 1980). The Cu requirements for cattle are generally higher than for sheep (A.R.C., 1980).
The evidence for involvement of Cu in problems of infertility is conflicting. Those studies in which response to Cu therapy has been observed have generally been uncontrolled clinical trials (Munro, 1957; Pickering, 1975; Hunter, 1977) and Cu status of animals has been poorly defined. Increases from 40% to 75% in conception rate have been reported after supplementation. In the absence of control animals and further information on actual Cu status such data must be viewed with caution, since in some studies at least, the response to supplementation in herds diagnosed as being deficient was only seen in 50% of herds treated.

Much greater reliance can be placed on controlled trials such as those of Phillippo et al. (1982a). In this study fertility in 17 beef herds was related to herd Cu status based on serum Cu levels within a month of the bull being put out. The results are given in Figure 3 and show that over a wide range of herd mean serum Cu concentration there was no effect on percentage of cows calving within 28 days. It should be noted that a

Figure 2: Effect of changing dietary molybdenum (Mo) and sulphur levels on the absorption of copper (Cu). (From A.R.C., 1980; by permission of Commonwealth Agricultural Bureaux.)
Figure 3: Relationship between mean serum copper (Cu) level and distribution of calving in beef herds. (After Phillippo et al., 1982a; by permission of Cambridge University Press.)

Cu concentration of 0.5 mg/l is generally considered to be the lower limit of the range of normality.

A further study involved supplementation of cattle on four farms selected on the basis of a mean herd serum Cu concentration of less than 0.3 mg/l. Herbage Cu status was low (4.7 — 5.8 mg Cu/kg DM) and herbage contained molybdenum and sulphur at levels (1 — 3 mg Mo/kg DM; 1 — 3 g S/kg DM) which would interfere with absorbability of Cu (Fig. 2). Half of the cows were supplemented with a single injection of 100 mg Cu one month prior to the introduction of the bull. The results are shown in Fig. 4 and demonstrate that despite low fertility and initially very low serum Cu, elevation of serum Cu levels, in some cases into the normal range, had no effect on fertility. These data suggest that Cu requirement for reproduction is lower than for growth.
Figure 4: Effect of copper (Cu) supplementation one month prior to introduction of the bull on serum Cu concentration and fertility in four beef herds. (After Phillippo et al., 1982a; by permission of Cambridge University Press.)

Figure 5: Effect of reduction in copper (Cu) status by iron (Fe) and molybdenum (Mo) loading of a diet containing 4 mg Cu/kg DM and 28 g sulphur/kg DM on cow fertility (n = 4 per group). (After Phillippo et al., 1982b; by permission of Cambridge University Press.)
On the other hand Phillippo et al. (1982b) demonstrated normal pregnancy rates in cattle with low Cu status (0.23 mg Cu/l serum) induced by high intakes of iron as many occur, for example, with high soil intake. In contrast, however, very low pregnancy rates were observed in cattle with low Cu status (0.16 mg Cu/l serum) induced by dietary molybdenum excess (Fig. 5). This raises the question as to whether poor fertility associated with low Cu status is, in fact, due to low Cu status per se or to molybdenum excess. This may offer one explanation for the marked variation in response to Cu therapy which has been widely observed. Many copper deficiency problems in N.Z. are associated with high pasture molybdenum levels (molybdenosis). Mention should be made of a post-parturient haemoglobinuria which has been recorded in association with molybdenum-induced low copper status in Northland (Smith and Coup, 1973). The symptoms include post-parturient anaemia, haemoglobinuria, and absence of or weak signs of oestrus.

**Selenium (Se)**

Selenium and vitamin E (tocopherol) are associated because the vitamin and a Se containing enzyme, glutathione peroxidase, appear to be involved together in the maintenance of cell membranes; operating as antioxidants. Their involvement in a condition involving rapid degeneration and retention of placentae with subsequent re-breeding problems, has been demonstrated in cows calving during winter in U.K. by Trinder et al. (1969; 1973). Supplements of Se, while effective appeared to be not quite as effective as Se plus vitamin E. The problem, interestingly, did not occur during summer. The cows were housed in winter and the difference in incidence was attributed to the normally high pasture content of vitamin E, perhaps having some sparing effect on requirement for Se during summer. In N.Z., where exclusive use of pasture is made, it would appear that simple Se deficiency might exist in cattle as Se related reproductive problems have been well documented in sheep (Hartley, 1963).

The data of Trinder et al. (1973) suggest that situations where blood Se levels below 0.08 mg/l and herbage Se levels of less than 0.06 mg/kg DM occur would be worthy of close examination for response to Se supplementation, particularly where cows in a herd are observed to retain placentae. In sheep, however, growth responses to Se supplements are not usually observed on pastures containing more than 0.03 mg Se/kg DM. Moreover, retained placentae do not appear to be a problem in dairy cattle in N.Z. even in animals with very low Se status (R.G. Clark, pers. comm.). In the same animals significant responses in milk production were not found in cows with blood Se levels below 0.007 mg/l (Ryan et al., 1984).

**Cobalt (Co)**

A Co deficiency in ruminants is really a vitamin B12 deficiency: in the presence of Co vitamin B12 is synthesised by rumen micro-organisms. A
lack of dietary Co inhibits vitamin B12 synthesis. In deficiency states the ability of the animal to utilize propionate is impaired and intermediary products are excreted in urine. As a consequence appetite declines. Effects of Co deficiency on fertility are therefore likely to operate through excessive general bodyweight loss rather than through a specific effect of deficiency. Deficiency of Co can be expected where herbage Co is below 0.9 mg/kg DM and where liver reserves of vitamin B12 fall below 0.10 g/g fresh weight or 0.05 mg Co/kg DM. A continuous dietary supply of Co is preferable to intermittent enhancement by drenching to ensure continuous absorption of vitamin B12.

Iodine (I)

Iodine is required for synthesis of the thyroid hormones, tetra- and tri-iodo thyronine. These are transported throughout the body where they are active in controlling energy and protein metabolism of cells. Three types of deficiency occur; simple uncomplicated deficiency due to low dietary I intake, thiocyanate-induced deficiency in which impaired uptake of I by the thyroid gland occurs, and thiouracil-induced deficiency in which thyroid hormone metabolism is impaired. Thiocyanate-induced I deficiency can be a problem in stock consuming brassica crops, but can be overcome by I supplementtion.

While there is one report of reduction of number of services per conception and minor increase in milk fat production on I supplementation of dairy cattle in N.Z. (McGowan, 1983), the subject needs more thorough research before we could classify I deficiency as a likely problem in dairy cattle. It is generally considered that I deficiency is unlikely if herbage levels exceed 0.5 mg/kg DM when goitrogens are not present. In the presence of goitrogens such as the thiocyanates dietary I levels should be increased to 2 mg/kg DM.

Manganese (Mn)

Manganese, which is a co-factor for many enzyme systems, and is concerned with energy and protein metabolism, has been associated with infertility in cattle. Munro (1966) and Rojas et al. (1965) demonstrated poor conception rates when the dietary Mn concentration was below 20 mg/kg DM. It has generally been a problem on light sandy soils with a high pH enhanced by liming. Data currently available for N.Z. pastures suggest that Mn deficiency is unlikely (Metson et al., 1979).

Zinc (Zn)

Zinc is essential for several enzymes involved in carbohydrate metabolism and protein synthesis. There are insignificant stores of Zn in the body and the animal relies on a continuous adequate intake. Zn deficiency has a primary effect on feed intake in growing animals, and there is some evidence (Somers and Underwood, 1969) that this is consequent on impaired protein metabolism. In calves open wounds of the
skin around the eye, hoof and scrotum and bowing of hind limbs and stiffness of the joints are typical symptoms of severe deficiency. In sheep failure of normal development of male sexual organs (Underwood and Somers, 1969) and reduced reproductive rate (Egan, 1972) are established symptoms of chronic moderate deficiency. There are however, no reports of similar reproductive problems in cattle.

The dietary requirement for Zn probably lies in the range between 20 and 30 mg/kg DM, and most pastures in N.Z. contain in excess of this concentration. Some pastures, however, notably on pakihi soils on the West Coast of the South Island and others grown on soils in Southland have had values below 20 mg Zn/kg DM and their adequacy for dairy cattle should be investigated.

**General**

Examination of data from M.A.F Animal Health Laboratory Diagnostic Services during the 5 year period covering 1979 to 1983 shows that of cattle (dairy and beef) blood samples submitted for mineral analysis, 80% of those found to be 'abnormally low' were for Cu and Se. In the north of the North Island 60% and 20% of abnormal values were for Cu and Se respectively, while in the South Island the distribution was 38% Cu and 48% Se. Magnesium was the next most frequently 'deficient' element, representing about 13% of abnormal samples. Individual case histories can not be examined for subsequent response to treatment. Moreover, one must assume that the most appropriate analyses were always requested. Notwithstanding this, the data do perhaps indicate where greatest attention to assessment of status should be directed.

**References**


THE DIAGNOSIS OF MINERAL DEFICIENCIES AND METHODS OF THERAPY

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Introduction

If a deficiency of a mineral such as copper, phosphorus, iodine or selenium is suspected to be causing infertility it is necessary to confirm this before treatment is instituted. Not only does this prevent unnecessary use of minerals and possible poisoning, but also if mineral deficiencies are eliminated other possible causes of the infertility can be investigated.

It also may be necessary to assess the mineral status of a herd to demonstrate that there are no deficiencies present. There is no evidence that minerals given to cattle with a normal mineral status will artificially stimulate their reproductive rate.

If the levels of one or more minerals are below normal they should be supplemented by suitable material in controlled amounts so as to provide adequate mineral intake without risk of toxicity. Methods and amounts vary with the mineral being supplemented, the degree of deficiency and the situation where the deficiency arises.

Diagnostic tests are laboratory analyses of tissue samples and/or production response trials. In the latter a representative sample of animals is supplemented with the mineral being tested. The response to the treatment is carefully measured and compared with the control group. This is the most definitive test (Underwood, 1981).

Determination of the mineral status of a herd with an infertility problem is only part of the total investigation. It needs to be done in association with investigations into other causes of infertility such as nutritional status, mating management and infectious disease.

Diagnosis of Mineral Deficiencies

Clark (1983) breaks the diagnosis of mineral deficiencies into three stages.

(a) Defining or describing the problem.

This involves a careful, accurate and complete definition of the degree and extent of the problem and its background. Information is required on:
— the type and severity of the problem, e.g. anoestrus, irregular returns to service,
— number and type of animals affected (age, sex, breed)
— other disease conditions and-or symptoms present, e.g. diarrhoea,
— expected performance (previous performance, district and national performance),
— soil type,
— pasture type and production,
— climate, and
— management practices, e.g. topdressing programme, pasture irrigation, mating management.

(b) Defining the likely cause(s) of the problem.

Possible causes are listed and examined, taking into consideration the information obtained in (a).

(c) Selection of appropriate tests to diagnose the cause.

In the case of minerals this involves analysis of submitted materials for
particular substances. The mineral status of a ruminant is a reflection of the mineral status of the soil and the availability of the mineral to the animal. However the concentration of a mineral in the soil is an uncertain indicator of its concentration in herbage (Underwood, 1981). Soil mineral levels may nevertheless give some indication as to what deficiencies may occur (Towers and Clark, 1983).

Herbage analysis is useful for determining interactions between minerals, e.g. copper-molybdenum-sulphur, and for monitoring the effectiveness of topdressing (Towers and Clark, 1983). It is of limited value in assessing the mineral status of an animal because the effective mineral uptake by grazing cattle varies with:
— pasture intake,
— mineral concentration in the herbage,
— herbage mineral availability, and
— soil contamination of the herbage.

