# SOME ASPECTS OF DYSTOCIA IN SHEEP WITH PARTICULAR REFERENCE TO ROMNEY STUD EWES

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Keith David McSporran
B.V.Sc. (Massey)

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## ABSTRACT

Three studies were undertaken to investigate dystocia in Romney stud ewes.

In the initial study an analysis was made of 4,400 individual performance records collected over a period of nine years from a Romney stud flock. On the basis of the records, dystocia in the flock was attributed to a physical disproportion between the lamb and the maternal pelvis, and its incidence was shown to be highly correlated with the mean birth weight of single lambs ($r=0.84$). Dystocia appeared to be unrelated to the effects of parity, weight at mating, or litter size of ewes. A high repeatability of the condition was demonstrated. Differences between sires with respect to dystocia in their progeny at birth were demonstrated in some years and were shown to be related to lamb weight, such that those sire groups with higher average lamb weight experienced the greatest incidence of dystocia. The decline in the incidence of dystocia, apparent from the records, was attributed to a reduction in mean birth weight of lambs and a possible increase in pelvic dimensions of the ewes, brought about by selective breeding.

Secondly, a tocometric study of 18 Romney ewes was made using intra-amniotic open ended catheters and intra-abdominal balloons implanted at laparotomy. Dystocia occurred in 12 ewes and, with the exception of one ewe that developed uterine inertia, was associated with abnormalities in presentation, position or posture (maldisposition) of the lamb at birth. By comparison, the presentation, position and posture (disposition) of the lambs born to the eutocous ewes was normal. A significant difference in birth weight of lambs was demonstrated between ewes that gave birth to lambs in normal disposition as opposed to those that gave birth to maldisposed lambs, and between ewes that experienced eutocia and dystocia. Uterine activity during late pregnancy, characterised by alternate periods of activity and quiescence, was not related to the disposition of the lamb at birth. During first stage labour uterine activity was higher in those ewes that experienced dystocia. However, this was considered to be a reflection of the higher lamb birth weight in this group as birth weight was correlated with uterine activity during the final three hours of first stage labour. Low abdominal bearing down effort was thought

to contribute to the lack of progress during parturition in three ewes with posteriorly presented foetuses. Except for one case of uterine inertia, low uterine pressures or abdominal bearing down effort was not implicated as a primary cause of dystocia in these ewes.

In the final study a method of radiographic pelvimetry was developed which was used to study the relationship between pelvic size and lamb size at birth in ewes with histories of eutocia and dystocia. In addition, three different age groups of ewes were radiographed to provide information on changes in pelvic dimensions with age. Large differences in respect to the relationship between estimated area of the pelvic inlet and the size of the lamb were demonstrated between ewes with histories of eutccia and dystocia. The relatively large pelvic area of the eutocous ewes was considered to be largely responsible for differences in the recorded incidence of dystocia between the groups. Estimates of correlations between internal and external pelvic measurements taken from the radiographs were thought to be too low to be of practical use in selection for larger internal pelvic area. Furthermore the relationship between internal and external pelvic measurements was found to alter with age in some cases, indicating that the effect of age on these relationships would have to be examined further if selection by means of external pelvic measurements were to be attempted.

As a result of these investigations, the hypothesis was advanced that dystocia in Romney stud ewes is commonly caused either by the relatively small size of the pelvic inlet of the ewe, or the relatively large size of the lamb, or both. There were indications from the first and third studies that the flock incidence of dystocia can be reduced by genetic selection.

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# I: INTRODUCTION

Parturition in domestic animals, whether for anthropomorphic or economic reasons, has attracted more attention from livestock breeders than almost any other physiological event. Yet, despite the zealous care and supervision of parturient animals, difficulties at parturition are still relatively frequent and particularly so in animals reared under intensive conditions.

In New Zealand dystocia has been shown to be of primary importance as a cause of peri-natal lamb mortality in both stud and grade flocks and represents a source of considerable economic loss to the sheep industry every year. On the basis of McFarlane's estimate of lamb losses from dystocia (McFarlane, 1955) an annual loss of in excess of 1,000,000 Romney lambs alone, can be expected from this cause. To this loss must be added the loss of a proportion of ewes and the high cost of labour for shepherding.

With the exception of recent pelvimetric studies few attempts have been made to elucidate the causal relationships involved in dystocia in sheep. As a result, past attempts to reduce the problem have been largely of an empirical nature.

This study was undertaken in the hope that it might contribute to a better understanding of the condition and by so doing assist in formulating a rational means of reducing its incidence in the national flock.

The following approach was taken:

## (1) A definition of the problem

A number of extensive lamb mortality surveys have shown the extent of lamb losses from dystocia in the national flock, however, no reliable information on dystocia under New Zealand conditions has been published. A study was therefore undertaken of a Romney stud flock in an attempt to define the problem of dystocia in the Romney stud ewe. The choice of a stud flock was primarily determined by the availability of accurate and comprehensive individual performance records and while it is recognised that this flock may not be representative of commercial flocks, or indeed other stud flocks, the paucity of reliable flock information relating to dystocia from other sources necessitated this approach. The particular stud selected was ideally suited to such a study because, through a personal interest in dystocia, the breeder had for some years collected information relating to the problem that was not normally recorded. The records were so extensive that it was not only possible to define the problem of dystocia in the flock but also to attempt to identify some of the factors responsible for the decline in the incidence of dystocia observed over recent years.

(2) An investigation of the basic causes of dystocia[1]

In terms of mechanical forces, the passage of the lamb during parturition could be expected to be influenced, firstly, by the expulsive forces of the uterine and abdominal muscles and, secondly, by the physical resistance of the genital tract of the ewe. Dystocia, then, may either be a manifestation of inadequate expulsive forces, high physical resistance to the passage of the lamb, or both. On this basis two studies were undertaken:

(a) In the first a comparison was undertaken of uterine pressures during parturition in ewes experiencing eutocia and dystocia. Uterine activity during the final two weeks of gestation was also recorded in an attempt to determine whether uterine activity before birth influenced foetal disposition[1] at parturition.

(b) The second study was of the nature of a comparison which was designed to determine whether differences in the relationship of lamb size to pelvic size existed between ewes with histories of eutocia and dystocia.

In section (b) the ewes with the histories of dystocia were all stud ewes, while in section (a) some of the ewes that experienced dystocia were commercial grade ewes. Because there was no apparent difference in dystocia between these two groups of ewes they were considered together.

[1] This term is defined in Appendix I

# II: LITERATURE REVIEW - DYSTOCIA IN SHEEP AND CATTLE

## II.1. Introduction

Few critical studies have been reported on the functional basis of dystocia in the ewe. Thus a review of dystocia in cattle, a species anatomically and physiologically related to the sheep, and in which understanding of birth difficulties is more advanced, is also included in this section of the thesis. Because of the considerable difference in understanding of dystocia between the two species the reviews are considered separately.

## II.2. Dystocia in Sheep

### II.2.1. Importance and incidence

On the basis of necropsy findings up to 64% of perinatal lamb deaths have been attributed to dystocia (Table II (i)). These estimates however, take no account of mortality resulting from the indirect effects of dystocia, for example, lambs that die from starvation as a result of impaired maternal behaviour which often follows a prolonged birth (Wallace, 1949; Alexander, 1960; Alexander and Peterson, 1961; Bray and Wodzicka-Tomaszewska, 1973). Consequently the losses could be expected to be greater than these necropsy studies indicate. Nevertheless it is unlikely that dystocia is primarily responsible for all parturient lamb deaths, since a significant proportion of lambs dying during birth have been shown to exhibit pre-parturient lesions, suggesting that dystocia may be secondary to pre- parturient disease in a proportion of cases (McFarlane, 1961).

In comparing the levels of dystocia reported by various authors in a number of breeds and from a number of countries, consideration must be given to the differing interpretations of what constitutes dystocia and to the lack of standardization of criteria on which these studies are based.

TABLE II (i): LAMB MORTALITY ATTRIBUTED TO DYSTOCIA (BASED ON NECROPSY FINDINGS)

| Source | Breed | Total dead lambs | Parturient deaths (%) |
|---|---|---|---|
| Moule (1954) | Merino | 453 | 4.9 |
| McFarlane (1955) | N.Z. Romney | 2,212 | 24.2 |
| Hartley and Boyes (1955) | N.Z. Romney | 288 | 29.9 |
| Safford and Hoversland (1960) | Rambouillet<br>Targhee<br>Columbia | 1,051 | 5.0 |
| Hartley and Boyes (1964) | N.Z. Romney | 880 | 26.3 |
| Hughes *et al.* (1964) | Merino | N R * | 11.0 |
| | Merino x B. Leicester | N R * | 16.0 - 26.0 |
| Smith (1964) | Merino | 981 | 12.0 |
| Dennis (1965) | Mixed | 4,417 | 20.4 |
| Trail and Sacker (1966) | East African - black headed | 208 | 0 |
| Hight and Jury (1969) | N.Z. Romney<br>N.Z. Romney x B. Leicester | 814 | 32.0 |
| Dennis and Nairn (1970) | Merino | 791 | 1.8 |
| Dennis (1970) | Southdown | N R * | 64.0 |
| Fogarty (1971) | Dorset Horn | N R * | 80.0 [1] |
| Gunnarsson *et al.* (1972) | Mixed Swedish breeds | 247 | 2.4 |

* N R - not recorded

[1] Assessment of cause of death not recorded

The report of Grommers (1967) for instance revealed that 77% of lambs delivered on three Dutch sheep farms were assisted at birth; from the reasons given for assistance however, it was estimated that a large proportion of these lambs would probably have been delivered spontaneously without human intervention. The incidence of dystocia reported in a number of studies is shown in Table II (ii).

TABLE II (ii): THE INCIDENCE OF DYSTOCIA IN SHEEP

| Source | Breed | Incidence (%) | Total ewes |
|---|---|---|---|
| Quinlivan *et al.* (1966 a) | N.Z. Romney | 28.6 | 111 |
| Gunn (1968) | Cheviot<br>Scottish Blackface | 4.2<br>2.5 | 15,584 |
| Naaktgeboren and Stegeman (1968) | Texel | 31.0 | 96 |
| Aamdal and Lyngset (1970) | Dala<br>Rygja<br>Sjeviot<br>Spael<br>Steigar | 24.3<br>26.5<br>18.2<br>2.6<br>7.9 | 1,237<br>543<br>671<br>998<br>709 |
| Buchi (1970) | Swiss White Alpine | 14.8 | N R * |
| Fogarty (1971) | Dorset Horn | 32.0 | N R * |
| Naaktgeboren *et al.* (1971) | Heath<br>Texel | 8.0<br>70.0 | 97<br>103 |

* N R - not recorded

Breed differences with respect to dystocia have been demonstrated by Hughes *et al.* (1964), Gunn (1968), Aamdal and Lyngset (1970) and Naaktgeboren *et al.* (1971) - see Tables II (i) & (ii). A genetic predisposition to dystocia has also been described in an experimental flock of Merino ewes selected for skin fold development (Dun and Hamilton, 1965). Although the mean body weight of the ewes with a high level of skin fold development was 5% lower than that of the ewes selected against this condition, the birth weights of their lambs were significantly higher, with the result that a high proportion experienced difficulties when giving birth.

## II.2.2. Immediate causes of dystocia

### II.2.2.1 Foeto-pelvic disproportion

The most common form of dystocia encountered by McHugh and Edwards (1958) and Dun and Hamilton (1965) was that associated with a physical disproportion between the correctly disposed lamb and the pelvis of the ewe. The latter reported that labour was arrested by impaction of the foetal shoulders in the pelvic inlet.

II.2.2.2. Foetal maldisposition[1]

The association between dystocia and foetal maldisposition has been reported by a number of authors (Alexander and Peterson, 1961; Grommers, 1967; Gunn, 1968; Naaktgeboren and Stegeman, 1968; Aamdal and Lyngset, 1970; Naaktgeboren et al., 1971). According to Quinlivan et al. (1966 a), Grommers (1967), Gunn (1968) and Naaktgeboren and Stegeman (1968) 13%, 62%, 67% and 65% respectively of lambs assisted at birth were maldisposed, while Aamdal and Lyngset (1970) reported that approximately 90% of assisted births were associated with maldisposition of the lamb in the five breeds included in their survey. Whether these marked differences in the relative importance of maldisposition of the lamb to dystocia are ascribable to differences in breed or management of the ewes is not clear.

Maldisposition of the lamb has been reported to be relatively common in sheep, the incidence varying from 8% to 43% of all lambs born (Table II (iii)). This can be compared with the incidence of 4.2% and 4.7% recorded in cattle by Dreyer (1965) and Grommers (1966) respectively and cited by Grommers (1967). The types of disposition described in three different breeds (Table II (iv)) indicate that irregularities of posture account for the majority of maldispositions. The forms most commonly associated with dystocia appear to be flexion of one or both shoulders (46% - 71%), posterior presentations (16% - 17%), and flexion of the neck (6% - 22%) (Grommers, 1967; Gunn, 1968; Aamdal and Lyngset, 1970).

1 This term is defined in Appendix I

TABLE II (iii): THE INCIDENCE OF MALDISPOSED LAMBS AT BIRTH IN SHEEP

| Source | Breed | Country | Incidence (%) | Total lambs born |
|---|---|---|---|---|
| Wallace (1949) | Romney | New Zealand | 30 | 283 |
| Alexander and Peterson (1961) | Merino | Australia | 16 | 50 |
| Grommers (1967) | Texel | Holland | 29 | 434 |
| Naaktgeboren and Stegeman (1968) | Texel | Holland | 26 | 42 |
| Naaktgeboren *et al.* (1971) | Texel | Holland | 43 | 195 |
| | Heath | Holland | 8 | 97 |

Grommers (1967) maintained that there was a positive relationship between the relative or absolute size of the lamb and the occurrence of maldisposition. A similar conclusion was reached by Naaktgeboren *et al.* (1971) who attributed the higher incidence of maldisposed lambs found in purebred Texel ewes compared with that recorded by previous authors in grade flocks (Grommers, 1967; Naaktgeboren and Stegeman, 1968) to selective breeding for large "square built" lambs, with no adaptive increase in the size of the pelvis of the ewes. Naaktgeboren *et al.* (1971) also showed that the incidence of maldisposed lambs was similar in twin and single births indicating that litter size *per se* had no appreciable effect.

### II.2.2.3. Non-dilatation of the cervix uteri

A form of dystocia colloquially known as 'ring womb' and characterised by failure of the cervix to dilate, has been reported in the ewe (Edwards, 1952; McKinnon and Bayliss, 1952; Edwards and Jones, 1957; Gibson, 1957; Malone, 1957; Walsby, 1957; Ellis, 1958; Straiton, 1960; Hindson and Turner, 1962). The incidence of the condition has not been reported, although it is believed to vary both between season and locality with lowland sheep being more often affected than hill country sheep. Ewes carrying twin lambs appear to be more commonly affected than those carrying singles (Hindson and Turner, 1962).

TABLE II (iv): TYPES OF FOETAL DISPOSITION SEEN IN SHEEP WITH THEIR FREQUENCIES OF OCCURRENCE (From Wallace, 1949 and Naaktgeboren *et al.*, 1971)

| Foetal disposition | Breed of ewe: Texel | Heath | Romney |
|---|---|---|---|
| I ANTERIOR PRESENTATION | | | |
| (i) Lumbo-sacral position | | | |
| Extended posture | 111 | 89 | 191 |
| Shoulder flexion (unilateral) | 26 | 1 | 49 |
| Shoulder flexion (bilateral) | 9 | 1 | 18 |
| Elbow flexion (unilateral) | 7 | 1 | |
| Elbow flexion (bilateral) | 7 | 3 | Others |
| Carpal flexion | 1 | | 17 |
| Neck flexion | 9 | | |
| Vertex presented | 4 | | |
| Neck and shoulder flexion | 1 | | |
| Head beside forelegs | 1 | | |
| Head between forelegs | 2 | | |
| Carpal and tarsal flexion | 1 | | |
| Tarsal flexion | 3 | | |
| Fetlock flexion | 1 | | |
| (ii) Ventro-sacral position | | | |
| Extended posture | 2 | 1 | |
| Shoulder flexion (unilateral) | 1 | | |
| Neck flexion | | 1 | |
| (iii) Lateral position | | | |
| Extended posture | 3 | | |
| II POSTERIOR PRESENTATION | | | |
| (i) Lumbo-sacral position | | | |
| Extended posture | 4 | | |
| Tarsal flexion (unilateral) | 1 | | |
| III TRANSVERSE PRESENTATION | | | |
| Back presented | 2 | | |
| Total lambs born | 196 | 97 | 275 |

A condition simulating 'ring womb' has been produced in ewes injected with 20 mg of diethyl stilboestrol during pregnancy. Intra-uterine pressure tracings from these ewes could not be distinguished from those of ewes that did not develop the condition (Hindson et al., 1967; Hindson and Turner, 1969), and it was tentatively concluded that 'ring womb' is primarily a functional disorder of the cervix possibly resulting from an endocrine disturbance. In support of this view it has been observed that 'ring womb' may be produced in ewes to which suboptimal levels of a corticosteroid (Dexamethasone) have been administered for the advancement of parturition (G.C. Liggins - personal communication). Plasma progesterone levels, which normally decline to a low level prior to labour in the sheep (Liggins et al., 1972), are said to be maintained at pre-treatment levels in these ewes.

II.2.2.4. Vulval stenosis and uterine inertia

Bennetts (1944) and Bennetts et al. (1946) reported on a hitherto undescribed form of dystocia in sheep. Dystocia appeared as one manifestation of a serious breeding problem which was first recognised in Western Australia in 1941. The other two important features of the disease were infertility of the ewes, and prolapse of the uterus, often some time after lambing. The problem was confined to pastures of the Dwalganup strain of early subterranean clover (Trifolium subterranean.L.var.Dwalganup). The dystocia was considered to be of maternal origin resulting from primary uterine inertia and was characterised by lack of evidence of external signs of parturition and the death of the full term foetus. Quite commonly the incidence of the condition was high, accounting for the death of 30% - 40% of lambs carried to full term and the death of 15% - 20% of all ewes mated. The incidence in the more susceptible groups, notably ewes first mated at 2½ years was often considerably higher; for example, a mortality of 40% - 50% of ewes was cited. Merino and Corriedale ewes were more susceptible to dystocia than crossbreds formed by crossing the Romney Marsh, Border Leicester and English Leicester breeds with the Merino. Pelvic measurements of ewes experiencing trouble were reported to be within the normal range. The disease was thought to have an endocrine basis and was tentatively attributed to oestrogenic compounds or precursors in the clover. Underwood et al. (1953, 1959) were later able to reproduce the clinical disease by administering diethyl stilboestrol to ewes. A high level of infertility was induced by all treatments, and in the few ewes that did conceive, dystocia was common.

More recently, Maxwell (1970) has described four outbreaks of maternal dystocia occurring in one season in Merino ewes grazing subterranean clover in Western Australia (Table II (v)). Initially the ewes appeared to be in normal second stage labour but on closer examination the lamb, in anterior presentation, was found to be lying immediately behind the vulva which was contracted as in the non-parturient state. Parturition was accomplished only by a great deal of traction and, in some cases, an episiotomy was found to be necessary. Mean birth weight of lambs dying during dystocia was $3.6 \pm 0.47$ kg, within the normal range for this breed.

TABLE II (v): INCIDENCE OF DYSTOCIA IN FOUR FLOCKS (MAXWELL, 1970)

| Flock | Ewes lambing | % with dystocia |
|---|---|---|
| 1 | 99 | 30.3 |
| 2 | 109 | 11.9 |
| 3 | 89 | 16.8 |
| 4 | 67 | 16.4 |

The apparent difference between these clinical observations and those of Bennetts et al. (1946) probably stems from the time relative to parturition at which they were made. It was suggested by Maxwell (1970) that the uterine inertia described by Bennetts et al. (1946) was probably secondary to the obstruction caused by the undilated vulva since the frequent occurrence of a contracted vulva had been described by these authors.

With the introduction of modern hormone assay techniques efforts were directed to elucidating the patho-physiology of this disease. Thus in 1971 Obst et al. examined the plasma progesterone levels of ewes grazing Yarloop clover (*Trifolium* subterranean. L.var.Yarloop) and rye grass. While the pattern of change during pregnancy was similar in the two groups, the mean values determined from day 90 of gestation in ewes grazing Yarloop clover were significantly lower than for those grazing on grass. Some of those ewes grazing Yarloop clover experienced dystocia whereas all births in the rye grass group were normal. Lamb weights in the two groups were comparable. The authors suggested that the low level of progesterone was not itself instrumental in producing the effects. Rather it reflected a more general metabolic and endocrine disturbance which was the cause of the dystocia. The transitory rise in free plasma oestrogens normally seen 16 - 24 hours before birth in the ewe (Liggins et al., 1972), was apparently neither inhibited nor enhanced in ewes grazing Yarloop clover (Obst and Seamark, 1972 a) although in a subsequent study Obst and Seamark (1972 b) were able to show that oestrogen levels in maternal plasma tended to be higher in ewes grazing Yarloop clover than those seen in ewes grazing rye grass, with significant differences existing between days 119 - 120 and days 140 - 145 of gestation. Moreover, plasma corticoid levels of these ewes were significantly higher between 120 - 140 days of gestation and a significant positive relationship was demonstrated to exist eight hours before birth between plasma corticoid concentrations and the duration of labour.

Today the incidence of the more spectacular signs of this syndrome, dystocia and uterine prolapse, has declined, either as a result of control measures adopted by the farmer or through a change in pasture composition from clover to grass dominance.

### II.2.3. The influence of the lamb on dystocia

Dystocia and lamb mortality resulting from dystocia have been widely reported to increase with birth weight of the lamb (Alexander et al., 1955; McHugh and Edwards, 1958; Alexander and Peterson, 1961; Gunn and Robinson, 1963; Hartley and Kater, 1964; Hughes et al., 1964; Purser and Young, 1964; Smith, 1964; Dennis, 1965, 1970: Gunn, 1968; Hight and Jury, 1969; Fogarty, 1971; Naaktgeboren et al., 1971). The higher birth weight of single and ram lambs (Dun and Hamilton, 1965; Fogarty, 1971) probably explains the reported higher incidence of dystocia in these categories (Gunn and Robinson, 1963; Purser and Young, 1964; Dun and Hamilton, 1965; Gunn, 1968; Hight and Jury, 1969; Dennis, 1970; Fogarty, 1971). In horned breeds delivery of male lambs has been found to be further prolonged by the presence of well developed horn buds at birth (Fogarty, 1971; Naaktgeboren et al., 1971).

### II.2.4. The influence of the ewe on dystocia

The incidence of dystocia has been reported by some authors to be higher in primiparous than in multiparous ewes. Purser and Young (1964) found that 3.2% and 1.6% of lambs from Scottish Blackface maiden and older ewes respectively died as a result of dystocia. The corresponding figures for Welsh Mountain ewes were 1.4% and 1.2%. These results are unfortunately based on the subjective assessment of cause of death since no necropsies were performed and, for this reason, should be interpreted with some reservations. In a study conducted by McDonald (1966) 26% of perinatal deaths in maiden three year old ewes was attributed to dystocia. The proportion of deaths from dystocia in the 4, 6 and 7 year old ewes was 3.7%, 7.9% and 4.3%. Also Fogarty (1971) stated that in autumn 30% of maiden ewes were assisted at birth compared with 20% of older ewes. In spring the proportions assisted were 48% and 35% respectively. He considered that the higher rate of twinning, as well as the culling of some ewes because of lambing trouble, contributed to the lower level of dystocia observed in the older ewes. Clearly more information from more representative flocks than those described by McDonald (1966) and Fogarty (1971) needs to be collected before an accurate assessment of the effect of age and parity of the ewe on dystocia can be made.

Recent studies by Quinlivan (1971), Naaktgeboren et al. (1971) and Fogarty and Thompson (1974) have implicated the size of the maternal pelvis in dystocia in sheep. These authors have demonstrated differences in the area of the pelvic inlet between groups of ewes classified on the basis of their past lambing performance. A detailed discussion of the relationship of pelvic dimensions with dystocia is presented later (see V.2.3.7.).

Inasmuch as lamb weight is influenced by nutrition of the ewe (Thomson and Fraser, 1939; Underwood and Shier, 1942; Underwood et al., 1943; Wallace, 1948; Barnicoat et al., 1949; Thomson and Thomson, 1948, 1953; Coop, 1950; Palsson and Verges, 1952; Russel et al., 1967), and lamb size is associated with dystocia (see II.2.3.) nutrition is likely to influence the incidence of this condition. It is therefore surprising that no reliable evidence linking nutrition and dystocia has been published.

## II.3. Dystocia in Cattle

### II.3.1. Importance and incidence

As in sheep, dystocia in cattle has been established as an important cause of perinatal calf mortality (Woodward and Clark, 1959; Politiek, 1965; Lindhé, 1966; Anderson and Bellows, 1967; Heiman, 1968; Laster and Gregory, 1973; Young and Blair, 1974). In addition, undesirable effects on subsequent reproductive performance, including a longer interval between calving and conception, a lower conception rate, lower weaning weights and less calves weaned at the following calving, have been reported (Van Dieten, 1963 cited by Politiek, 1965; Brinks et al., 1973; Laster et al., 1973).

Losses of 1.1% and 0.9% of calves born in mixed and dairy herds in Britain were attributed to dystocia by Withers (1953) and Wright (1958), while Young (1968 a) and Rice and Wiltbank (1972) recorded losses of 14.6% and 10% of calves from beef heifers in their respective studies. It is primarily in the field of beef production that in recent years vigorous efforts have been directed toward reducing this important source of economic loss.

The incidence of calving difficulties reported from a number of studies is shown in Table II (vi). Breed differences with respect to dystocia have been reported by some authors. For instance, it has been shown that Friesian cattle experience more difficulties at calving than Ayrshire cattle (Wright, 1958; Anon., 1960; Monteiro, 1969), while the report of Boudon (1961) cited by Anon. (1963) indicates that the incidence of dystocia in the French Charolais is higher than that observed in most British breeds, the difference being particularly pronounced in primiparas. The accentuation in primiparas of between breed differences in dystocia has also been noted by Lindhé (1966). In general, the larger breeds of cattle experience more calving difficulties than do the smaller breeds (Monteiro, 1969; Mason, 1971). A similar trend has been noted in sheep (Aamdal and Lyngset, 1970).

TABLE II (vi): THE INCIDENCE OF DYSTOCIA IN CATTLE

| Source | Breed | Country | Incidence (%) | Total No. Parturitions |
|---|---|---|---|---|
| Withers (1953) | Mixed dairy and beef | Britain | 2.1 | 9,123 |
| Wright (1958) | Friesian | Britain | 8 | 436 |
| | Friesian | Britain | 11.7 | 119 |
| | Ayrshire | Britain | 2.7 | 788 |
| | Ayrshire | Britain | 3 | 754 |
| Anon. (1960) | Friesian | Britain | 8.8 | N R * |
| | Ayrshire | Britain | 2.5 | N R * |
| Boudon (1961) cited by Anon. (1963) | Charolais - heifers | France | 36.7 | N R * |
| | Charolais - cows | France | 12.1 | N R * |
| Young (1968 a) | Mixed beef breeds - heifers | Australia | 15 | 777 |
| | Mixed beef breeds - heifers | Australia | 13.5 | 419 |
| Monteiro (1969) | Friesian | Britain | 40 | 70 |
| | Ayrshire | Britain | 8.5 | 82 |
| | Jersey | Britain | 0 | 42 |
| Rice and Wiltbank (1972) | Angus heifers | United States | 35.6 | 93 |
| | Hereford heifers | United States | 83 | 90 |

* N R not recorded

Within recent years crossbreeding has been introduced in a number of countries in an attempt to increase the beef production of the existing beef and dairy breeds. A popular breed in this respect has been the Charolais. This breed was probably first used to cross with Jersey cattle in Denmark (Hansen, 1966) where it was instrumental in improving the beef production of calves from dairy herds. Subsequently it was mated with a number of indigenous British and European breeds, which, almost without exception, experienced increased calving difficulties as a consequence (Anon., 1960; Anon., 1963; Reyneke and Penzhorn, 1964; Anon., 1966; Hansen, 1966; Lindhé, 1966; Sagebiel et al., 1969; Laster and Gregory, 1973; Laster et al., 1973). Almost all the increased dystocia was associated with male Charolais cross calves which, because of their large size, experienced difficulty passing through the maternal pelvis (Anon., 1963). A report by Creek and Nestel (1962) however, which described the use of Charolais sires in grade herds in Jamaica, indicated that dystocia was not a problem under their conditions. They recorded five dystocias from 467 calvings over a period of four years, only one of which was caused by foeto-pelvic disproportion.

More recently other breeds, for example, the Simmental, Limousin and South Devon, have been investigated for use in crossbreeding programmes. Reports to date indicate that these breeds are also likely to increase calving difficulties when they are bred to existing beef breeds (Anon., 1970: Laster et al., 1973).

It appears that crossbreeding per se does not reduce the incidence of dystocia in cattle (Laster and Gregory, 1973: Laster et al., 1973), although crossbred calves experiencing dystocia may have a higher survival rate than purebred calves (Laster and Gregory, 1973). A summary of the results of some large crossbreeding experiments appears in Table II (vii).

TABLE II (vii): CROSSBREEDING AND DYSTOCIA IN CATTLE

| Source | Sire | Dam | Dystocia (%) | Total No. of parturitions |
|---|---|---|---|---|
| Anon. (1963) (Brita n) | Charolais | Friesian | 15.4 | 162 |
| | Charolais | Ayrshire | 18.8 | 170 |
| | Friesian | Friesian | 5.1 | 138 |
| | Ayrsh re | Ayrshire | 3.5 | 257 |
| Anon. (1965) (Britain) | Charolais | British dairy breeds | 9.5 | 1,462 |
| | Hereford | British dairy breeds | 1.9 | 929 |
| | Purebred matings | British dairy breeds | 1.7 | 1,474 |
| Hansen (1966) (Denmark) | Charolais | Jersey | 13.3 | 376 |
| Lindhé (1966) (Sweden) | Swedish Red and Wh te | Swedish Red and Wh te | 8.7 | 218 |
| | Swedish Friesian | Swedish Red and White | 13.1 | 267 |
| | Red Danish Milk breed | Swedish Red and Wh te | 12.2 | 131 |
| | Angus | Swedish Red and White | 4.1 | 218 |
| | Hereford | Swedish Red and White | 12.8 | 257 |
| | Charolais | Swedish Red and White | 17.3 | 164 |
| Klosterman et al. (1968) (United States) | Hereford | Hereford | 11.2 | 98 |
| | Charolais | Charolais | 14.0 | 107 |
| | Hereford | Charolais | 5.4 | 55 |
| | Charolais | Hereford | 33.3 | 54 |
| Bellows et al. (1971 a) (United States) | Hereford | Angus | 50.5 | 103 |
| | Angus | Hereford | 44.2 | 95 |
| Laster and Gregory (1973) (United States) | Brown Swiss | Brown Swiss | 12.9 | 298 |
| | Red Poll | Red Poll | 16.2 | 387 |
| | Hereford | Hereford | 30.1 | 357 |
| | Angus | Angus | 17.0 | 324 |
| | Angus | Hereford | 22.6 | 381 |
| | Hereford | Angus | 23.4 | 464 |
| | Jersey | Hereford | 10.9 | 129 |
| | Jersey | Angus | 6.6 | 181 |
| | South Devon | Hereford | 28.6 | 119 |
| | South Devon | Angus | 32.5 | 120 |
| | Limousin | Hereford | 24.4 | 355 |
| | Limousin | Angus | 18.2 | 347 |
| | Simmental | Hereford | 26.6 | 411 |
| | Simmental | Angus | 16.4 | 503 |
| | Charolais | Hereford | 39.4 | 198 |
| | Charolais | Angus | 28.5 | 221 |
| | Charolais | Charolais x Hereford | 41.4 | 133 |
| | Charolais | Charolais x Angus | 45.6 | 136 |

## II.3.2. Immediate causes of dystocia

### II.3.2.1. Foeto-pelvic disproportion

Foeto-pelvic disproportion was reported to be responsible for 55% and 46% of dystocia encountered in mixed age cattle by Wright (1958) and Sloss and Johnston (1967) respectively while in studies involving primiparous dams incidences of 42% - 90% have been recorded (Anon., 1960; Williams, 1968; Rice and Wiltbank, 1972). Some authors (Williams, 1968; Rice and Wiltbank, 1972) state that the condition is most often observed in primiparous dams but provide no supporting evidence. However, Morten and Cox (1968) undertook a statistical analysis of 50 cases of foeto-pelvic disproportion and demonstrated a significantly high incidence in primiparous dams and in births involving male calves, thus supporting this view.

Breed differences with respect to foeto-pelvic disproportion have also been reported. A study of dystocia in Friesian and Ayrshire heifers following purebred matings, showed that a significantly high proportion of dystocia in the Friesian heifers was attributed to foeto-pelvic disproportion (Anon., 1960). When the results of mixed breed matings were analysed, no differences in this respect could be demonstrated between the two breeds of heifers. Boudon (1961) cited by Anon. (1963) reported that a high proportion (75%) of difficulties encountered in Charolais cattle was attributable to this cause.

Foeto-pelvic disproportion has been reported to lead to the arrest of labour through impaction of the humero-radial joints in the pelvic inlet, friction between the foetal head and the first sacral vertebra or the inability of the foetal iliac bones to pass through the pelvic inlet (Williams, 1968; Young, 1968 b).

### II.3.2.2. Maldisposition of the foetus

According to Tutt (1944), Wright (1958), Anon. (1960), Donald (1963) and Sloss and Johnston (1967), 78%, 27%, 24%, 61% and 26% respectively of calves which were assisted at birth exhibited some form of maldisposition. Deviations of presentation and posture have been shown by Tutt (1944) and Morten and Cox (1968) to account for the majority of maldispositions associated with dystocia in the bovine species.

In anterior presentation lateral deviation of the head and flexion of the shoulder, elbow and carpus are the most frequent forms of malposture observed (Tutt, 1944; Morten and Cox, 1968) with there being apparently no difference in their incidence between single and twin births (Morten and Cox, 1968).