Analysis of tissue gives the best measure of the mineral status of an animal. The tissue selected for analysis will depend on the reasons for the analysis (Clark, 1983). These will include the following.
(a) Problem investigation. To diagnose the cause of poor production select a sample that reflects mineral content where it functions, e.g. plasma for copper.
(b) Disease prevention. To determine if supplementation is necessary to prevent a deficiency occurring select the tissue where the mineral is stored, e.g. liver for copper.

The time of sampling depends on when the problem occurs and the reason for the investigation. If the problem is one of infertility then sampling as close as possible to the time that the problem occurs is necessary. With infertility problems this will probably be in the spring.

If the sampling is carried out to determine whether or not mineral supplementation is necessary to prevent a problem, it should be done before the problem period. As mentioned above the tissue sampled should indicate the reserves of the mineral. Tests to indicate intake also may be relevant.

Concurrent disease may affect some tests, e.g. liver damage may affect serum ferroxidase levels for copper analysis. Also haemolysis of blood may affect some serum levels. These can be prevented by sampling animals showing no disease other than that being investigated and by protecting blood samples from the sun and decanting the serum as soon as possible.

The numbers of samples to take depends on the mineral being analysed because different minerals show different degrees of variation of level between animals. This is caused by biological variation and variation in intake associated with selective grazing and soil ingestion. Ellison (1982) has used these variations to calculate the numbers of samples needed (see Table 1). The samples should be selected from the group (e.g. age group) of animals suspected of being deficient. Animals to be sampled should be selected at random from within this group (Clark, 1983).
**TABLE 1.**

Diagnosis of mineral deficiencies affecting fertility.

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Does a deficiency affect reproduction?</th>
<th>Samples required for diagnosis</th>
<th>Number of samples</th>
<th>adequacy</th>
<th>Reference range deficient if below</th>
<th>units</th>
</tr>
</thead>
<tbody>
<tr>
<td>copper (Cu)*</td>
<td>yes</td>
<td>serum, liver</td>
<td>7</td>
<td>8</td>
<td>&gt;45 f.tmol/l</td>
<td>μmol/1</td>
</tr>
<tr>
<td>iodine (I)</td>
<td>yes</td>
<td>history of thyroid gland</td>
<td>4-16</td>
<td>&gt;45</td>
<td>45 f.tmol/kg</td>
<td>μmol/kg</td>
</tr>
<tr>
<td>phosphorus (P)</td>
<td>yes</td>
<td>serum (unhaemolysed), bone (ash)</td>
<td>6</td>
<td>1.5</td>
<td>currently no reference range available</td>
<td>μmol/1</td>
</tr>
<tr>
<td>selenium (Se)</td>
<td>currently not confirmed in N.Z.</td>
<td>blood, liver</td>
<td>3</td>
<td>250</td>
<td>130 nmol/l</td>
<td>nmol/1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>450</td>
<td>250 nmol/kg</td>
<td>nmol/kg</td>
</tr>
</tbody>
</table>

*high dietary molybdenum and/or sulphur levels may induce copper deficiency.*
Sophisticated and expensive equipment is necessary for analysis of the small amounts of minerals present in body and blood. Analysis of animal tissue is done mainly by the Animal Health Laboratories of the N.Z. Ministry of Agriculture and Fisheries (M.A.F.) at no charge. Some private laboratories also offer these tests.

Details of the type of specimens required for analysis and the number of animals to be sampled for each of the elements; copper, iodine, phosphorus and selenium are given in Table 1.

The reference ranges quoted in Table 1 have been established from published data and from M.A.F. experimental and investigative work. This work is ongoing, thus the values may change. Veterinarians are kept informed of such changes.

Also the reference ranges quoted here are specific for the M.A.F. animal health laboratory service. If other analytical services are used reference ranges relevant to their methods should be used.

Ideally the results of tissue analyses should be reliably related to a measured response following treatment. Unfortunately with bovine fertility the degrees of response to some minerals at certain tissue levels are not well defined. Where this information is not known or results are equivocal, a production response trial is indicated (Towers et al., 1983). In the simplest form this means that:
- a group of animals is divided into treated and control groups on a random basis,
- the criteria used to compare the two groups, e.g. calving to first oestrus interval, are set,
- one group is given the mineral being tested, and
- the response of the treated group is compared against that of the control group.

While such trials provide valuable information it is very important to ensure that;
- the objectives of the trial are carefully defined,
- the trial is properly planned,
- the allocation of animals to groups is done randomly,
- treatments are given carefully,
- responses are accurately recorded, and
- the data generated are analysed statistically.

A variation of the simple trial, a multifactorial trial, can be used providing sufficient numbers of stock are available. The planning of these trials is intricate and the analysis of the data is more complex.

As seasonal variations in mineral availability may occur, analytical tests and/or dose-response trials may need to be repeated in different seasons. Changes in farm management such as the introduction of irrigation or the use of molybdenized superphosphate also may change the mineral status of animals, necessitating retesting.

**Treatment and Prevention**

Treatment of a deficiency necessitates the prompt administration of a rapidly acting form of the mineral to the affected animal. It is preferable
that the formulation will provide a source of mineral for several weeks. The metabolism of the element involved will determine the most effective method. While treatment of individual animals is labour intensive it will produce the best results.

Injectable organic complexes of copper and iodine provide a convenient and long acting method of supplementing these elements. This method obviates the need for regular dosing with copper or iodine salts.

Forms of minerals for oral use such as drenching are the cheapest but usually require repeated administration. Many are suitable for mixing with other animal remedies, e.g. anthelmintics, and given as drenches. Other methods such as including the element in salt licks are not sufficiently reliable. Cunningham (1949) showed that grazing sheep dosed with mineral to overcome deficiencies in the pastures ate as much mineralized lick as similar undosed animals. An animal's appetite for a mineral is not a reliable measure of its needs.

Indirect methods of mineral supplementation such as adding copper sulphate to fertiliser are applicable to many situations. The method is usually very economical and supplies adequate supplemental element. However some doubts as to its effectiveness for copper have been expressed (Farquharson, 1983) and continual monitoring may be advisable if it is used. Advice should be sought before utilising this method of deficiency correction.

Methods of mineral supplementation used are given in Table 2. The prices of the various treatments have not been included as they may vary considerably.

Recently the use of copper oxide needles which are given by mouth and lodge in the abomasum has been reported as being an effective methods of controlling copper deficiency (Underwood, 1981). However these are not currently available in N.Z.

It is important that the amounts of minerals prescribed for treating and/or preventing deficiencies are not exceeded. Each year instances of production loss and death in farm animals in N.Z. occur from overzealous use of minerals.

**Conclusion**

The diagnosis, treatment and prevention of mineral deficiencies in any situation is a task for professional investigators such as veterinarians. They may work in association with Animal Health Laboratories, scientists and other farm consultants, particularly where fertiliser programmes and economic planning are necessary.

It is important to be aware of the role of minerals in all forms of animal production. It is equally important to be aware that little is to be gained from the haphazard institution of patent mineral remedies at any time, let alone when problems of disease and production become apparent.

The aspects of mineral deficiency diagnosis and therapy discussed here are those known today. It is likely that our knowledge on both the range of minerals involved as well as diagnosis and therapy will change over the years. Veterinarians and farm consultants working in cattle production should be sure that they are conversant with new information as it becomes available.
**TABLE 2.**
Treatment and prevention of mineral deficiencies causing infertility in cattle.

<table>
<thead>
<tr>
<th>Mineral</th>
<th>TREATMENT</th>
<th>PREVENTION</th>
<th>Pasture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Oral</td>
<td>Injectable</td>
<td>Animal Oral</td>
</tr>
<tr>
<td>copper (Cu)</td>
<td>copper sulphate</td>
<td>120 mg copper*</td>
<td>see treatment every week</td>
</tr>
<tr>
<td>iodine (I)</td>
<td></td>
<td>4 ml iodised oil*</td>
<td>see treatment every 2 years</td>
</tr>
<tr>
<td>phosphorus (P)</td>
<td>sodium or calcium</td>
<td>see treatment</td>
<td>phosphorus phosphate salt to give 20—30 g P daily (e.g. 1 kg bone meal per week)</td>
</tr>
<tr>
<td>selenium (Se)</td>
<td>40 mg*</td>
<td>40 mg* (give 20 days pre partum to reduce the incidence of retained foetal membranes)</td>
<td>see treatment every 2 months</td>
</tr>
</tbody>
</table>

*follow manufacturers' instructions
IMPROVED REPRODUCTIVE PERFORMANCE
SUMMARY OF THIS SECTION

Management of the herd.

In commercial and stud beef herds there is considerable scope for improving reproductive performance. The prime objective for reproductive management is to get as many cows in calf as possible within a short time span.

Mating (or calving) should not last more than 45 days for heifers or 63 days for cows. Management tools which are essential for achieving these objectives include the production of calving pattern histograms so that a visible record of herd performance can be established. Another factor is nutrition which is monitored by weighing animals throughout the mating period. In addition to this is the need to score body condition so that females in the herd are kept within a target score range.

Pregnancy testing must be carried out; ideally at 90 days from the start of mating for heifers and 105 days in the case of cows.

Breeding soundness of bulls is another critical element in the management programme. Important measures of a bull are his score in a serving capacity test and his scrotal circumference.

Emphasis must be placed on managing heifers so that they achieve a target weight (critical mating weight) by the time of their first mating.

Achievement of these objectives will result in one calf per cow per year with good weaning weights, a far better utilisation of pasture, and eased feed management.

Mating of 'yearlings'.

The third paper in this section describes the results of work at beef research stations in N.Z. which has examined the feasibility of mating heifers at 14—15 months of age, i.e. 'yearling' mating. These studies have achieved 65 to 70 calves weaned per 100 heifers mated. Comparisons of the performance of these heifers with those not mated until 2 years old have shown no differences in weaning percentages as 4-year-old or older cows, or in longevity.

In addition the heifers mated as 'yearlings' did not experience any greater incidence of calving difficulty than 2-year-old mated heifers. The results from cross-bred cattle are even more encouraging. Nevertheless to achieve acceptable lifetime performance the lightest heifer has to have a mating weight of 215 kg. To reach this target the average live weight of a mob of heifers needs to be 250 kg for Angus, 260 kg for Hereford, and higher for cross-breeds.

At present about one quarter of beef heifers in N.Z. are mated as 'yearlings' so there is scope for more widespread mating of heifers at this age.
MANAGEMENT OF BEEF COWS FOR OPTIMUM REPRODUCTION

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Introduction

Reproductive management includes understanding the contribution and management of first the growing replacement females (heifers,) secondly the mixed age cows, and thirdly the bulls. The objective for any beef reproducing unit is to achieve the greatest number of cows in calf, over as short a period of time as possible. Not enough attention is paid to this important management objective. To a great degree genetic selection and recording systems have tended to overshadow this prime objective, however, the systems are compatible and should be used together.

Just as in genetic selection, so it is in breeding management that clear definitions are essential for the step-by-step programme of evaluating breeding management success. Records must be kept and evaluated.

Definitions

Calving pattern.

Calving pattern is the number of cows which calve in each elected period from the planned start of calving (or calved before this date). This elected period can be daily, weekly or 3-weekly, or multiples thereof depending on the span or spread.

The calving pattern can be divided into: heifer, cow, combined, or sire calving pattern (individual sires for checking serving capacity).

Calving spread (or span).

Calving spread is the period over which calving occurs. Calving pattern and span are independent in their effect on economic analysis — at no stage does reduction in span by withdrawing the bull produce a more concentrated pattern. Farmers who withdraw bulls, without data on calving patterns, are likely to get 50% less cows in calf.

Histogram of calving.

A histogram of calving is a frequency bar graph representing the frequency of the pattern of calving over 21 day periods. This is done by expressing the number of calves born as a percentage of the total cows due to calve each 21 days from the planned start of calving.

Planned start of calving (PS).