Although the majority of calves assisted at birth is presented anteriorly, on the basis of Williams' (1931) estimate that only 5% of calves born in cattle are posteriorly presented, the reported incidence of posterior presentations amongst assisted births of from 32% to 50% (Wright, 1958; Donald, 1963; Sloss and Johnston, 1967; Young, 1968 b), is disproportionately high and indicates that a high proportion of posteriorly presented calves experience difficulties at birth. Deviations of posture in posterior presentation commonly involve flexion of the hock or hip joints and, in contrast to those in anterior presentation, are reported to occur significantly more frequently in twin than in single births (Tutt, 1944; Morten and Cox, 1968).

The cause of foetal maldisposition is not clear. Dufty (1972) has reported an instance of carpal flexion which was produced by marked to and fro movement along the birth canal during a series of abdominal contractions, while posterior presentations have been associated with excessively fat heifers (Wiltbank et al., 1965) and in one report with a particular sire (Woodward and Clark, 1959). Size of calf appears to play little part in the determination of this type of presentation, since posteriorly presented calves have been shown not to differ significantly in weight from those born unassisted within the same sex and age of dam classes (Laster and Gregory, 1973) or from calves assisted in anterior presentation (Morten and Cox, 1968). These latter authors did show, however, that a high proportion of posterior presentations occurred in twin births, suggesting that lack of uterine space may play a part in bringing about this malpresentation, possibly by preventing the calf from turning in utero.

**II.3.2.3.** Functional stenosis of the posterior vagina and vulva

A form of dystocia described in beef cattle which is characterised by functional stenosis of the posterior vagina and vulva was reported by Rice and Wiltbank (1972) and Dufty (1972). In their respective studies this condition accounted for 55% and 27% of all difficulties encountered at birth. The cattle appeared to have little difficulty forcing the calf through the pelvic inlet early in labour, but further progress was prevented by the presence of a distinct unyielding band corresponding with the *constrictor vestibuli* muscle (Sisson, 1953) at the junction of the posterior vagina and vulva. On the basis of the differences in the incidence of the condition observed between supervised and unsupervised heifers during the investigation, Dufty (1972) proposed that excessive interference both prior to and during labour was responsible for the problem and suggested that the constriction was possibly mediated by excessive sympathetic stimulation.

**II.3.2.4.** Incomplete cervical dilatation, and uterine inertia

Both of these conditions have been reported to occur in cattle (Arthur, 1964; Morten and Cox, 1968; Roberts, 1971) but there is no critical information on either in the literature.

**II.3.3.** The influence of the dam

**II.3.3.1.** The effect of age and parity of the dam

The incidence of dystocia in heifers has been convincingly shown to exceed that in multiparous animals (Table II (viii)).

TABLE II (viii): THE INFLUENCE OF PARITY OF THE DAM ON THE INCIDENCE OF DYSTOCIA

| Source | Dystocia (%) Primiparae | Multiparae | Total No. of parturitions |
|---|---|---|---|
| Withers (1953) | 3.8 | 2.1 | 9,123 |
| Boudon (1961) cited by Anon.(1963) | 36.7 | 12.1 | N R * |
| Donald (1963) | 4.0 | 1.8 | 2,002 |
| Heiman (1968) | 9.1 | 1.6 | 61,596 |
| Monteiro (1969) | 19.9 | 4.1 | 458 |
| Brinks et al. (1973) | 29.7 | 5.1 | 2,534 |

* N R not recorded

This difference was considered to be primarily an effect of parity rather than age by Van Dieten (1963) cited by Politiek (1965), Politiek (1965) and Young (1968 a), although there is not complete agreement on this point in the literature. Young (1968 a), for example, failed to demonstrate any difference in dystocia between two groups of heifers first calving at two and three years of age, whereas Lindhé (1966) maintained that peri-natal mortality, which was closely linked with dystocia, was higher in calves born to heifers calving at less than two years than in those calving between two and four years. The occurrence of dystocia has been shown to decline progressively with increasing parity (Anderson and Bellows, 1967; Brinks et al., 1973; Laster et al., 1973) through to about 10 years of age, when the problem again becomes more frequent (Brinks et al., 1973).

### II.3.3.2. The influence of the genotype of the dam on dystocia

The influence of the dam on dystocia has been demonstrated by a number of authors in crossbreeding experiments, although the results are by no means consistent. For example, Hereford cows experienced significantly more difficulties than Angus cows in the studies of Laster and Gregory (1973) and Laster et al. (1973), while Angus cows experienced significantly more difficulties than Hereford, and Hereford and Charolais cows respectively in the studies of Bellows et al. (1969) and Sagebiel et al. (1969).

Apart from the genetic differences associated with different breeds, genetic differences between paternal half sib groups of dams have been shown to exert a significant influence on dystocia and peri-natal mortality (Van Dieten, 1963 cited by Politiek, 1965; Dreyer, 1965 cited by Lindhé, 1966; Smidt and Cloppenburg, 1967; Brinks et al., 1973). Paternal half sibs from sire lines which produced over 13% of dystocia in their progeny were themselves shown to experience a high proportion (over 12%) of dystocia by Brinks et al. (1973).

Levels of inbreeding of the calf and the dam have also been shown to affect the occurrence of dystocia (Brinks et al., 1973). At low levels of inbreeding the incidence of dystocia was below the herd mean, but at higher levels of inbreeding (above 30%) increased difficulties were encountered.

Estimates of the heritability of dystocia considered as a trait of the dam have been calculated by Brinks et al. (1973) and Smidt and Cloppenburg (1967). They reported heritabilities of 0.13 and 0.04 in cows and 0 and 0.04 in heifers in their respective studies. Brinks et al. (1973) interpreted their findings as evidence that genotype of the dam is somewhat more important in determining dystocia in older age groups of dams than among two year old heifers. When dystocia was considered as a trait of the calf, the heritability in cows was calculated to be 0.07 and in heifers 0.13 suggesting that genotype of the calf is more important in contributing to dystocia in heifers than in older dams (Brinks et al., 1973). This explanation would seem to be borne out by the finding that between sire differences in dystocia are greater when sires are mated with heifers than they are when the same sires are mated with cows (see II.3.4.). It is clear from these estimates however, that additive genetic effects are of minor importance in determining calving difficulty.

### II.3.3.3. The influence of pelvic size on dystocia

The importance of pelvic size to normal parturition was demonstrated by Wiltbank and Le Fever (1961) by attempting to predict dystocia from pelvic measurements in a group of three year old heifers. Seventy per cent of those with pelvic areas below 230 $cm^2$ experienced difficulties compared with 12% in those with pelvic areas above 230 $cm^2$. Since this report several authors have noted a significant negative relationship between dystocia and the area of the pelvic inlet (Young, 1968 b, 1970; Bellows et al., 1971 a; Rice and Wiltbank, 1972; Laster, 1974). Rice and Wiltbank (1972) and Laster (1974) showed that pelvic area was the principal maternal determinant of dystocia, a finding confirmed by Bellows et al. (1971 a) in Hereford cattle but not in Angus cattle. Although pelvic area exerted a significant influence on dystocia in Angus cattle in this study, pre-calving body weight was found to be more important, possibly as a result of sub-optimal body weights for calving in this group as opposed to the Herefords. The use of pelvic measurements to predict dystocia at breeding time in heifers destined to calve at two years however, appears to be limited by the low variability in pelvic dimensions at this age and the overriding influence of calf birth weight on dystocia (Rice and Wiltbank, 1972).

Level of nutrition during the final third of pregnancy has been shown to affect pelvic growth such that the reduced pelvic growth which occurs in animals on a low plane of nutrition results in a similar incidence of dystocia to that observed in animals on a high plane of nutrition, despite significantly reduced calf birth weights (Young, 1970). A similar finding has been reported by Bellows et al. (1971 a) in relation to the effect of nutrition during the first half of gestation on dystocia. They were able to show that weight gains in beef heifers during the first half of pregnancy were significantly related to pre-calving pelvic area, and that although pre-calving pelvic area was positively correlated with calf birth weight, it was negatively correlated with dystocia as a result of the predominant influence of nutrition on the size of the pelvic inlet.

## II.3.3.4. The influence of nutrition on dystocia

Studies on the effects of different levels of nutrition during pregnancy have revealed no marked effect on the incidence of dystocia (Young, 1970; Scarth and Dorton, 1972; Tudor, 1972; Wiltbank and Price, 1973; Laster, 1974). Although it has been possible, using different nutritional levels, to influence calf birth weight by the order of 2 - 3 kg, skeletal size of the calf is apparently not affected, the changes in birth weight being referable to changes in soft tissue (Laster, 1974). Presumably these changes are of less importance to dystocia than genetic or environmental factors that affect skeletal size of the calf at birth. An increase in calving difficulties has been described however in heifers fed high levels of nutrition from weaning to first calving (Wiltbank *et al.*, 1965). These animals were excessively fat and, although calf birth weight was the same as that recorded in the moderately nourished group, dystocia occurred more frequently. The reason for the increased difficulties appeared to be a high incidence of posterior presentations and restriction of the size of the pelvic canal by excess fat.

## II.3.3.5. Dystocia referable to pathology of the pelvis and reproductive tract

Dystocia frequently occurs in association with a number of well recognised conditions of the female reproductive tract. Congenital defects resulting in dystocia include hymeneal constriction (Tutt, 1944; Spriggs, 1945) and partial duplication of the anterior vagina (Spriggs, 1946) while acquired conditions, often traumatic in origin, include uterine torsion, rupture of the pre-pubic tendon, rupture of the uterus and pelvic fracture (Arthur, 1964; Roberts, 1971). As a group these pathological conditions tend to be sporadic in nature and in the total context of the problem are of relatively minor significance.

## II.3.4. The influence of the sire

Considerable variation has been reported to exist between sires and sire lines with respect to the incidence of dystocia (Van Dieten, 1963 cited by Lindhé, 1966; Anon., 1965; Politiek, 1965; Heiman, 1968; Brinks *et al.*, 1973; Wiltbank and Price, 1973) and peri-natal mortality (Van Dieten, 1963 cited by Lindhé, 1966; Politiek, 1965; Heiman, 1968) in their progeny. An example of these differences recorded in heifers by Heiman (1968), is shown in Table II (ix).

TABLE II (ix): INFLUENCE OF THE SIRE ON THE INCIDENCE OF DYSTOCIA AND PERI-NATAL MORTALITY

| Sire | No. Heifers | % Dystocia | % Dead at birth |
|---|---|---|---|
| A | 2,144 | 4.9 | 7.0 |
| B | 105 | 6.6 | 8.6 |
| C | 1,875 | 9.2 | 12.9 |
| D | 192 | 11.4 | 15.1 |
| E | 100 | 11.0 | 16.0 |

Defining the manner in which the sire exercises this influence has proved difficult. For example, Van Dieten (1963) cited by Arthur (1966) and Bannerjee-Schotsman (1964) cited by Politiek (1965) reported that although it was generally true that heavy calves experienced more difficulties than light calves, it was clear that the living calves of some sires had a higher mean birth weight than the calves of other sires which died at parturition.

These sire differences in dystocia and peri-natal mortality are reported to be most pronounced when the bulls are mated with primiparas (Van Dieten, 1963 cited by Politiek, 1965; Politiek, 1965; Lindhé, 1966; Heiman, 1968). An analysis of 109,329 births in the Dutch Red and White breed, corresponding to 25 progeny groups, revealed that the incidence of calves dead at birth from heifers ranged from 4.7% to 39.4%. The corresponding figures for the two bulls responsible for these divergent levels of peri-natal mortality when mated to cows, were 2.8% and 6.5% respectively (Van Dieten, 1963 cited by Politiek, 1965).

Further evidence for the effect of the sire on dystocia comes from reductions of calf mortality in heifers that have been noted following the use of sires selected against peri-natal mortality. Heiman (1968) recorded an incidence of peri-natal mortality of 5.8% when such sires were mated with heifers, a reduction of more than a third. A similar decline was noted by Politiek (1965) when citing Van Dieten's findings in 1963 (see Table II (x)).

TABLE II (x): THE EFFECT ON PERI-NATAL MORTALITY OF USING SIRES SELECTED AGAINST THIS TRAIT IN AN ARTIFICIAL BREEDING PROGRAMME INVOLVING HEIFERS

| Year | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 |
|---|---|---|---|---|---|---|---|---|---|
| Peri-natal deaths % | 15.9 | 13.2 | 12.9 | 11.5 | 9.2 | 7.7 | 7.8 | 8.0 | 6.4 |

## II.3.5. The influence of the calf on dystocia

### II.3.5.1. The effect of birth weight

Many authors have reported a positive influence of birth weight of the calf on dystocia (Anon., 1963; Politiek, 1965; Monteiro, 1969; Sagebiel *et al.*, 1969; Young, 1970; Nelson and Huber, 1971; Rice and Wiltbank, 1972; Laster *et al.*, 1973; Laster, 1974). Further to this, Bellows *et al.* (1971 a), Rice and Wiltbank (1972) and Laster (1974) have shown that calf birth weight is the principal determinant of dystocia in heifers calving at two years of age.

II.3.5.2. The effect of calf sex

Male calves are in general heavier at birth than female calves (Hansen, 1966; Klosterman et al., 1968; Sagebiel et al., 1959; Nelson and Huber, 1971; Laster et al., 1973) and probably as a result of this weight difference, experience more dystocia than female calves. This is illustrated in Table II (xi).

TABLE II (xi): INFLUENCE OF CALF SEX ON INCIDENCE OF CALVING DIFFICULTIES

| Source | Incidence of dystocia (%) Male calves | Female calves | Total calves born | Total births |
|---|---|---|---|---|
| Anon. (1963) | 24 | 10 | 380 | |
| | 8 | 5 | 254 | |
| Hansen (1966) | 17 | 10 | 360 | |
| Sagebiel et al. (1969) | 41 | 32 | 46 | |
| Bellows et al. (1971 a) | 67 | 27 | | 95 |
| | 63 | 34 | | 103 |
| Nelson and Huber (1971) | 30 | 15 | 231 | |
| Brinks et al. (1973) | 10.5 | 7.1 | | 2,971 |
| Laster and Gregory (1973) | 30 | 16 | 5,064 | |
| Laster et al. (1973) | 25 | 13 | | 993 |
| | 32 | 21 | | 879 |

II.3.5.3. The effect of gestation length on dystocia

Although the gestation lengths of purebred calves sired by different bulls may show significant variations (Kortstee, 1963 cited by Politiek, 1965), these differences do not appear to be related to peri-natal mortality or presumably dystocia (Bannerjee-Schotsman, 1964 cited by Politiek, 1965). In cross-breeding however, when the gestation length of the sire breed is much greater than that of the breed of dam, dystocia apparently is related to gestation length. Extensive trials conducted in Britain to ascertain the effect on parturition of mating Charolais sires (relatively long gestation length) with indigenous cattle, indicate a positive relationship between dystocia and this trait. The incidence of dystocia was 15.8% for crossbred progeny compared with 4.4% for purebred calves and the gestation length of the crossbred calves was approximately seven days greater than that of the purebred calves (Anon., 1963). Further support for this principle comes from the work of Sagebiel et al. (1969), who showed, in a reciprocal crossbreeding experiment, that gestation length was significantly correlated with dystocia in Angus dams but not in either Hereford or Charolais dams; the effect being manifested in the breed of dam with the shortest gestation length.

### II.3.5.4. The effect of conformation of the calf on dystocia

Although conformation of the calf has been suggested to explain unaccountable sire differences with respect to dystocia (Williams, 1968), as well as the effect of calf sex and breed on dystocia when calf birth weights are of a similar order, there is no published evidence to substantiate such a suggestion in the absence of foetal malformations. In an extensive study conducted to investigate this proposition, Laster (1974) measured shoulder width, hip width, chest width, wither height and body length of calves born in a large crossbreeding experiment involving heifers of 14 breeds; he was unable to demonstrate any significant effect of conformation on dystocia when birth weight was held constant.

Muscular hypertrophy, an hereditary condition of cattle, in which there is excessive development of muscles, particularly of the hind quarters, often causes severe dystocia especially in heifers if it is present in its most marked form (MacKellar, 1960). The condition is considered desirable in its mild form (MacKellar, 1960) and is encountered in a number of breeds, including South Devon, Friesian, Ayrshire, Shorthorn, Charolais, Hereford and Galloway (Weber and Ibsen, 1935; MacKellar, 1960).

## II.3.5.5. The effect of pathology of the foetus

A number of foetal monstrosities are commonly associated with dystocia in cattle. These include Schistosoma reflexus, Perosumus elumbis, Schistocormus, limb contractures, joint anchyloses, anasarca, hydrocephalus and achondroplasia (Tutt, 1944; Arthur, 1964; Morten and Cox, 1968; Roberts, 1971). Hydramnios and hydrallantois, because of their frequent association with uterine inertia and foetal abnormalities, have also been cited as causes of dystocia (Arthur, 1964; Roberts, 1971).

Metabolic or morphologic abnormalities that result in prolonged gestation, usually by interfering with the integrity of the pituitary-adrenal axis, may indirectly lead to dystocia if foetal growth in utero is not impaired. Calves born to vitamin A deficient cattle are often carried two to three weeks past normal term and experience a high incidence of dystocia (Alvarez, 1947) which is presumably referable to a disparity in size between the large post-mature calf (Olafson, 1947) and the maternal pelvis. In contrast, the syndrome of genetic origin, which occurs in the Ayrshire and Friesian breeds (Holm, 1967) and which is also associated with large post-mature calves, is seldom terminated spontaneously and, for this reason, dystocia is not a prominent feature.

## II.3.6. The influence of season of birth on dystocia

A number of authors have reported on the effects of the season of the year on the incidence of dystocia and peri-natal losses - findings are generally inconsistent and explanations for differences not clear. Thus Politiek (1965), citing Van Dieten (1963) and Stegenga (1964), described a higher incidence of calves dead at birth in autumn and early winter than in spring and summer calving, while Lindhé (1966) recorded a higher incidence of peri-natal mortality in summer and winter than in autumn and spring. Brinks et al. (1973) in their study recorded a significant effect of calving sequence on dystocia and calves born later in the 90 day calving period beginning in spring experienced less dystocia than those born earlier. Both gestation length and birth weight in cattle have been shown to be influenced by the seasons (Dickinson, 1961; Young, 1968 b, 1970), however their effects on dystocia, if any, could be expected to be in conflict, since gestation length has been shown to decrease from winter to summer, while birth weights have been reported to increase. Thus, whether seasonal changes in either gestation length or birth weight are in any way related to the seasonal patterns of dystocia described above is difficult to determine.

# III: DYSTOCIA IN A ROMNEY STUD FLOCK

## III.1. Introduction

A study was undertaken of a Romney stud flock that had in the past experienced a high incidence of dystocia. The objective was to define the problem of dystocia in the stud flock, investigate its causes, and attempt to explain the apparent progressive reduction in the incidence of the problem that had occurred over recent years.

## III.2. Materials and Methods

### III.2.1. Breeding management and lambing

The stud was situated ten miles from Palmerston North on flat poorly drained country, the predominant pasture type being perennial rye grass with some white clover. In 1972 this property was sold and the flock was relocated in Hawke Bay. It was from this new environment, situated in rolling hill country, that the final year's records were derived. Plates III (1 & 2) illustrate the topography of the two properties.

Mating was carried out in individual sire groups after which the ewes were combined into larger groups and set stocked with no preference being given to the maiden ewes. At lambing the ewes were inspected three times daily, assistance being given to ewes when the life of the lamb was thought to be endangered or when the ewes were first observed in difficulty at night fall. The majority of those assisted at birth were assisted by the breeder himself.

In 1966 the breeder became concerned at the high level of dystocia occurring in his flock and decided to attempt to reduce the incidence by culling and selective breeding. His selection policy was to line breed to a strain of Romney sheep which he considered produced lower lamb birth weights, less lambing trouble and more vigorous lambs at birth. Culling of ewes that

Plate III.1. Lockwood Romney Stud (Kairanga).

Plate III.2. Lockwood Romney Stud (Hawke Bay).

1

2

were repeatedly assisted was implemented.

III.2.2. Collection and processing of data

Accurate and reliable individual performance records were kept for all ewes and these were made available to the author for the purpose of this study. As the flock originated in 1964 from maiden ewes the records from years 1964 up to and including 1972 were analysed.

The following parameters were transcribed from the stud cards onto IBM punch cards for computer analysis :

(i) Year of a particular record.

(ii) Parity of the ewe. This indicates the total number of times the ewe has lambed.

(iii) Body weight of the ewe at 18 months of age. Ewes were weighed just prior to being joined with the ram. Weights were not available in 1972.

(iv) Ewe identification number.

(v) Number of lambs born to a ewe in a particular year.

(vi) Sire identification number.

(vii) Whether or not the birth was assisted. Births classified as dystocous were mostly terminated with human help, but if a ewe was found to have delivered a lamb with obvious sub-cutaneous oedema, such as a swollen head, this was classified as a dystocous birth. When the cause of death of any lamb found dead in the paddock was in doubt it was classified as a 'normal' birth. Lambs found dead within the foetal membranes were considered for the purposes of this analysis to have died from dystocia; there were few such cases.

(viii) Sex of lamb(s).

(ix) Disposition of the lamb. Most of the data concerning disposition of the lamb were collected when assistance was rendered at birth; only the disposition of the first assisted lamb was utilised in this study. In most cases the breeder himself assisted the sheep and entered details of the birth in his lambing book. At times other personnel assisted, noting details in a field book and transferring the information to the stud cards later. Lambs presenting with elbow flexion were not differentiated by the breeder from those in extended posture and are therefore included in the group of correctly disposed lambs that were assisted at birth.

(x) Birth weight of the lamb(s). Lambs were weighed to the nearest half pound soon after birth using a spring balance with a sling attached. The time at which this was done varied, but the majority of the weights were obtained within 15 hours of birth. Although some variation could be expected in birth weights according to the time relative to parturition at which they were measured, the work of Campbell and Nel (1967), suggests that changes in the birth weight of lambs within the first 12 hours of life are relatively small. Birth weights of twins and triplets were presented as mean weights and for this analysis all weights were converted to kilograms.

Programs for most analyses were constructed in FORTRAN and processed on an IBM computer. A specialised Bar 3 program was employed for the sire regression analysis and was processed on an IBM 1620 computer. In all cases cards with missing information were eliminated from the particular analyses concerned.

## III.2.3. Statistical methods

Differences between means of groups were tested for significance using Student's t statistic (Sokal and Rohlf, 1969), while tests of independence of groups with regard to the incidence of dystocia were made by submitting the data to Chi-square contingency table analysis. Yates correction was used in all 2 x 2 analyses. Product-Moment correlations (Sokal and Rohlf, 1969) were used to define the relationship of two variables. The effect of lamb weight on the occurrence of dystocia in groups of ewes mated to individual rams was investigated by fitting a multiple regression equation with percentage of ewes with dystocia as the dependent variable and mean lamb weight and standard deviation of lamb weight as the independent variables (Snedecor and Cochran, 1967). The parameters of the regression equation were estimated separately for each of the seven years. A modified least squares procedure was employed, in which variance minimised was the weighted residual squares of deviations of the dependent variable from the fitted plane. The weight employed for each observation was the reciprocal of the number of lambs born in the sire group constituting that observation. The effect of transformation of the scale of the dependent variable, the arcsine or angular transformation, was without material effect on the estimate obtained for the influence of lamb weight.

## III.3. Results

The number of maiden and older ewes which lambed in each of the nine years of the survey, together with the frequency of dystocia in the flock and that observed in twin and single bearing ewes, is shown in Table III (i). Apart from 1966 both single and twin bearing ewes experienced similar levels of difficulty, while the overall level of dystocia declined progressively from 1966 to 1972. (Fig III (i)).

Bodyweight of maiden ewes as measured just prior to their first joining (Table III (ii)) was not related to difficulties at their first lambing; nor was age of ewes, with the exception of 1966, related to dystocia (Table III (iii)).

A comparison of ewes on the basis of their previous year's lambing performance (Table III (iv)), revealed significant differences between groups in all years except 1966, where numbers were large enough to be meaningful. Even in 1965, 1966 and 1972 a similar trend was evident. The overall results indicate that a definite relationship exists between lambing performance of ewes in consecutive years.

The influence of birth weight of the lamb on lambing difficulties is examined in Table III (v). The mean birth weight of assisted single lambs exceeded that of their unassisted counterparts in all years, and, furthermore, a significant correlation was demonstrated between the mean birth weight of single lambs born in a particular year and the incidence of dystocia Fig III (i). Of the single lambs that were assisted at birth a significantly high proportion were males (Table III (vi)). a finding consistent with the higher birth weight of lambs in this group (Table III (vii)). The proportion of ram lambs amongst assisted singles varied in different years according to the difference in birth weight between male and female lambs (Fig III (ii)), although in 1971 and 1972, despite a relatively large difference in birth weight between the sexes, the proportion of ram lambs assisted was lower than would have been expected.

Maldisposition of the lamb was more often a feature of assisted twin births than single births (Table III (viii)), although this was very variable and the reverse occurred in three years. Also foetal maldisposition was more often observed in assisted lambs from multiparous ewes than primiparous ewes (Table III (ix)).

Individual sire group differences with respect to dystocia were demonstrated in certain years (Table III (x)). The extent to which these differences were related to differences in lamb weight was investigated by a regression analysis for which the results are summarised in Table III (xi). The proportion of variance in

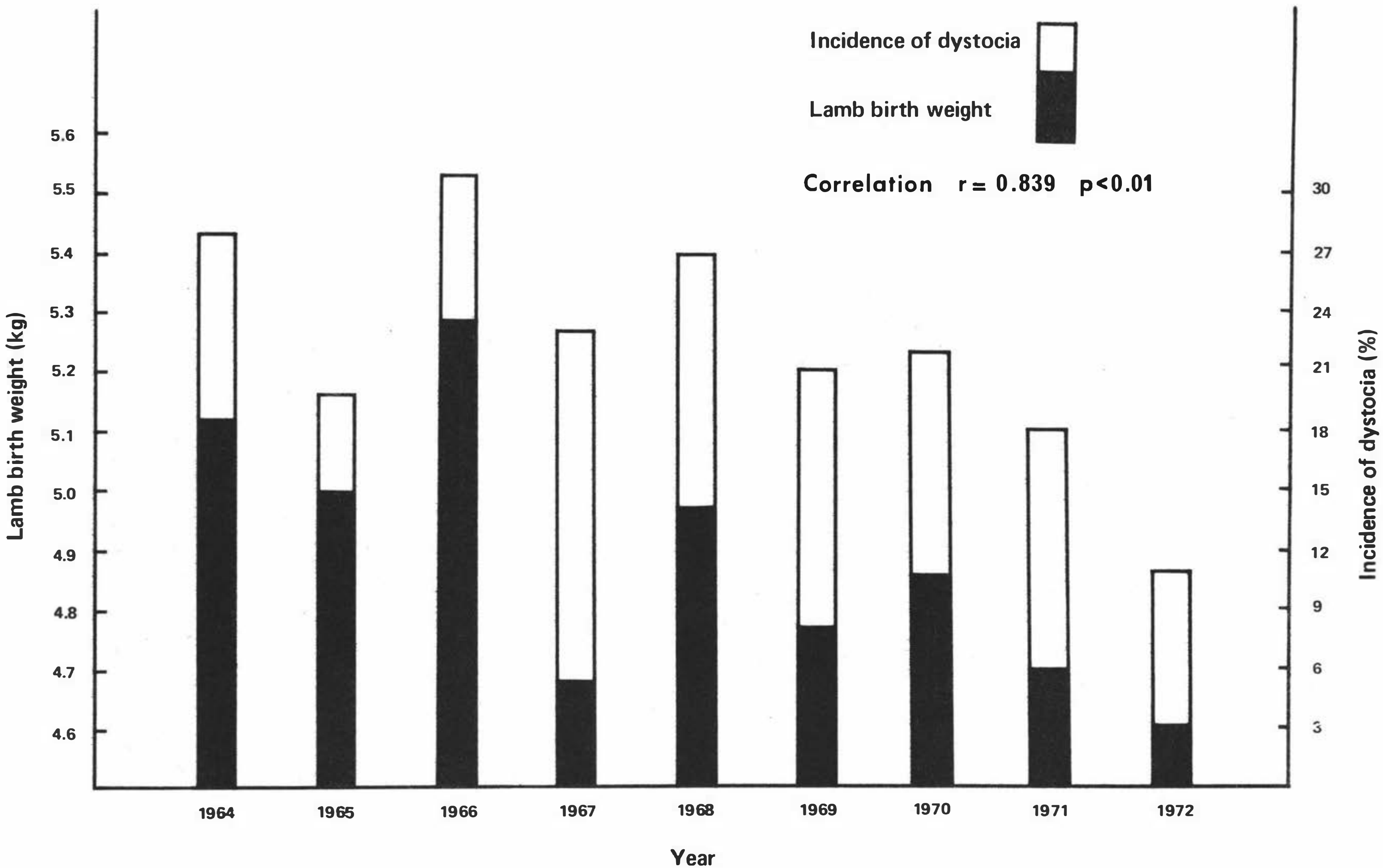



Fig. III (i). Incidence of dystocia and mean birth weight of single lambs.


Fig. III (ii). Difference in birth weight between male and female lambs and the percentage of assisted single lambs that were males.

TABLE III (i): FLOCK HISTORY OF DYSTOCIA

| Year | Total number of ewes lambing | Number of maiden ewes lambing | Incidence of dystocia as % of ewes lambing | | |
|---|---|---|---|---|---|
| | | | Single births | Twin births | Total |
| 1964 | 145 | 143 | 28 | 28 | 28 |
| 1965 | 293 | 170 | 22 | 17 | 20 |
| 1966 | 636 | 181 | 37 | 23 | 31 *** |
| 1967 | 594 | 208 | 21 | 23 | 23 |
| 1968 | 597 | 198 | 25 | 29 | 27 |
| 1969 | 587 | 178 | 20 | 21 | 21 |
| 1970 | 574 | 201 | 21 | 23 | 22 |
| 1971 | 581 | 217 | 17 | 19 | 18 |
| 1972 | 474 | 177 | 12 | 10 | 11 |

*** More single than twin births were assisted in this year, ($\chi^2 = 20.8$, $p < 0.001$, 1 d.f.)

TABLE III (ii): COMPARISON OF EWE WEIGHTS AT 18 MONTHS IN RELATION TO DYSTOCIA AT 2 YEARS

| Year | Ewes assisted at lambing | | | Ewes unassisted at lambing | | | |
|---|---|---|---|---|---|---|---|
| | Number lambing | Mean Weight (kg) | S.D. | Number lambing | Mean weight (kg) | S.D. | t ø |
| 1964 | 28 | 55.15 | ± 3.41 | 92 | 54.99 | ± 4.55 | 0.17 |
| 1965 | 31 | 53.39 | ± 4.42 | 113 | 52.97 | ± 3.62 | 0.04 |
| 1966 | 66 | 59.19 | ± 4.88 | 101 | 58.54 | ± 4.67 | 0.86 |
| 1967 | 45 | 57.45 | ± 4.50 | 157 | 56.09 | ± 5.12 | 1.61 |
| 1968 | 6 | 57.14 | ± 4.41 | 25 | 58.04 | ± 6.00 | 0.34 |
| 1969 | 40 | 57.17 | ± 5.08 | 131 | 57.29 | ± 4.80 | 0.13 |
| 1970 | 38 | 53.38 | ± 3.35 | 157 | 53.21 | ± 4.62 | 0.21 |
| 1971 | 48 | 50.51 | ± 4.99 | 164 | 50.56 | ± 4.33 | 0.06 |

ø t not significant ($p > 0.05$)

TABLE III (iii): THE INCIDENCE OF DYSTOCIA IN RELATION TO PARITY OF EWE

| | Primiparous Ewes | | Secundiparous Ewes | | Multiparous Ewes | | |
|---|---|---|---|---|---|---|---|
| Year | Number lambing | % dystocia | Number lambing | % dystocia | Number lambing | % dystocia | $\chi^2$ |
| 1964 | 143 | 28 | - | - | - | - | - |
| 1965 | 170 | 23 | 121 | 17 | - | - | - |
| 1966 | 181 | 41 | 159 | 28 | 296 | 25 | 13.8 ** |
| 1967 | 208 | 22 | 100 | 28 | 256 | 21 | 2.02 |
| 1968 | 198 | 32 | 160 | 21 | 239 | 26 | 5.15 |
| 1969 | 178 | 23 | 132 | 19 | 277 | 21 | 0.77 |
| 1970 | 201 | 19 | 109 | 17 | 264 | 27 | 6.04 |
| 1971 | 217 | 22 | 152 | 16 | 212 | 15 | 4.22 |
| 1972 | 177 | 16 | 120 | 10 | 177 | 8 | 5.8 |

** Significant ($p < 0.01$, 2 d.f.)

TABLE III (iv): THE INCIDENCE OF DYSTOCIA IN EWES IN RELATION TO THEIR PERFORMANCE IN THE PREVIOUS YEAR

| Year | Ewes assisted previous year | | Ewes not assisted previous year | | |
|---|---|---|---|---|---|
| | Number lambing | % assisted | Number lambing | % assisted | $\chi^2$ |
| 1965 | 31 | 26 | 93 | 12 | 1.99 |
| 1966 | 46 | 26 | 200 | 22 | 0.11 |
| 1967 | 98 | 43 | 277 | 15 | 30.37 *** |
| 1968 | 80 | 36 | 293 | 21 | 6.96 ** |
| 1969 | 78 | 33 | 326 | 17 | 9.63 ** |
| 1970 | 50 | 40 | 317 | 20 | 8.87 ** |
| 1971 | 40 | 28 | 320 | 13 | 4.60 * |
| 1972 | 29 | 17 | 242 | 6 | 3.14 x |
| Total all years | 452 | 34 | 2,068 | 16 | 76.73 *** |

Levels of significance

x ($p < 0.1$, 1 d.f.)
* ($p < 0.05$, 1 d.f.)
** ($p < 0.01$, 1 d.f.)
*** ($p < 0.001$, 1 d.f.)

TABLE III (v): SINGLE LAMB WEIGHTS OF ASSISTED EWES COMPARED WITH THOSE OF UNASSISTED EWES

| | Assisted births | | | Unassisted births | | | |
|---|---|---|---|---|---|---|---|
| Year | Number | Mean weight (kg) | S.D. | Number | Mean weight (kg) | S.D. | t |
| 1964 | 31 | 5.80 | ± 0.79 | 74 | 4.82 | ± 0.74 | 6.07 *** |
| 1965 | 38 | 5.81 | ± 0.62 | 125 | 4.76 | ± 0.87 | 6.92 *** |
| 1966 | 116 | 5.71 | ± 1.10 | 188 | 5.03 | ± 0.79 | 6.25 *** |
| 1967 | 63 | 5.30 | ± 0.76 | 225 | 4.51 | ± 0.78 | 7.14 *** |
| 1968 | 91 | 5.87 | ± 1.06 | 268 | 4.68 | ± 0.77 | 11.50 *** |
| 1969 | 41 | 5.28 | ± 1.31 | 227 | 4.69 | ± 0.81 | 3.85 *** |
| 1970 | 79 | 5.46 | ± 1.07 | 288 | 4.69 | ± 0.76 | 7.25 *** |
| 1971 | 59 | 5.03 | ± 1.19 | 293 | 4.64 | ± 0.79 | 3.14 ** |
| 1972 | 34 | 5.43 | ± 0.89 | 255 | 4.49 | ± 0.90 | 5.72 *** |

*** Significant ($p < 0.001$)

** Significant ($p < 0.01$)

TABLE III (vi): PROPORTION OF RAM LAMBS IN TOTAL ASSISTED SINGLE BIRTHS

| Year | Number of assisted single lambs | % rams | $\chi^2$ | |
|---|---|---|---|---|
| 1964 | 31 | 70 | 5.45 | * |
| 1965 | 38 | 45 | 0.42 | |
| 1966 | 116 | 60 | 4.96 | * |
| 1967 | 63 | 56 | 0.78 | |
| 1968 | 92 | 60 | 3.52 | |
| 1969 | 60 | 69 | 8.07 | ** |
| 1970 | 80 | 65 | 7.2 | ** |
| 1971 | 61 | 56 | 0.80 | |
| 1972 | 35 | 51 | 0.03 | |
| Total all years | 575 | 59 | 17.74 | *** |

Levels of significance * ($p < 0.05$)
** ($p < 0.01$)
*** ($p < 0.001$)

Yates correction not applied.

TABLE III (vii): THE INFLUENCE OF SEX OF LAMB ON SINGLE LAMB WEIGHT

| Year | Number of ewe lambs | Mean ewe lamb weight (kg) | S.D. | Number of ram lambs | Mean ram lamb weight (kg) | S.D. | t | |
|---|---|---|---|---|---|---|---|---|
| 1964 | 48 | 4.90 | ± 0.66 | 57 | 5.29 | ± 0.87 | 2.54 | * |
| 1965 | 82 | 4.98 | ± 0.94 | 81 | 5.03 | ± 0.93 | 0.34 | |
| 1966 | 145 | 5.12 | ± 0.82 | 157 | 5.46 | ± 1.05 | 3.11 | ** |
| 1967 | 151 | 4.59 | ± 0.81 | 133 | 4.81 | ± 0.86 | 2.22 | * |
| 1968 | 176 | 4.85 | ± 0.92 | 180 | 5.11 | ± 1.05 | 2.48 | * |
| 1969 | 126 | 4.52 | ± 0.90 | 140 | 5.03 | ± 0.80 | 4.89 | *** |
| 1970 | 166 | 4.66 | ± 0.80 | 199 | 5.02 | ± 0.94 | 3.90 | *** |
| 1971 | 179 | 4.43 | ± 0.82 | 167 | 4.99 | ± 0.85 | 6.24 | *** |
| 1972 | 148 | 4.38 | ± 0.88 | 140 | 4.85 | ± 0.96 | 4.33 | *** |

Levels of significance * ($p < 0.05$)
** ($p < 0.01$)
*** ($p < 0.001$)

TABLE III (viii): PROPORTION OF DYSTOCOUS BIRTHS WHICH WERE ASSOCIATED WITH A MALDISPOSED LAMB IN EWES BEARING SINGLE AND TWIN LAMBS

| Year | Assisted single births | | Assisted twin births | | $\chi^2$ | |
|---|---|---|---|---|---|---|
| | Number | % lambs maldisposed | Number | % lambs maldisposed | | |
| 1964 | 31 | 35 | 9 | 78 | 3.42 | x |
| 1965 | 38 | 24 | 21 | 57 | 4.27 | * |
| 1966 | 116 | 41 | 72 | 51 | 1.41 | |
| 1967 | 63 | 32 | 66 | 21 | 1.29 | |
| 1968 | 92 | 28 | 65 | 48 | 5.40 | * |
| 1969 | 60 | 18 | 61 | 41 | 6.38 | * |
| 1970 | 80 | 49 | 43 | 39 | 1.40 | |
| 1971 | 61 | 26 | 42 | 12 | 2.32 | |
| 1972 | 34 | 21 | 18 | 50 | 2.64 | |
| Total all years | 575 | 32.5 | 397 | 40 | 5.22 | * |

* Significant $(p < 0.05)$

x Significant $(p < 0.1)$

## TABLE III (ix): PROPORTION OF DYSTOCOUS BIRTHS WHICH WERE ASSOCIATED WITH A MALDISPOSED LAMB IN PRIMIPAROUS AND MULTIPAROUS EWES

| | Primiparous ewes assisted at birth | | Multiparous ewes assisted at birth | | |
|---|---|---|---|---|---|
| Year | Number | % maldisposed lambs | Number | % maldisposed lambs | $\chi^2$ |
| 1964/5 | 78 | 38 | 21 | 43 | 0.01 |
| 1966 | 74 | 42 | 120 | 45 | 0.07 |
| 1967 | 46 | 24 | 89 | 25 | 0.01 |
| 1968 | 64 | 25 | 96 | 45 | 5.64 * |
| 1969 | 42 | 12 | 84 | 39 | 8.7 ** |
| 1970 | 39 | 36 | 88 | 51 | 3.43 |
| 1971 | 48 | 19 | 55 | 24 | 0.13 |
| 1972 | 28 | 21 | 26 | 42 | 1.84 |
| Total all years | 419 | 31 | 579 | 40 | 8.22 ** |

* Significant ($p < 0.05$)

** Significant ($p < 0.01$)

TABLE III (x): INFLUENCE OF THE SIRE ON DYSTOCIA

| Year | Number of sire groups | $\chi^2$ | | |
|---|---|---|---|---|
| | | Multiparous ewes | Primiparous ewes | Over all ewes |
| 1964/5 | 30 | 33.4 | 33.5 | 37.8 |
| 1966 | 11 | 39.9 ** | 19.2 * | 55.6 *** |
| 1967 | 20 | 26.5 | 46.5 ** | 15.5 |
| 1968 | 11 | 9.6 | 17.6 | 11.5 |
| 1969 | 12 | 30.8 ** | 8.8 | 34.9 *** |
| 1970 | 11 | 12.8 | 18.3 * | 20.1 * |
| 1971 | 21 | 66.1 ** | 61.8 ** | 38.6 ** |
| 1972 | 16 | 32.5 ** | 13.5 | 22.0 |

Levels of significance * ($p < 0.05$)
** ($p < 0.01$)
*** ($p < 0.001$)

TABLE III(xi): ESTIMATES OF COEFFICIENTS FOR THE MULTIPLE REGRESSION EQUATION RELATING % DYSTOCIA TO MEAN LAMB WEIGHT AND STANDARD DEVIATION OF LAMB WEIGHT FOR SIRE GROUPS IN SEVEN YEARS

| Year | Degrees of freedom | Coefficient of multiple determination[1] $\bar{R}^2$ | Mean lamb weight partial regress. coeff. (± 95% confidence limits)[2] | S.D. of lamb weight partial regress. coeff. (± 95% confidence limits) |
|---|---|---|---|---|
| 1966 | 7 | 0.297 | 10.09 ± 10.67 | 5.69 ± 22.8 |
| 1967 | 15 | 0.284 | 5.13 ± 4.37 | -5.66 ± 5.56 |
| 1968 | 6 | 0.325 | 10.46 ± 11.76 | 4.40 ± 21.26 |
| 1969 | 9 | 0.283 | 5.39 ± 7.74 | 9.55 ± 11.17 |
| 1970 | 7 | 0.630 | 6.28 ± 5.23 | 6.22 ± 4.75 |
| 1971 | 14 | 0.320 | -1.37 ± 5.99 | 11.55 ± 8.23 |
| 1972 | 10 | 0.780 | 8.53 ± 2.98 | 1.57 ± 7.42 |

1. The coefficient of multiple determination (Snedecor and Cochran, 1967) has been corrected for bias, viz. $\bar{R}^2 = 1 - \frac{n-1}{n-3}(1 - \bar{R}^2)$ where n is the number of sire groups.

2. The partial regression coefficients are shown with 95% confidence limits based on the standard error of the coefficient and the tabular value of student's t for p = 0.05 and n - 3 degrees of freedom (Snedecor and Cochran, 1967).

TABLE III (xii): COMPARISON OF SINGLE LAMB WEIGHTS OF MAIDEN AND OLDER EWES

| | Maiden Ewes | | | Older Ewes | | | |
|---|---|---|---|---|---|---|---|
| Year | Number | Mean lamb weight (kg) | S.D. | Number | Mean lamb weight (kg) | S.D. | t |
| 1964 | 104 | 5.104 | ± 0.805 | 1 | 5.89 | ± 0.00 | 0.977 |
| 1965 | 109 | 4.913 | ± 1.019 | 54 | 5.194 | ± 0.705 | 1.817 |
| 1966 | 112 | 5.110 | ± 1.010 | 192 | 5.391 | ± 0.950 | 2.43 * |
| 1967 | 149 | 4.367 | ± 0.723 | 137 | 5.028 | ± 0.832 | 7.180 *** |
| 1968 | 169 | 4.965 | ± 0.945 | 190 | 5.004 | ± 1.037 | 0.364 |
| 1969 | 107 | 4.483 | ± 0.791 | 161 | 4.979 | ± 0.954 | 4.444 *** |
| 1970 | 179 | 4.606 | ± 0.787 | 187 | 5.095 | ± 0.933 | 5.407 *** |
| 1971 | 168 | 4.599 | ± 0.844 | 184 | 4.815 | ± 0.908 | 2.304 * |
| 1972 | 126 | 4.488 | ± 0.859 | 163 | 4.693 | ± 1.007 | 1.826 |

* Significant ($p < 0.05$)

*** Significant ($p < 0.001$)

percentage dystocia between sires measured by the estimates obtained for the square of the multiple correlation coefficient (coefficient of multiple determination) varied from 0.28 - 0.78 for individual years. In most years the greater part of the 'explanation' of between sire differences in percentage dystocia was due to the effect of lamb weight, for which the partial regression coefficient was large and positive in all years other than 1971. On the other hand, the standard partial regression coefficient for the effect of standard deviation of lamb weight was more variable and was significant and positive for two years, including 1971 and significant and negative in 1967. In most years there was a significant negative correlation between the standard deviation and the mean of lamb weights for sire groups and there was a consequent change in the estimate for the regression of dystocia on mean weight when the standard deviation was included as a second dependent variable.

## III.4. Discussion

The problem of dystocia in this flock was related to the birth of heavy lambs, more often males than females, of which the majority were correctly disposed, although it should be noted that the incidence of lambs assisted with elbow flexion and included in this group is not known. The occurrence of difficulties appeared to be unrelated to the effects of age, weight at tupping and litter size of the ewes. It is also reasonable to expect that the body weight of ewes at their first lambing in this study was unrelated to the occurrence of dystocia since Dalton (1962) estimated that 60% of the variation in lambing weight of mixed age ewes was attributable to variation in tupping weight.

The level of assistance at lambing encountered in this flock, particularly in the early years of the study, was similar to that recorded by Quinlivan et al. (1966a) in a survey of pre-and perinatal mortality in Romney stud ewes. In the same survey they reported that of the lambs assisted at birth 13% were described by breeders as being maldisposed, which is within the wide range observed in the present data.

The pronounced effect of lamb birth weight on dystocia in this flock is in agreement with the findings of other authors. Both Fogarty (1971) and Naaktgeboren _et al._ (1971) noted a higher incidence of dystocia in large lambs, while necropsy data clearly demonstrate the relationship between high lamb birth weight and dystocia (Section II.2.3.).

The concurrence of a significantly higher level of dystocia in the maiden ewes, with a significantly higher level of dystocia in single lambs in 1966, both singular events, suggest a common basis. According to the breeder, conditions for pasture growth were very favourable in that year resulting in an abundance of feed; this is reflected in the mean birth weight of lambs which was higher in that year than in any other. The association of nutrition of the pregnant ewe with birth weight of the lamb has previously been reported in the sheep (Thomson and Fraser, 1939; Underwood and Shier, 1942; Underwood _et al._, 1943; Wallace, 1948; Barnicoat _et al._, 1949; Thomson and Thomson, 1948; 1953; Coop, 1950; Palsson and Verges, 1952; Russel _et al._, 1967). Thus it is possible that the high level of nutrition was responsible for the anomaly evident in TableIII(iii) in 1966, and was a contributing factor to the high incidence of dystocia in that year, but for reasons discussed below it is difficult to explain the higher incidence of dystocia in single as opposed to twin lambs on this basis.

The similar incidence of dystocia in single and twin lambs is in agreement with the findings of Quinlivan and Martin (unpublished) who found that slightly more twins than singles died from the effects of dystocia; it differs from the results reported by Purser and Young (1964) and Hight and Jury (1969) in which less than 6% and 21.3% respectively of dystocous lamb deaths under hill country conditions were assigned to multiple births. An explanation for the relatively low incidence of deaths from dystocia in twin and triplet lambs in these studies may be found in the lower level of nutrition which could be expected under hill country as compared with lowland conditions. It has been shown that when ewes are maintained on a high level of nutrition during the final third of gestation both singles and twins approach the upper genetic limit for birth weight and are often of similar weights (Palsson and Verges, 1952). Therefore it could be expected that twins would experience a similar level of dystocia to singles. By contrast when ewes are maintained on a moderate to low plane of nutrition during the final third of gestation the difference in birth weight between single and twin lambs becomes marked owing to the greater influence of prenatal nutrition of the ewe on the growth of twins (Wallace, 1948; Palsson and Verges, 1952). The incidence of dystocia under these conditions would be expected to be higher in single born lambs. In support of this explanation Purser and Young (1964) stated that dystocia was only a major cause of lamb mortality when birth weights exceeded a critical value and in general the birth weights of twins remained below this level.

The observation that parity of the ewe had little influence on the occurrence of dystocia is similar to the findings of Quinlivan and Martin (unpublished) and Purser and Young (1964). Quinlivan and Martin (unpublished) reported a similar percentage of deaths from dystocia in each of the four age groups of Romney stud ewes in their study while Purser and Young (1964) showed that although maiden ewes lost more lambs from dystocia than the older age groups the difference was only 1.6% for Blackface lambs and 0.2% for Welsh Mountain lambs. Consistent with these reports is the observation that the incidence of dystocia in Drysdale and Romney ewes lambing at 12 months of age at Massey University has been found not to differ appreciably from that observed in older ewes (A.N. Bruere- personal communication). In contrast to these reports is that of McDonald (1966) who recorded a highly significant difference between the incidence of lamb deaths from dystocia in maiden three year old and older ewes. It is noteworthy, however, that this closed Polwarth flock had a history of poor reproductive performance extending back 16 years and for this reason probably represents a special case. Fogarty (1971) also recorded a higher incidence of dystocia in maiden ewes in a Dorset Horn flock, although the magnitude of the difference was obscured by the practice of culling troublesome ewes and the increased fecundity of the older ewes since twin and triplet lambs were seldom implicated in dystocia. Further evidence of a presumptive nature relating parity of the ewe to dystocia is provided by Quinlivan et al. (1966a, b) from a study of the lambing performance of New Zealand Romney stud ewes. These authors showed that a significantly high percentage of lambs born to primiparous dams were dead at birth. The results of a previous study had indicated that dystocia was the major cause of perinatal mortality in Romney stud ewes in this area (Quinlivan and Martin (unpublished)). Clearly the literature relating to the effect of parity of the ewe on dystocia is conflicting, and while the present findings are consistent with some reports they are at variance with others.

The demonstration of a relationship between the occurrence of dystocia in individual ewes in consecutive years is suggestive of a dam effect. A similar analysis was made by Brinks et al. (1973) in cattle. They showed that of 195 heifers which had no difficulty in calving at two years of age 7.2% had difficulty as three year olds while of the 77 that experienced dystocia as two year olds 11.7% had difficulty again as three year olds. Their results may be confounded by the predisposition of primiparous dams to dystocia in cattle thereby indicating a low repeatability, but if they are an accurate estimation of the repeatability of dystocia in that herd then the estimate is considerably less than that reported in this present study with sheep.

Quinlivan (1971) reported the existence of differences in pelvic dimensions between ewes with histories of repeated assistance at lambing and others which had never been assisted, the conjugate diameter of the pelvis being significantly greater in the unassisted ewes. Similar relationships between the incidence of dystocia and pelvic dimensions have recently been reported in Dorset Horn ewes by Fogarty and Thompson (1974). Thus it is likely that inadequate pelvic size contributes to the need for repeated assistance at birth. Whether it did contribute to the problem in this particular flock could not be tested but further investigations of the influence of pelvic dimensions on dystocia are considered later in this thesis.

The influence of maternal environment on birth weight of lambs has been shown by egg transfer experiments to be much less than that of genotype of the lamb (Dickinson et al., 1962). It would therefore be surprising if this influence was responsible for the relatively high repeatability of dystocia observed in this flock.

Differences between sire groups clearly related to lamb weight such that those sire groups with higher average lamb weights showed the greatest incidence of dystocia. Estimates of the multiple correlation do not differ significantly between years, with the pooled estimate corresponding to slightly in excess of 40% of the 'explanation' for between sire group differences. In some years the effect of lamb weight seemed to be modified by spread of lamb weight but this effect, unlike that of mean lamb weight, was inconsistent. The relationship between standard deviation and mean was surprising, not with respect to its existence, but with respect to its sign. Whereas a positive relationship between mean and standard deviation is commonly seen in animal weights and is indicative of a log normal distribution (Bliss, 1967), the author is unable to offer any explanation for the negative relationship seen in these data.

Sire differences with regard to dystocia have been reported in cattle (Van Dieten, 1963 - cited by Politiek, 1965; Anon, 1965; Politiek, 1965; Heiman, 1968; Brinks et al., 1973) but no information is available for the sheep, although Moule (1954) recorded differences in lamb mortality between sire groups in his study and suggested that an influence of the sire was a possible explanation. Wiltbank and Price (1973), in a study of the influence of the sire on dystocia in cattle, showed that the mean birth weight of calves played little part in the determination of between sire group differences. Of more importance they suggested, were differences in the variance of birth weight which were observed between sire groups and which corresponded with differences in the incidence of dystocia. This does not seem to be the case in this study in sheep.

An interesting feature of the relationship between the proportion of single lambs assisted at birth that were males, and the mean difference in birth weight between male and female lambs (Fig III (ii)), is the anomaly observed in 1971 and 1972, coinciding with the lowest mean birth weights in the study, apart from 1967. It is suggested that this anomaly constitutes a real effect and resulted from a threshold being reached in respect to the relationship of lamb size to pelvic size so that small fluctuations in lamb weight mediated by sex of lamb no longer produced a differential effect as far as dystocia was concerned. Naaktgeboren et al. (1971) reported that the duration of parturition in Heath sheep was independent of birth weight of the lamb, and that although delivery of ram lambs took an average of three minutes longer than that of ewe lambs, this was because of the presence of well developed horn buds in the ram lambs. This finding was in direct contrast to the situation in Texel sheep in which the duration of birth was closely related to the birth weight of lambs. The difference was explained by the finding that the size of the pelvis of Texel ewes was, in relation to the mean birth weight of the lambs, smaller than that of the Heath ewes. The estimated pelvic area of the Texel ewes (measured by the product of the transverse diameter and the conjugate diameter of the pelvis) was 960 $cm^2$, or approximately 10% larger than that of the Heath ewes, while the mean birth weight of the Texel lambs was 4.5 kg or 67% greater than that of the Heath lambs. Thus it was proposed that even the heaviest Heath lambs were yet so small in relation to the pelvis that expulsion could take place very easily. The situation in 1967, in which the mean birth weight was even lower than that in 1971, yet the proportion of the ram lambs experiencing dystocia was in accord with the weight differences between the sexes, suggests that in the intervening four years, pelvic dimensions have been altered by selection and culling, and that the results observed in 1971 and 1972 represent the combined effect of reduced lamb weight and increased pelvic size of the ewe.

The reduction in mean birth weight of the lambs between 1966 and 1972 was approximately 0.7 kg. Although this may be exaggerated by a particularly high mean birth weight in 1966 it should be noted that in 1964 and 1965 the lower mean birth weights were associated with a high proportion of maiden ewes whose lamb weights were shown to be consistently less than those of multiparous ewes in all years of the study (Table III (xii)). Mean birth weights of lambs from maiden ewes have been reported to be less than those of multiparous ewes by a number of authors (Dalton, 1962; Dickinson et al., 1962; Purser and Young, 1964). Despite the reported influence of nutrition on birth weight (as discussed earlier) it appears unlikely that a change in management of the ewes would produce a progressive decline in lamb weight of the order observed.

This decline in the birth weight of lambs is construed as a manifestation of genetic change produced by selection of sires on the basis of birth weight of their progeny. Few reports have appeared in the literature on the influence of sires within a breed on lamb weight. Hammond (1932) reported sire differences with respect to lamb weight at one week of age in the Suffolk breed, although few ewes were involved in the study and the results as they relate to weight at birth are questionable. However, sire differences in mean weight of their lambs were demonstrable in the investigation reported here and, on the basis of estimates of heritability for this trait which have been reported to range from 0.19 - 0.45 in the sheep (Dalton, 1962; Osman and Bradford, 1965), the above explanation of the progressive decline in birth weight would seem possible.

In support of the progressive nature of the decline in dystocia in this flock, apparent from the data, the incidence of dystocia in 1973 and 1974 is reported to have been 3.3% and 4% respectively (R. Buchanan - personal communication). The effect, if any, of the change of environment of the flock on the incidence of dystocia cannot be determined, but may have contributed to the low incidence recorded in 1972, 1973 and 1974, possibly mediated by a reduction in the level of nutrition or through other effects.

## III.5. Conclusion

Dystocia in this flock was highly correlated with the mean birth weight of single lambs ($r = 0.839$, $p < 0.01$) and is considered to result from a physical disproportion between the lamb and the maternal pelvis. The decline in the incidence of dystocia is attributed to a reduction in lamb birth weight and a possible increase in pelvic dimensions achieved by selective breeding. It is also possible that the change in the environment of the flock has played a part in the reduction of the problem in the final three years.

# IV : A TOCOMETRIC STUDY OF THE OVINE UTERUS

## IV.1. Introduction

In 1965 Hindson *et al.* first described their studies of the activity of the parturient sheep's uterus. The results of this and subsequent studies (Hindson *et al.*, 1967, 1968a, 1968b, 1969), as well as providing important information on the condition known as 'ring womb', have contributed largely to our present understanding of the normal physiological events leading up to the delivery of the lamb in the domestic sheep. It is on this background that the present study was designed to investigate the role of uterine activity in dystocia and maldisposition of the lamb.

## IV.2. Literature Review: Internal Tocometry [1]

### IV.2.1. Introduction

In spite of the many investigations into the activity of the parturient human uterus, it is only in relatively recent years that tocometry has been applied to domestic animals. It is therefore not surprising that many of the methods employed in animals were initially developed for use in women. For this reason a review of the development of methods of internal tocometry in human obstetrics forms the first part of this section. Inasmuch as the results of those studies and also studies involving polytocous species are thought likely to be of little relevance to the present investigation, they are not further considered here. The second part of this section comprises a review of internal tocometry in domestic ruminants in which both the methodology and the results are discussed.

[1] For a definition of this term refer to Appendix I

## IV.2.2. Internal tocometry in women

The first successful attempt to measure the fluid pressure of the parturient human uterus is generally credited to Schatz (1872), cited by Dodeck (1932) and Harris and Gillespie (1950), who used a water filled balloon placed between the foetal membranes and the endometrium. Schatz's careful observations were confirmed in 1938 by Woodbury *et al.* (1938) using superior methods. (A summary of the development of methods of internal tocometry is presented in Table IV (i)).

In the late 19th and 20th centuries a number of modifications of the Schatz technique were described (reviewed by Dodeck (1932) and Harris and Gillespie (1950)) but none improved materially upon the results obtained with the original apparatus.

Despite objections that large balloons might disturb the contraction patterns of the parturient uterus (Westermark (1893) cited by Harris and Gillespie (1950)) these continued to be used for sensing pressures (Moir, 1933, 1936: Adair and Davis, 1934; Salerno, 1938) and up to 1944 the most significant improvements occurred in the method of recording. Schatz's recording system, like others of that period, used the mercury manometer which has the disadvantage of a low frequency response because of its high inertia. However, mercury manometers were gradually replaced by systems such as the optical differential manometer (Woodbury *et al.*, 1938) and more recently by the electromanometer which has a much superior frequency response.

Karlson (1944, 1949) cited by Harris and Gillespie (1950), in an attempt to overcome some of the shortcomings of previous tocometers, used a sensor based on the granular carbon microphone, which was introduced into the uterine cavity by means of a probe. Several of these devices could be placed in the uterus at one time and such preparations were used by Karlson (1944, 1949) 'to make a closer study of the process of motility within the various parts of the uterus ...'.

In 1948 the method of measuring uterine pressures developed by Wieloch (1927) for use in cases of hydramnios was first used to monitor normal labour graphically (Alvarez and Caldeyro, 1948). In 1950 Alvarez and Caldeyro, and Caldeyro *et al.* described extensive studies of amniotic fluid pressures during pregnancy and parturition using their adaptation of the trans-abdominal intra-amniotic catheter method. A large bore hypodermic needle was inserted through the abdominal wall to penetrate the amniotic sac and was then connected by way of a rubber tube to a water or mercury manometer recording on a kymograph. Abdominal pressures were recorded also from a catheter in the urinary bladder connected to another mercury manometer. Caldeyro-barcia and Alvarez (1952) further improved the technique of Alvarez and Caldeyro (1948) by introducing a thin catheter through the puncture needle which could then be withdrawn, thereby reducing trauma to the patient and making records easier to obtain. In addition an electromanometer and chart recorder were substituted for the water or mercury manometer and kymograph. In this form, the method was employed in many subsequent studies (Caldeyro-barcia et al., 1957 a, b; Caldeyro-barcia and Poseiro, 1959; Hendricks et al., 1959, 1962). A comparable method has been used by Fuchs et al. (1965) but in contrast to that of Alvarez and Caldeyro (1950) the intra-amniotic catheter was passed through a needle inserted in the anterior uterine wall from the anterior fornix of the vagina.

Williams (1952) and Williams and Stallworthy (1952) first reported the use of the trans-cervical open ended catheter, combining the accuracy of direct fluid recordings with the relative simplicity of vaginal techniques. High rupture of the foetal membranes was effected by a Drew Smythe catheter, through which the recording catheter was then introduced. The recordings of intra-uterine pressure so obtained (Williams and Stallworthy, 1952), agreed closely with those reported by Alvarez and Caldeyro (1950). As in the trans-abdominal technique, obstruction of the catheter by mucus or vernix caseosa was a shortcoming, largely overcome by the use of an electromanometer (Carey, 1954) or, more recently, by using a vinyl catheter with helical slits cut in the end (Jenssen, 1973).

With the development of miniature strain gauges it became feasible to measure intra-uterine pressure directly by introducing electromanometers into the uterus itself. The first instrument of this type was described by Ingelman-Sundberg et al. (1953). It consisted of a flexible probe on which was mounted one or more pressure transducers which could be located at selected levels of the uterus. The probe was introduced through the external os uteri and placed between the endometrium and the intact foetal membranes. As originally designed this instrument suffered from the production of artifacts when the transducers came in contact with the foetus during delivery, and an improved version was subsequently developed (Ingelman - Sundberg and Lindgren, 1955).

Radiotelemetry, which enables internal sensing devices to be used without the need for wires connecting patient to recording apparatus, was first applied to measurements of intra-uterine pressures by Smyth and Wolff (1960) and later by Persianinov and Chernukha (1971). A capsule containing a pressure transducer, miniature transmitter and power supply was inserted through the cervix and placed intra- or extra-amniotically from where it relayed information to a receiver situated on or near the maternal abdomen. This device, in common with the probe method (Ingelman-Sundberg et al., 1953), had the particular advantage that actual pressures were recorded as compared with the pressures recorded by balloons which were relative to their inflation pressure. Bangham et al. (1966) have described the shortcomings of endoradiosondes from their experiences with the use of this technique in studying uterine activity in Rhesus monkeys.

A method which, unlike many others, enabled intra-uterine pressure to be recorded throughout the three stages of labour was described by Hendricks et al. (1962). In this an open ended catheter was embedded in the myometrium by needle puncture of the abdomen and connected to an electromanometer and an electronic recorder. These authors demonstrated that pressures recorded from such a catheter reflected changes in the pressure of the amniotic fluid. They were able to confirm all the major features of uterine activity reported by earlier workers.

An important advance was made when Csapo (1964) developed a technique which was more suitable for the routine monitoring of labour. A saline-filled micro-balloon was placed between the intact foetal membranes and the endometrium, and was connected by a teflon catheter to an electromanometer and chart recorder. This method had the advantages of avoiding injury to maternal and foetal blood vessels and also of eliminating catheter blockages, although according to Bengtsson (1968) it did have the disadvantage of difficulty in maintaining the balloon at exactly the same volume throughout many hours of recording, which presumably resulted in drift of the baseline of the recording.

The sponge tipped catheter (Bengtsson, 1968) was claimed to overcome the problems experienced with the intra-uterine micro-balloon. In contrast to the open ended catheter method from which it was developed, this method could be used for measuring pressures in both the pregnant and the non-pregnant uterus. The essential new feature was the presence of a small cylinder of inert synthetic sponge secured over the end of the saline filled catheter. This system had the advantage of eliminating the need to flush the catheter - a limitation of the open ended catheter. However. care had to be taken to select a suitable sponge to avoid artifacts.

In a recent report Lima and Montenegro (1972) have described a pneumatic system for measuring intra-uterine pressures which they developed for the routine monitoring of labour. By using a pneumatic rather than a hydraulic system the authors claimed that connection and disconnection of the catheter was easier and that the hydrostatic effects which in hydraulic systems necessitated levelling of the transducer and the uterus were eliminated.

TABLE IV (i): THE DEVELOPMENT OF INTERNAL TOCOMETRY IN HUMAN OBSTETRICS

| Author | Date | Method [1] | Comment |
|---|---|---|---|
| Schatz | 1872 | 1. Intra-uterine balloon<br>2. Trans-cervical<br>3. Hydraulic<br>4. Mercury manometer and simple kymograph | High inertia recording system and large balloon (80 cc) were disadvantages. Pressures relative. |
| Westermark | 1893 | 1. Intra-uterine balloon<br>2. Trans-cervical<br>3. Hydraulic<br>4. Mercury manometer and kymograph | Small balloon (2 cc) avoided possible disadvantage of large balloons disturbing uterine contraction patterns. |
| Rucker | 1922 | 1. Intra-uterine bag<br>2. Intra-cervical<br>3. Hydraulic<br>4. Mercury manometer and kymograph | Pressures could only be recorded in first stage labour. |
| Bourne and Burn | 1927 | 1. Intra-uterine balloon<br>2. Trans-cervical<br>3. Hydraulic<br>4. Mercury manometer and kymograph | Small balloon an advantage. |
| Wieloch | 1927 | 1. Intra-amniotic open-ended catheter<br>2. Trans-abdominal<br>3. Hydraulic<br>4. Mercury manometer | Recorded resting pressures during pregnancy in women with hydramnios. |
| Moir | 1933, 1936 | 1. Intra-uterine balloon<br>2. Trans-cervical<br>3. Hydraulic<br>4. Mercury manometer and kymograph | Used multiple balloons. |
| Adair and Davis | 1934 | 1. Intra-uterine bag<br>2. Trans-cervical<br>3. Hydraulic and pneumatic combined<br>4. Mercury manometer and kymograph | Used mainly in the post-partum uterus. |
| Salerno | 1938 | 1. Intra-uterine bag<br>2. Trans-cervical<br>3. Hydraulic and pneumatic combined<br>4. Mercury manometer | Very large 800 cc bag (used for cervical dilatation) was a distinct disadvantage. |
| Woodbury <u>et al</u>. | 1938 | 1. Intra-uterine balloon<br>2. Trans-cervical<br>3. Not described<br>4. Optical differential manometer | Differential pressures measured using gastric balloons and arterial catheters. Low inertia system. |
| Karlson | 1944, 1949 | 1. Intra-uterine granular carbon sensor<br>2. Trans-cervical<br>3. None - direct<br>4. Milliammeter | Low inertia system. More than one sensor could be used simultaneously. Calibration non-linear. |
| Alvarez and Caldeyro | 1948 | 1. Intra-amniotic open ended catheter<br>2. Trans-abdominal<br>3. Hydraulic<br>4. Water and mercury manometer and kymograph | Placental haemorrhage, passage of amniotic fluid into peritoneal cavity, obstruction of the needle and, in certain cases, scarcity of amniotic fluid were problems. |
| Schild <u>et al</u>. | 1951 | 1. Intra-uterine and intra-cervical balloons<br>2. Trans-vaginal<br>3. Hydraulic<br>4. Mercury manometer and kymograph | Used for measuring intra-cervical and intra-uterine pressures during pregnancy. |
| Williams and Stallworthy | 1952 | 1. Intra-amniotic open ended catheter<br>2. Trans-cervical<br>3. Hydraulic<br>4. Mercury manometer and kymograph | Obstruction of the catheter, scarcity of amniotic fluid and descent of the catheter with the foetus were problems. |
| Ingelman-Sundberg <u>et al</u>. | 1953 | 1. Intra-uterine strain gauge sensor<br>2. Trans-cervical<br>3. None-direct<br>4. Oscillograph | Artifacts produced when sensor came in contact with foetus during labour. Actual pressures. |
| Smyth and Wolff | 1960 | 1. Intra-uterine sensor and transmitter (radiotelemetry)<br>2. Trans-cervical<br>3. None - direct<br>4. Chart recorder | Actual pressures. Transmitter had short life. |
| Hendricks <u>et al</u>. | 1962 | 1. Intra-myometrial open-ended catheter<br>2. Trans-abdominal<br>3. Hydraulic<br>4. Electromanometer and chart recorder | Capable of recording pressures during the three stages of labour. |
| Csapo | 1964 | 1. Intra-uterine balloon<br>2. Trans-cervical<br>3. Hydraulic<br>4. Electromanometer and chart recorder | Avoided injury to foetal and maternal blood vessels and eliminated catheter blockages. Difficult to maintain exact volume? |
| Fuchs <u>et al</u>. | 1965 | 1. Intra-amniotic open-ended catheter<br>2. Trans-vaginal<br>3. Hydraulic<br>4. Electromanometer and chart recorder | Used for monitoring labour in cases of therapeutic abortion. |
| Bengtsson | 1968 | 1. Sponge-tipped catheter<br>2. Trans-cervical<br>3. Hydraulic<br>4. Electromanometer and chart recorder | Enabled pressures in pregnant and non-pregnant uterus to be measured. Eliminated catheter blockages. |
| Lima and Montenegro | 1972 | 1. Intra-uterine balloon<br>2. Trans-cervical<br>3. Pneumatic<br>4. Electromanometer and chart recorder | Connection and disconnection easy. Hydrostatic effects eliminated. |

[1] 1 - method
2 - approach
3 - transmission of pressure
4 - recording system

### IV.2.3. Internal tocometry in ruminants

Uterine and cervical activity during pregnancy in ruminants was the subject of an early report by Fitzpatrick (1951) in an extension of the investigations of Schild (1951) and Schild et al. (1951) into the activity of the human uterus and cervix. Using the same cannula as that employed in the human studies Fitzpatrick (1951) was able to show that the cervices of cattle, sheep and goats were capable of spontaneous contractions independent of the body of the uterus. Recordings were obtained from cattle in the standing position with epidural analgesia and from goats and sheep in dorsal recumbency under pentobarbitone and cyclopropane anaethesia. In a further report Fitzpatrick (1957) determined the response of the bovine uterus and cervix to pituitrin throughout pregnancy. His results indicated a trend towards a greater uterine response to pituitrin as parturition approached, while the response of the cervix remained constant.