For analysis purposes PS is the date 282 days after the bulls are introduced at the commencement of mating. Earlier born calves are included as if they had been born on day one of the planned start.

Median calving date.

Median calving date is the point at which 50% of (1) heifers, (2) cows or (3) the herd have calved. Do not confuse with the mean calving date.

Mean calving date.

Mean calving date is the average calving date of the herd.

Conception rate (CR).

CR is the chance of a cow getting in calf when it is cycling (oestrus); usually expressed as a percentage.

Service Rate.

Service rate is the average number of cycles a cow needs to get in calf; e.g. at a 60% conception rate it requires 1.64 cycles to get an average cow in calf.
Submission rate (SR).
Submission rate is the number of cows presented which are cycling expressed as a percentage of a group of cows over a specific period of time. In beef cattle 21 days is the preferred period.

In calf rate.
In calf rate is a combination of submission and conception rate in the female. It is a measure of 'breeding management success'. It is a combination of all the hereditable and management factors in reproduction.

Critical mating weight (C.M.W.).
C.M.W. is the average weight of a group of heifers at the start of mating which will achieve an 84% in calf rate over 45 days, irrespective of the age at first mating. It should be analysed in an on-farm situation.

Heifers are weighed on day one of mating, on day 45, and again on day 90. Pregnancy testing is carried out on day 90. Those in calf between days 1 and 45 are identified at day 90 and those in calf from day 45 to day 90 are identified by pregnancy testing on day 135. Tag numbers, individual heifer weights and in calf status are recorded.

Calculation can give approximate weights required to achieve 84% in calf rate. From the values of weights and in calf rates, a graph similar to that shown in Figure 1 is drawn.

Two extremely important points to note about the body weight of heifers are the following. First, the sudden increase in in-calf rate between 240 kg and 280 kg, i.e. 40% in 45 days vs 84% in 45 days. Secondly, the possible fall off in in-calf rate at weights in excess of 360 kg. This can occur in 2+ year-old first mating. Using high serving capacity bulls, the C.M.W. is lower (Blockey, 1984).
TABLE 1.
Critical mating weights (C.M.W.) in kg for beef cows at different conception rates (CR).

<table>
<thead>
<tr>
<th>Breed</th>
<th>60% CR</th>
<th>70% CR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hereford</td>
<td>280</td>
<td>270</td>
</tr>
<tr>
<td>Angus</td>
<td>275</td>
<td>256</td>
</tr>
</tbody>
</table>

Concentrated Calving

The objective of all good management systems is to have heifers and cows calving in a 45 day period with a specific pattern, and which results in one calf per cow per year, an even line of bull and heifer calves, greater average weaning weights, and improved feed management. If on top of this you have a good genetic selection programme — you will make substantial gains. Let us now use all these definitions in a simple model to illustrate the points of management.

If you take 100 well grown heifers at C.M.W. and mate them to serving capacity tested bulls, then a 60% CR, a 100% SR at the start of mating and an oestrous cycle length of 21 days, will produce the situation given in Table 2.

TABLE 2.
Conception pattern for 100 heifers at the critical mating weight (C.M.W.).

<table>
<thead>
<tr>
<th>Days</th>
<th>Number submitted for mating</th>
<th>In calf rate</th>
<th>Carrying over to the next cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>100</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>42</td>
<td>40</td>
<td>24</td>
<td>16</td>
</tr>
<tr>
<td>63</td>
<td>16</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>84</td>
<td>6</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>105</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Totals</td>
<td>164</td>
<td>100</td>
<td>64</td>
</tr>
</tbody>
</table>

This will result in the calving pattern shown in Figure 2 (A). The date at which 50% of the heifers have calved is 17 days (arrowed). That is, in
21 days 60% have calved, so at 3 calves per day the median calving date is 17. In practice CRs can be higher. Herds on management schemes in our area have median calving dates of 14 days. By the 14th day from the planned start of calving 50% of the group of animals have calved.

Thus you establish an acceptable normal pattern of calving: a 'normal' histogram. How many of you approach this pattern in your herds? If you are not, you should be. By pregnancy testing (at 6 weeks after 45 day mating) changes in the calving pattern will occur, depending on how many dry heifers are culled.

Analysis of heifer calving patterns can reveal shortcomings in management technique. For example a histogram such as in Figure 2 (B) (median calving date arrowed). Would mean that you have not reached the C.M.W. for your heifers at the start of mating — you have mated 21 days too early, or 21 days at 1 kg per day body weight gain too light!

Let us look further at the normal histogram of calving and at how important it is to concentrate calving. As 84% are in calf over 45 days — it takes theoretically another 63 days to get the last 16% in calf. This is unacceptable for two good reasons. One, you cannot manage a herd with a wide span of calving and two, if a cow herd has a calving spread of 90 days or greater then the calves will have widely differing body weights. The average difference in weight at 15 months between those calves born between days 0 and 45 versus those born between 45 and 90 days will be 45 days times the weight gain during the growing period. This average difference can be as much as 40 kg, due to spread of birth dates. From Figure 1 (on C.M.W.) it can be seen that 280 kg gets 84% in calf, 240 kg gets about 40% in calf. Similar reasoning can be applied to calves with long calving spans when they themselves start breeding. Thus the system reproduces itself with widely differing body weights at
the start of mating 15 months after calving. In turn this has a direct effect on the in calf rate since correction factors for birth date do not overcome management facts.

If 2-year-old mating is practised, then the heifers may be too heavy and fat to achieve a successful in calf rate, there is less management control. This is referred to later under Condition Scoring.

No beef cow herd in N.Z. should mate or calve for more than 45 days in heifers — and using the same principle, no more than 63 days in cows (preferably 45 days). By appropriate planning of management, it is possible to correct many failings.

Mixed age cows.

Calving pattern analysis of the cows can pinpoint areas for improvement of management. As a guide for optimal calving patterns, commence mating 282 days from 17 days before the median calving date of the previous year's histograms of calving. This principle is extremely important in the design of artificial insemination (A.I.) programmes. Many A.I. programmes are commenced to early. Even though cows may be exhibiting oestrus, the conception rate is low due to mating at the first oestrus after calving. Often A.I. is completed with a 25% to 40% in calf rate, yet the follow up bull settles the balance at what appears to be a higher conception rate. All this means is that you have selected the wrong time for A.I. You have made the wrong management decision. This also highlights the value of using histograms to determine the optimal mating times. The difference between the median calving date of heifers versus that of second calvers should be the interval between heifer and cow mating. This also corrects for environmental influences so that a more even line of offspring can be obtained.

A method of monitoring the herd progress is to draw a histogram of the calving pattern of each mob of mated cows and the herd as a whole. Initially this can be compared with the target calving pattern. The performance in subsequent years can be compared with that of previous years to monitor progress achieved. It also may indicate bull failure, although bulls should always be tested. From the model, the target pattern is as in Figure 2 (C). A pattern like that in Figure 2 (D) is totally unacceptable but this pattern is typical of many commercial and stud herds.

With concentrated calving and better nutrition, smaller areas of easy contour can be selected for calving paddocks which will all help to increase the calving percentage.

In the case shown in Figure 2 (E), the average difference of actual recorded weaning weight of calves born during each 21 day period is in fact 21 days multiplied by the weight gain (say 1 kg) per day. If Calf (1) weighs 300 kg, then Calf (2) weighs 280 kg, Calf (3) weighs 260 kg, Calf (4) weighs 20 kg, and Calf (5) weighs 20 kg. These are actual weights not corrected weights.

Would it not be much more advantageous to have a target calving pattern such as in Figure 2 (F)? These calves 1, 2 and 3 weigh 300 kg and
calves 4 and 5 weigh 280 kg. The first pattern (E in Fig. 2) is more common than the second (F in Fig. 2).

If you condense all the recorded information on calving dates in bull sale catalogues, you can easily see who has approached achieving the correct management system; possibly those stud farms with the highest serving capacity bulls.

Again, look at the relationship between 2 female calves born 80 days apart and the mating weight. A 40 kg difference in weight, say between 240 and 280 kg, means a 40% difference in the in calf rate over 45 days. You can appreciate how a spread calving can affect dramatically the reproductive rate of a herd. If all the heritable factors outlined earlier can be included into in calf rate — I know which breeder I would be buying bulls off for commercial use.

**Condition Scoring**

Management for successful concentration of calving patterns involves condition scoring of cows. Some cows are too fat, although most farmers have them too thin.

A scale of 0 — 5 to estimate fat cover over the loins and tail (Fig. 3) provides a simple and practical system to monitor changes in condition (Graham, 1982).

![Fat cover](image)

*Figure 3: Sites and technique for condition scoring of beef cattle.*

Each unit change in condition score represents approximately 70 kg liveweight for a 500 kg liveweight cow, i.e. 500 kg at condition score 3.

**Scoring system.**

1 — Individual short ribs (at loin) are sharp to touch and no tail head fat can be felt.
2 — Individual ribs can be felt but are rounded rather than sharp.
3 — Short ribs can be felt only with firm pressure. Areas either side of tail head have some easily felt fat cover.
4 — Short ribs cannot be felt and fat cover around tail is easily seen as slight mounds. Folds of fat beginning to develop over ribs and thighs of animal.

5 — Bone structure of animal is no longer noticeable and tail heat fat is almost completely buried in fat tissue. Folds of fat are apparent over ribs and thigh.

From research data and experience, target condition scoring ranges have been developed for cows (Fig. 4) and heifers (Fig. 5).

![Figure 4](image)

*Figure 4: Target condition score ranges throughout the reproductive year for cows.*

![Figure 5](image)

*Figure 5: Target condition score ranges throughout the reproductive year for heifers.*
The herd should be managed so that females remain within the target range.

Why? If breeding cows are too fat, they are more prone to calving difficulties, milk fever, and poor milk production. If these fat cows lose excess weight in late pregnancy, pregnancy toxaemia, grass tetany, and delayed return to oestrus are likely.

If cows are too thin, then poor milk production, reduced calf growth and delayed return to oestrus will occur.

A simpler way is to look at the pelvic area and imagine a cross section of the pelvis (Fig. 6).

![Cross section](image)

Score
1. Too thin
2. Just right
3. Too fat

*Figure 6: Simplified scale for condition scoring of beef cattle.*

Condition scoring is valuable in the estimation of return to heat times.

**Pregnancy Testing.**

In new management techniques pregnancy testing is essential. No longer should a farmer just be interested in whether his cows are in calf or not, but he should want to know the time-span and concentration. There is a right time to pregnancy test for each property depending on the analysis of the data collected, e.g. for heifers — 90 days from the start of mating, and for cows — 105 days from the start of mating, if 63 days span is desired.

**Mature Bulls**

Another part of breeding management success concerns the bulls. Breeding Soundness Examination (B.S.E.) is well documented in the literature (Blockey, 1984). B.S.E. should be carried out on an annual basis in commercial herds and before the annual sale of 2-year-old commercial bulls from the studs.

Serving capacity (S.C.) is the number of services a bull achieves in a 3-week paddock-mating period, and is predicted with 90% accuracy by the number of services the bull completes in a standardised 40 minutes
yard test (see Mossman, earlier in this publication). The higher the S.C., the better the bull. How do the bulls with a low S.C. get on? These produce poor histograms of calving, i.e. spread calvings. Many breeders do not realise that they may have a bull with a low S.C. The calving percentage may appear to be acceptable, but the calving span (and histogram of the calving pattern) is not and it is heritable. Table 3 demonstrates the effect of S.C. on conception rates.