In a study initiated to determine the relative amounts of work done by the abdominal and uterine muscles during parturition in cattle, Gillette and Holm (1963) used plastic micro-balloons to detect both uterine and abdominal pressures. These balloons were sutured between the myometrium and the endometrium (uterine activity) and on the serosal surface of the uterus (abdominal pressure). Of 0.1 cc, they were blown in the end of sealed plastic tubes which became the recording catheters and were connected to a pair of electromanometers attached to the cow's side. A flexible overhead lead linked the electromanometers to the stationary amplifier and recorder. Based on a comparison of areas under the tracings obtained from the uterine and abdominal balloons, it was estimated that the uterus contributes 90% or more of the effort required to expel the foetus. Uterine pressures recorded by this technique reflected both local and generalised myometrial activity since balloons situated some distance apart often recorded similar pressure waves at different times. On the other hand abrupt pressure changes ascribed to activity of the circular muscles of the uterus produced pressure changes in other balloons which were simultaneous although reduced in amplitude. It is not clear whether the results obtained with this technique give an accurate reflection of intra-uterine pressures, since they were apparently not validated by the simultaneous use of an open ended catheter.

The first report of uterine activity during parturition in the ewe was that of Murdick (1964). He recorded intra-uterine pressure in three ewes prior to and during parturition by surgically implanting rubber balloons between the foetal membranes and the endometrium. A polyethylene catheter attached to the balloon was passed subcutaneously to the thorax where it was secured for periodic monitoring using an electromanometer and recorder. Pressure changes recorded up to 12 hours before delivery ranged from 6-30 mm Hg, while within 12 hours of birth, pressures in excess of 100 mm Hg were recorded from two sheep and 65 mm Hg from the third. Pressure changes in two sheep caused by abdominal straining during second stage labour reached mean levels of 48 mm Hg and 96 mm Hg. On the basis of subsequent reports (see below) it seems likely that both the uterine and abdominal pressures recorded by Murdick (1964) were abnormally high.

Intra-uterine pressures in pregnant ewes were monitored by Hindson et al. (1965) with the aid of radiotelemetry. They surgically implanted pressure sensitive radio transmitters (endoradiosondes) between the foetal membranes and the endometrium in ten ewes, two to three weeks before term. Uterine activity was monitored daily while the sheep were restrained in a metabolism crate surrounded by a loop aerial. During parturition, however recordings were made continuously with the ewe on straw in a pen. An undesirable feature of this instrument, which obscured changes in uterine tone (Ward, 1968 cited by Hindson and Turner, 1969) was the variation in the baseline of the recording caused by carrier frequency drift. But in comparison with the endoradiosonde of Smyth and Wolff (1960) which was not capable of transmitting for more than 24 hours, this instrument had the advantage of being able to transmit for up to three months. Observations by Hindson et al. (1965) indicated that until about 12 hours prior to parturition the uterus was quiescent and that up to this time all pressure changes could be ascribed to extraneous sources, chiefly body movement. Uterine pressures first became apparent about 12 hours before birth and increased progressively in amplitude until birth, at which time they ranged from 15 - 23 mm Hg. An important observation was that abdominal expulsive effort was closely synchronised with the peaks of the uterine pressure waves. With the aid of two radiosondes, one implanted in each gravid horn Hindson et al. (1968a) were able to show that in the case of a ewe carrying twins the uterine pressures developed in one horn were approximately twice the amplitude of those developed in the other horn and that invariably the lamb located in this dominant horn was delivered before its twin.

In an attempt to determine the cause of 'ring womb' in the ewe Ward (1966) examined the relationship between uterine activity and cervical dilatation during parturition. He employed two methods, one of which was similar to that of Caldeyro-barcia and Alvarez (1952), a polyethylene catheter being inserted into the allantoic cavity by needle puncture of the abdominal wall. The other resembled that described by Murdick (1964) in which a balloon catheter was placed between the foetal membranes and the endometrium, although in this case the system was filled with air. Both methods yielded similar results. Regular pressure waves were found to begin between 6 and 15 hours before parturition, appearing first as three or four contractions followed by quiescent periods of about five minutes which grew progressively shorter until two or three hours later the waves became continuous. An intra-abdominal balloon was used to record abdominal bearing down efforts and artifacts caused by body movement. The magnitude of the uterine contractions ranged from 20 mm Hg to 45 mm Hg although bearing down effort increased these pressures to 100 mm Hg.

Hindson et al. (1967), having previously established the normal pattern and intensity of uterine pressure changes occurring in ewes at parturition (Hindson et al., 1965), attempted to induce the condition of 'ring womb' by administering 20 mg of diethyl stilboestrol to a number of ewes during pregnancy. Uterine pressures in these ewes were monitored by radiotelemetry (Hindson et al., 1965) to investigate the possibility that inadequate uterine activity was responsible for the failure of the cervix to dilate. Fourteen ewes were injected with diethyl stilboestrol and two developed 'ring womb' necessitating caesarean section. The intra-uterine pressure waves of these ewes however, were indistinguishable from those of the controls. It was therefore concluded that 'ring womb' is not caused by inadequate uterine activity but is probably a primary disorder of the cervix itself. In a further investigation Hindson et al. (1968 b) studied the effect on uterine activity and cervical dilatation of a deficiency of vitamin D and of injections of progesterone. Ewes maintained on a diet deficient in vitamin D showed no significant abnormalities, but the uterine activity of the nine ewes treated with progesterone was found to be low compared with that of the controls. In six of the progesterone treated ewes cervical dilatation was delayed, although full dilatation was eventually achieved; there was, however, little indication of 'ring womb' in these ewes and no apparent similarity to the experimental 'ring womb' induced by diethyl stilboestrol.

In an extension of the previous study Hindson et al. (1969) examined the effect on uterine activity of a single dose of 80 mg of progesterone administered by intra-muscular injection at the onset of labour at term. Oxytocin sensitivity was also measured by observing the effect of intravenous injections of oxytocin on uterine activity. It was found that a single injection of progesterone had a marked depressant effect on the myometrium, abolishing or considerably diminishing the pressure waves in most ewes and delaying the delivery of lambs. In general the threshold dose of oxytocin was found to decrease with approaching parturition.

## IV.3. Materials and Methods

### IV.3.1. Animals

Ewes employed in this study were drawn from a group of 67 which had been selected on the basis of past lambing performance from a number of Romney flocks. Thirty ewes bought from a commercial flock had never required assistance at birth while the balance were stud ewes, most of which had been assisted to lamb at least once. Following shearing in January 1973 the ewes were set stocked on predominantly rye grass pasture on the Massey No. 2 Sheep Unit and maintained in good health.

Since only two sheep could be monitored simultaneously with the facilities available for recording uterine pressures, it was necessary to extend lambing over a number of months so that a sufficient number of ewes could be studied. To this end mating was planned so that approximately two or three ewes would lamb per week. Thus every seven days a Romney ram fitted with a mating harness and crayon (Appendix II) was joined with the ewes and after three or four ewes had been marked he was then removed. The harness was replaced fortnightly until a sequence of four different colours had been used. At this point any coloured wool present was clipped off the ewes and the sequence of colours was repeated. To enable easy identification of the ewes during mating large numbers were sprayed on their flanks with aerosol stock marker (Appendix III). For the first three months a single ram was used. Later in the season an additional ram was used as the first appeared to have reduced libido. Individual tupping dates were recorded from which lambing dates were estimated.

Approximately 90 days after mating the ewes were radiographed to diagnose pregnancy and to determine the number of foetuses present. A ventro-dorsal radiograph of the abdomen was taken while the sheep lay in dorsal recumbency on a cassette holder (for technical details see Appendix IV). It was found that the ewes would remain in this position without support while under the influence of a tranquillizing dose (0.01 g) of xylazine (Rompun-Bayer). With this dose most of the ewes were able to walk when they were assisted to their feet and could be returned to pasture at the conclusion of the procedure. Chemical restraint was chosen to eliminate the danger of excessive radiation exposure, which would have existed had the ewes been held.

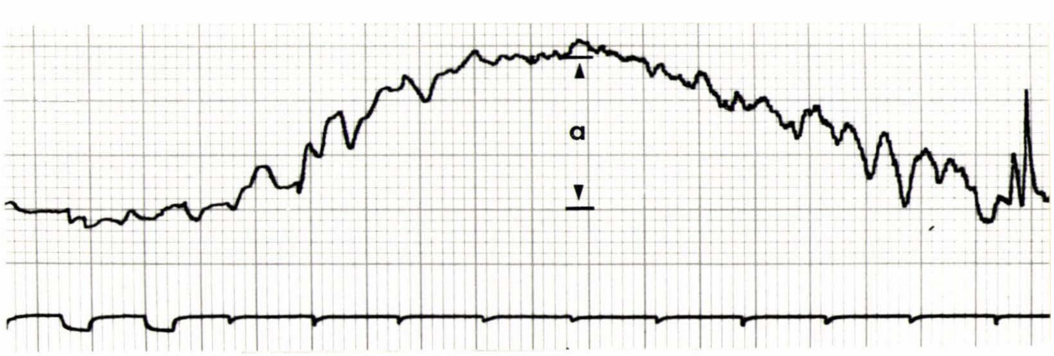
One month prior to the expected date of lambing, ewes with single foetuses were transferred to indoor pens where they were fed clover hay and linseed cake. For a week they were allowed to grow accustomed to their new environment and adjust to the changed diet, then, before surgery, food and water were withheld for a period of 18 hours. On their return from surgery the ewes were placed in a wooden stall similar to that which was used during recording (Plate IV.1.) where they were tethered with another ewe for company. While in the stalls they were given approximately 2.5 kg of hay and 700 g of kibbled linseed cake daily. Water was provided _ad lib._ Later in the course of the experiment the

Plate IV.1. Ewes in recording stall during monitoring of intra-uterine and intra-abdominal pressures (D.S.I.R.).

Plate IV.2. Active period 14 days before labour in sheep 75R showing amplitude measurement 'a'. Time signal in minutes. Each large division corresponds to 2.5mm Hg.

1

2



ration of linseed cake was reduced to half in an effort to produce more moderate birth weights. The ewes soon became used to having the straw in their stalls replaced and most readily accepted their confinement. After about a week the ewes were transferred to the animal recording room at the Department of Scientific and Industrial Research Laboratory (D.S.I.R.) near the Massey University campus and continuous monitoring of uterine pressures was commenced. Throughout the recording period the ewes were restrained loosely in wooden stalls. A collar and chain attached to the front of the stall prevented them from turning round and dislodging the catheters (Plate IV.1.). Visual contact between individuals was preserved by incorporating large openings in the partitions. These also provided access to water. Hay and linseed cake were supplied in troughs fixed to the front of the stall and accessible through the front division. In order to facilitate free drainage of urine, polyethylene sheeting was placed under the straw, and the front of the stall was elevated slightly.

During second stage labour the partition was moved to widen the stall and allow the ewe more freedom of movement. As each ewe lambed she was replaced by another, thus the animals were only alone for a short while during changeover. This was an important consideration as it was found that most of the ewes became highly agitated when left alone in the stalls.

### IV.3.2. Surgery

Amniotic pressures were measured using open ended vinyl catheters (Appendix V) surgically implanted in the amniotic cavity. The distal end of the 120 cm long catheter was perforated for a distance of approximately 7 cm to prevent blockage and a collar of larger diameter vinyl tube was heat welded on to it to retain it in the uterus (Fig IV (i)). Abdominal pressures were measured using a rubber balloon attached to a catheter of similar length and size to the amniotic catheter (Fig IV (i)). The balloons, which were obtained from cuffed endotracheal tubes, were coated with silicone rubber (Silcoset 151 - I.C.I.) to reduce tissue reaction and the risk of abdominal adhesions and were tested for linearity of response to external pressures using a sealed

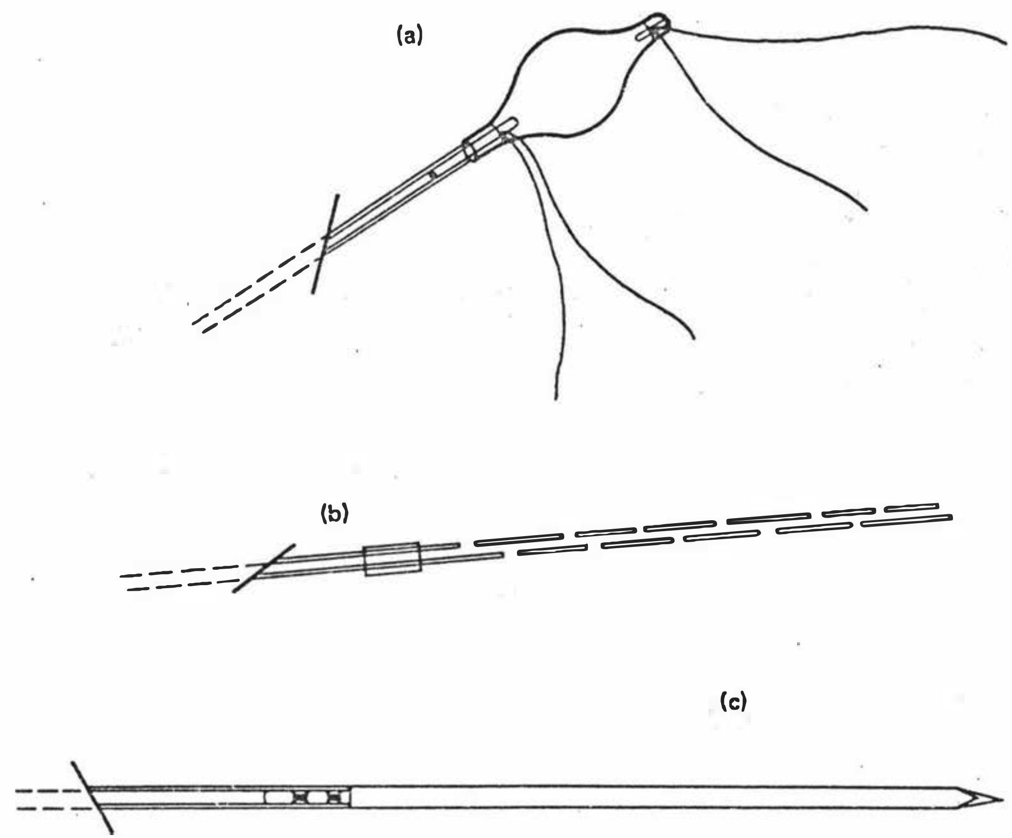



Fig. IV (i). Intra-abdominal balloon (a), intra-amniotic catheter (b) and stainless steel probe (c).

chamber and water manometers. The balloon catheter was filled before surgery with a dilute air free solution of detergent by inserting a thin polyethylene catheter through the length of the catheter into the balloon. The proximal end was then sealed by a stainless steel probe fashioned from a Steinman orthopaedic pin (Appendix VI) see Fig IV (i), which was designed to thread the catheter under the skin.

Anaesthesia was initially induced by an intravenous injection of pentobarbitone sodium (Nembutal-Abbot) but this drug was found to cause prolonged respiratory depression which was considered to be responsible for the deaths of two sheep at the end of surgery. For this reason a mixture of 180 mg of alphaxalone and 60 mg of alphadalone acetate (Saffan - Glaxo) was subsequently used with good results. Following induction, the ewes were intubated with a 12 mm cuffed endotracheal tube and connected to an anaesthetic machine (Appendix VII) operating as a semi-closed system and supplying a mixture of halothane (Fluothane - I.C.I.) and oxygen. The left flank was prepared for surgery over an area extending from the last rib to the quadriceps muscles. After draping the site an incision 10 cm in length was made equidistant from the last rib and the quadriceps muscles and 10 - 15 cm below the lateral processes of the lumbar vertebrae. The abdomen was entered and the pregnant uterus located. By palpation, the foetal lamb was identified and a fore or hind limb was partly exposed by gentle traction, to be held by an assistant. A purse string suture of 2/0 linen was now placed in the uterine wall and in the centre of this a 5 mm incision was made to expose the wool of the foetal lamb. When this stage had been reached, the exposed part of the pregnant horn was draped with moistened towels while the catheters were prepared for insertion.

Both balloon and open ended catheters were rinsed in sterile saline to remove all the traces of the 5% chlorhexidine in which they had been soaking for 24 hours. Saline was injected into the open ended catheter to expel all air and a stainless steel probe was fitted to the proximal end. The distal perforated end of this catheter was then inserted into the amniotic cavity making sure that all the air bubbles were displaced by the amniotic fluid as it rose in the catheter to meet the column of saline. When in place, all air was expelled from the amniotic cavity by exerting pressure on the pregnant horn and the purse string suture was tightened proximal to the collar of the catheter. A further stay suture was placed about 8 cm from the purse string suture to secure the catheter to the serosal surface of the uterus. Using the attached linen suture material the balloon was then secured to the serosal surface of the uterus and, as with the amniotic catheter, a further stay suture was employed to fix the free catheter to the uterus. Both catheters were then led through the abdominal wall at the dorsal end of the incision where they were coiled until the skin incision had been closed.

The peritoneum and inner muscle layers were closed with horizontal mattress sutures of No. 2 monofilament nylon then the fascia and external muscle layers were closed with a continuous suture of No. 2 chromic catgut. Finally the skin was closed with a continuous blanket suture of encapsulated braided nylon (medium Supramid - Weissner). At the completion of surgery the catheters were threaded subcutaneously to the dorsal midline where they were fastened to the fleece with tape.

Prophylactic antibiotic cover was provided for four days with intra-muscular injections of 875 i.u. procaine benzyl penicillin and 0.875 g streptomycin (Streptopen - Glaxo) or with 500 mg ampicillin (Penbritin - Beecham), administered 12 hourly for the first two days and 24 hourly for the following two days.

At the cessation of recording, after parturition, the vinyl catheters were cut with a blade and tied off. A further laparotomy was then performed to remove them from the sheep. A paramedian incision in the left flank provided access to the involuting uterus, enabling the securing sutures to be removed and the catheters withdrawn.

### IV.3.3. Experimental procedure

The arrangement of the electronic recording equipment is illustrated diagrammatically in Fig IV (ii). Use was made of existing landlines at the D.S.I.R. laboratory linking animal experimentation rooms with the central recording laboratory. This meant that the animal room, which in this study was situated

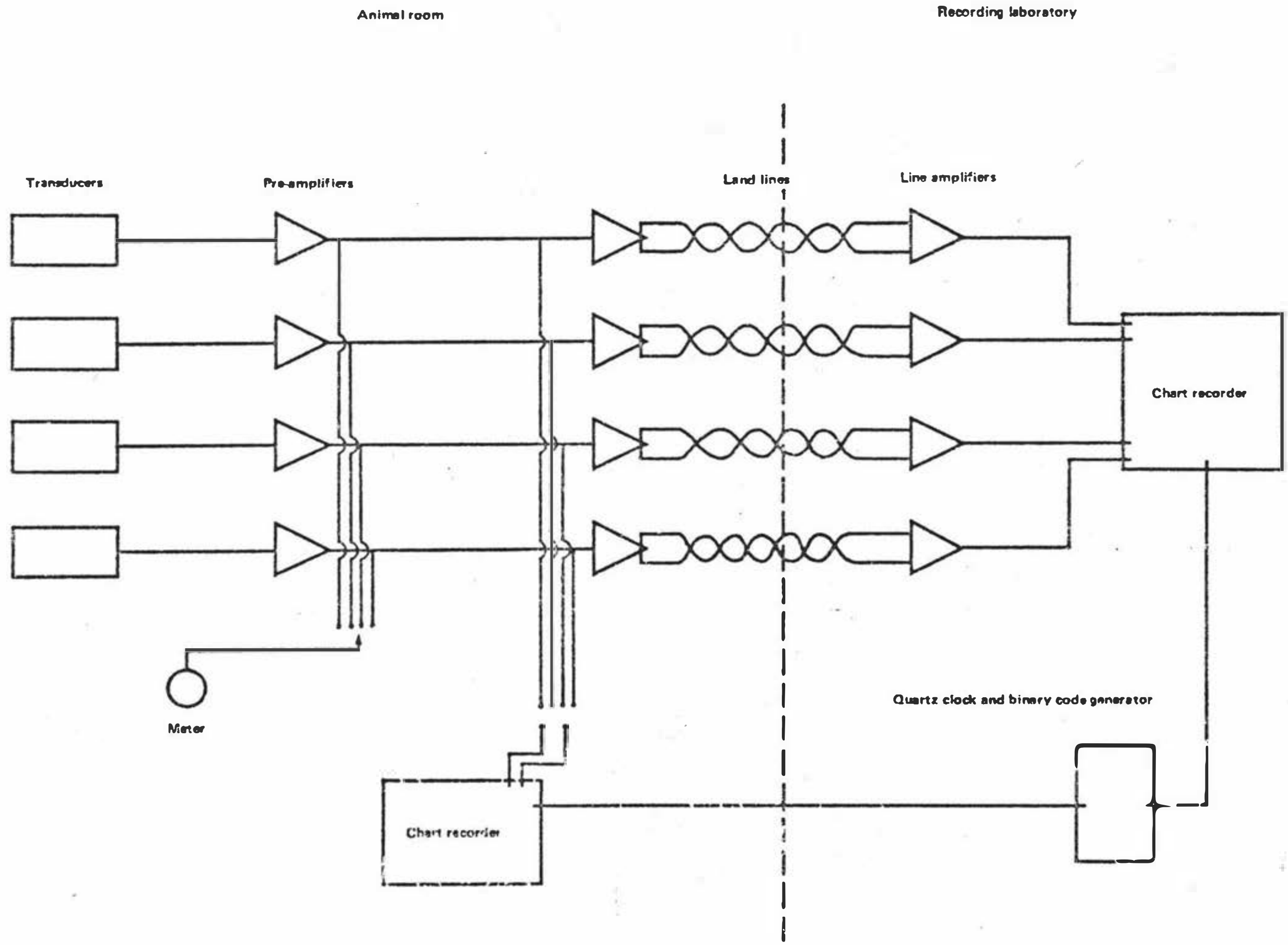



Fig. IV (ii). Block diagram showing arrangement of equipment used for monitoring intra-uterine pressure.

100 metres from the recording laboratory, was not cluttered with sensitive recording equipment and, in addition, frequent checks could be made without disturbing the sheep. This latter feature was particularly advantageous in view of the effects which have been attributed by other authors (Naaktgeboren and Stegeman, 1968; Dufty, 1972) to interference near parturition in both cattle and sheep.

Changes in intra-uterine pressures were detected by strain gauge type pressure transducers while pressure changes in the intra-abdominal balloon were measured using differential transformer type transducers operating in simple (non-differential) mode, with one side open to the atmosphere. (Technical details are described in Appendix VIII.)

Analogue signals from the animal room were relayed to a four channel recorder in the recording centre by the landline. A quartz crystal clock and binary code generator connected to the marker of this recorder and to a portable recorder in the animal room provided a time signal in hours and minutes, and served to synchronise the recordings.

When the sheep had been transferred to the animal room the catheters, still sealed by the probes, were uncoiled and prepared for connection to the transducers. Particular care was taken to prevent bacterial contamination of the amniotic fluid. To stop fluid flowing back into the amniotic cavity the tube was clamped, a section adjacent to the probe swabbed with tincture of chlorhexidene and cut through with a sterile scalpel blade, and the cut end pushed onto the shaft of a blunt 14 gauge hypodermic needle attached to the saline filled transducer head. The balloon catheter was simply attached to the needle adaptor on the transducer after the probe had been cut off. Resting pressure was adjusted by overfilling the balloon with saline and allowing the excess to flow out with the transducer held at the level of the sheep's back. Precautions were taken to ensure that all air was eliminated from both hydraulic systems.

At the commencement of recording the transducers were balanced and the gain of the pre-amplifier connected to the intra-uterine transducer was set to give a full scale deflection of 25 mm Hg. Quantitative records from the intra-abdominal balloon were only required during second stage labour, thus the calibration of these transducers was checked after each sheep had lambed. In the period of recording before labour the intra-uterine and intra-abdominal pressure records were electronically damped to eliminate as much as possible the extraneous pressure changes associated with body movement (see Appendix VIII). Damping was removed during parturition since the pressures developed by the uterus at this time dominated those caused by body movement.

Throughout the study the continuous record of intra-uterine pressure changes was checked at least every 6 - 8 hours for the first sign of labour activity. Once it was established that labour had started, the activity was monitored intermittently and then continuously from the recording centre until the beginning of second stage labour. During second stage labour the ewes were observed by the author, great care being taken to disturb the ewes as little as possible. For example, at night minimal lighting was used for the observations. Except for two ewes, all were left for at least two hours in second stage labour before the progress of parturition was checked by vaginal examination. The two exceptions were the first ewe to lamb (see below IV.4.) and the ewe that developed uterine inertia. In the majority of cases the ewes were then left for a further two to three hours to ascertain whether further progress could be made. When it was obvious that spontaneous parturition could not occur however (e.g. breech birth) or when no further progress had been made after two or three hours, the ewe was assisted to lamb.

## IV.3.4. Analysis of records

Initial studies showed that the most reliable way to identify pre-partum activity was from the occurrence of simultaneous pressure increases recorded by the intra-uterine catheter and the intra-abdominal balloon. Presumably this occurred because localised uterine activity affected the anchor sutures securing the intra-abdominal balloon to the uterine wall. By examining the uterine and abdominal traces for common activity it was possible to recognise some active periods of low amplitude which otherwise would have been overlooked, particularly when the sheep were standing and movement artifacts obscured the fine details of the trace.

Although recordings were made continuously, pre-partum activity was only measured over a 21 hour period from 1800 hours on one day to 1500 hours on the next. This 21 hour examining period allowed for three hours in which the sheep pens could be cleaned and maintenance carried out on the equipment.

Pre-partum activity was measured by the number of periods of uterine activity and the cumulated sum of the amplitudes of the individual pressure changes for the 21 hour period. The method of measuring the amplitude 'a' of a typical pressure change is shown in Plate IV.2.

A problem encountered in some sheep was the occurrence during an active period of pressures below the resting level. In this event 'a' was regarded as zero. However, in the majority of sheep this type of change occurred sporadically and when it was observed frequently, or when activity could not be measured precisely for any other reason, that particular 21 hour period was omitted from the results. A note was made for each ewe of all the active periods in which uterine tone fell more than 2.5 mm Hg below the baseline and the number of these was recorded for each 24 hour interval during the pre-partum period.

Because the form of uterine pressure waves recorded in first stage labour was often irregular, units such as the Montevideo unit[1] appeared unsuitable for describing labour activity in the sheep. Activity was therefore measured as the area under the pressure waves during a 25 minute period every hour. The pressure waves were traced onto heavy tracing paper, cut out and weighed on an electronic balance. Uterine activity was then expressed as $mm^2$ per 25 minutes. As the paper was hygroscopic the weight of a standard area was checked daily to allow correction for the changes in the density of the paper with changing humidity. A problem with this method was encountered in some ewes in which first stage labour activity was superimposed on tone changes similar to those of pregnancy. In such cases tone changes were included in the estimate of uterine activity.

No attempt was made to quantitate uterine pressures during second stage labour, firstly, because of the

[1] Appendix I

difficulty in measuring them in the face of almost continuous abdominal presses, and, secondly, because of the inaccuracies inherent in measuring pressures in a non-pascalian[1] system. An estimate of the work done by the accessory bearing down movements was made by measuring the height of the abdominal pressure changes recorded by the abdominal balloons and summing these over five minute intervals for a period of half an hour from the beginning of second stage labour. Measurements were expressed in mm Hg per 5 minutes.

## IV.4. Results

A total of 23 ewes were operated on in the course of the study, of which 18 provided useable records. Two ewes died at the conclusion of surgery, apparently as a result of hypoxia, one aborted a dead lamb five days after surgery, another lambed unobserved and unassisted seven days before term, and one timid ewe refused to eat or drink and eventually had to be destroyed.

A summary of the type of birth, disposition of the lamb and history of the 18 ewes in the experiment is given in Table IV (ii), while in Table IV (iii) are given birth weights of lambs and gestation lengths of ewes. Each ewe was radiographed according to the procedure outlined in the next chapter (see V.3.1.) to measure its pelvic dimensions: these data are also given in Table IV (iii). Five ewes that had previously not required assistance experienced difficulty at birth under the experimental conditions. There was a significant difference in birth weight of lambs between ewes that gave birth to normally disposed and ewes that gave birth to maldisposed lambs ($p < 0.01$) and also between ewes that experienced dystocia (group B)[2] and eutocia (group A) ($p < 0.05$). The ratio of pelvic area to lamb weight at birth for the group of

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1 Appendix I

2 Ewe 62R excluded from group B because of the unusual nature of the dystocia

TABLE IV (ii): TYPE OF BIRTH AND HISTORY OF EWES IN THE STUDY

| | Identi-fication | Type of birth | Disposition of lamb | Age of ewe (years) | History of ewe |
|---|---|---|---|---|---|
| Group A (eutocia) | 66R | Unassisted | Normal | 6 | Assisted three times before |
| | 84W | Unassisted | Normal | 4 | Assisted once before |
| | 72R | Assisted prematurely | Normal | 6 | Not assisted before |
| | 82Y | Unassisted | Normal | 6 | Not assisted before |
| | 64R | Unassisted | Normal | 6 | Not assisted before |
| | 73W | Unassisted | Normal | 5 | Not assisted before |
| Group B (dystocia) | 96Y | Assisted | Bilateral shoulder flexion | 6 | Assisted three times before |
| | 69Y | Assisted | Bilateral shoulder flexion, one elbow extended, one flexed | 5 | Assisted twice before |
| | 74R | Assisted | Unilateral shoulder flexion | 6 | Not assisted before |
| | 56Y | Assisted | Breech birth | 3 | Assisted once before |
| | 73R | Assisted | Unilateral shoulder flexion | 6 | Not assisted before |
| | 74Y | Assisted | Bilateral shoulder flexion | 5 | Assisted three times before |
| | 52R | Assisted | Posterior present-ation extended posture | 6 | Not assisted before |
| | 80W | Assisted | Breech birth | 4 | Assisted once before |
| | 89Y | Assisted | Bilateral elbow flexion dorso-sacro oblique position | 4 | Assisted once before |
| | 75R | Assisted | Bilateral elbow flexion | 6 | Not assisted before |
| | 34Y * | Unassisted | Bilateral shoulder flexion | 4 | Assisted once before |
| | 62R** | Assisted (uterine inertia) | Normal disposition | 6 | Not assisted before |

* Assigned to Group B because lamb died during birth

** This ewe is considered separately in analyses relating to dystocia because of the unusual nature of the dystocia and thus is not included in Group B

TABLE IV (iii): LAMB BIRTH WEIGHT, GESTATION LENGTH, PELVIC AREA AND THE RATIO OF PELVIC AREA TO LAMB BIRTH WEIGHT IN RELATION TO DISPOSITION OF THE LAMB AT BIRTH

| Disposition of lamb | Group | Ewe No. | Lamb[1] weight (kg) | Gestation length (days) | Pelvic area ($mm^2$) | Pelvic area / Lamb weight |
|---|---|---|---|---|---|---|
| Normal disposition | Group A (eutocia) | 66R | 6.35 | 147 | 10,302 | 1,622 |
| | | 84W | 5.22 | 147 | 9,220 | 1,766 |
| | | 72R | 4.53 | 147 | 9,849 | 2,174 |
| | | 82Y | 4.76 | 146 | 9.579 | 2,012 |
| | | 64R | 4.99 | 148 | 10,591 | 2.122 |
| | | 73W | 4.53 | 144 * | 8,086 | 1,699 |
| | | 62R | 3.4 | 142 | 9.538 | 2.805 |
| | Mean | | 4.83 | 146.2 | 9.595 | 2,029 |
| | n | | 7 | 6 | 7 | 7 |
| | S D | | 0.89 | 2.14 | 814 | 403 |
| Mal-disposition | Group B (dystocia) | 75R | 5.44 | 148 | 9,264 | 1,703 |
| | | 69Y | 5.9 | 146 | 9,191 | 1.558 |
| | | 96Y | 6.12 | 149 | 7,667 | 1,523 |
| | | 56Y | 5.67 | 144 | 9,350 | 1,649 |
| | | 52R | 5.44 | 149 | 10,735 | 1,973 |
| | | 74Y | 6.58 | 148 | 8,311 | 1,263 |
| | | 89Y | 5.22 | 148 | 9,363 | 1,794 |
| | | 80W | 5.22 | 148 | 9,657 | 1,850 |
| | | 73R | 6.12 | 151 | 9,118 | 1,490 |
| | | 34Y | 5.9 | 145 | 9,080 | 1,539 |
| | | 74R | 6.8 | 150 | 9,790 | 1,440 |
| | Mean | | 5.86 | 147.8 | 9,230 | 1,592 |
| | n | | 11 | 11 | 11 | 11 |
| | S D | | 0.52 | 2.09 | 782 | 230 |

Difference in mean birth weight between normally and maldisposed lambs $t = 3.12$, $p<0.01$

Difference between ewes giving birth to normally and maldisposed lambs in respect to mean gestation length $t = 1.5$, $p>0.05$

mean pelvic area $t = 0.95$, $p>0.05$

mean ratio pelvic area to birth weight $t = 2.95$, $p<0.01$

Difference in mean birth weight of lambs between group A and group B $t = 2.70$, $p<0.05$

* This ewe was induced to lamb prematurely, see text

1 Lamb weight immediately after birth

Correlation between birth weight and gestation length = 0.4, $p<0.1$

ewes that gave birth to normally disposed lambs differed significantly from that of ewes that gave birth to maldisposed lambs ($p < 0.01$), although this is probably largely a reflection of the significant difference in birth weight of lambs between the groups.

Because it was not known how well the ewes would tolerate being confined in the stalls during parturition, the first ewe to lamb was observed continuously throughout labour: probably as a result of being frequently disturbed she appeared to have an unusually long first stage labour and was eventually assisted before the commencement of second stage labour. The lamb with nose and forefeet presented at the partly dilated cervix was readily delivered by manually dilating the cervix. Because this animal would almost certainly have lambed normally had assistance not been given, it was assigned retrospectively to the group of ewes that lambed normally (group A).

One ewe, 73W, was induced to lamb prematurely in the holding stalls so that records could be obtained from three ewes which were due to lamb on the same day. Delivery occurred on the 144th day of gestation, 44 hours after a single intra-muscular injection of Dexamethasone (Dectane-Hoechst).

## IV.4.1. Pre-partum activity

Pressure changes attributable to activity of the myometrium and lasting between five and ten minutes were seen to occur at regular intervals throughout the period of recording during the final two weeks of gestation. The frequency of these active periods ranged from once every half hour (sheep 52R) to once every two hours (sheep 96Y) and exhibited no diurnal rhythm. Similar activity was observed as early as day 109 of pregnancy during preliminary recordings and was shown then to be abolished by administration of a myometrial relaxant (Isoxsuprine ((Duphaspasmin - Phillips Duphar) ) 46 mg given intra-muscularly). At about two weeks prior to term the active periods in the majority of sheep were characterised by a gradual increase in uterine pressure above the resting level to a peak which, in some individuals, reached 10 mm Hg, followed by an equally gradual decline to the former resting level (Plate IV.2.); and pressure waves of variable amplitude superimposed on the changes in baseline. The frequency of active periods and the summed amplitude of the pressure changes for the 21 hour examination periods are shown in Figs. IV (iii), (iv), (v), (vi), (vii) for the individual ewes. Sheep 73W was omitted from this analysis because of the poor quality of the pressure recordings obtained from it. No significant difference in mean amplitude of activity was found between the ewes giving birth to normally disposed lambs as compared with those giving birth to maldisposed lambs (Table IV (iv) ).

TABLE IV (iv): PRE-PARTUM UTERINE ACTIVITY AND DISPOSITION OF THE LAMB

| | Disposition of the lamb | |
|---|---|---|
| | Normal | Abnormal |
| Mean pre-partum uterine activity (mm Hg / 21 hours) | 76.1 | 75.6 |
| Number of ewes | 5 | 11 |
| S D | 42.9 | 31.5 |

$t = 0.02,\ p > 0.05$

Mean pre-partum activity was also not related to mean uterine activity during the final three hours of first stage labour ($r = 0.1,\ p > 0.05$).

As parturition approached, in a number of sheep, the pressure waves superimposed on the tonal changes increased in amplitude to become a dominant feature of the records (Plate IV.3.). In other individuals however, such a change was not apparent. In some of the sheep exhibiting enhanced pressure waves, the change evolved progressively into first stage of labour, but in others first stage labour appeared independently of the active periods. A feature of the pre-partum activity in a number of ewes was the occurrence of active periods in which uterine pressures fell below the resting level, sometimes by as much as 8 mm Hg for all or part of the period. This type of activity is illustrated in Plates IV. 4, 5 and 6 and its occurrence for individual sheep is shown in Table IV (v). Again there did not appear to be any relationship between

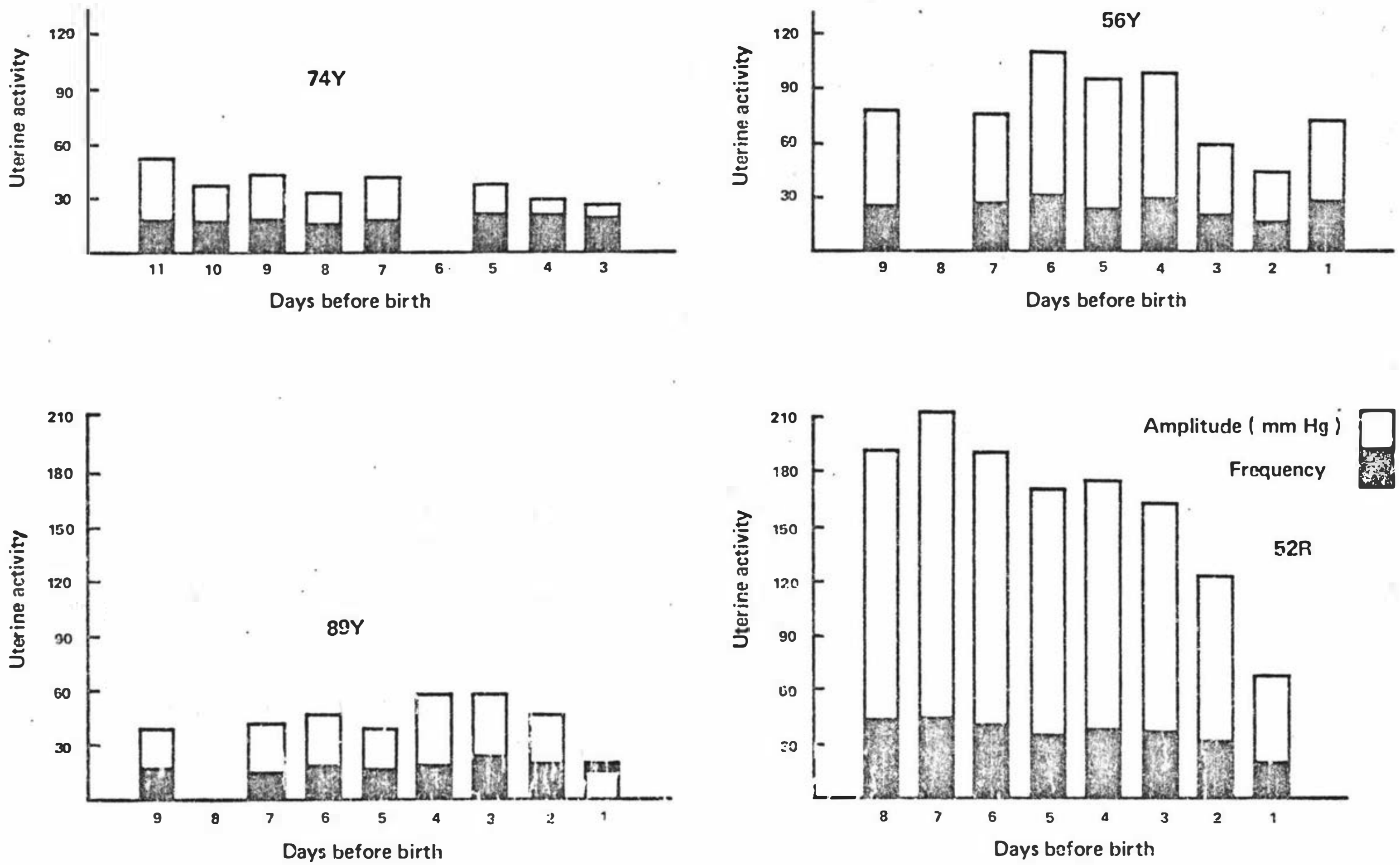



Fig. IV (iii). Pre-partum uterine activity.

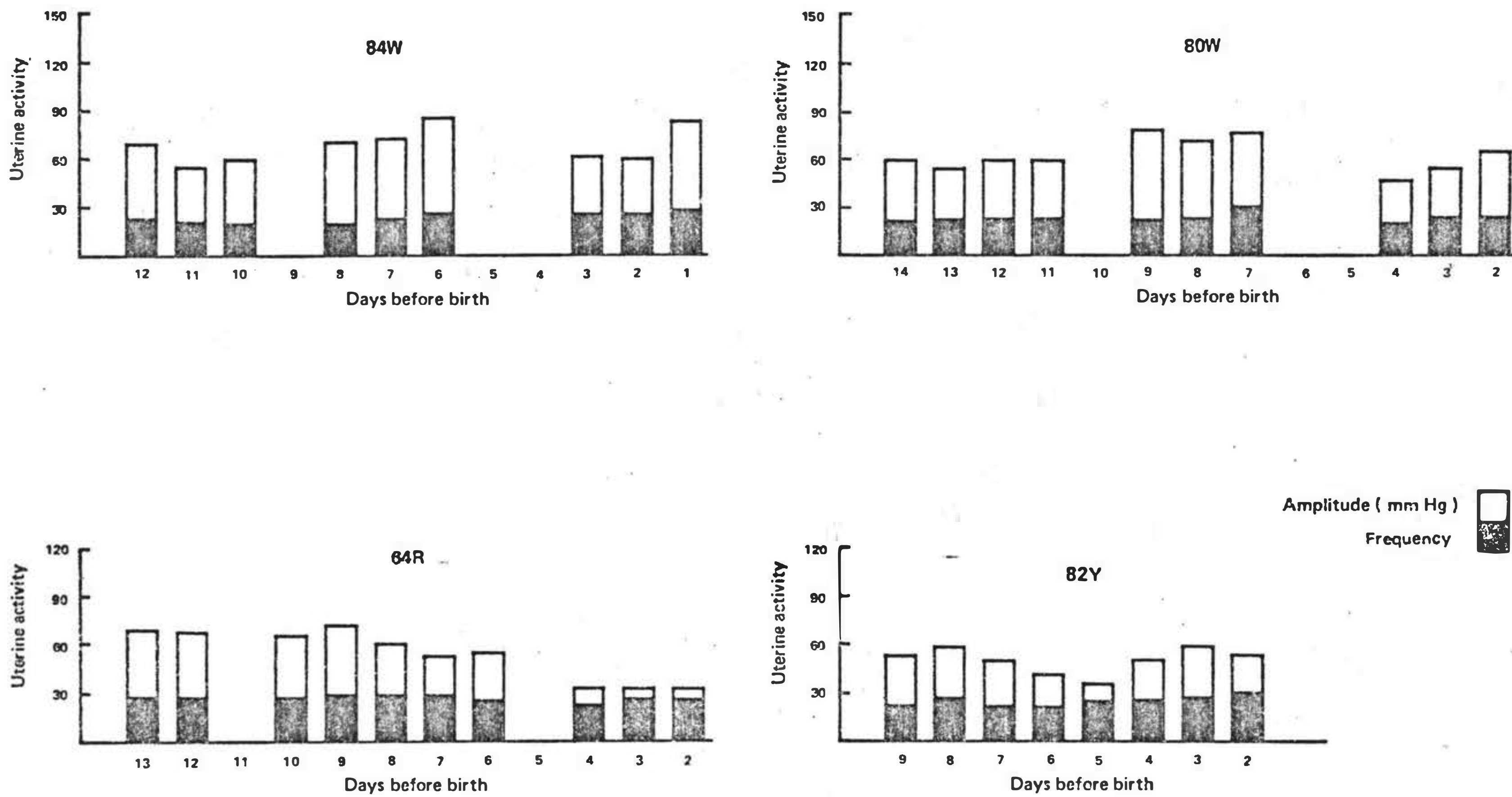



Fig. IV (iv). Pre-partum uterine activity.

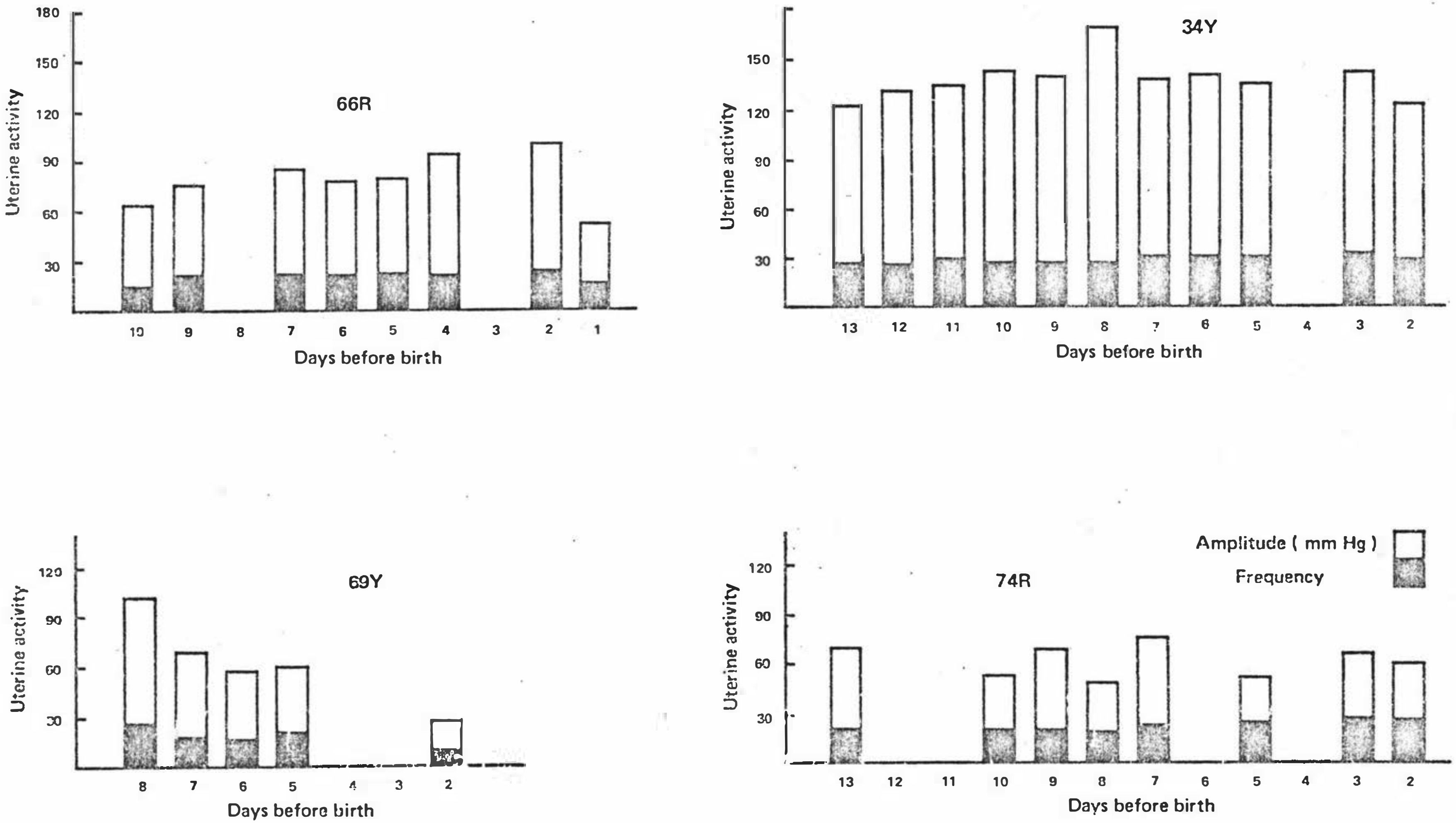



Fig. IV (v). Pre-partum uterine activity.

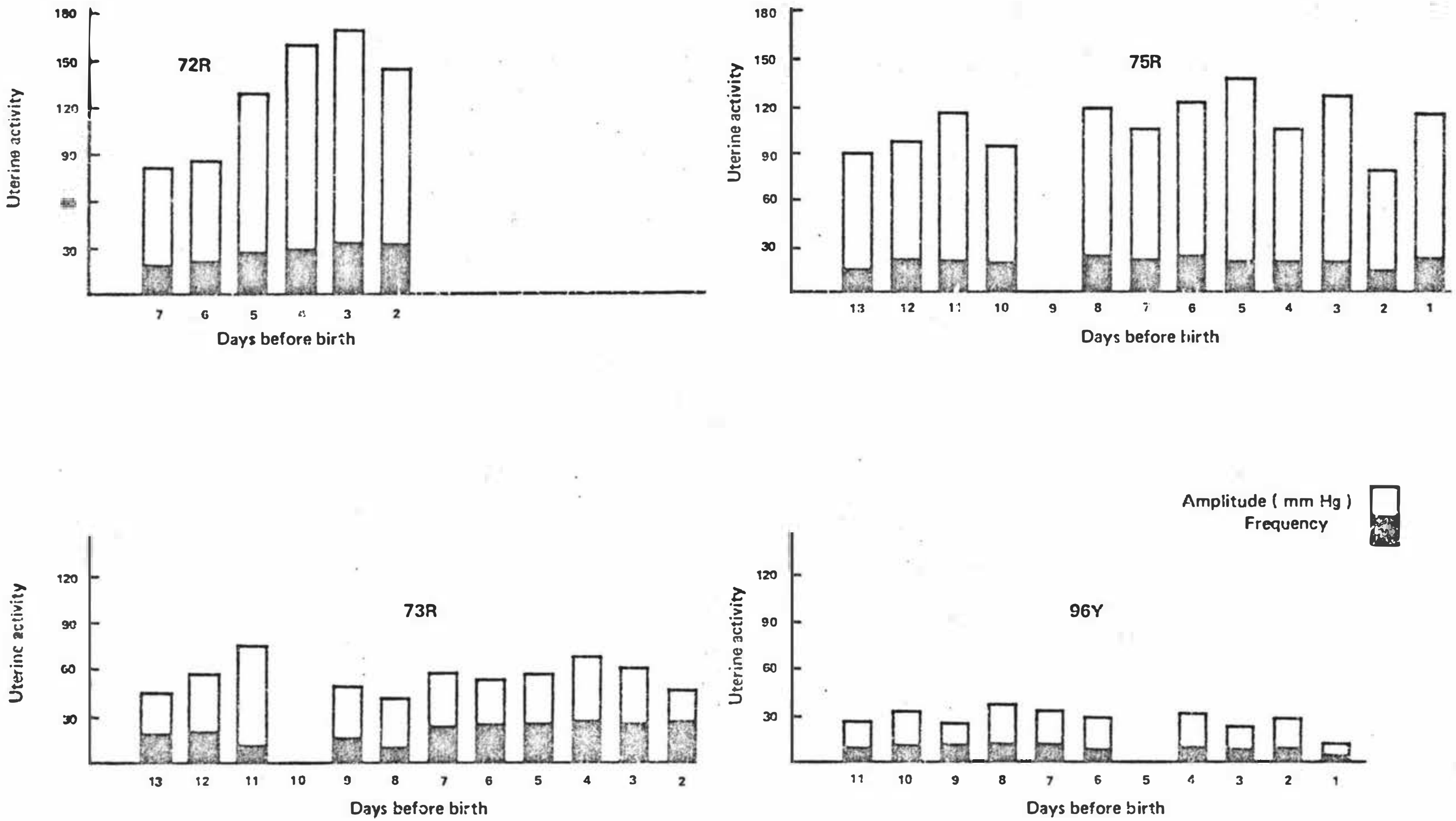



Fig. IV (vi). Pre-partum uterine activity.

62R

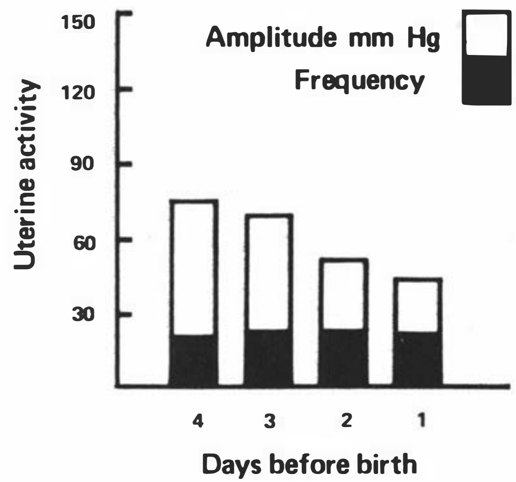



Fig.IV (vii) Prepartum uterine activity.

TABLE IV (v): ACTIVE PERIODS IN WHICH UTERINE TONE FELL MORE THAN 2.5 mm Hg BELOW THE RESTING PRESSURE



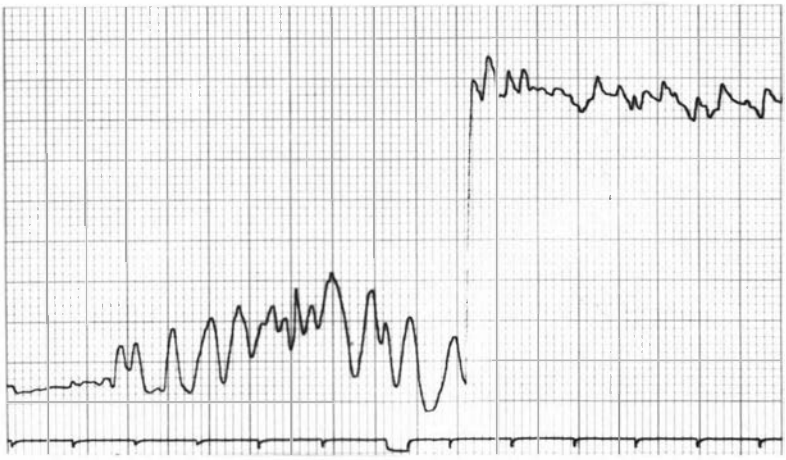
| | | Days before birth | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sheep No. | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | Total |
| Normal disposition | 62R | | | | | | | | | | | - | - | - | - |
| | 72R | | | | | | | 4 | 8 | 4 | 6 | 7 | 7 | 7 | 43 |
| | 66R | | | | - | - | - | - | - | - | - | - | 1 | - | 1 |
| | 82Y | | | | | 6 | 2 | 2 | 4 | 5 | 5 | 7 | 6 | 2 | 39 |
| | 64R | - | - | - | - | - | - | - | 1 | 4 | 9 | 12 | 14 | 8 | 48 |
| | 84W | | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Maldisposition | 96Y | | | - | - | - | - | - | - | - | - | - | 2 | 3 | 5 |
| | 75R | - | - | - | - | - | - | - | - | - | - | - | 3 | 1 | 4 |
| | 69Y | | | | | | - | - | - | - | - | - | 1 | - | 1 |
| | 74R | 1 | 1 | 3 | 5 | 2 | 2 | - | - | 5 | 11 | 2 | 2 | 6 | 40 |
| | 56Y | | | | | - | - | - | - | - | 1 | 1 | 2 | 1 | 5 |
| | 34Y | - | - | - | - | - | - | - | - | - | - | - | - | 9 | 9 |
| | 52R | | | | | | - | - | - | - | - | - | - | - | - |
| | 73R | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 |
| | 74Y | | | - | - | - | - | - | - | 2 | 5 | 5 | 4 | 6 | 22 |
| | 89Y | | | | | - | - | - | 3 | 5 | 8 | 4 | 5 | 2 | 29 |
| | 80W | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 2 |

Plate IV.3. Active period in sheep 82Y 2 days before labour. Baseline shift caused by change in hydrostatic level of uterus with respect to transducer as sheep stood up. Time signal in minutes. Each large division corresponds to 2.5mm Hg.

Plate IV.4. Decrease in resting pressure during an active period in sheep 64R 1 day before labour. Initial baseline shift caused by the sheep standing up. Time signal in minutes. Each large division corresponds to 2.5mm Hg.

Plate IV.5. Decrease in resting pressure for part of an active period in sheep 64R 1 day before labour. Time signal in minutes. Each large division corresponds to 2.5mm Hg.

3



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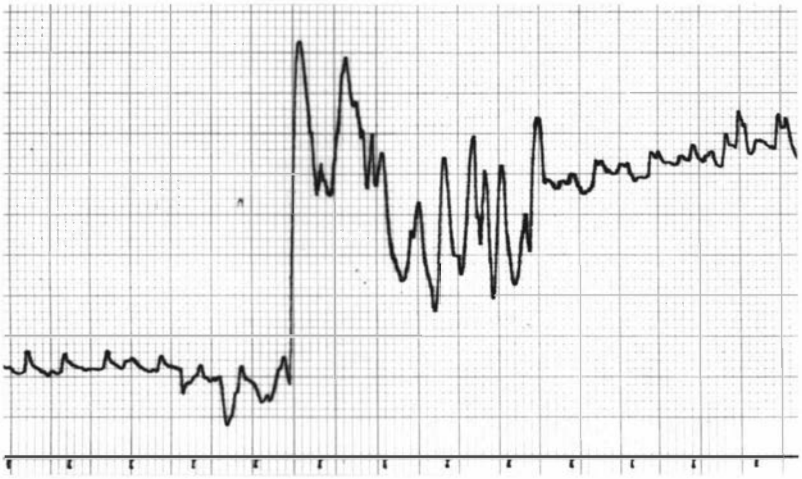

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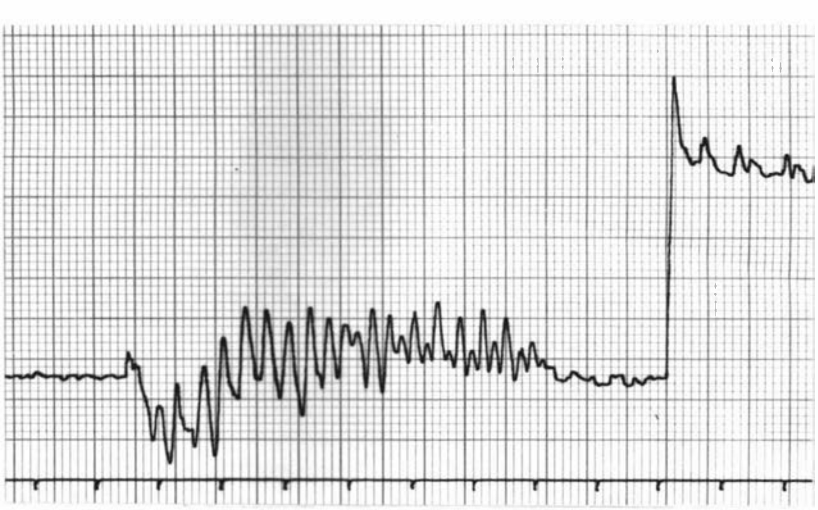
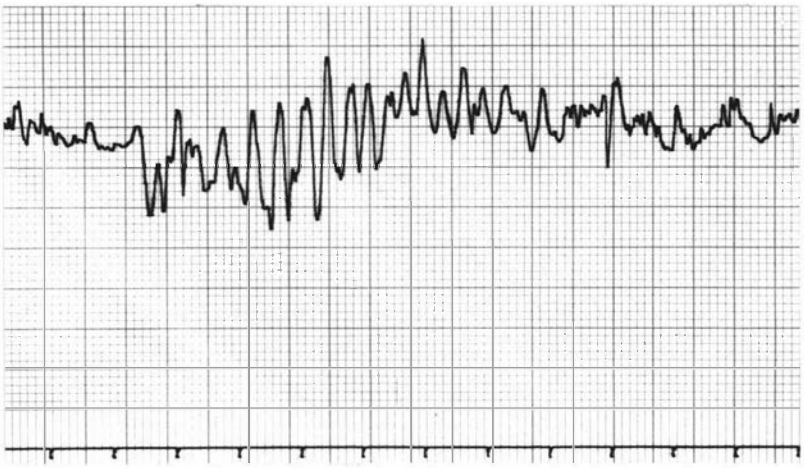


Plate IV.6. Decrease in resting pressure during an active period in sheep 64R 1 day before labour.
Time signal in minutes.
Each large division corresponds to 2.5mm Hg.

Plate IV.7. Onset of first stage labour in sheep 57R.
Baseline shifts caused by changes in the position of the sheep (see Plate IV.3.).
Time signal in minutes.
Each large division corresponds to 2.5mm Hg.

Plate IV.8. Onset of first stage labour in sheep 82Y 18 hours 30 minutes before delivery.
Time signal in minutes.
Each large division corresponds to 2.5mm Hg.

6



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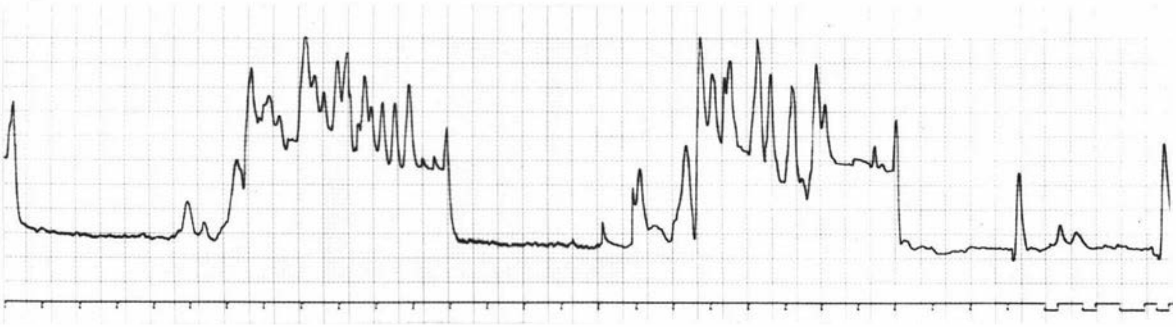

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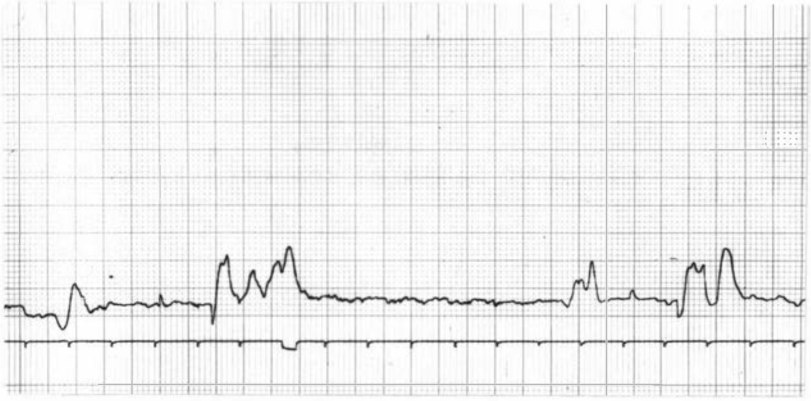


this type of activity and the disposition of the lambs at birth.

## IV.4.2. First stage labour

As with the considerable variation observed in pre-partum activity of ewes in this study so also was there considerable variation in the form of onset of first stage labour. In ewe 96Y pre-partum active periods during the day preceding labour were infrequent and of low amplitude, and the onset of labour was heralded by small random pressure waves similar to those illustrated in Plate IV.16. In other ewes, for example 57R, first stage labour 'evolved' from the active periods (Plate IV.7.) and in this particular case the advent of labour was so atypical that it was not recognised and the ewe lambed unobserved less than eight hours after the record had been checked. More often the onset of labour assumed a form intermediate between these two extremes. Random low amplitude pressure waves were sometimes seen more than a day in advance of labour, while in other individuals this activity was only observed within 12 hours of birth. The development of labour is illustrated in Plates IV. (8 - 18) for sheep 82Y and 64R. In general the pressure changes in first stage labour were of the order of 10 mm Hg although pressures of 20 mm Hg were recorded from sheep 34Y.

Uterine activity for each sheep, estimated by measuring the area under the pressure tracing, is shown in Figs. IV (viii), (ix), (x), (xi), (xii). Mean uterine activity during the final three hours of first stage labour was significantly correlated with birth weight of the lambs ($r = 0.58$, $p < 0.05$). Also ewes that gave birth to normally disposed lambs had significantly lower mean uterine activity over the final three hours of first stage labour than did ewes that gave birth to maldisposed lambs (Table IV (vi)).