**TABLE 3.**
Effect of breeding soundness of bulls on conception rate in cows (from Blockey, 1984).

<table>
<thead>
<tr>
<th>Serving capacity (S.C.)</th>
<th>Conception rate (C.R.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(40 minute test)</td>
<td></td>
</tr>
<tr>
<td>0 to 2 (low)</td>
<td>mean %</td>
</tr>
<tr>
<td></td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>range %</td>
</tr>
<tr>
<td></td>
<td>4—40</td>
</tr>
<tr>
<td>3 to 6 (medium)</td>
<td>60</td>
</tr>
<tr>
<td>7 to 11 (high)</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td>70 — 78</td>
</tr>
</tbody>
</table>

Now remember how important it is to achieve your target histograms of the calving pattern. If you are using a bull with low S.C., your management is poor. Mating potential (M.P) or the number of cows a bull can successfully get in calf, be it 20, 40, 60 or 80, is a combination of serving capacity and scrotal circumference. The greater the mating load, the larger the scrotal circumference needs to be. Good M.P. bulls are under-used. Poor M.P. sires are over-used. This is because farmers do not know which is which. Thus it is essential that all associated with beef breeding management become familiar with S.C. testing, scrotal size and M.P.

How would you feel if you paid $5,000 for a bull and it has a low S.C.? Or even worse, if you did not recognise it when it could have been tested easily. The insurance company will not pay out for this sort of omission.

With all the examinations of bulls currently being carried out on commercial sires, the demand will filter back into the studs; so be prepared. By leaving an interval between heifers and cows at the start of mating, considerable savings in bull costs are achieved and good bulls can be used more extensively.

**Summary**

To summarise then, I hope I have introduced you to aspects of cattle management that may be generally known, although the methods required for improving or applying the data collected may not yet be fully understood. The important parameters and techniques are; condition scoring of breeding cows, critical mating weights, breeding soundness examination of bulls, collection of calving patterns, analysis of histograms of calving, analysis of calf loss due to unsuitable paddocks (especially in hill country), pregnancy testing, disease control and concentrated calving. Emphasis must be placed on the performance targets expected for the heifers.
Planned Management Production (PMP) is a combined approach by your veterinarian and farm adviser. This approach will bring the beef farmer increased income, increased understanding of herd performance and a great deal of farming satisfaction.

References
MANAGEMENT CHANGES WHICH HAVE ACHIEVED CONCENTRATED CALVING

D.L. Munro
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Introduction
I have been asked to discuss changes in management which have improved the reproductive performance of our beef herd.

Beef cattle and breeding cows in particular will continue to play an important role in the management and profitability of our hill country operation. My aim is therefore to obtain the highest production and profitability possible.

Our cattle enterprise returns approximately 35% of our gross farm income from approximately 40% of the stock units. If supplements were withdrawn from sheep and wool returns the share would rise to approximately 45%.

The objectives of our breeding and finishing policy are to achieve the following.

(a) Better than 95% calving to cows wintered.
(b) Less than 3% death rate.
(c) Concentrated calving pattern (70% in 1st cycle).
(d) 245 kg minimum carcase weights at 18 to 20 months.
(e) Excess females (culled and aged) sold to best possible advantage.

I propose to discuss the key factors which have enabled us to reduce our calving span from 3 months to 45 days. In doing so we have produced a more even line of weaners and made feed budgeting and our work load a great deal easier.

I believe we achieve our objectives, with the exception of the 245 kg carcase weight, in most years.

Our Farm
I farm 525 ha 16 km north of Wairoa in partnership with my father. We run 11 s.u./ha on the property which is 55% of steep and very steep mudstone, 30% of rolling pumice and 15% of flats.

Wairoa generally has a well spread rainfall, humid summers, some winter frosts, which with the soil types, add up to a great grass growing climate. The exception being 1982/83 summer and autumn.

Stock carried include; 2750 Romney ewes, 1100 other sheep, 195 Angus cows, 169 mixed-sex weaners and 125 2-year-old cattle, with 3 Angus bulls and 2 South Devon bulls.

Key Management Changes
Monitor calving patterns.

This can be done by counting calves daily but we do the counts weekly. It is then easy to convert results to 21 day histograms. I have found it more difficult to count calves accurately as concentration of calving increases.

Analyze calving patterns.

This is undertaken with the veterinarian and farm adviser and has to consider three main factors:
(a) the market aimed for (i.e. weaners or 2.5 year-old-steers),
(b) local pasture production (When is the spring flush?), and
(c) the total farm management objectives (What are the competing resources?).
We used to have cows and heifers calving over a period of 3 months. In adjusting calving date we mated our heifers at the same date and delayed commencement of cow mating. We have subsequently delayed both groups a further week. Mating of heifers is delayed until 28th October (previously 20th Oct.) and mating of cows until 18th of November (previously 10th Nov.).

Determined heifer body weights.

In the first year our heifers averaged 346 kg with a range of 300 to 400 kg. We have not weighed our heifers since.

We usually over mate to the extent of 20% to 25%. This allows a culling margin as well as the expected empty heifers. Care is needed to ensure that the heifers put to the bull have acceptable mating weights, i.e. 270 kg and above.

At this stage we still mate heifers as 2-year-olds. A move to 14 months mating will be considered in the near future.

Test mate bulls.

Probably the most important factor.

The bull problems we have had, have been horrendous.

(a) In 1975 50% of heifers and 37% of cows calved in their respective 1st cycles. Of the 60 cows still to calve in the 3rd cycle that year, 32 proved to be empty. The reason for the poor performance was unsoundness in bulls.

(b) The conception rates in our cows and heifers since 1975 may be of interest and are summarised in Table 1.

(c) Since 1972 we have purchased 15 Angus bulls.

The fate of these bulls is of interest:

5 culled for corkscrew penis, (38%)
1 culled for poor quality semen, (7%)
2 culled for hip problems, (13%)
i.e. total wastage for these faults is 55%!
2 culled
1 dead
1 sold to stud
3 on property now

(d) Since we started test mating bulls in the spring of 1981 we have had a 20% rejection rate. We also identified the bulls causing problems in the years from 1980 to 1983. With more experience and confidence in the
method we should have identified the problem bulls earlier.
You will understand then why I consider this a key factor.

Determine mating dates.

Mating dates are determined by analysis of calving patterns. The mixed-age cow herd is the main determinant. Our aim is to have 50% of mixed-age cows calved by day 17 or 18 of calving. In practice this has varied from 45% calving in first 21 days to approximately 70%. This enables the bulk of cows to calve down on good autumn-saved pasture. The spring flush usually occurs shortly after this.

We calve our heifers 3 weeks prior to the cows and intend to continue doing this for the following reasons.

(a) Easier calving management.
(b) Economies of bull usage.
(c) The extra 3 weeks’ growth compensates for age of dam effects on weaning weight.

Length of mating period.

I believe a short mating period has many advantages that outweigh the possibility of a disaster. For example in 1980 despite a 57% conception rate in heifers and 83% in cows, we were able to maintain cow numbers because of over-mating in the heifers and by keeping older cows.

If it is not possible to maintain numbers within the herd the early knowledge of problems (mid Feb.) should enable one to make adequate replacement arrangements.

Pregnancy diagnosis.

This is carried out as early as possible, as shown below.

Heifers — mating 42 days plus 42 days gestation — 18th Jan
Cows — mating 45 days plus 49 days gestation — 15th Feb

This enables us to give priority feeding and thus finish our dry heifers to better weights. With the cows we cull dries, aged and those with obvious faults, and immediately wean any calves at foot and give priority feeding to cull cows. In last summers’ drought we sold both heifers and cows immediately after pregnancy diagnosis.

Later at weaning in early April we can cull further by identifying, with their mothers, the poorest calves and keeping them back (but maintaining equal numbers of steer and heifer calves). The number of calves kept back depends on our culling margin. Thus cows which rear the smallest calves at weaning are culled annually. In the past this policy would have culled only the late calvers.

Saving feed for calving.

We were initially forced to save feed to combat losses from rye-grass staggers. Prior to 1975 approx 1 ha per 2 cows was shut in early April for the cows to calve on in early August. Calving was generally excellent at 90% to 95% (no pregnancy diagnosis), but spread over 3 months.

With concentrated calving the system has been refined to the following.
Approximately 1 ha per 3 cows is saved. The selected paddocks are usually grazed from late April until early May. Nitrogen is used if required (D.A.P. in April 1983). Other stock may graze some areas if the amount of feed available is likely to cause a depression in grass growth.

Winter grazing management.

Since 1976 we have adopted the large mob system of winter grazing. For example this year 195 cows plus 2750 ewes (3900 s.u.) will graze 30 hill country paddocks on a 70 day rotation.

The cows fare pretty well in the system until the end of the first rotation. In the past, rotation lengths have tended to be shorter. Grass available to cows (with competition from ewes) has tended to be inadequate. This meant that body condition of the cows was lower than optimum.

The longer rotation has provided more available dry matter in the July-August period. Thus cows calve down in a higher body condition.

Heifers are removed from the rotation in the 1st week of August and the main rotation is broken up 3 weeks later. In 1983 cows were wintered on maize silage completely separate from ewes.

Calving paddocks and calving management.

The selection of calving paddocks is a crucial factor (as it is for lambing paddocks).

Calf losses can vary up to 20% between paddocks. We do not have a safe area on our farm but we generally select paddocks with easier contour. These are more southerly in aspect with the calving being on the steeper northerly faces.

With heifers, we would prefer to calve on relatively short feed (daily hay and magnesite) and shed out (remove dam and calf) as required onto saved feed. Because of mis-mothering problems, we have moved to break grazing behind an electric fence with daily shedding out.

The need to disturb the heifers and calves daily does concern me. This is because the bonding process is easily upset. Heifers in particular have not learned the nurse/mother cow system and mis-mothering can occur.

In the past, the cows were spread onto the saved feed, just after calving began. The cows calved down well but this system tends to waste the precious saved feed. In addition it can give problems with large calves in the latter calving cows.

Last year, the cows also calved behind an electric fence (2- to 3-day shifts). This system appeared to work fairly well. Adequate feed was available through to the end of calving.

Summary

The key factors I have outlined could be summarised as follows.

Calving analysis: knowing what is happening on a particular herd.

Adjusting mating dates: this takes into account calving analysis, marketing requirements and competing resources.

Bull management: test mating of bulls and continued observation throughout mating.
Strategic pregnancy testing: whether restrictive mating is followed or not, early pregnancy testing is a powerful weapon.

Feeding levels: have cows in medium calving condition and calving onto saved feed (rationed)

Calving paddocks: take care to calve on areas where losses from misadventure are acceptable.

The Future

Cross-breeding is obviously going to help us, particularly to achieve 245 kg and over carcase weight. We have chosen to use South Devon bulls over our Angus cows. We plan to mate these back to the horned Hereford sires.

With the cross-breeding programme will come the opportunity to mate our heifers as yearlings. These will be mated to the Angus bull. A major benefit will be to reduce the mature size of our cross-bred cows.

Our general aim will be to concentrate calving patterns further. That is, to achieve more cows calving in the first cycle of mating. The use of larger-framed animals (with higher maintenance requirements) may make this more difficult in some years.

With bull selection the first criterion is that they come from herds with restricted mating periods, i.e. 45 days or less. We will then select those with better growth rate potential provided this is not going to increase calving difficulties. Obviously bulls that have been test mated and have high serving capacities and adequately sized testes will be more desirable.

Conclusion

I am probably preaching to the converted but I must stress that this system really works. However you must make it fit your own circumstances. It gives a much greater control over a system which is generally given a low priority for management.

Concentrated calving enables the whole herd to be fed at optimum levels, thus ensuring a high calving percentage, an even line of well grown weaners and reduced cow and calf deaths. This enables a farmer to have the satisfaction of running a profitable operation as well as one to be proud of.
THE EFFECT OF AGE AT FIRST MATING ON REPRODUCTIVE PERFORMANCE OF BEEF COWS

C.A. Morris
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Feasibility of Mating Yearling Heifers

There are now extensive N.Z. data, reviewed by Morris (1980), indicating the feasibility of mating 'yearling' (14-15 month) heifers. More recently at Ruakura we have summarised the yearling heifer in-calf rates from Goudies Research Station, 430 — 520 m above sea level on the Central Plateau between Rotorua and Taupo. From 580 yearling heifer matings, 86% were recorded as in calf following an 8 week mating period; Hereford and Angus pure-breeds achieved 75% in calf, whereas at the other extreme 1/2 Friesian crosses achieved 90% (C.A. Morris, N.G. Cullen & R.L. Baker, 1984; unpublished data).