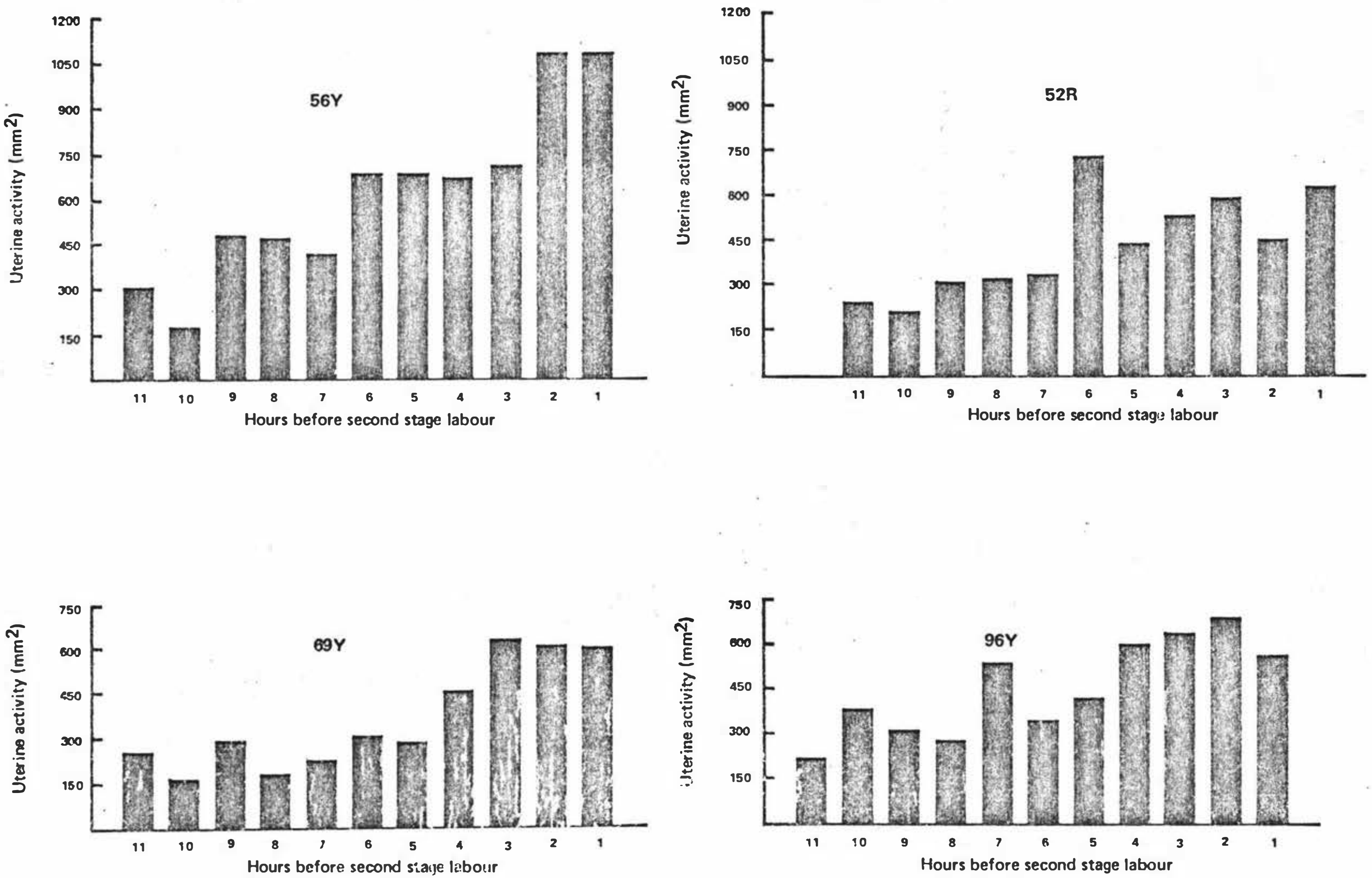



Fig. IV (viii). Uterine activity during first stage labour.

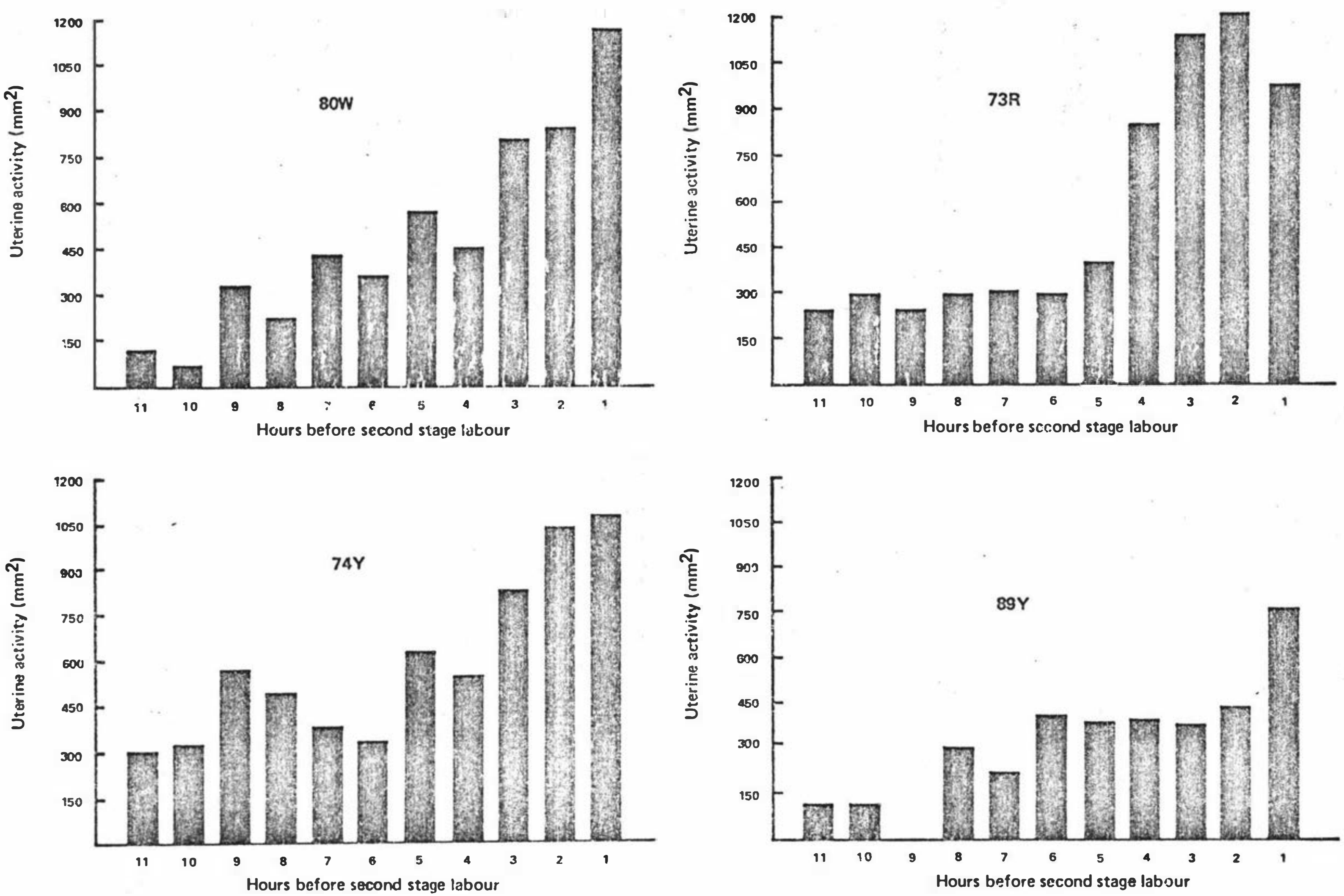



Fig. IV (ix). Uterine activity during first stage labour.

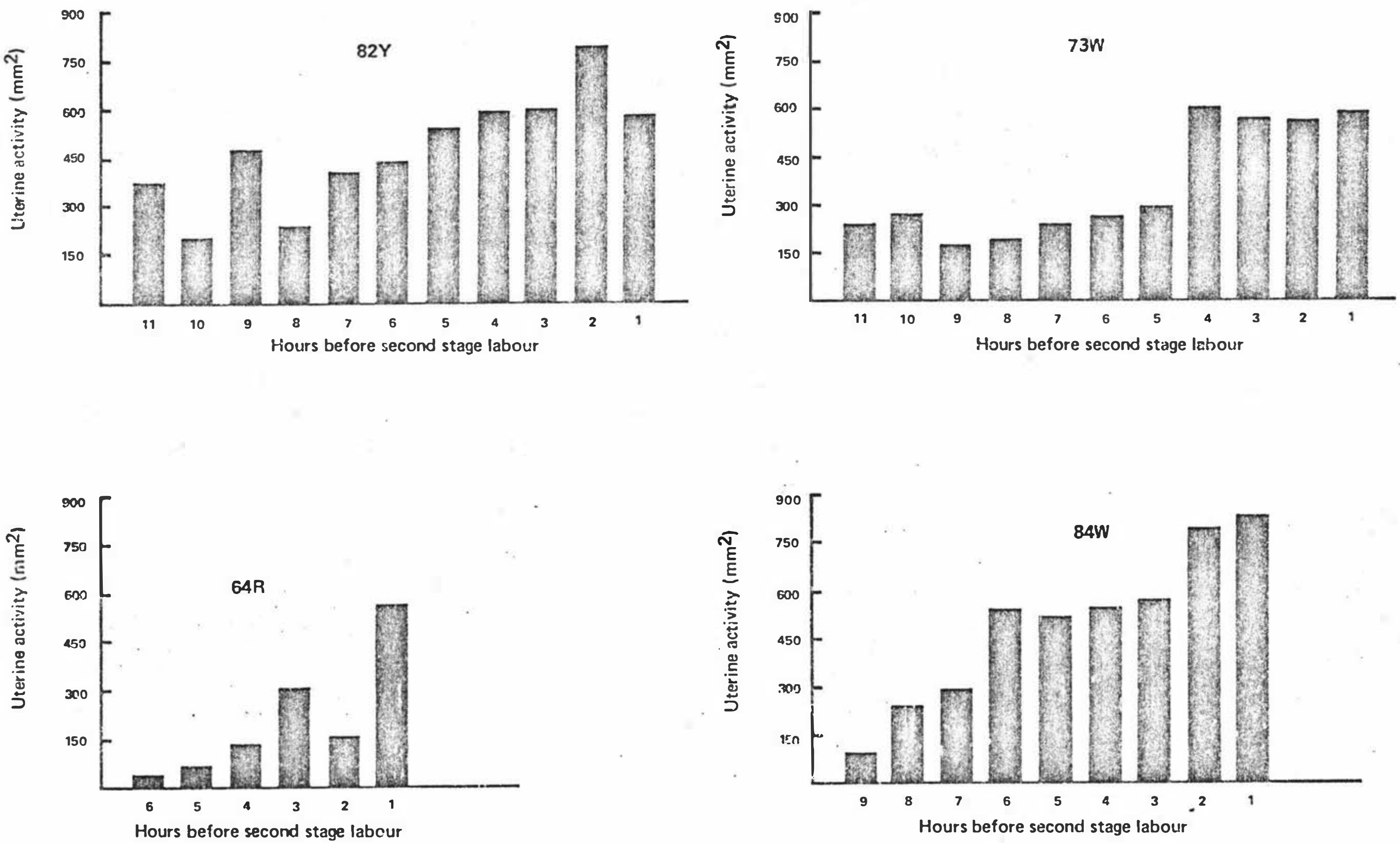



Fig. IV (x). Uterine activity during first stage labour.

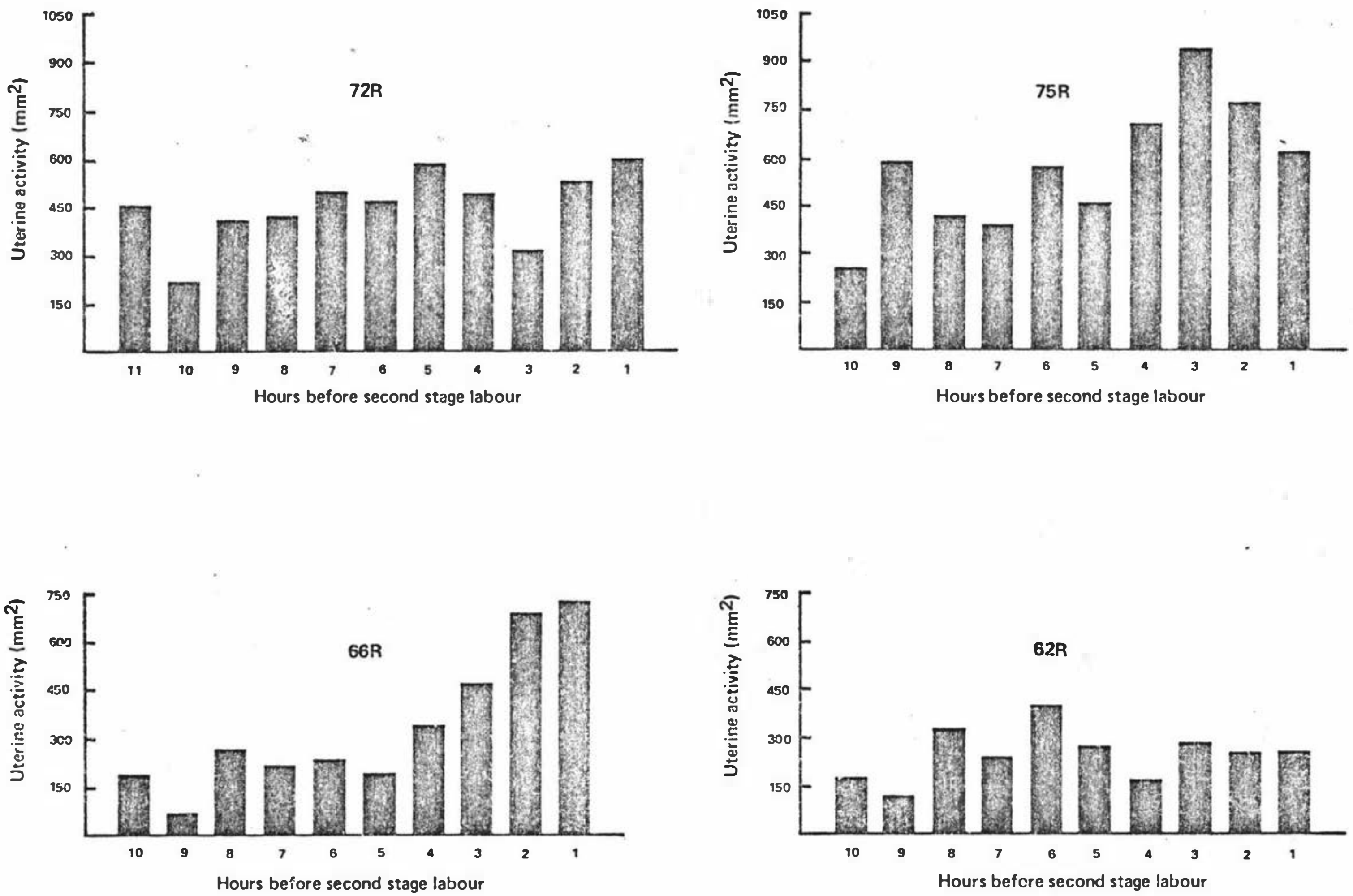



Fig. IV (xi). Uterine activity during first stage labour.

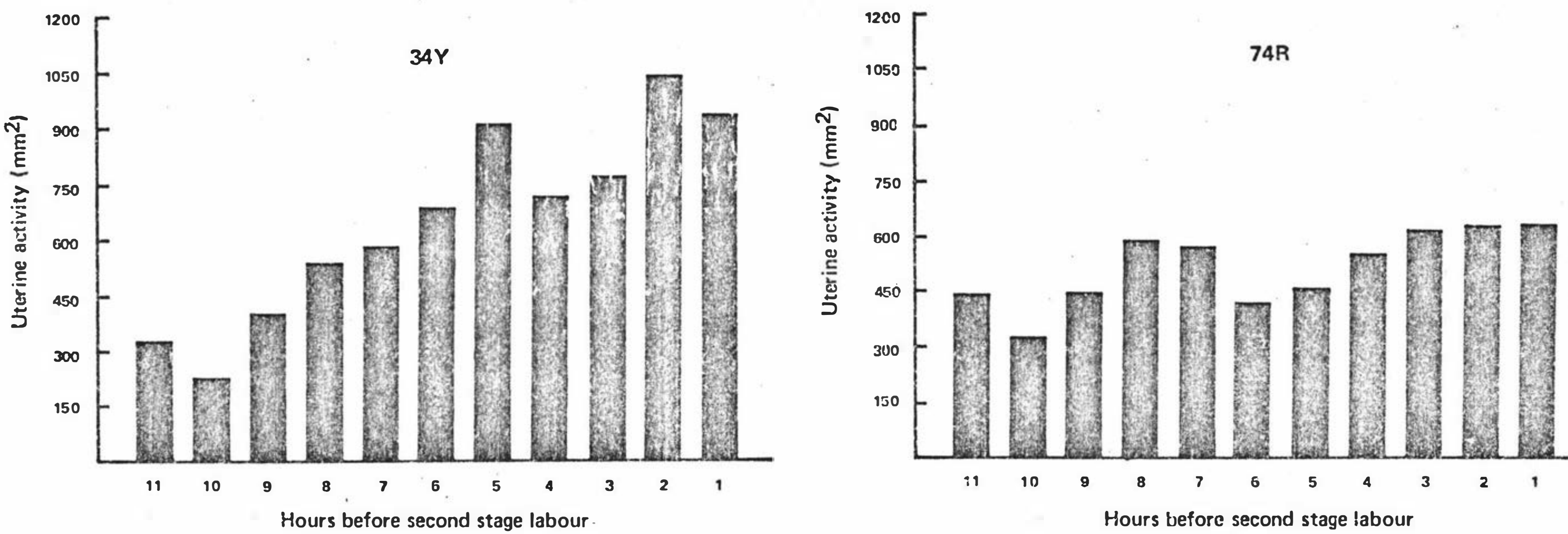


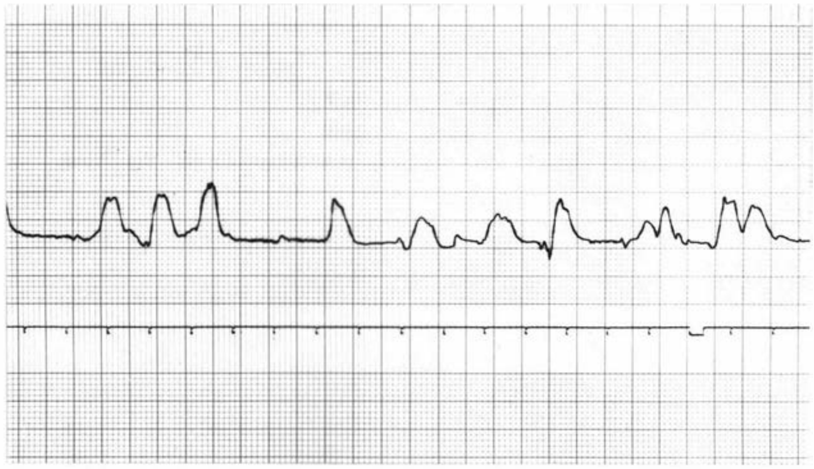

Fig. IV (xii). Uterine activity during first stage labour.

Plate IV.9. First stage labour in sheep 82Y 8 hours 30 minutes before delivery.
Time signal in minutes.
Each large division corresponds to 5mm Hg.

Plate IV.10. First stage labour in sheep 82Y 6 hours before delivery.
Time signal in minutes.
Each large division corresponds to 5mm Hg.

Plate IV.11. First stage labour in sheep 82Y 5 hours 30 minutes before delivery.
Time signal in minutes.
Each large division corresponds to 5mm Hg.

9



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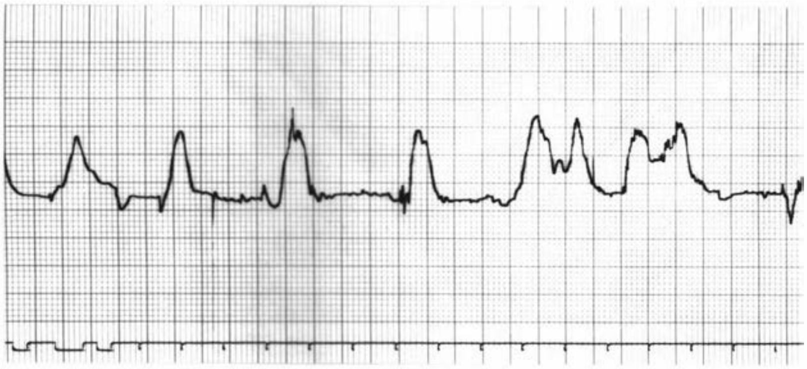

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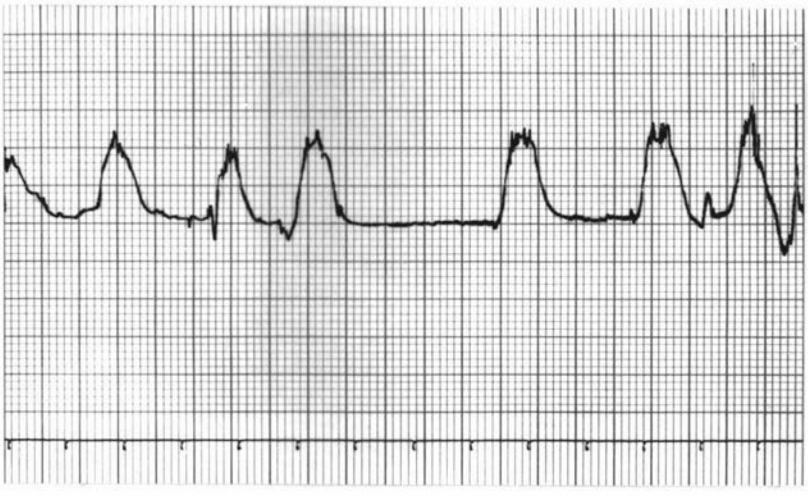
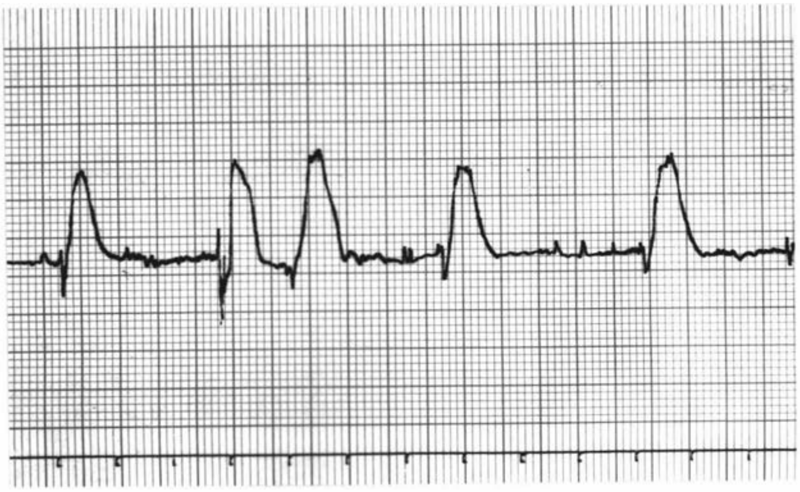


Plate IV.12. First stage labour in sheep 82Y 2 hours before delivery.
Time signal in minutes.
Each large division corresponds to 5mm Hg.

Plate IV.13. Second stage labour in sheep 82Y. Abdominal pressure.
Trace speed 7.5mm per minute.
Each large division corresponds to 11.5mm Hg.

Plate IV.14. Active period in sheep 64R 2 days before labour.
Time signal in minutes.
Each large division corresponds to 2.5mm Hg.

12



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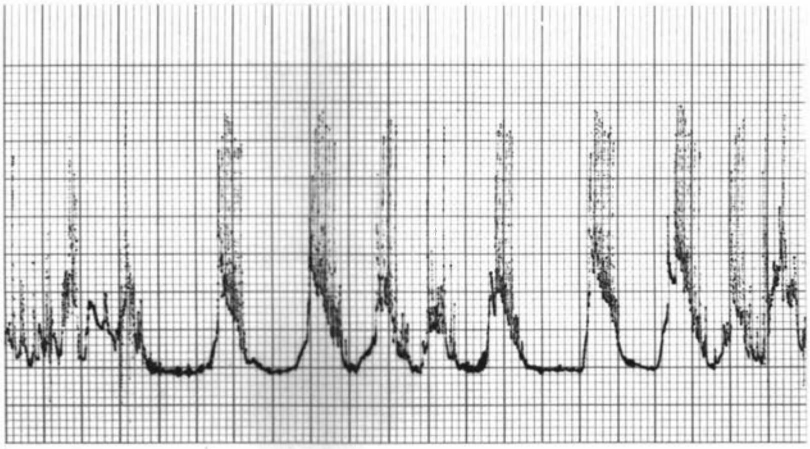

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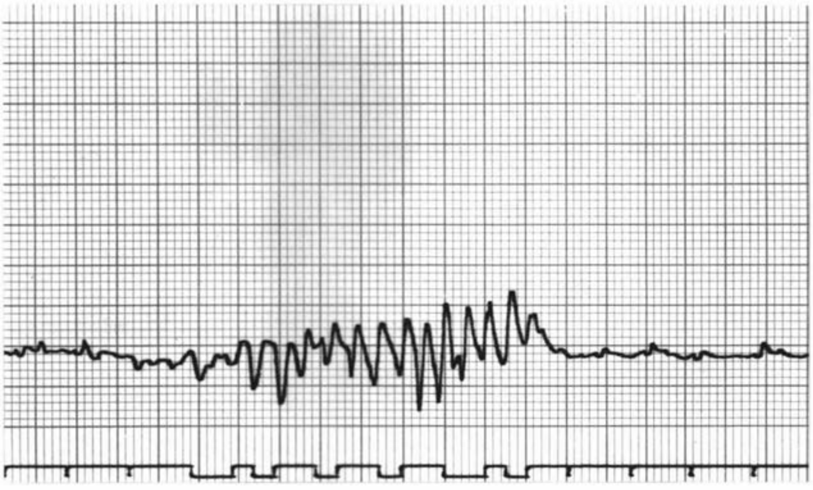
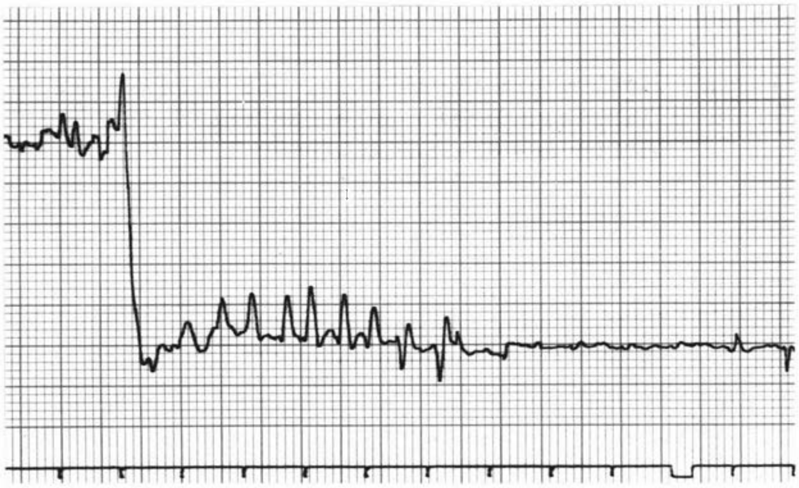


Plate IV.15. Active period in sheep 64R 2 days before labour. Initial baseline shift caused by sheep changing position.
Time signal in minutes.
Each large division corresponds to 2.5mm Hg.

Plate IV.16. Onset of first stage labour in sheep 64R 10 hours before delivery.
Time signal in minutes.
Each large division corresponds to 2.5mm Hg.

Plate IV.17. First stage labour in sheep 64R 6 hours 30 minutes before delivery.
Time signal in minutes.
Each large division corresponds to 2.5mm Hg.

15



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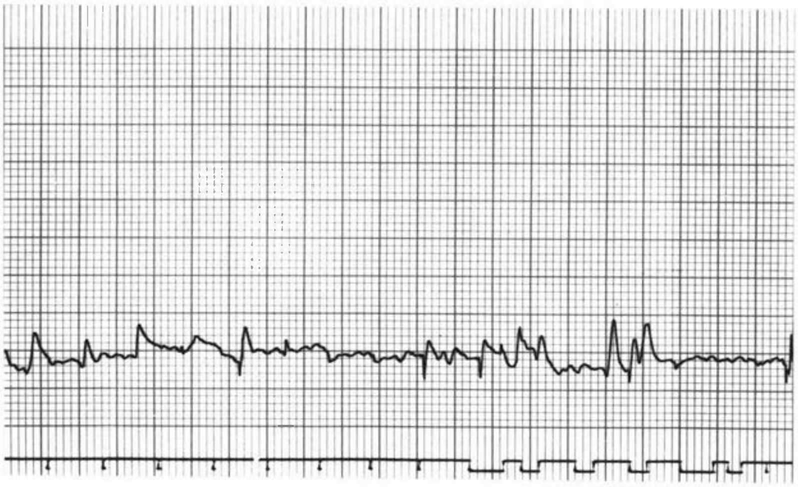

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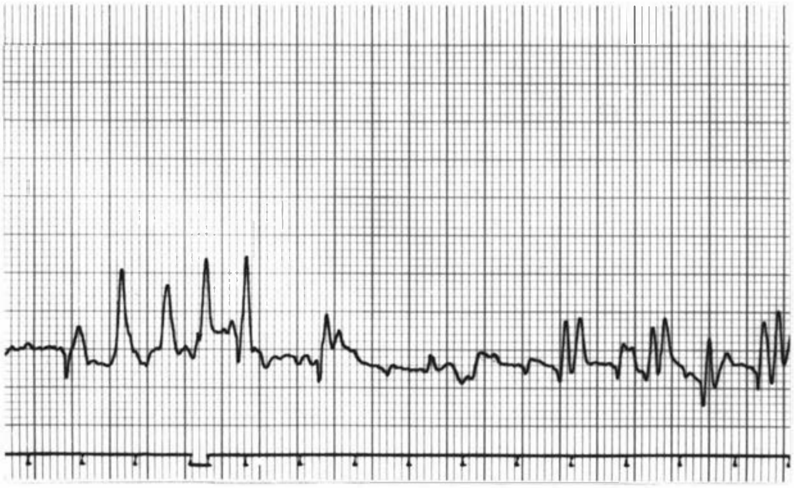


Plate IV.18. First stage labour in sheep 64R 30 minutes before second stage labour, 50 minutes before delivery.
Time signal in minutes.
Each large division corresponds to 5mm Hg.

18

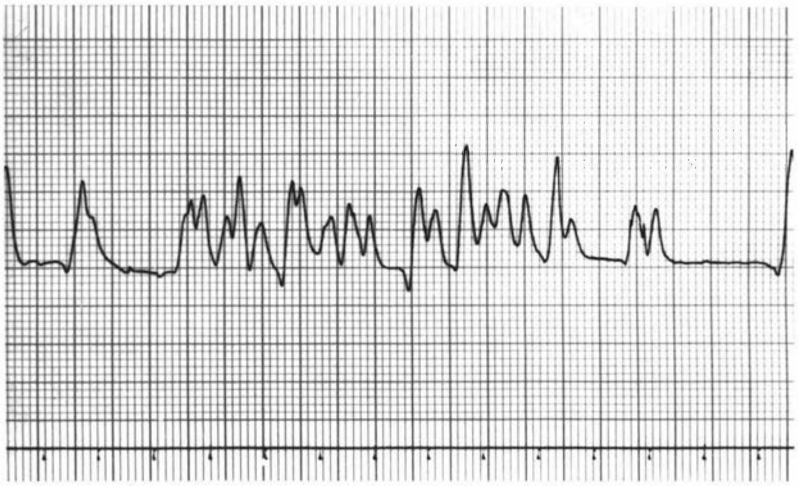


TABLE IV (vi): FIRST STAGE LABOUR ACTIVITY AND TYPE OF BIRTH

| | Group A (eutocia) | Group B (dystocia) |
|---|---|---|
| Mean uterine activity during final three hours of first stage labour ($mm^2$/25 minutes) | 573.0 | 786.3 |
| Number of ewes | 6 | 11 |
| S D | 141.2 | 202.9 |

$t = 2.28$, $p < 0.05$

The weak labour activity observed in ewe 62R may have been related to the nervousness of this particular ewe, which did not settle down well in the stalls. The animal showed signs of uterine inertia and was therefore given an intramuscular injection of 40 units of posterior pituitary extract (Crookes) following which the ewe delivered a live lamb with no further difficulty.

### IV.4.3. Second stage labour

During second stage labour uterine pressures became more regular and of greater amplitude than in the first stage, reaching a maximum pressure of 35 - 40 mm Hg in some individuals. Augmenting this uterine pressure were the powerful bearing down efforts of the dam which appeared to play a major part in the delivery of the lamb. Bearing down produced intra-abdominal pressures in general twice as great as uterine pressures, reaching peaks of 90 mm Hg on occasions; Figs IV (xiii), (xiv), (xv) show total effort measured during the first half hour of second stage labour. Unfortunately the chart speed of the recorder was too slow to allow confident resolution of the trains of fast abdominal contractions occurring in some ewes and the results of only 11 animals are shown in the figures. Ewes giving birth to lambs in posterior presentation produced

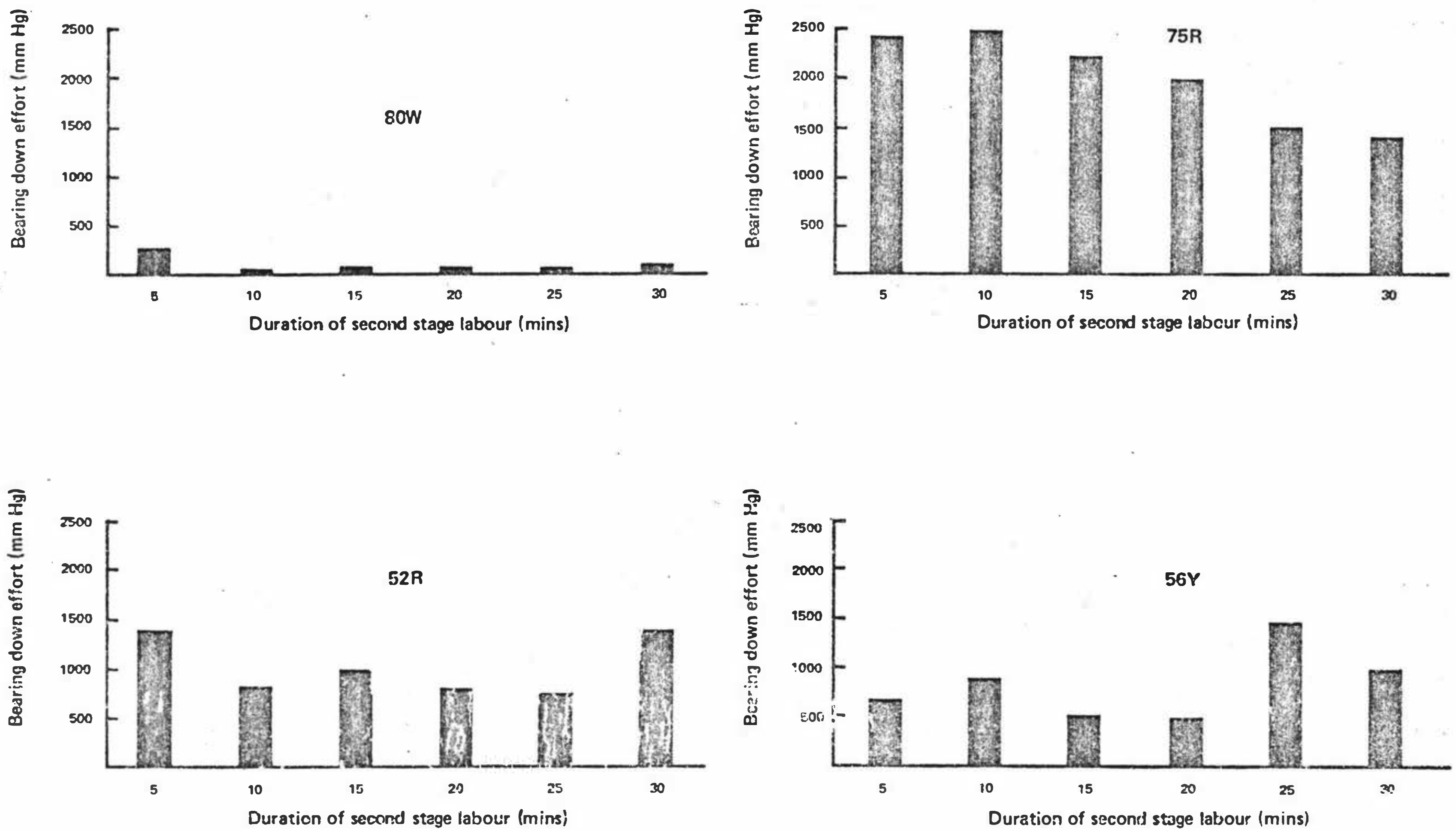



Fig. IV (xiii). Work done by the accessory muscles during second stage labour.

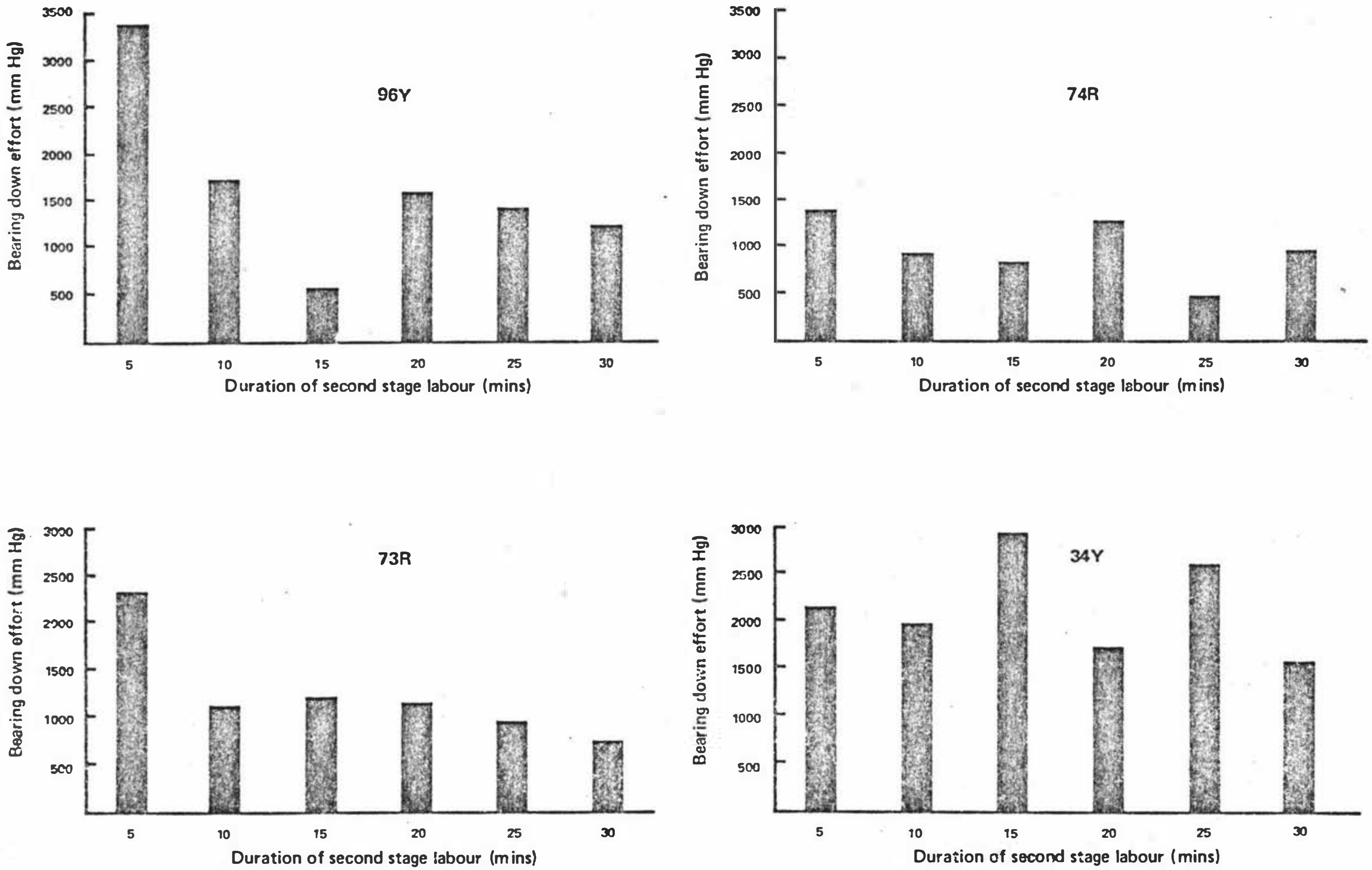



Fig. IV (xiv). Work done by the accessory muscles during second stage labour.

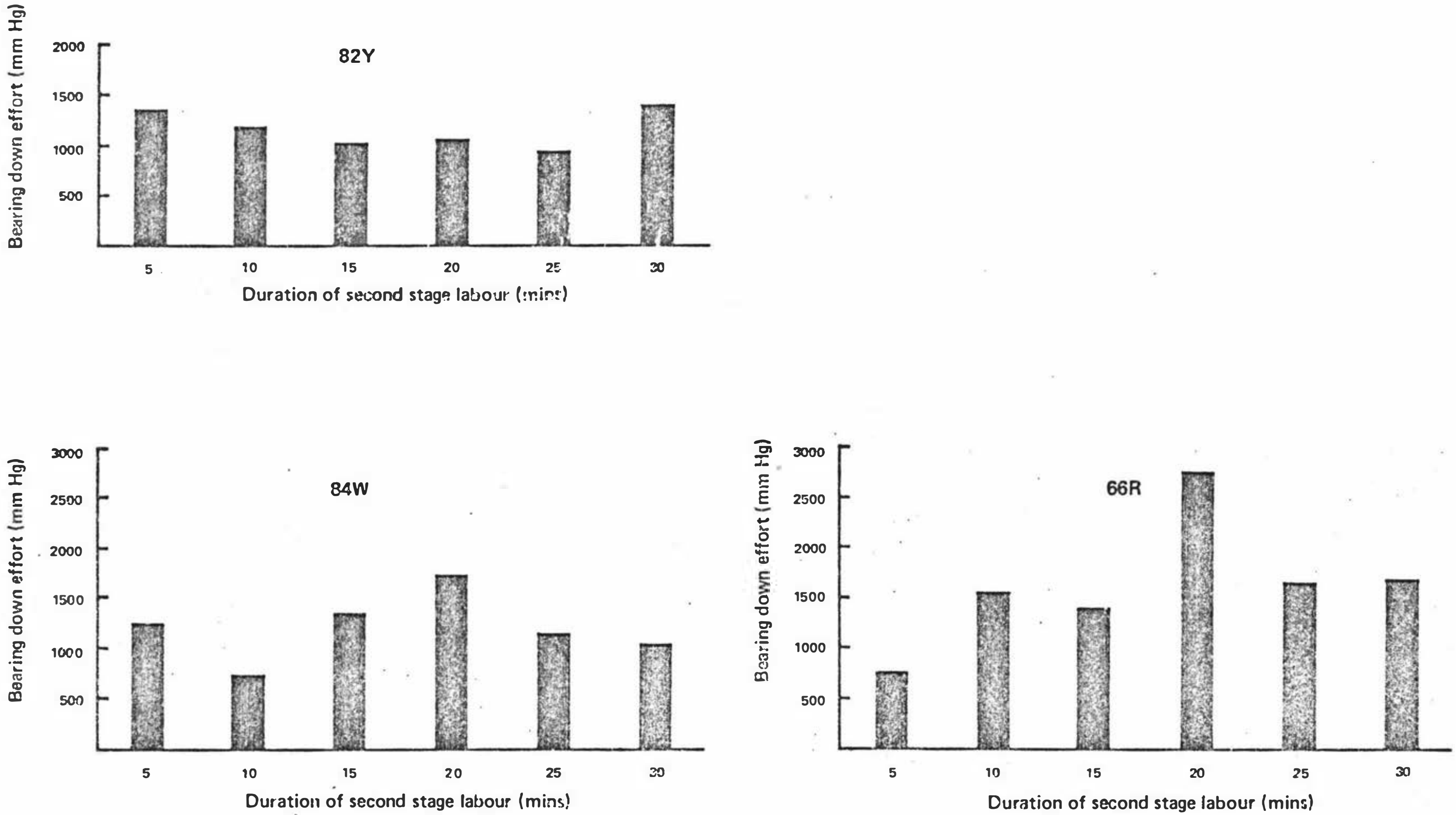



Fig. IV (xv). Work done by the accessory muscles during second stage labour.

some of the lowest bearing down pressures and appeared to lack the stimulus for full involvement of the abdominal muscles in second stage labour (see records for 56Y, 80W and 52R in Fig. IV (xiii) ).

When it was necessary to assist with the delivery of lambs, sterile obstetric lubricant was introduced into the vagina and following repositioning of the foetal limbs delivery was achieved by simple traction in all cases.

## IV.5. Discussion

The occurrence of alternate periods of myometrial activity and quiescence, unique amongst the species studied up to that time, was first reported in the ewe by Murdick (1964) in a study of the electrical activity of the pregnant sheep's uterus. He calculated the mean duration of active periods to be six minutes, with intervening quiescent periods ranging from five to twenty-seven minutes. However, he was unable to detect intra-uterine pressure changes which could be correlated with electrical activity of the myometrium until seven days before parturition in one ewe and three days before parturition in another two. Murdick (1964) gave little attention to the pre-partum pressure changes; their amplitude was reported to range from 6 - 30 mm Hg, considerably higher than those found here. However, the present results do agree with those of Murdick (1964) in that no general change in the frequency of the active periods was apparent during the two weeks up until the beginning of first stage labour. As well, the mean amplitude of the tone changes remained fairly constant in most sheep, with the exception of 52R, in which a progressive reduction in both frequency and amplitude of activity was recorded (Fig. IV (iii) ).

Pre-partum pressure changes similar to those recorded here have been described by both Ward (1968) cited by Hindson and Turner (1969) and Hindson and Ward (1973). They were observed to last between five and ten minutes and occurred with some regularity at intervals of about 30 minutes. The amplitudes of two representative pressure changes illustrated from the work of Ward (1968) of seven and eight mm Hg are within the range recorded in the present study.

Pre-partum uterine activity resulting in pressures falling below the baseline has not been previously reported in sheep. It is possible that this activity represents a change in the position of the uterus in the abdomen, similar to that described in cattle by Russe (1965) and which was considered by him to influence foetal position *in utero*. He determined that when uterine tone decreased, the uterus sank deeper in the abdomen to occupy a more ventral position, thus allowing the foetus to extend and alter its position; and, conversely, when uterine tone increased, the uterus was drawn closer to the pelvis and became more spherical in form, restricting movements of the foetus. Evidence has been provided by Gillette and Holm (1963) in cattle, suggesting that the longer duration lower amplitude pressure waves observed in the days preceding labour in that species, are brought about by the activity of the longitudinal uterine muscle. The higher amplitude short duration waves were attributed to localised activity of the circular muscle. If a similar situation exists in sheep, then the periodic pre-partum rises in uterine baseline pressure would represent increases in the tone of the longitudinal muscle and the fluctuations of pressure associated with these would represent activity of the circular muscle. Separate contributions from the two muscle layers would also explain the observation that during the active periods in which uterine baseline pressure fell, superimposed pressure waves similar to those recorded in other active periods were still present (Plates IV.4, 5 and 6). Such behaviour could be caused by specific relaxation of the longitudinal muscle. As in cattle, relaxation of the longitudinal muscle could result in a change in position of the uterus in the abdomen, but whether in fact it did was not determined. No evidence was obtained that would indicate that pre-partum activity plays a major role in determining foetal positioning at birth in sheep.

A positive relationship between birth weight of the lamb and the occurrence of foetal maldispositions has previously been reported by Naaktgeboren *et al.* (1971). They observed that foetal maldispositions in singles, twins and triplets were more common when the birth weight of the lambs exceeded five kilograms than when it was less than this weight. They considered that deviations of posture are produced during parturition when a normally disposed lamb experiences difficulty entering the pelvic inlet, owing to a disparity in size between itself and the pelvis. As successive attempts are made to force the foetus into the pelvic inlet the forelegs or the head are retained, thus allowing the presenting part to enter the pelvic inlet but often preventing further progress. The finding of a significant difference in the ratio of estimated pelvic area of the ewe to birth weight of the lamb, between ewes bearing normally disposed and maldisposed lambs, in this study, while consistent with the hypothesis of Naaktgeboren et al. (1971), does not necessarily support it. The important factor, so far not determined, is the stage at which lambs become maldisposed, be it before labour, during labour, or both. Only when this is known is the observed relationship between birth weight and disposition of the lamb likely to be explained.

It is probable that the relatively high birth weight of lambs born in this study was due to the high level of nutrition of the ewes (see II.2.4) and that this contributed to the high incidence of maldispositions observed here as compared with the incidences reported by Wallace (1949), Naaktgeboren and Stegeman (1968) and Naaktgeboren et al. (1971).

Posterior presentations occurred in three of the eighteen ewes in this study representing an incidence of 17%. This contrasts with the incidence of 3.6% (10/275) recorded by Wallace (1949) in Romneys and with the incidences of 2.5% (5/196) and 0% (0/97) reported by Naaktgeboren et al. (1971) for Texel and Heath ewes respectively, although the difference could simply be a random chance occurrence. Reimers et al. (1973) have observed a marked increase in the proportion of foetuses presented anteriorly in sheep at around 120 days of gestation. The authors suggested as a possible explanation for the change in orientation at this time, a change in the centre of gravity of the foetus, which produces version within the fluid filled amnion (Reimers et al., 1973). It would seem likely that a change in the orientation of the foetus at this late stage in gestation would be facilitated by movements of the dam, which, under the experimental conditions, are likely to have been less than those of sheep on pasture. It is therefore feasible that the restrictions imposed by the stalls, together with the ready access to food in the pens influenced the incidence of posterior presentations by reducing maternal activity. Certainly if foetal weight influenced disposition of the lamb at birth it appeared to have little effect on presentation *per se*, as birth weights of the three posteriorly presented lambs were not excessive compared with others in the group.

The influence of gestation length on birth weight which is suggested in the present study (Table IV (iii)) has also been observed by Thrift and Dutt (1972), who reported a regression of gestation length on birth weight of single lambs of 0.35 ($p < 0.01$).

Uterine activity during labour closely resembled that recorded in the control ewes of Hindson *et al.* (1965, 1968 a) and that recorded by Ward (1966), and Ward (1968) cited by Hindson and Turner (1969) and Hindson and Ward (1973). In the studies of Hindson *et al.* (1965, 1968 a) uterine activity was quantitated by recording the amplitude, frequency and duration of six consecutive waves every hour. Direct comparison with the uterine activity as quantitated in the present study is therefore not possible. However, the range of pressure obtained by Hindson *et al.* (1965, 1968 a) of 10 - 28 mm Hg and that reported by Ward (1966) of 20 - 45 mm Hg both agree well with the 10 - 40 mm Hg found here. On the other hand it is difficult to reconcile these several observations with those of Murdick (1964) who reported uterine pressures in excess of 100 mm Hg in two out of three sheep. Some of the differences in uterine activity between ewes may reflect differences in circulating hormone levels.

In two recent papers Rawlings and Ward (1972, 1973) have related uterine activity in late pregnancy and parturition in the ewe with the levels of progesterone and total free oestrogens in maternal and foetal blood. These authors have shown that the onset of parturient uterine contractility is preceded by a rapid increase in maternal peripheral oestrogens and is significantly correlated with it in magnitude ($r = 0.42$, $p < 0.05$). They also demonstrated a significant negative correlation between maternal plasma progesterone and uterine contractility ($r = 0.39$, $p < 0.05$). On the basis of the temporal association between the rise in total free oestrogens and uterine contractility, Rawlings and Ward (1972, 1973) have suggested that oestrogens could be a stimulus to parturient uterine contractions.

The finding of a significant positive correlation between birth weight of the lamb and mean uterine activity during the final three hours of first stage labour is similar to the situation described in cattle by Gillette and Holm (1963). Uterine activity in their study appeared to be related to 'foetal resistance' which they defined as a function of foetal diameter divided by the diameter of the birth canal. In the present study the significant difference in mean uterine activity between groups of ewes giving birth to normally and maldisposed lambs is considered to be simply a reflection of the difference in birth weight between the groups and not associated with maldisposition per se. Certainly previous studies (Hindson et al., 1965, 1968 a) have not revealed a difference in parturient uterine activity between ewes giving birth to normally disposed and maldisposed lambs.

During second stage labour pressures created by the bearing down movements of the ewe appeared to play a major role in the delivery of the lamb. As previously reported by Hindson et al. (1965, 1968 a), and Ward (1966), these pressures were in general twice the amplitude of the uterine pressures created by myometrial activity and coincided with the peak of the uterine pressure waves. Murdick (1964) recorded mean pressure changes caused by bearing down movements of 48 mm Hg and 96 mm Hg during the final 30 minutes of second stage labour in two sheep. As in the case of the uterine pressures reported by this author these pressures are considered to be abnormally high.

Hindson et al. (1965) observed that the expulsion of the lamb appeared to be accomplished largely by abdominal muscular contractions and straining movements. The results of the present study support this view. Uterine activity was responsible for initiating bearing down movements which began as the uterine pressure rose. The superimposed bearing down pressure was often so intense that it completely obscured the uterine pressure wave. It is probable that bearing down movements are triggered by the stimulation of nervous receptors situated in, or associated with, the cervix or vagina or both, as the foetus is forced into the pelvis by the initial increase in uterine pressure. Support for this hypothesis is given by the finding that in those ewes in which the foetus was prevented from entering the pelvis, abdominal straining was desultory and of low amplitude. Thus in two ewes, 80W and 56Y, whose foetuses were presented posteriorly with double flexion of the hip, bearing down effort was lower than that recorded from the other ewes in the study, and no progress was made during labour (Fig. IV (xiii)). Another ewe, 52R, whose foetus was presented posteriorly in extended posture, also exhibited relatively weak straining during second stage labour which, again, was thought to be related to the lack of sufficient stimulation of the cervical or vaginal nervous receptors by the hindlimbs of the foetus. This ewe was given 40 units of posterior pituitary extract (Crookes) and quickly delivered the hindquarters of the lamb, although assistance had to be given to complete delivery after the costal arch became lodged at the pelvic inlet. The effect of the pituitary extract appeared to be to increase intra-uterine pressure to a level sufficient to force the hindquarters of the lamb into the pelvis, thus stimulating strong and frequent abdominal contractions which were mainly responsible for the rapid progress made. A similar association between 'weak and poorly defined straining efforts' and posterior presentation of the foetus has been reported by Dufty (1973) in cattle.

Both Hindson <u>et al.</u> (1965) and Hindson and Ward (1973) have reported an increase in uterine activity during second stage labour similar to that found here. This increased amplitude and regularity of pressure waves during second stage labour probably coincides with the appearance of co-ordinated uterine activity. Ruckebusch (1971) has shown that, up until approximately one hour before the appearance of the foetal membranes, uterine activity is unco-ordinated, electrical activity travelling both anteriorly and posteriorly in the myometrium, but during the final stages of labour these waves of excitation become co-ordinated and travel in a cephalo-caudal direction. The reasons for this change are not known. It is possible that the high levels of prostaglandin F $2\alpha$ which appear particularly during second and third stage labour in sheep (W.B. Currie - personal communication) may play a part, since the pressure waves recorded after delivery have been observed to be quite regular. It is also possible that oxytocin or local nervous pathways could be involved. An improvement in the co-ordination of uterine contractions in women has been reported by Caldeyro-barcia and Poseiro (1959) following the infusion of oxytocin in the appropriate doses.

## IV.6. Conclusion

The main conclusion from these tocometric studies is that lack of expulsive forces was not a major cause of dystocia. Low uterine pressures almost certainly accounted for the lack of progress in one ewe with uterine inertia, while in another, bearing down effort was desultory, probably as a result of the type of foetal maldisposition, and labour was eventually terminated by human intervention. However, the most common immediate cause of dystocia was a disproportion between the maldisposed foetus and the maternal pelvis. The disparity in size impeded progress directly by creating a high physical resistance to the passage of the lamb and, in two cases indirectly, by preventing the foetus from stimulating nervous receptors thought necessary for the involvement of the abdominal muscles in second stage labour.

Uterine activity during the final two weeks of gestation is found to be unrelated to the occurrence of foetal maldisposition at parturition. While the cause of foetal maldispositions was not determined, the results suggest that lamb birth weight *per se* or the relationship between lamb birth weight and the area of the pelvic inlet is important in influencing the disposition of the lamb at birth, in particular, the posture of those presenting anteriorly.

# V: A COMPARATIVE PELVIMETRIC STUDY OF EWES WITH HISTORIES OF EUTOCIA AND DYSTOCIA

## V.1. Introduction

Pelvimetry studies in sheep have previously been based on post slaughter measurements and as a result the number of ewes involved, with one exception, has been small. This study was undertaken with the twofold aim of developing a method that would enable pelvic measurements to be taken from the live ewe, and of employing it to investigate the relationship of pelvic dimensions to dystocia in a large number of ewes from different sources.

## V.2. Literature Review

### V.2.1. Introduction

Since most pelvic studies have involved non-parturient animals it is necessary to relate these measurements to those of the parturient animal if they are to provide an estimate of the size of the pelvic canal at the time of lambing. Thus the anatomy of the pelvic canal in the ewe and the physiological changes which are known to occur at parturition are reviewed as a basis for the subsequent discussion of pelvimetry in sheep and cattle.

### V.2.2. The anatomy of the pelvic canal in the ewe and physiological changes which occur during pregnancy and parturition

A number of structures determine the size of the pelvic canal in the ewe. These include the pelvic girdle, sacro-sciatic ligaments, and sacro-iliac joints together with the ischiococcygeus and perineal muscles and their related fascia (Bassett, 1965). The inlet to the pelvic canal is demarcated by the well defined shafts of the ilia, the sacrum and the pubic bones, which are connected ventrally by the ischiopubic symphysis and dorsally by the sacro-iliac joints to form an apparently rigid structure. In the ewe the ischiopubic symphysis is composed of a plate of hyaline cartilage which in older animals may become completely fused (Bassett, 1965) and which probably prevents significant separation of the two halves of the pelvis during parturition. Radiographic studies have failed to show any increase in the separation of the pubic bones in the ewe during pregnancy (Bassett and Phillips, 1955a) although this has been observed in the mouse and the guinea pig (Hisaw and Zarrow, 1950). Whether significant separation occurs during parturition has not been reported. However, radiographs taken during labour in women, in which the symphysis is composed of fibro-cartilage, indicate that lateral movement does occur, but is only of the order of a few millimetres (Borell and Fernstrom, 1967).

An increase in the width of the sacro-iliac joints of the order of 1-3 mm has been observed in some ewes during the later stages of pregnancy (Bassett and Phillips, 1955a) but whether this relaxation permits separation of the bones during parturition is questionable. In the human, radiographic studies revealed a widening of the joints by a few millimetres which did not affect the transverse diameters of the pelvic inlet (Borell and Fernstrom, 1967). Thus it is probable that little change occurs in the dimensions of the pelvic inlet in the sheep during parturition. However, radiographic evidence of partial luxation of the sacro-iliac joints in some ewes in the present study that had experienced dystocia, suggests that under certain conditions an increase in the transverse diameter of the inlet may be achieved by excessive abduction of the sacro-iliac joints.

The pelvic canal posterior to the pelvic inlet is bounded ventrally by the ischium and the pubis, laterally by the sacro-iliac ligaments and dorsally by the sacrum and coccygeal vertebrae. The outlet itself is surrounded by the ischiococcygeus and perineal muscles with their related fascia. During pregnancy physiological changes occur that enable the capacity of the pelvic canal to be greatly increased at parturition, thus facilitating the passage of the lamb. Although, as previously described, only a small increase is demonstrable in the separation of the ilium and the sacrum during pregnancy, a progressive relaxation of the sacro-iliac joint does occur, making possible increased rotational movement of the ilia about the sacrum (Bassett and Phillips, 1955a). In non-pregnant ewes, and ewes in the first two months of pregnancy, only a small amount of rotational movement can be produced at this junction by the application of tension on the sacrum. However, from the third month of gestation a progressive increase is observed, reaching a peak in the post partum period (Bassett and Phillips, 1955a). Flexion of the sacro-iliac joints by the action of the abdominal muscles, the action of the psoas minor muscle or by postural changes involving the flexor muscles of the hind limb, increases the capacity of the pelvic outlet by increasing its sagittal diameter. A similar increase in the range of movements of the sacro-iliac joints with concomitant changes in the sagittal diameter of the pelvic outlet has been described in women (Borell and Fernstrom, 1967). Probably because of this variation in the mobility of the sacro-iliac joints, both between individuals and with physiological state (Bassett and Phillips, 1955a, b), measurements of the pelvic outlet have seldom been included in reports of pelvic dimensions in ewes.

To accommodate the increased mobility of the sacro-iliac joints a number of other structures undergo changes during pregnancy. The sacro-sciatic ligament increases in length such that even when the sacrum is raised to its fullest extent the ligament remains slack (Bassett and Phillips, 1955a). In addition the ischiococcygeus, biceps femoris and perineal muscles increase in weight, and changes occur in their fascia and tendons of origin.

The degree of movement of the sacro-coccygeal joint varies considerably in the sheep (Bassett, 1955) and may also be of obstetric significance. For example, a significantly lower incidence of partial or complete fusion of this joint has been observed in ewes with a history of vaginal prolapse as compared with ewes that have not experienced this condition (Bassett, 1955). Nevertheless there is no documented evidence to suggest that the anatomy of this joint is related to the occurrence of dystocia.

It is likely that the changes observed in many tissues of the pelvis during pregnancy are mediated by endogenous hormones (Bassett, 1963). In support of this, relaxation of the sacro-iliac joints similar to that observed in ewes in late pregnancy has been induced in spayed ewes by treatment with diethyl stilboestrol (Bassett and Phillips, 1954; Bassett, 1963).

### V.2.3. Pelvimetry in the ewe

#### V.2.3.1. Methodology

Although efforts have been made to predict internal pelvic dimensions from external pelvic and other body measurements in live ewes these have met with only limited success, with the result that all pelvic studies reported to date have been based on dissected preparations.

#### V.2.3.2. The effect of age on pelvic dimensions of sheep

The pelvis has been shown to increase in weight relatively rapidly after birth (Hammond, 1932; Wallace, 1948; Palsson and Verges, 1952) and pelvic measurements in Romney ewes suggest that growth is sustained until at least three years of age. The estimated pelvic area of three year old ewes in Bassett's study (Bassett, 1955) was significantly less than that of mature ewes (five years and older) while that of the four year old ewes was found not to differ. A change in pelvic shape with age was also reported by this author, the inlet becoming rounder and the external shape becoming broader, but these differences are not statistically significant.

#### V.2.3.3. The effect of breed of ewe on pelvic dimensions

Despite the large within breed variation that exists in pelvic dimensions (Bassett, 1955; Quinlivan, 1971; Fogarty and Thompson, 1974) several authors have demonstrated significant between breed differences. Quinlivan (1971) compared the pelvic dimensions of Border Leicester, Perendale and Romney ewes in a preliminary study of dystocia in sheep. The Romney ewes comprised six animals that had not previously required assistance at birth and five that had required repeated assistance, while the ewes of the other two breeds had never experienced dystocia. Significant differences in conjugate diameter were established between the assisted Romney ewes and Border Leicester ewes, the assisted Romney ewes and unassisted Romney ewes, and also between unassisted Romney ewes and Perendale ewes. Since 68% of the variability in estimated area of the pelvic inlet was attributable to the conjugate diameter it is not unexpected that significant differences in area of the pelvic inlet were also established between the assisted and unassisted Romney ewes and between the unassisted Romney ewes and Perendale ewes. Transverse diameter of the pelvic inlet was not significantly related to breed of ewe neither was the width between the lateral and medial tuberosities of the ischium nor the width between the two acetabula.

This study emphasises the need for caution when extrapolating from results obtained in small groups of ewes, to breeds, since differences between the means of the different parameters for the two Romney groups were, on a number of occasions, greater than the between breed differences. The finding that the dimensions of the pelvic inlet in assisted Romney ewes was not significantly different from those of the Perendale ewes (a breed reputedly free from dystocia) is probably a reflection of the smaller body size of the Perendale ewes underlining the need for pelvic dimensions to be related to either size of the ewe or lamb for meaningful interpretation. In their present form the between group differences in Quinlivan's study could simply be attributed to differences in body weight, since pelvic area has been shown to be correlated with body weight in sheep (Fogarty and Thompson, 1974).

Naaktgeboren et al. (1971) compared the pelvic dimensions of Heath and Texel sheep, two breeds which differ considerably in size and in the incidence of obstetric difficulties. The Texel ewes, being almost twice the weight of the Heath ewes had significantly greater conjugate and transverse diameters of the pelvic inlet, although the difference in pelvic inlet area between groups was effectively reduced by the presence in this region of prominent muscle groups and fat in the Texel ewes. When the dimensions of the pelvis were related to the body weight of the ewe and the birth weight of the lamb however, it was clear that the pelvis of the Heath ewe was relatively the larger. The mean estimated area of the pelvic inlet in the Texel ewes was 10,500 $mm^2$ which was 22% larger than that of the Heath ewes, while the mean birth weight of the Texel lambs (4.5 kg) was 67% greater than that of the Heath Lambs (Between breed differences in birthweight were apparently related to changes in girth rather than body length of the lambs in this study).

More recently Fogarty and Thompson (1974) have demonstrated differences in a number of pelvic measurements between Dorset Horn and Border Leicester ewes (Table V (ia) ). This comparison is, however, based on measurements taken from only six Border Leicester ewes selected in an undefined manner from a Border Leicester flock.

TABLE V (ia): DIFFERENCES IN PELVIC DIMENSIONS BETWEEN DORSET HORN AND BORDER LEICESTER EWES

| | | Pelvic measurement | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Breed | n | LIT (cm) | TC-LIT (cm) | CD (cm) | TD (cm) | Pelvic area[1] ($cm^2$) | CDxTD ($cm^2$) | CD/TD |
| Dorset Horn | 29 | 13.9 | 17.8 | 10.6 | 9.26 | 80.7 | 98.6 | 1.15 |
| Border Leicester | 6 | 15.0 | 19.2 | 12.4 | 9.15 | 97.6 | 113.3 | 1.36 |
| Significance | | ** | ** | ** | NS | ** | ** | ** |

| | |
|---|---|
| LIT | Distance between the lateral tuberosities of the ischium |
| TC-LIT | Distance between the tuber coxae and the lateral tuberosity of the ischium |
| CD | Conjugate diameter |
| TD | Transverse diameter |
| CDxTD | Estimate of pelvic inlet area |
| CD/TD | Estimate of pelvic shape |
| ** | $p < 0.01$ |
| NS | Not significant $p > 0.05$ |
| 1 | Pelvic inlet area measured by planimeter |

Despite the lighter mean body weight of the Border Leicester ewes their mean pelvic area was greater than that of the Dorset Horn ewes. Conjugate diameter was more variable than transverse diameter within the Dorset Horn ewes and, in contrast to transverse diameter, differed between the two breeds of ewes.

The apparent difference between the reports of Quinlivan (1971) and Fogarty and Thompson (1974) and that of Naaktgeboren et al. (1971), in which it was shown that significant differences with respect to both transverse diameter and conjugate diameter existed between breeds, is probably explained by the greater disparity in body weight between ewes of the Heath and Texel breeds.

### V.2.3.4. The relationship between external and internal measurements of the dissected pelvis

In her study of the pelvic dimensions of Romney ewes Bassett (1955) demonstrated correlations between the width between the tubera coxarum and the transverse diameter of the pelvic inlet, the distance from the iliac crest to the posterior promontory of the ischium and the conjugate diameter of the pelvic inlet, and between estimates of internal and external pelvic shape. She concluded from her study however, that although in some cases there was a reasonably high degree of relationship between internal and external dimensions of the pelvis, it was not possible to form an accurate estimate of internal structure from external measurements. A finding of particular significance, in view of the potential use of these measurements for selection, was that quite large differences in correlation coefficients for some characteristics were observed between age groups.