A critical point with joining 'yearling' heifers is that in herds where bulls are joined with heifers three weeks earlier than with cows, there may be problems during poor seasons when up to 40% fewer heifers could be cycling at the start of joining. The heifers are only 13 months old at joining if this practice is followed. Therefore all age groups should be joined with the bull on the same date.

Many farmers report problems getting lactating 2-year-olds back in calf. Whether or not there is a problem depends on the choice of calving date, as discussed by Montgomery (this publication). At Goudies, the data recorded so far from 430 2-year-old heifers which had previously experienced yearling joining, have shown 90% of these in calf. The Hereford and Angus pure-breeds achieved 84% in calf and the 1/2 Friesian crosses and 1/2 Jersey crosses 91%. The 'dairy' crosses have been less of a 'problem' to get back in calf than Hereford and Angus pure-breeds.

Net calfcrop weaning percentages of 65% to 70% (calves weaned per 100 heifers joined) have been regularly obtained from yearling heifer mating. Some of the data for weaning percentages from the less productive breed types have been reported by Carter et al. (1980), e.g. Angus at Waikite (69%) and Waikeria (66%), and by Baker and Carter (1976), e.g. Hereford (65%) at Waikite. The Hereford-Angus yearling heifers at Waikite achieved a 76% calfweaning rate (Baker and Carter, 1976).

Puberty in Heifers

North American and Australian data seem to be irrelevant for actual joining weight targets in N.Z. although their comparisons of cross-bred versus pure-bred heifers are consistent with the N.Z. data, showing that cross-breeds such as Hereford-Angus, Friesian-Angus and Friesian-Hereford reach puberty younger and heavier than Angus or Hereford pure-breeds. Other points to note about heifer puberty are the following.

(a) Yearling weight selection leads to puberty in heifers at lower ages and higher weights.

(b) Data from Goudies Research Station (R.L. Baker, C.A. Morris & A.H. Carter, 1980; unpublished data) have shown that a heifer’s own birth date is not independent of her age at first oestrus, thus late- born heifers have a late first oestrus date. The result is that wide calving spreads tend to cause even more problems in daughters as the years progress. Data
analyses of beef heifers should be available soon from Research Stations at Waikeria, Waikite and Whatawhata to check on this last relationship.

**Calf Weaning Weights from Heifers**

Calf weaning weights from 3-year-old heifers are 5 to 10 kg higher than those from 2-year-olds, but 3-year-old second-calvers have 2 to 3 kg heavier calves than 3-year-old heifers. The net result on a herd basis is that mating of yearling heifers leads to about a 5 kg (2%) reduction in average weaning weight. However this is more than balanced by the 10% to 17% extra calves produced. Carter *et al.* (1980) calculated on a herd basis, that mating yearling heifers was about 9% more efficient biologically than delaying mating for a year.

**Subsequent Productivity of Heifers**

Data from the Waikite and Waikeria trials (Carter *et al.*, 1980) show that regardless of whether heifers are allocated to first joining at 15 or 27 months of age, there is no difference in calf numbers weaned in subsequent calf crops. The Waikite and Waikeria data (summarised in *Table 1*) show that weaning percentages from older cows (3 years or more at joining, i.e. 4 years and older at calving) were not influenced by differences in first joining age. Carter *et al.* (1980) also have reported lifetime calf crop production data from Angus females classified according to yearling joining weight. Above 215 kg there was no difference in the number of calves produced per lifetime between any weight group. When the mob average was about 250 or 260 kg, i.e. the target joining weight, the lightest heifer in the mob weighed 215 kg. Equivalent Hereford weights would be about 5 kg higher.

**Calving Difficulty in Heifers**

Heifers generate more calving difficulty than second- or later calvers, whatever the age of the heifers. Perinatal deaths of calves at Waikite over a ten year period (Morris *et al.*, 1983) in two Angus herds which utilised 2-year-old first joining have been 4.4% (controls) and 2.0% (18-month weight-selection herd), compared with 7.8% in a yearling weight-

<table>
<thead>
<tr>
<th>1st Joining Age</th>
<th>No. of Heifers</th>
<th>1¼ Years kg</th>
<th>W%</th>
<th>2½ Years kg</th>
<th>W%</th>
<th>&gt;3 Years kg</th>
<th>W%</th>
<th>All Years in herd W%*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waikite 1¼ years</td>
<td>315</td>
<td>251</td>
<td>69</td>
<td>315</td>
<td>76</td>
<td>361</td>
<td>86</td>
<td>79</td>
</tr>
<tr>
<td>2¼ years</td>
<td>229</td>
<td>—</td>
<td>—</td>
<td>295</td>
<td>82</td>
<td>354</td>
<td>84</td>
<td>63</td>
</tr>
<tr>
<td>Waikeria 1¼ years</td>
<td>619</td>
<td>260</td>
<td>71</td>
<td>364</td>
<td>76</td>
<td>463</td>
<td>82</td>
<td>78</td>
</tr>
<tr>
<td>2¼ years</td>
<td>419</td>
<td>—</td>
<td>—</td>
<td>341</td>
<td>75</td>
<td>446</td>
<td>83</td>
<td>60</td>
</tr>
</tbody>
</table>

*Includes 0% from the yearling data for first mating at 2¼ years.
selected yearling-joined herd. However, adding the subsequent calf deaths gives overall figures of 12.2, 6.0 and 12.0% respectively, i.e. for calf mortality the 'yearling' herd (with weight selection) was not different from the unselected 2-year-old joined herd. These losses by death have been included in the net weaning rates discussed earlier. Cross-bred 2-year-old heifers at Waikite and Goudies have experienced fewer calf death losses than pure-breeds.

Conclusions
The recommended formula for mating yearling heifers includes the following points.
(a) Join heifers with bulls at the same time as cows are joined with bulls.
(b) Target live weights for the mob should be about 250 kg (Angus), 260 kg (Hereford), or higher for cross-breeds.
(c) Over join, i.e. join more heifers than are required to calve.
(d) Cull the late pregnant and empty heifers on pregnancy diagnosis.
(e) Aim to have all retained heifers pregnant in about a six-week period.

National Potential
I believe that over 80% of beef heifers in N.Z. should be mated as yearlings rather than the 25% mated at present. The potential for this includes many South Island farms. Conception rates of 85%, as advocated by Mossman and Hanly (1977), will be achieved only in occasional years, but conception rates of 0% will be guaranteed every year if yearling heifers are not joined (except as a result of the unwelcome favours of the neighbour's bull).

As noted already, cross-bred yearling heifers achieve higher in-calf rates than Angus or Hereford heifers, so the 'problem' of yearling mating is reduced by using cross-breeds.

References
MODIFIED REPRODUCTION
SUMMARY OF THIS SECTION

Oestrous synchronisation.

Many of the objectives of reproductive management can be enhanced by synchronisation of oestrus. This is achieved by using prostaglandins or progestagens to induce the next oestrous cycle. Although these two groups of drugs work quite differently, the final result is the same. In either case the essential requirement is that each cow must be experiencing oestrous cycles at the time of treatment.

Most of the systems in use involve giving 2 prostaglandin injections 11 or 12 days apart. Use of progestagen-releasing devices will be limited until regulations which prevent the inclusion of oestrogens are rescinded.

Induction of parturition.

Induction of premature parturition is another management tool for use in planned reproductive programmes, provided it is not used as a salvage operation to tidy up late-calving cows.

Treatment must be timed so that the last cows calve at least 5 weeks before the start of the next mating season. The induction programme has to be planned early and decisively. Most procedures use a 'priming' treatment of a slow-acting corticosteroid followed, 10 or 11 days later, by a 'trigger' dose of a prostaglandin or a short-acting corticosteroid.

Issues of concern such as, retained foetal membranes, subsequent reproductive performance and calf survival, appear to have been overcome in most situations.

Embryo transfer.

There is still a requirement for the transfer of embryos in N.Z. cattle and the technology involved also may be utilised in other techniques which could play a part in cattle reproduction in the near future.

An initial step in an embryo transfer procedure is the production of a large number of eggs in the donor cow. This is achieved by using follicle-stimulating hormone (FSH) or preparations such as pregnant mare serum gonadotrophin (PMSG) which act like FSH. Eggs are harvested from the donor's uterus either by a surgical or a non-surgical collection process. Viable eggs are then transferred singly to recipient cows which have been synchronised to match the ovarian status of the donor.

Full results are not always reported and show much variation in success, but in general 4 to 5 pregnancies could be expected from each donor operation where surgical collection and transfer are used.
PRACTICE AND PLACE OF OESTROUS SYNCHRONISATION AND INDUCTION OF PARTURITION IN BEEF HERDS

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Introduction
Attempts to synchronise oestrous cycles of the majority of a group of females are being rewarded with increasing success. Perhaps the earliest reason for exploring this concept was to provide for herd owners a means to achieve the required number of inseminations within a short period of time. The application of artificial breeding (AB) with whole groups of heifers, insemination of batches of town supply dairy cows, and the concentration of natural mating programmes are further examples of objectives which are made easier to achieve by synchronisation. However the potential for concentrated conception patterns is no longer exploited just for greater ease of convenience during the mating season.

Once synchronised pregnancies have been achieved and identified, the winter management of the pregnant herd and the management of calving and group calf-rearing, all become areas with potential for increased efficiency. Similarly the changes in calving pattern and median calving date which result from the high conception rate at the start of mating will allow the suitability of traditional dates for the start of calving to be reassessed. None of these possibilities should be dismissed by either beef breeders or milk producers as being of little consequence to their particular operation.

Techniques
Drugs presently available attempt to produce synchrony in one of two ways—the prostaglandins (PGs) hasten the onset of the next cycle, while the progestagens (usually) delay it. With both the initial result is the same. The hormone (progesterone) which prevents the next heat declines in all correctly treated animals at about the same time, although the interval from this decline to oestrus and ovulation can vary quite markedly from cow to cow. Consequently highest pregnancy rates are obtained when insemination or hand mating is based on detected oestrous behaviour. Mass insemination, either once at a certain time, or twice at two set times, used to be widely recommended and still is in situations where the efficiency of heat detection is poor, but on average 20% of such a group will be inseminated with little or no chance of conceiving. Some of this loss or wastage will be offset when PGs are used, through the 10% improvement in the conception rate of treated animals which are inseminated at the correct time. This fertility effect will clearly be more obvious when all inseminations are made following heat detection. Thus, with present methods of treatment, the term 'oestrous synchronisation' is somewhat misleading.

Note the use of the phrases 'next cycle', 'next heat' and 'correctly treated animals' in the preceding paragraph. Animals which have not had one cycle obviously cannot have the intervals between their cycles shortened or lengthened. When there is uncertainty about the cyclicity of some of a group, unsuitable animals are bound to be treated. Such animals may be anoestrous for any of a number of reasons, including
pregnancy, and PG treatment may well result in more harm than good. Progestagens occasionally appear to have shortened the interval from calving to first post-partum heat. However their use for this purpose in herds with a high incidence of anoestrus is unlikely to be effective.

Ovarian activity is thus a pre-requisite for the selection of animals for treatment. The use of tail paint or harnessed bulls for three weeks before treatment is often recommended. Veterinary examination of those cows not detected by these methods can be made on the day of treatment. The first ovulation after calving may not be associated with oestrous behaviour, but such silent heats still leave the animal in a state suitable for treatment.

A variety of synchronisation programmes have been devised, and the individual herd owner needs to be very clear in his own mind about his objectives and the amount of time and expense he is prepared to commit to achieving them. Only then can he and his advisers decide on the programme most suitable for his purposes. Few systems can be regarded as cheap, nor will the most expensive ones always be successful, especially when animal identification and handling facilities are of a poor standard.

Some treatment systems are better suited to heifers, others to lactating cows. In the following examples it is assumed that only suitable animals will be treated, i.e. that their cyclicity has been confirmed either by heat detection beforehand or by veterinary examination on the day of treatment.

Prostaglandins: heifers and dry cows.
(a) System PGa.
Inject all animals twice with PG, with an interval of 11 or 12 days between injections. The majority will be in oestrus during the period 60 h to 120 h after the second injection. Five yardings should therefore be all that are required — two for injecting and three for AB. The number not cycling by the end of the third session of AB is usually too few to warrant a fourth session, unless this can be achieved very easily. With care, weekend work can be avoided, which makes the system very suitable for run-off or agistment situations.

(b) System PGb.
Inject the whole group, and inseminate those detected in oestrus during the third, fourth and fifth day after treatment. Draft these off and inject the rest with a second PG dose, 11 or 12 days after the first injection. A second AB session commences three days later. This system reduces drug costs, but increases labour requirements and produces a slightly longer calving spread. One day of the programme will fall at a weekend — the day of first injection for example.

(c) System PGc.
As against the above two examples, which require no knowledge of heats prior to treatment (other than that they have occurred and did so
during the three weeks before treatment), this system uses slightly more detailed information. It avoids wastefully treating those animals which are about to come into oestrus naturally (and therefore do not need treatment), and also those which were on heat during the few days immediately beforehand (and therefore will not respond since neither PGs nor progestagens can cause an animal to have two heats within a week). Animals in both of these categories can respond only to the second injection, and if their inclusion in the first treatment can be avoided, up to half the drug costs can be saved. Heat dates are recorded during the 21 days (Day 1 to Day 21) before the first treatment date (Day 22). Only those animals bulling on or between Days 7 to 17 are treated on Day 22, while all animals are injected on Day 33 (or 34). Insemination upon detection of heat can then be confined to a three-day session as in System PGa. Alternatively, those in oestrus after the Day 22 treatment can be inseminated (this will include some of the untreated cattle) and the balance injected on Day 33 (or 34). This produces two AB sessions 11 or 12 days apart as in System PGb.

(d) System PGd.

Of the many variations suitable for use in dry stock, this system may appeal to those wishing to inseminate some (50% or less) rather than all available animals. It can be adopted also by those who make a late decision to concentrate their AB programme. For example, if only 40% of a group is to be inseminated, then heats are detected and recorded for as many days as it takes 40% to show oestrus, providing that this period does not exceed 12 days. The balance are removed and joined with the bull. The 40% are left for one week, injected once and inseminated upon heat detection. It is obviously not suitable for use in groups where anoestrus is common. If the number selected is short of the target by 12 days, the system must either be abandoned or else proceeded with as described but with fewer animals than planned.

Prostaglandins: Suckling beef cows.

Two factors commonly combine to reduce the level of success achieved with PGs when groups of beef cows with calves at foot are treated. First the interval from calving to the resumption of ovarian cycles is often so long that many cows have not been in oestrus before the bulls are joined. This obviously reduces the proportion available for inclusion in the programme. Secondly the repeated yardings, the separation of selected cows from their calves, and the restraint required for the injections, examinations and inseminations are often associated with difficulties. These reduce not only the commitment of the owner and AB technician, but also the suitability of the cows for insemination.

Both of these problems can be reduced if an early decision is made to inseminate only a proportion of the herd — perhaps only the best cows. This group and their calves are run separately from those to be put with the bull, fed preferentially and observed for signs of oestrus. This period may extend beyond the joining date for the naturally mated cows. Until
all of this selected group are known to be cycling, no treatment should be started. Once the programme is under way, much of the lost time will be regained by the concentrated conception pattern which it achieves and the resulting mean calving date will be only slightly delayed. The frequent visits to this group for pre treatment heat detection and recording should result in a more easily handled mob.

Depending on how widely the pre treatment heat dates are scattered, systems PGb or PGc can be adopted. A few moments with a calendar will help the owner and his adviser decide which system will result in the best submission rate during one or two short inseminating periods, without extravagant use of PG.

Progestagens.

Devices impregnated with a progestagen are placed in the vagina, from where the drug is continuously absorbed. With proper timing, the removal of the devices will leave all animals in the same state — i.e. about to start their next cycle. As with PG injection, the interval from treatment to standing oestrus varies between cows. AB following efficient heat detection will usually produce more conceptions than the more usual mass insemination of all animals at 56 h after device removal. The additional cost and inconvenience of inseminating on detection over two or three days may make this option unattractive. However it should be considered seriously if the amount of oestrous behaviour evident immediately before the 56 h mass insemination does not involve nearly all animals.

The current costs of the devices will usually prevent their use throughout a herd. Even when cheaper products become available, recognition of the limitations of the technique will improve the results obtained.

Only if or when devices which supply an oestrogen as well as progesterone are licensed for this purpose will it become possible to treat effectively a whole group of naturally cycling females. For the time being it is recommended that animals which were in oestrus during the week before the device is to be inserted are identified and either treated differently or not at all. This week of heat detection before the devices are inserted also will provide an indication of the level of anoestrus present in the group. If about one-third are seen to cycle during the seven days, then it is usually safe to assume that the group includes few anoestrous members and that the other two-thirds will respond to the devices. If less than 20% cycle during this week of observation, then the reasons should be ascertained — e.g. pregnancy, poor heat detection, abnormalities such as freemartinism, and, of course, anoestrus. Animals due to come out of shallow anoestrus in the near future probably will respond to the devices, however where the anoestrous proportion of a group exceeds 20%, it is likely that the degree of anoestrus is too profound in many of them for this effect to occur.

Most published reports describing the use of these devices in N.Z. refer to beef cattle. Systems have now been designed which allow all
classes of cycling females to be considered — cows or heifers, beef or dairy.

System Prog device.

The selected group is monitored for oestrus for at least five, preferably seven, days. Devices are inserted into the remainder (which did not show oestrus) and are removed after 10 to 12 days. Mass insemination at 56 hours after removal or insemination on detection of heat are carried out, depending on the response pattern or ease of management.

The two most attractive options for dealing with the animals which cycled during the pre treatment week would appear to be the following. (a) Leave them untreated — a number of them will return to oestrus during the period when the treated cows are being inseminated and these can be included in the AB sessions, or (b) leave them untreated until the day before the devices are to be removed from their treated herd mates. Then they can be injected with PG and expected to cycle during the same period as the others.

Even when devices which supply an oestrogen as well as progestrone are licensed for use as aids in mating management (with all animals treated identically, as one group), at least a week of heat observation will still be an invaluable indicator of the likely response rate.
General comments.

The systems described above are examples of the many options available for consideration. Additional systems are being designed and tested as further alternatives which may be even more suitable for some of the many different breeding operations used in the industry. Two most important features are common to all systems and will remain so. These are, (a) the need for careful planning of day by day activities, which is best done with a calendar in hand, and (b) the value of excluding unsuitable animals.

Arrangements with the veterinarian, the semen supplier, the AB technician, etc., must be made well in advance. Cattle will not remain in oestrus while deficiencies in organisation are made good, nor will they respond as well as they could if they are treated on the wrong day. Inseminating facilities should not accelerate inseminator fatigue, and sufficient help must be available so that the technician can confine his activities to doing his job.

Best results with PGs are associated with morning injections and morning inseminations. Other combinations, such as afternoon injections and morning inseminations, tend to increase the number of animals inseminated on two consecutive days, usually because they were just coming into oestrus when first inseminated and were actively ridden for some hours afterwards. This extravagant use of semen is also associated with the progestagen-releasing devices. It is also far more likely with dry or beef cattle, where the selection of animals to be inseminated is made at the time of insemination, rather than two or more hours beforehand. The dairy farmer rarely presents the same cow for AB on two consecutive days, even though the system of charging adopted by the L.I.A. may not discourage him from doing so.

Relying on tail paint wear as the only indicator of which animals to inseminate is not without risk. Where a high proportion of a group is in behavioural oestrus simultaneously, some will lose little or no tail paint because they are too busy riding to be ridden themselves. Large eartags and adequate time for frequent observations and recording are essential if bulling animals are not be be missed.

Harnessed teaser bulls are not always reliable for the detection and marking of oestrous females. Lameness and illness will become apparent rapidly, however less-obvious problems are not uncommon. Some bulls do not put their chin on the animal they are mating, others are so big and/or vigorous that both parties collapse to the ground, especially with small heifers. In large paddocks, groups of riding females may be more widely scattered than the bull is prepared to travel. Marker bulls should thus be observed closely during the first few days and checked for their enthusiasm and mating ability, so that these attributes are proven rather than assumed. Small, flat paddocks are almost essential for this.

The semen to be used needs careful selection. The finding that that a high proportion of the calf crop was by a certain bull, which for an unforseen reason did not meet the required standards, has spoiled at
least one highly successful programme. Now that at least one bull has been linked with pregnancies which are, on average, ten days shorter than normal, other bulls with similar powers to disrupt expected calving patterns are sure to be identified.

The different effects of PGs and progestagens on existing pregnancies must not be overlooked. The PGs terminate early pregnancies, the progestagens (without an oestrogen) do not. Therefore the harnessed bull which identifies heat dates before PG treatment need not be vasectomised. However, if progesterone-releasing devices are to be used, all entire bulls should be kept well away. During the interval between PG injection and insemination an entire bull would again be a competitor with the AB technician.

Finally, a few comments on cost. In early 1984 the cost per injection of PG was between $4.50 and $5.00, while the progestagen-releasing devices were about $18.00 each. This difference diminishes when systems which require two doses of PG per animal are used, or if the devices are reinserted for the purpose of synchronising the animals returning to service and protecting some early pregnancies. On the other hand, the use of PGs will lift the normal conception rate of a herd by 10%. No such fertility effect has been found with the intra-vaginal devices. At the moment, reports describing very successful programmes with PGs are far more numerous than those using the progesterone-releasing devices, especially in dry stock and lactating dairy cows.

Examples of oestrous synchronisation in N.Z. beef herds.

Some examples of results obtained and problems encountered with different systems of oestrous synchronisation are provided on the following pages.

(a) June 1977, Parakai.
(This was a pilot study to explore the use of System PGa with natural mating)
Problems. Angus heifers almost small enough to walk under the only two bulls available. One bull broke into mob between 55 h and 62 h after the second injection. The peak of oestrus coincided with a severe and prolonged storm, with cattle yards flooded above gumboot level. Heifers which collapsed when mounted were almost in danger of drowning. However, excellent reminder of the type of facilities and animals required.
Method and results. 17 injected twice (15 heifers and 2 cows) and yarded 62 h after second injection. Put singly or in pairs into pen with one bull and removed when mated or ignored. Eight put with bull during first 40 minutes, 5 served of which 4 conceived. By this time underfoot conditions had deteriorated beyond safe limits, and as neither bull could mount when put in the race, the yard study was abandoned. The 12 unmated females were examined, six diagnosed as anoestrous, and one was found to have been mated; doubtless by the
bull found in the mob at first light. This heifer conceived. Comment and conclusion. The details of subsequent events are not relevant to the present discussion. It was concluded that oestrous synchronisation programmes need not be confined to mating by artificial insemination. The staggered onset of standing oestrus allows a bull to cope in a paddock mating situation, although the paddock should be small and the yards not too far away. In this situation the bull would, if allowed, mate each female twice and then inspect the rest of the mob, returning to the cows just mated if no others are available. Hand mating in yards reduces this wastage.

(b) September-October 1978, Kerikeri. (System PGc — slightly modified)
Method. Heifers tail painted and divided into two groups 11 days later — those ridden, and those not. The ridden animals were injected six days later and inseminated when detected in oestrus. The non-ridden group was re-inspected 10 days after the first tail paint readings, i.e. 21 days after painting, and those still not ridden were examined for deformity, pregnancy, anoestrus, etc. Suitable animals were injected six days later, and inseminated on detection of oestrus. Thus two insemination sessions were needed, each of 4 days, but 10 days apart. Frozen semen was used.

Problems. Unsatisfactory batch of tail paint, and some of the second group were injected later than planned. However, excellent Angus heifers, good facilities and technicians, and very good heat detection by observation which made up for the poor quality tail paint.

Results. 164 2-yr Angus heifers
59 injected in first group, all inseminated, 45 (76.3) conceived
64 injected in second group, 63 inseminated, 37 (67.2%) conceived
41 not treated, 2 freemartins
30 inseminated during peak AB sessions
7 inseminated at a later date
2 not inseminated at all
18 of 37 (48.6%) conceived

Comments. With only one treated animal not detected, the efficiency of heat detection and the suitability of the treated animals were clearly very high. The fact that 1978 was the third consecutive year in which synchronised oestrous trials had been conducted on this property was undoubtedly responsible for the ease with which the programme was managed. Also some benefit was probably derived from the delayed mating date.

The start of mating was 10 days later than for many years, based on a comparison of calf growth rates following the previous trials. This showed that the calves born during the first 10 days of calving gained less weight per day to weaning than did calves born during any other 10 day period.
One hundred and thirty-four beef heifers were tail painted on Day 1, and the 41 that had been ridden by Day 8 were drafted off. Devices were inserted into the other 93 on Day 8 and removed on Day 18, while the group of 41 had devices inserted on Day 15 and removed on Day 25. Each group was observed twice daily for heat, although the trial design required that mass insemination took place 56 h after the devices were removed. Results. See Table 1.

### TABLE 1.
Reproductive performance of beef heifers following treatment with progesterone-releasing devices.

<table>
<thead>
<tr>
<th></th>
<th>First Group (93)</th>
<th>Second Group (41)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. in oestrus before AB</td>
<td>62</td>
<td>25</td>
<td>87</td>
</tr>
<tr>
<td>No. conceiving</td>
<td>31</td>
<td>14</td>
<td>45 (52%)</td>
</tr>
<tr>
<td>No. in oestrus after AB</td>
<td>18</td>
<td>12</td>
<td>30</td>
</tr>
<tr>
<td>No. conceiving</td>
<td>4</td>
<td>5</td>
<td>9 (30%)</td>
</tr>
<tr>
<td>No. not seen in oestrus</td>
<td>9</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>No. conceiving</td>
<td>4</td>
<td>0</td>
<td>4 (30%)</td>
</tr>
<tr>
<td>No. not inseminated due to deformity</td>
<td>4</td>
<td>0</td>
<td>4</td>
</tr>
</tbody>
</table>

Problems. Some, possibly all, of the devices of the particular batch used were unable to supply adequate progestagen and this undoubtedly contributed to the delay in the onset of oestrus in the 30 heifers on heat after AB.

Comment. Insemination upon detection of heat may have increased the number in this category that conceived, although the four conceptions in the 13 heifers not detected in oestrus would have been forfeited.

(59 pregnancies, 134 devices, 130 inseminations, 6 yardings).

### THE INDUCTION OF PREMATURE PARTURITION

**Introduction**

The use of corticosteroids for the treatment of problems in heavily pregnant cows used to be contra-indicated due to the inevitable loss of the pregnancies. However this 'undesirable side-effect' is now the major objective of the use of these drugs in N.Z. The present large-scale usage is likely to increase as the reliability of present methods and the benefits attainable become more widely appreciated.

The initial objective was to eliminate the situation where two distinct groups of calving cows occur in seasonal dairy herds. The last cows to conceive during the previous mating season were induced to calve...
prematurely and thereby start converting valuable spring feed into milk fat rather than body fat. This objective remains important and is easy to achieve — a bovine pregnancy can be terminated almost at a moment's notice. When used merely as a salvage operation to reduce the length of the calving season, the technique becomes associated with such poor cow and calf survival rates, and infertility in the induced cows, that herd owners become hesitant about using it again. When fully exploited however, the technique can become a major tool for the routine annual management of seasonal herds, and the future will see beef farmers cautiously applying it.

**Concentration of the Calving Pattern**

Induction of premature parturition in cows can be used to cause the majority to calve in daylight on one selected day. Results from one herd where this has been attempted are shown below.

<table>
<thead>
<tr>
<th></th>
<th>No. treated</th>
<th>No. calving at intervals from treatment</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt;24h</td>
<td>25-36h</td>
<td>37-48h</td>
<td>&gt;48h</td>
</tr>
<tr>
<td>Te Awamutu 1977</td>
<td>93</td>
<td>14</td>
<td>46</td>
<td>22</td>
<td>11</td>
</tr>
<tr>
<td>Te Awamutu 1978</td>
<td>62</td>
<td>9</td>
<td>35</td>
<td>7</td>
<td>1</td>
</tr>
</tbody>
</table>

The improved supervision possible clearly will be of advantage to the weak calves. Those initially too weak to stand and unable to drink often respond beyond expectations to shelter and tube-feeding, and with well-prepared facilities and supplies only the very premature are necessarily hopeless causes. The day of bobby-calf collection may determine the best timing for the induction treatments.

**Retained Foetal Membranes (RFM)**

Induction of premature calving can reduce the importance and (less successfully) the incidence of retained foetal membranes. Present techniques are always associated with more retained membranes than is normal for full-term calvings in the same herd. However, in the absence of concurrent disease, the problem can be influenced by; (a) cow condition (e.g. 31% of 127 thin cows and 14% of 56 cows of condition score 5 or above had RFM), (b) induction treatment (some regimes result in far more RFM than others), and (c) post calving treatment.

Far more cows have RFM than is apparent without internal examination, e.g. 138 cows induced, 42 with obvious RFM and 23 with internal RFM. The cows with internal RFM have a lower incidence of metritis and sub-fertility, possibly due to the absence of a 'wick' of tissue along which pathogens, particularly of faecal origin, gain entry into the uterus. Any external membrane should be cut away (not pulled). Manual removal can be considered five or more days later.
Milk Fat Production
In parturition-induced cows milk fat production can be as good as, or possibly better than, it would have been had the cows calved at full term. Production per day is reduced, but with more days of the lactation on spring feed, total production for the season does not suffer to any extent. This is also evident from the growth rates of calves born prematurely to beef cows (see below).

Subsequent Reproductive Performance
Various factors conspire to reduce the fertility of induced cows. Having calved late, and maybe having retained their foetal membranes, the establishment of normal ovarian activity and uterine environment could be delayed in many cows, perhaps until the third cycle of a mating programme.

Induced cows also are associated with a long return interval to first service, especially when they have not had a pre mating heat. The assumption that they did not conceive is not always correct — such cows are prone to lose pregnancies at or around the normal time for implantation. Induced cows which have not cycled before the start of mating may be best left unmated at their first heat. Prostaglandins can be used to shorten the delay until the next oestrus, at which a higher 'viable conception' rate can be expected.

Following induced calving, submission rate (SR) and conception rate (CR) during the next mating can be high enough, not only for most induced cows to conceive, but also to avoid being induced again the following year. The following examples support this statement.
(a) The Ruakura No. 2 herd has had 150 cows induced during the last five years. Of these, 91 have conceived with average intervals from calving to first mating and conception of 48 and 67 days respectively, and an average of 1.77 matings per conception. During these days the average number of matings per conception in the rest of the herd (i.e. not induced cows) has ranged from 1.44 to 1.62.
(b) Of 47 Angus cows prematurely induced to calve by an average of 18 days, 42 conceived during the next mating season, and did so only 1 week later on average than 36 untreated cows which had calved (full-term) during the same week. Seven other untreated cows did not conceive.

Timing the induction programme to allow five weeks between calving and mating should be done to improve SR and CR in the early weeks of mating. The value of good condition at calving, and a high level of nutrition thereafter must be emphasised. Continuing to manage the induced cows in a separate group, preferentially fed, may be the best way of undermining the contention that induced cows are automatically of reduced fertility.

Calf Survival
Premature calves can thrive. The interval from the day of the first injection of an induction treatment to the day of calving will vary from
little more than a day to beyond two weeks. It will depend not only on how close to full term the cow is, but also on the treatment regime employed. Intervals of more than 12 days are associated with an increase in the proportion of calves born dead or dying. Once the calf is 36 h old and has access to more shelter than is usually provided for full term calves, rearing problems are few. Three pertinent cases are reported below.

(a) (Waikato 1978) On three beef properties 47 cows were induced. These produced 46 live calves which averaged 164 kg at weaning in February. Average weaning weight for 42 calves born full term during the same week was 162 kg.

(b) (Ruakura 1981) Ten Jersey calves with an average birthweight of 21 kg had an average liveweight of 55.2 kg at 8 weeks.

(c) (Ruakura 1982) Five Friesian calves with an average prematurity of 18 days and an average birthweight of 22 kg, had an average liveweight of 50.2 kg at 8 weeks.

The assumption that weak, underweight calves will inevitably die and should therefore be destroyed at birth is unfortunate. Such calves need more care than full term ones and may take longer to reach bobby-calf weights. However, the improved prices received in recent seasons has prompted many farmers to delay destroying induced calves. With colostrum, warmth and good hygiene, many of these calves have been successfully reared, and preparing for this deserves more attention and encouragement from veterinarians.

Planning the Induction Programme

The identity of the cows to be induced must be known months in advance — as early as the previous February, and certainly by weaning or drying off. Similarly the dates for the induced calvings and therefore the dates of treatment, the labour and feed requirements at and before that time, the calf rearing facilities etc., can all be arranged during the winter.

The cows to be induced should be fed to reach a condition score of six when treated, i.e. one score more than the cows calving full term. Cows with problems such as chronic mastitis or facial eczema are excluded as poor risks. Magnesium supplementation can be instituted at least a week before the first treatment.

To improve the subsequent reproductive performance, treatment is timed so that the last cows calve at least five weeks before the first day of the next mating season. With more treatment systems this means that all cows which conceived after the seventh week of the previous mating season will be treated with the first, or priming injection, seven weeks before the next mating season starts.

Induction Technique

In spite of the variety of techniques which have been employed successfully for induction of parturition, there appears to be general agreement on two important points:
(a) that rapid termination of pregnancy increases the chances of undesirable features such as retained placentae and poor production, and
(b) that an interval between first injection and calving of more than 14 days will increase the incidence of stillborn or dull and weak calves, irrespective of their degree of prematurity.

Nearly all the drugs commonly used for induction of parturition fall into the following two categories.

First, the 'primers' which initiate the gradual preparation of the cow and calf for calving by accelerating udder development, changes in the birth canal, and calf maturation. A variety of depot or slow-acting corticosteroids are used for this purpose. Secondly, the 'triggers' which precipitate the actual calving process — prostaglandins (F₂α and analogues such as cloprostenol), and the more soluble, quick-acting corticosteroids. There is also a betamethasone preparation which is designed to provide both effects.

The choice of actual treatment regime remains a matter for the individual veterinarian and will be based on experience, available information and discussions with colleagues and research workers. It is unlikely that comparative drug costs will play a significant part in dictating which products are used. The recommendations which follow evolved during a series of trials in which a variety of factors that influence the overall success of an induction programme were studied. Only a few of the available products were used. Various dose rates were compared, but in no instances were results improved by straying from label recommendations.

Procedure.

All cows are 'primed' with a depot corticosteroid. The date for this treatment is as close to seven weeks before the first day of the next mating programme as is practicable.

These cows are divided into two categories, based on conception date:
Category A those due to calve within the next three weeks, and
Category B those due after more than three weeks.

Seven days after the first treatment, cows in Category A are inspected. Those with udder development and filling similar to that of a full term cow immediately before calving are treated with cloprostenol. Cows in Category B are unlikely to have fully developed udders by this time. Any that are well advanced can also be treated on this date, but if there is doubt the cow should be left untreated.

Ten or 11 days after the depot corticosteroid, all uncalved cows are treated with cloprostenol. This can include the re-treatment of the occasional Category A cow which has not calved.

Any cows which were not originally in the group prepared for induction can be included. If their conception date is accurate, i.e. they are merely carrying their pregnancy for a little longer than average, then these cows can be induced successfully without corticosteroid priming.
The earlier in the day that the coprostenol is administered, the more 
cows will calve during daylight on the next day. It is possible therefore 
to arrange for the dates of treatments and peaks of calving to fall during 
the week.
Notes.
Milking the cows before calving may be necessary when the udders 
become severely distended but this may be followed by milk fever and 
will certainly dictate that calves receive colostrum from another 
source.
No mention has been made of inducing parturition in heifers. This 
practice is not recommended, due to the probability that it will leave 
heifers with underdeveloped udders. Late conceiving heifers are more 
suited to late calving herds.

Conclusion
In conclusion, it must be emphasised that the most successful 
induction programmes have been those which not only were 
thoroughly planned, but also were bold. All too often, the induced cows 
are still late-calving cows, and the potential offered by induction has not 
been realised. When early decisions are made not only to induce the 
cows which are due after the first five weeks of calving, but to do so at or 
soon after the start of calving, then, with the exception of calf survival, 
far better results will be achieved than those reported to date.
SUPER-OVULATION AND EMBRYO TRANSFER

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Introduction

Embryo transfer, strictly speaking, is the technique for the collection of early embryos from one animal (the donor) and the placement of these embryos into another animal (the recipient). It is however a term which has been widely used to describe allied techniques, such as super-ovulation, embryo storage, and cloning.

The monetary benefits resulting from super-ovulation and embryo transfer in the cattle industry will be substantial when techniques can be developed which are commercially viable to the average cattle producer. Techniques developed to date have already resulted in a very rapid increase of knowledge in the various fields associated with reproduction.

The first successful embryo transfer in mammals was achieved in 1890, but it was not until after the Second World War that research findings suggested that embryo transfer could become a feasible counterpart to artificial insemination. Subsequent work utilising more recent knowledge and techniques has proved that the technique is commercially viable in certain situations.

Successful commercial embryo transfer in cattle is dependent on a reliable method of super-ovulation, a simple atraumatic method of embryo collection, reliable storage, and a simple method of embryo transfer. Many of these criteria are being met, but not until all of these requirements have been achieved will routine embryo transfer be commonplace.

Super-ovulation

Super-ovulation is an effect produced on the ovary by the administration of certain treatment regimes, which causes the ovary to produce 4 to 20 mature follicles at oestrus. The attainment of consistent results from super-ovulation in donor animals has been one of the limiting factors in the success of embryo transfer work. It would appear that individual variation in the endocrine responses to exogenous hormones is a critical factor in the success of super-ovulation.

Most treatments now utilise follicle-stimulating hormone (FSH) type preparations such as pregnant mare serum gonadotrophin (PMSG), the use of which has become widespread due to its low cost and ready availability. Anterior pituitary extracts of FSH from horse, sheep, cattle, and pigs have been used. These give slightly better results than PMSG, which has the disadvantage of a more prolonged effect since it has a half-life of about 6 or 7 days, however the increased cost of anterior pituitary extracts and their need for frequent administration limits their widespread use. On the other hand recent developments suggest that porcine anterior pituitary extract used on a twice daily basis for 4 days may nevertheless be an economic proposition. Other workers have used various combinations of gonadotrophins, including for example human menopausal gonadotrophin (HMG), with acceptable results.

Initially many workers felt that there was variation between different batches of PMSG but subsequent research has proved that this is not
usually the case. It would appear that the most critical factors for optimal super-ovulation are the time of administration of PMSG and its dose level. The dosages of PMSG currently used range from 2000 i.u. to 3000 i.u. but the levels most frequently employed would be in the lower half of this range.

Appropriate timing of PMSG administration relates to the fact that the luteal phase of the ovary occurs from day 5 to day 15 of the oestrous cycle. Also it has been found that that most reliable response to these preparations does not occur until 4 days after administration, so if a dose of PMSG is given on day 16 and the cow is left to cycle normally, oestrus could occur at any time. This degree of uncertainty is unacceptable, however the development of luteolytic drugs such as the prostaglandins, has meant that much greater predictability of oestrus is now possible.

The standard treatment currently employed to achieve super-ovulation is a dose of 2000 — 2500 i.u. of PMSG administered between days 9 and 12 (the mid-luteal phase) followed by injection of prostaglandin F\(_2\alpha\) (PGF) 48 hours later. Donor cattle can be expected to exhibit oestrus approximately 48 hours after the PGF injection. Although this regime allows maximum effect from the PMSG there is still considerable variation both between individuals and between breeds in the follicular response.

Artificial insemination has been used extensively for fertilisation of donor cows, with both fresh or frozen semen producing similar results. Disease considerations usually preclude the use of bulls. Insemination is generally done at the commencement of the standing heat and again 12 hours later using either one or two straws of semen on each occasion. It is inadvisable to carry out insemination once the standing heat has finished. For successful fertilisation, semen used in super-ovulated cows should be obtained from bulls of proven high fertility.

Attempts have been made to induce super-ovulation in pre-pubertal calves, in order to reduce the generation interval in progeny testing schemes, but there has been little success in the recovery of viable embryos following such procedures.

**Embryo Transfer**

Embryo collection.

After the fifth day following insemination, 80% of the embryos can be found in the uterus of the superovulated cow, so most embryo transfer techniques will require collections to be done between days five and eight. In cattle, embryos have been collected by both surgical and non-surgical methods. Both methods have advantages and disadvantages.

(a) Surgical collection.

Three different surgical approaches have been used in cattle. These are; midventral laparotomy, flank laparotomy, and transvaginal laparotomy.

Generally the midventral site is preferred because this gives easy
access to the reproductive tract in both heifers and parous cows and because aseptic surgical techniques can be maintained easily. This technique does, however, require general anaesthesia.

With all surgical techniques adhesions can be untoward sequelae, particularly those occurring in the region of the ovaries and oviducts. This problem can be reduced considerably by using heparinised saline for moistening serosal surfaces and by the use of synthetic absorbable materials for sutures.

Total numbers of embryos recovered by surgical techniques are generally higher than can be recovered by other methods. Disadvantages are the cost of surgery and the limitation on the number of times the procedure can be repeated on an individual cow. Detailed descriptions of these techniques are discussed fully in the references cited in the bibliography.

(b) Non-surgical collection.

Various methods and equipment have been described for the collection of embryos by non-surgical techniques. These methods involve the passage through the cervix of some type of collection device, through which a flushing medium can be introduced and collected. The advantages of the procedure are the high repeatability of the technique in individual donors and the low degree of trauma produced.

(c) Flushing technique.

Both collection methods involve the introduction into the uterus of a cuffed catheter which is positioned in the horn and through which fluid is introduced and/or removed, either in a continuous flow or by the to and fro method. With the surgical collection method positioning is done by entry through the uterine wall, but with non-surgical collection method, entry is made through the cervix. Therefore visualisation and control of the flushing technique are better in the case of the surgical method, and embryo collection tends to be improved by 10% to 20% over that which is obtained by non-surgical means.

Transfer.

The recipient should be a fertile heifer or young cow which can be expected to maintain a pregnancy and deliver a calf at full term. Such animals should be in good nutritional condition for at least 6 weeks before and after the transfer. Synchronisation of the oestrous cycle with that of the donor is an important pre-requisite, because if the difference is greater than 24 hours either way, there will be a drop in the expected pregnancy rate. Synchrony can be achieved either by selecting animals in oestrus from a large number of suitable cattle, or by artificial means, using PGF or progesterone-like compounds to achieve synchronisation.

Transfer can be made either by using surgical or non-surgical techniques. The surgical methods currently used involve either a mid-ventral or a flank approach, while the non-surgical methods involve a technique similar to that used in artificial insemination with entry being achieved through the vagina and cervix. With both methods the embryo is placed in the uterus close to the utero-tubal junction of the horn on the same side as the ovary which has a functional corpus luteum.
The embryo.

Embryos are flushed from the uterus using a special tissue culture medium which must be adequately buffered as it has been found that changes in pH can be far more detrimental than changes in temperature. These embryos are then assessed microscopically for viability before transfer to the recipient is undertaken. The highest pregnancy rates in recipient cows have been achieved with 6- or 7-day old embryos. At this age the embryo is generally at the morula or early blastocyst stage, although considerable variation can occur as to which stage of development is present.

Successful long term storage of embryos has been achieved by deep freezing in liquid nitrogen using di-methyl sulphoxide (DMSO) or glycerol as cryoprotectants. Best results have been obtained using 6.5- to 7.5-day old embryos. There have been reports of up to 60% of these frozen embryos resulting in pregnancies after thawing, but many operators have obtained pregnancy rates of only about 30% from embryos stored in this manner.

Results

Results from these procedures are difficult to compile due to the different transfer techniques used, the different methods for expressing results (e.g. embryos/ donor operated on or embryos/donor treated) and the reluctance of many commercial establishments to publicise results. In general it is assumed that 6 to 8 viable embryos per treated donor can be obtained, with rates of 3.8 to 5.1 pregnancies per donor operation from surgical methods. Since 1976 techniques for nonsurgical collection and transfer have improved considerably and results are only 10% to 20% lower than those obtained using surgical methods.

Repeat collections can be performed after 6 weeks using either technique, but if PMSG treatment is used to induce super-ovulation, 2nd and 3rd responses are not as successful as at the initial collection. This subsequent lack of response appears to be considerably reduced by the use of porcine anterior pituitary extract as an FSH source. To undertake repeated surgical collections at this frequency, a very high degree of surgical expertise is required.

Selection of the Donor

As with artificial breeding it is imperative that only donors of high genetic merit are used. With the possibility of obtaining up to 19 calves from one donor at one transfer, diffusion of genetic material through a population can be very rapid. It is a valid criticism that many cattle of the European exotic breeds which were submitted for embryo transfer in N.Z. in the 1970s were possibly undesirable animals, as far as some of their traits were concerned. Breed societies should examine all cattle being used for this procedure to safeguard against similar situations arising in the future.
Conclusions

The field of embryo transfer is an exciting one with a multitude of possibilities for both the commercial sector and the researcher. Advances made to improve understanding of complexities in the area of reproductive physiology have been considerable during the last 30 years. Further developments in the techniques of embryo storage, sexing of embryos and cloning (artificial production of identical twins), and the establishment of pools of genetic material will continue. Long-distance importation of livestock will almost certainly become dependent on the use of deep-frozen embryos. In addition the use of cloned animals as experimental subjects will reduce the numbers required for trials and scientific experiments in the future. Another application is breeding from valuable though infertile dams, a feat which has been accomplished already and will undoubtedly continue to be utilised.

Successful commercial application of these techniques in the cattle industry will necessitate considerable refinements of the procedures outlined in this paper, but it is feasible that in future a farmer may be able to order sexed embryos from selected parents in much the same way as artificial insemination is requested today. In this case the future may be less than fifteen years away.

Finally there needs to be a note of caution. Animal breeding techniques involving the whole field of genetic engineering are going to become commonplace in the near future, so it is important that all those involved in this field abide by strict codes of ethics to ensure that any outcome from their efforts is of positive and lasting benefit to both man and animal.

Bibliography


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