A significant relationship between the distance separating the posterior promontories of the ischium and the estimated area of the pelvic inlet was reported by Quinlivan (1971) in his mixed group of Romney, Border Leicester and Perendale ewes. Unfortunately he calculated the correlation by combining these animals into one heterogeneous group rather than employing a Z transformation (Sokal and Rohlf, 1969) to combine the correlations from the individual groups. For this reason the estimate obtained may be quite inaccurate and should be regarded with caution. It is noteworthy that this relationship has not been substantiated either by Fogarty and Thompson (1974) or by the author (see Table V (v)).

It is surprising that Quinlivan (1971) has suggested that external pelvic dimensions could provide an accurate means of estimating internal pelvic dimensions. Certainly the correlation between the distance separating the posterior promontories of the ischium and the area of the pelvic inlet estimated by Quinlivan, although significant, would appear to be too low to be of practical use in selection, even if the measurement could be made accurately in the live ewe.

Fogarty and Thompson (1974) working with Dorset Horns showed that the transverse diameter of the pelvic inlet was related to the distance between the tubera coxarum, the distance between the lateral ischial tuberosities, and the distance between the tuber coxae and the lateral ischial tuberosity. The conjugate diameter of the pelvic inlet was correlated with the distance between the tuber coxae and the lateral ischial tuberosity. Pelvic area was correlated with the distance between the tubera coxarum and the distance between the lateral ischial tuberosity and the tuber coxae. These results are in general agreement with those of Bassett (1955). The degree of correlation between these measurements was such that Fogarty and Thompson (1974) also concluded that external measurements of the pelvis would be of little practical use in predicting internal pelvic dimensions.

### V.2.3.5. The relationship between measurements of the pelvis in the live ewe, and internal pelvic dimensions

Bassett (1955) stated that several of the external pelvic measurements obtained from the dissected pelves could be accurately defined in the live ewe, although she neither recorded these measurements nor compared them statistically with those obtained from dissected pelves. Fogarty and Thompson (1974) on the other hand, measured the distance between the tubera coxarum and the distance between the posterior promontories of the ischium in live Dorset Horn ewes and found both measurements to be significantly correlated with the transverse diameter of the pelvic inlet. Their relationship to conjugate diameter and pelvic area was small and was considered by these authors to be of little predictive value.

### V.2.3.6. The relationship between internal pelvic dimensions and other body measurements

Efforts to relate internal pelvic dimensions to a number of other body measurements have been made by both Quinlivan (1971) and Fogarty and Thompson (1974). Quinlivan (1971) was unable to demonstrate significant correlations between either length of the radius or length and diameter of the metacarpus and internal dimensions of the pelvic inlet in his investigations although the results, for reasons stated earlier (V.2.3.4.), must be regarded with reservation.

Fogarty and Thompson (1974) in their study, which involved 29 Dorset Horn ewes, measured length, weight and circumference of the dissected metacarpus and demonstrated significant relationships for all three parameters between pelvic area and conjugate diameter as well as between metacarpal circumference and weight and the transverse diameter of the pelvic inlet. Carcass length was found to be correlated with pelvic area, conjugate diameter and transverse diameter, while estimated fat free carcass weight was found to be related to transverse diameter and pelvic area.

A number of measurements taken from live ewes were also found to be related to internal pelvic dimensions. These included forelimb length and body length both of which were related to pelvic area, conjugate diameter and transverse diameter of the inlet, and forelimb circumference, head width and head depth which were correlated with transverse diameter of the inlet. On the basis of the correlation coefficients none of these measurements provided, in their view, sufficiently accurate estimates of pelvic area to be of practical use in selection.

### V.2.3.7. Pelvic dimensions and dystocia

The relationship between pelvic dimensions and dystocia was first examined in an individual breed by Quinlivan (1971). In a preliminary observation he reported significant differences in both estimated pelvic area and conjugate diameter between Romney ewes with histories of eutocia and dystocia. A similar result has recently been obtained by Fogarty and Thompson (1974) in Dorset Horn ewes. They found that ewes that had experienced dystocia at more than 65% of their lambings had significantly smaller pelvic areas and conjugate diameters than the remaining ewes. When the group was considered as a whole, the relationship between incidence of dystocia and pelvic area in individual ewes approached significance ($r = -0.34$, $p < 0.08$).

A comparison of the pelvic dimensions of ewes of the Heath and Texel breeds carried out by Naaktgeboren et al. (1971) and referred to in section (V.2.3.3.) lends further support to the findings of Quinlivan (1971) and Fogarty and Thompson (1974). These authors concluded that the high incidence of dystocia recorded in the Texel ewes compared with that in the Heath ewes. was attributable to inadequate pelvic size and high lamb birth weights.

## V.2.4. Pelvimetry in cattle

### V.2.4.1. Methodology

In cattle, in contrast to sheep, techniques have been developed which enable pelvic dimensions to be measured in the live animal.

An early report by Wiltbank and Le Fever (1961) first described a rectal pelvimetry method using a sliding calliper. The calliper was extended between the shafts of the ilia and between the sacrum and the pubis to estimate the horizontal and vertical diameters respectively. To obtain the reading the extended calliper had to be removed from the rectum. A similar method has been used by Young (1968b, 1970), Bellows et al. (1971a, b) and Laster (1974).

In 1972 Rice and Wiltbank reported on the use of a hinged calliper for internal pelvimetry in cattle. This instrument was also inserted into the rectum but had the advantage that the pelvic dimensions could be read directly from a graduated scale which remained outside. This technique has also been employed by Dufty (1972).

Attempts by the author to adapt this latter method for use in sheep suggest that the rectum in this species will not dilate sufficiently to allow its use.

V.2.4.2. The effect of age on pelvic dimensions

Bellows et al. (1971a, b) have demonstrated differences in pelvic width, height and area between two and three year old heifers suggesting that pelvic growth occurs after two years of age. The growth of the pelvis subsequent to three years of age has not been reported.

Because of the low variability in pelvic area observed in heifers at breeding at one year of age, and the relative importance of calf birth weight to dystocia, it has been found impracticable to use pelvic area measurements at this age to predict dystocia in heifers (Rice and Wiltbank, 1972).

V.2.4.3. The effect of breed on pelvic dimensions

Differences in the shape of the pelvic inlet have been reported between Angus and Hereford heifers (Bellows et al.,1971a). The vertical height of the inlet in Angus heifers was significantly greater and the horizontal diameter significantly less than the corresponding dimensions in Herefords. Pelvic area did not differ significantly between breeds. These between breed differences in pelvic shape may not be typical however, since significant negative correlations between body weight of the dam and dystocia score were recorded in the Angus but not in the Hereford cattle, suggesting that the body weight of the Angus cattle may have been below optimum for calving. This is supported by the findings of a recent study (Laster, 1974) in which it was shown that the pelvic area of Angus heifers exceeded that of the Herefords. In this latter investigation an examination of the influence of genotype on estimated pelvic area in crossbred heifers revealed an effect of breed of sire in both yearling and two year old cattle and an effect of breed of dam in the yearlings.

### V.2.4.4. The relationship between internal and external pelvic measurements

Probably as a result of the relative ease with which internal pelvic dimensions can be measured in cattle few authors have investigated the relationship between internal and external pelvic measurements. Bellows et al. (1971b) measured width between the tubera coxarum and the distance from the tuber sacrale of the ilium to the posterior promontory of the ischium in live animals and demonstrated a relationship with pelvic area. This relationship was however relatively small and, together with body weight, accounted for only 36% of the variation in pelvic area.

### V.2.4.5. Pelvic dimensions and dystocia

This has already been considered in section II.3.3.3.

### V.2.5. Summary

Although several authors have reported a relationship between internal pelvic dimensions and dystocia in sheep, it appears unlikely that selection against this condition could be achieved by the use of external pelvic or other body measurements, because of the relatively low correlation between these measurements and internal pelvic size. Both absolute and relative differences in pelvic dimensions have been demonstrated between breeds of sheep.

In cattle, internal pelvic measurements have been obtained by rectal methods. However, their use in selecting against dystocia appears restricted to animals calving at three years of age or later, owing to the low variability of pelvic measurements in younger animals.

## V.3. Materials and Methods

### V.3.1. Radiographic pelvimetry

#### V.3.1.1. Method

There are two common means of obtaining actual measurements of objects using radiography. The first is to reduce the inherent magnification of the X-ray beam to an acceptably low level by using a large target-film distance (teleradiography). The second is to estimate the degree of magnification produced and reduce the image size accordingly. The radiographic technique developed for this study incorporated both of these methods and involved the use of lateral and ventro-dorsal radiographs of the pelvis. For technical details see Appendix IV.

A target-film distance of 1.829 m was used routinely in this study which reduced the magnification of the pelvic diameters in most sheep to less than 8%. Clearly however, this error could not be disregarded and measurements taken from both ventro-dorsal and lateral films were corrected for magnification.

Estimates of the magnification of the pelvic diameters on the lateral radiograph were based on a modification of the method of Colcher and Sussman (1944). Thus instead of a radio-opaque ruler, a calibrated aluminium bar (Plate V.5.) was placed at the level of interest to provide an estimate of the magnification of the pelvic diameters in that plane. Colcher's and Sussman's method was not suitable for estimating the magnification on the ventro-dorsal radiograph since the diameters of interest in the ewes, unlike those in women, were at different distances from the film; furthermore, the location of their axes was difficult to determine in the live animal. Magnification at these different planes was therefore calculated by estimating their distance from the film using the lateral radiograph and employing the theorem of similar triangles thus :

$$\text{Object magnification} = \frac{\text{Target-film distance}}{\text{Target-film distance} - \text{Object-film distance}}$$

By first reducing the magnification of the X-ray beam the correction factors became less critical. This was of importance since the magnification of the different diameters on the ventro-dorsal radiograph could not be determined precisely in all cases.

V.3.1.2. Procedure

None of the ewes radiographed was more than three months pregnant thus ensuring that relaxation of the pelvic tissues was minimal (see V.2.2). It was found necessary to shear the ewes before radiography as the fleece, particularly when wet or damp, increased X-ray scatter and obscured the fine details of the pelvic outline.

Food and water were withheld for approximately 18 hours prior to the procedure to reduce the risk of regurgitation during anaesthesia. The ewes were anaesthetised using an intravenous injection of pentobarbitone sodium (Nembutal-Abbot) given slowly into the jugular vein. When good muscular relaxation had been achieved the needle was removed and the ewe was placed on a cassette holder in preparation for radiography. The anaesthetic provided adequate muscular relaxation for about 10-15 minutes which was generally long enough to obtain satisfactory radiographs even when the exposures had to be repeated.

With the aid of a pair of wooden supports (Plate V.6.) placed at the level of the thorax it was possible to position the ewes in a true ventro-dorsal plane. The X-ray beam was centred on the anterior brim of the pelvis. Care had to be taken to ensure that the beam was centred on the grid since the only grid available was focused for a target-film distance of one metre and serious cut-off of the image occurred in the peripheral areas when greater target-film distances were employed, as in this study.

For the lateral exposure the sheep were rolled onto their left side. Sandbags were used to raise the thorax and were placed below and between the hind legs to support the hindquarters in a lateral position. The X-ray beam was centred on the greater trochanter of the femur. At times considerable difficulty was experienced in achieving a true lateral position and repeated exposures were required. An automatic processor made it possible to check radiographs and repeat when necessary before the animal had recovered from the anaesthetic. Manual palpation of the dorsal borders of the iliac crests sometimes assisted in assessing the accuracy of the positioning but was not always reliable. A graduated aluminium bar, supported at each end by a retort stand and clamp, was placed against and parallel to the spine of the ewes in the lateral radiograph. This was used for calculating magnification factors and was also used for estimating object-film distances for the various diameters on the ventro-dorsal radiograph. For this reason the distance between the posterior promontories of the ischium and the bar was checked to ensure that it approximated the distance between the promontories and the cassette on the ventro-dorsal exposure.

V.3.1.3. Analysis of films

V.3.1.3.1. Pelvic diameters measured from radiographs (see Plates V.1. & 2.)

(1) The conjugate diameter (CD) was measured from the sacral promontory to a point 5 mm below the anterior crest of the symphysis pubis as it descends to form the anterior process. This point was chosen since the anterior process of the symphysis pubis varied greatly between individuals, was difficult to demonstrate radiographically, and, in many cases, the two points were equidistant from the sacral promontory.

(2) The pelvic outlet (Outlet) was estimated by measuring the distance between the highest point of the symphysis pubis and the posterior edge of the last fused sacral vertebra.

(3) The transverse diameter (TD) of the inlet was the greatest distance between the two shafts of the ilia.

(4) The interacetabular diameter (AC) was the distance between the medial aspects of the acetabula on a line passing through the centres of the femoral heads.

(5) The distance between the tubera coxarum (TC).

(6) The distance between the lateral ischial tuberosities (LIT).

(7) The distance between the posterior promontories of the ischium (PPI).

V.3.1.3.2. Calculations

Measurements were made using a pair of dividers and a transparent mm ruler with the radiograph placed on a horizontal fluorescent screen. Actual dimensions were obtained from the lateral radiograph by reducing the image measurement by the magnification of the calibrated bar which was placed at the same plane (mid-sagittal).

$$\text{Actual pelvic dimension (mid-sagittal plane)} = \text{Image measurement} \times \frac{\text{Actual distance between graduations on bar}}{\text{Apparent distance between graduations on bar}}$$

The distance from the bar of each of the diameters on the ventro-dorsal radiograph was measured from the lateral radiograph (Fig. V(i) ) and corrected for magnification as above, to estimate the distance of each from the top of the cassette holder at the time of the ventro-dorsal exposure. To these figures was added the distance from the top of the cassette holder to the film, giving an estimate of each object-film distance.

$$\text{Object-film distance} = \left\{ \text{Apparent Object-bar distance} \times \frac{\text{Actual distance between graduations on bar}}{\text{Apparent distance between graduations on bar}} \right\} + \text{Distance of film from top of cassette holder}$$

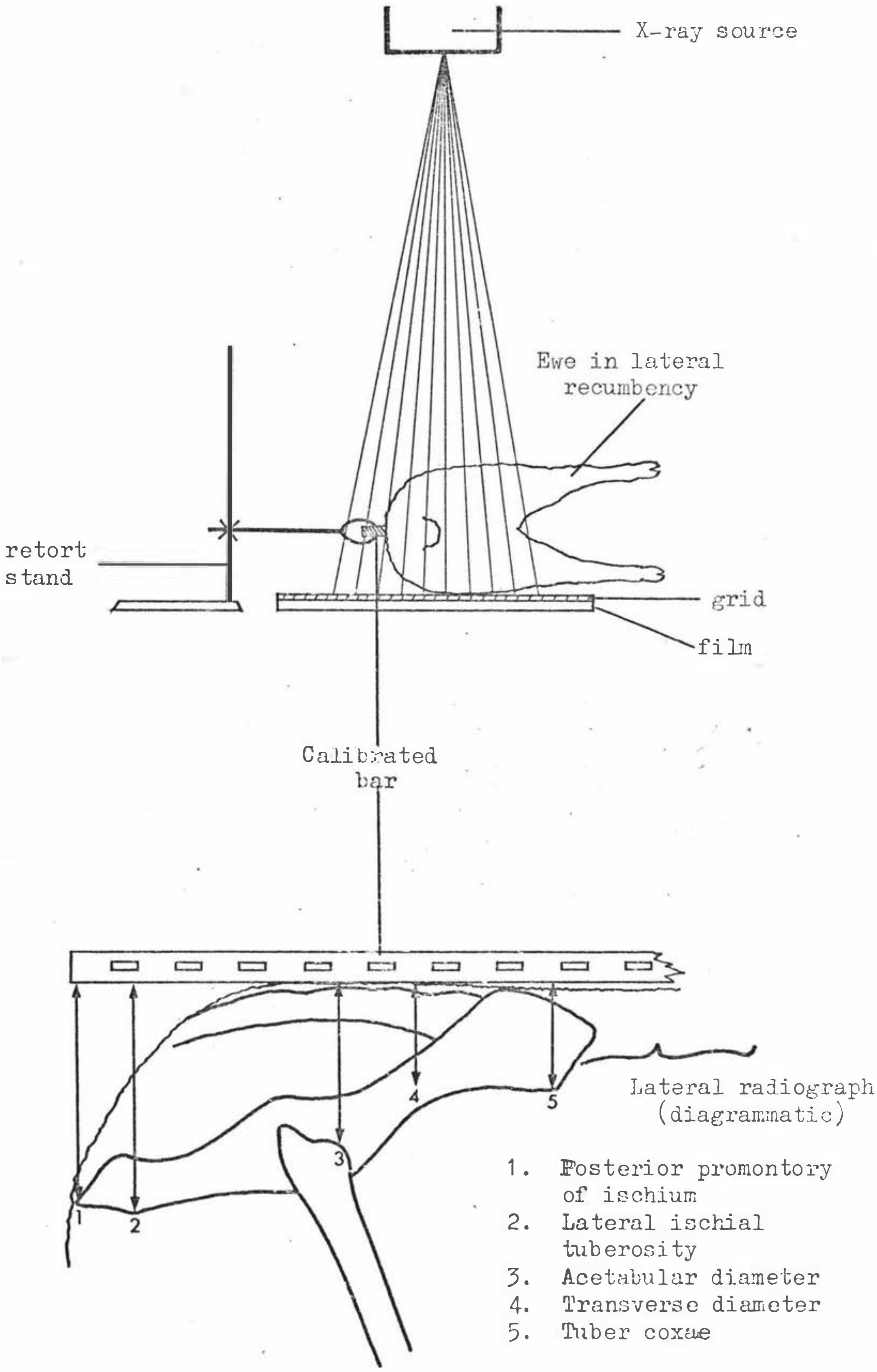



Fig. V (i): Schematic representation of method of determining distances of planes of interest from the cassette, for calculation of magnification factors.

Each measurement on the ventro-dorsal radiograph was then corrected by the theorem of similar triangles to obtain the actual dimension:

$$\text{Actual distance} = \text{Image measurement} \times \frac{\text{Target-object distance}}{\text{Target-film distance}}$$

V.3.2. Animals

A pilot study was conducted on 11 Romney ewes to assess the accuracy of the technique. These ewes were radiographed and their pelvic dimensions calculated and compared with measurements taken from the dissected carcass after slaughter, using internal and external calipers. A comparison of Romney ewes was then undertaken on the basis of their past lambing performance.

Because of the difficulty in persuading Romney stud breeders to provide valuable eutocous ewes for a procedure which was not without risk, the decision was taken at the outset of this part of the investigation to select the experimental animals from differing co-operating sources.

Group I ewes consisted of 32 mature Romney ewes selected from six different Romney studs and was the same group from which ewes were drawn for the tocometry study reported in Chapter IV. All of these ewes had been assisted to lamb at least once and the group mean for the number of assisted lambings per ewe was calculated to be 2.3. In 1972 these ewes were observed during lambing on the Massey No. 2 sheep unit, 27% experienced dystocia. All 18 single lambs were weighed within 12 hours of birth during these initial observations using a spring balance and a sling. The body weights of the ewes were measured in autumn in 1972 and 1973 after they had been shorn. However, because of the possibility that ewes which had not reared a lamb would be in better bodily condition than those which had, body weights of the former were excluded from the analysis. One of the ewes is shown in Plate V.3.

Group II ewes consisted of 26 mature Romney ewes selected from a commercial Romney flock. All had reared a lamb the previous year and none of these ewes had been assisted to lamb.

This history was known since all cull ewes, including those assisted to lamb, were identified by plastic ear tags. These ewes constituted a group of eutocous ewes some of which were used in the study described in Chapter IV. The remainder of the ewes that were not used for the tocometric study lambed on pasture on the No. 2 sheep unit at Massey in 1973, and of these only one was assisted by the shepherd. Body weights of this group were measured after shearing in the autumn of 1973. Unfortunately it was not possible to collect birth weights of lambs from this group. However, the author visited the property during the spring lambing in 1974 and recorded the birth weights of a sample of 18 single lambs from mature ewes, on the assumption that such a sample would give a reasonable approximation of the weights of lambs likely to have been born to the group II ewes under the same conditions.

To provide a further comparison, a group of 22 mature ewes was selected at random from a closed Romney flock, which, on account of the size of the property and the rugged nature of the country, had been unshepherded at lambing for approximately 40 years, and was reputed to have a low incidence of dystocia (GpIII). It was anticipated that these ewes, which differed in many respects from the 'typical' Romney ewes of groups I and II, would represent a group of sheep running under natural selection conditions with respect to dystocia. In addition, 29 three year old and 20 two year old ewes (GpsIV,V) were selected at random from this flock to enable a study of the effect of age on pelvic dimensions. The selected ewes, after radiography in autumn, were weighed and then returned to the property where they were run until lambing. During the lambing period a mob of about 100, including the ewes radiographed, was run on flatter country so that lambing information could be collected. The author visited the property during the peak of lambing for two days to make these observations and to examine any lambs from this group that had died during the lambing period. Dystocia was not observed in any of the ewes nor were any of the dead lambs examined found to have died during birth, as assessed by the necropsy technique of McFarlane (1965). Birth weights of a sample of 15 single lambs were collected at the same time using a spring balance and a sling. These sheep were very timid and when approached with the purpose of identifying their age marks would invariably turn and flee. For this reason it was not possible to

Plate V.1. Pelvic diameters on the lateral radiograph.

CD - conjugate diameter.

OUTLET - outlet diameter.

Plate V.2. Pelvic diameters on the ventro-dorsal radiograph.

TC - distance between the tubera coxarum.

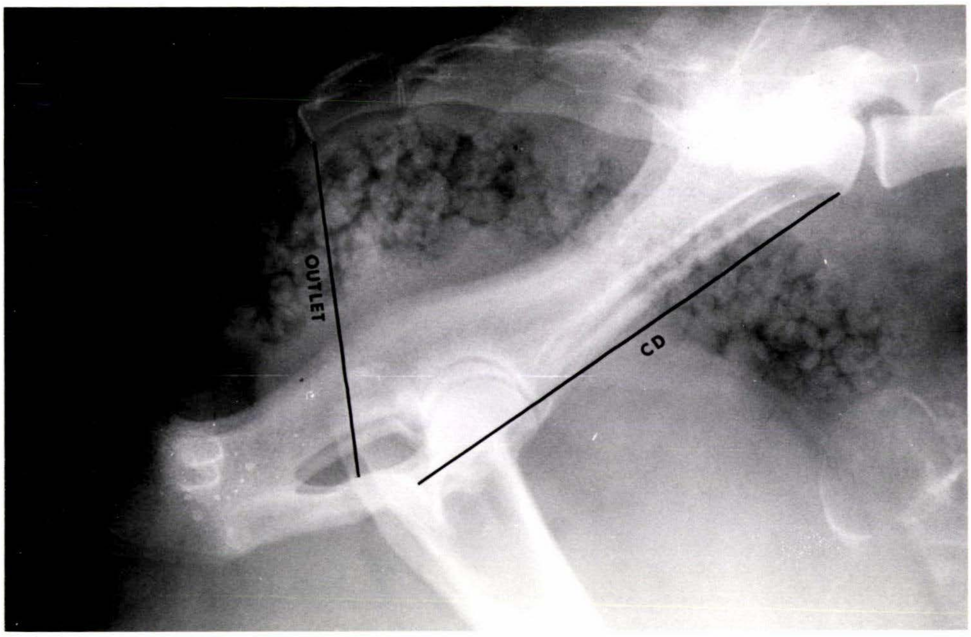
TD - transverse diameter.

AC - acetabular diameter.

LIT - lateral ischial diameter.

PPI - distance between the posterior promontories of the ischium.

1

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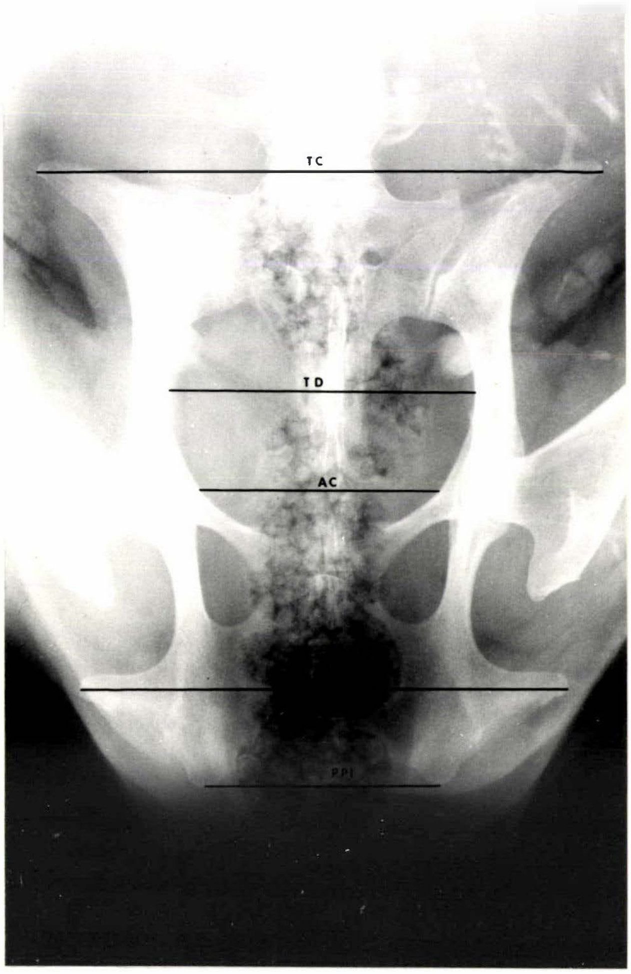
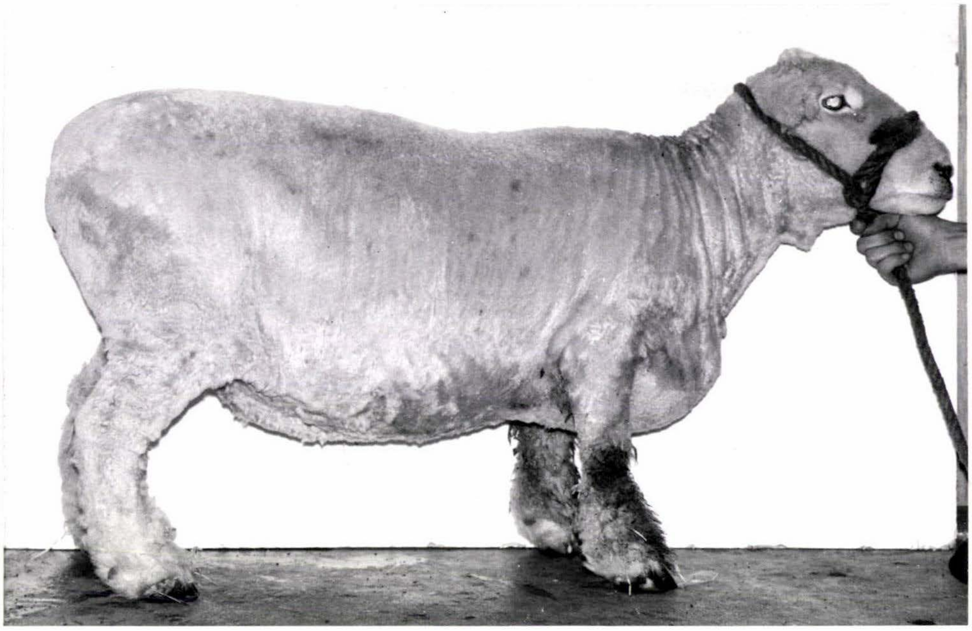


Plate V.3. Romney stud ewe from group I.

Plate V.4. Romney ewes from hill country property.
(Groups III, IV and V)

3

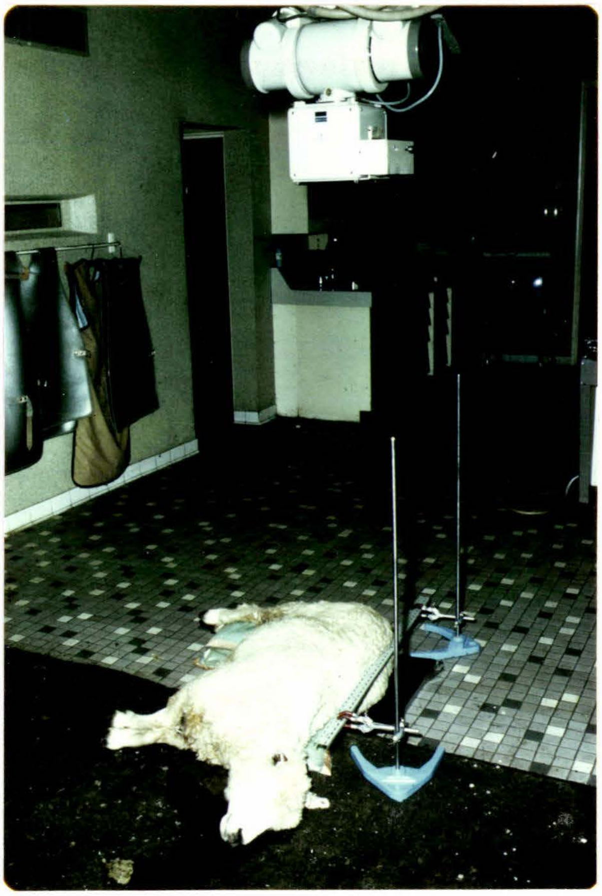


4

Plate V.5. Ewe being radiographed for pelvimetry. Lateral exposure.

Plate V.6. Ewe being radiographed for pelvimetry. Ventro-dorsal exposure.

5



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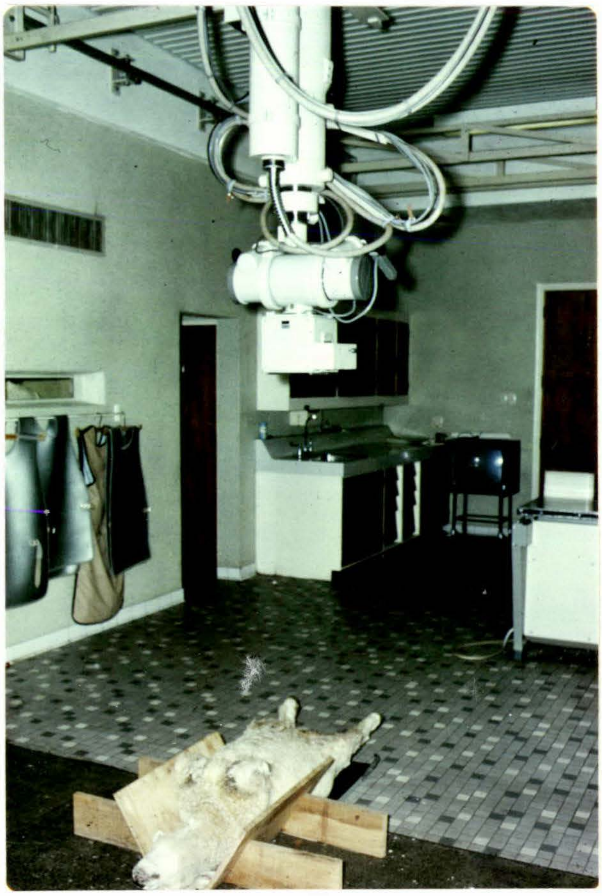

determine the age of each ewe from which a lamb was selected for weighing. The possible inclusion in the sample of lambs from secundiparous ewes, is not expected to materially affect the estimate of mean birth weight of lambs from mature ewes as the variation in birth weight was relatively low (coefficient of variation, 7.6%). Ewes from groups III, IV and V are shown in Plate V.4.

## V.4. Results and Discussion

### V.4.1. Pilot trial

#### V.4.1.1. Results

A comparison of pelvic measurements obtained by actual measurement and radiographic pelvimetry is shown in Table V (i). High correlations were demonstrated between measurements obtained by radiography and actual measurement for conjugate and transverse diameters and the distance separating the lateral ischial tuberosities. The correlations between the respective measurements for the pelvic outlet and the distance between the posterior promontories of the ischium were somewhat lower.

#### V.4.1.2. Discussion

Although cartilage present on the lateral tuberosities and the posterior promontories of the ischium was trimmed with a scalpel blade before measurements were taken with the calipers post slaughter, it is probable that the presence of some remaining cartilage has resulted in an error of measurement, explaining the discrepancy in the means obtained by the two methods. In particular the cartilage on the posterior promontory of the ischium made it difficult to accurately locate the most posterior point for measurement by the calipers and this is likely to have resulted in the lower correlation ($r = 0.84$) for this parameter.

Estimates of the outlet diameter from the radiographs were poorly correlated with the corresponding measurements taken from the carcass after slaughter ($r = 0.68$) and were considered to be of doubtful value in predicting the actual size

TABLE V (i): COMPARISON OF PELVIC DIMENSIONS OBTAINED BY RADIOGRAPHIC PELVIMETRY AND ACTUAL MEASUREMENT AFTER SLAUGHTER

| Sheep No. | | Method | Pelvic Measurement (mm) CD | Outlet | TD | PPI | LIT |
|---|---|---|---|---|---|---|---|
| 56 | | R P | 105 | 80 | 89 | 60 | 129 |
| | | A M | 104 | 80 | 89 | 68 | 131 |
| 76 | | R P | 104 | 86 | 89 | 64 | 139 |
| | | A M | 105 | 80 | 90 | 65 | 141 |
| 67 | | R P | 98 | 71 | 93 | N R | 140 |
| | | A M | 95 | 72 | 94 | 62 | 143 |
| 61 | | R P | 108 | 68 | 95 | 61 | 143 |
| | | A M | 109 | 65 | 95 | 65 | 145 |
| 75 | | R P | 92 | 78 | 91 | 68 | 143 |
| | | A M | 92 | 63 | 90 | 70 | 145 |
| 60 | | R P | 92 | 73 | 90 | 66 | 138 |
| | | A M | 92 | 70 | 92 | 67 | 140 |
| 58 | | R P | 107 | 69 | 88 | 61 | 141 |
| | | A M | 108 | 64 | 88 | 70 | 141 |
| 70 | | R P | 92 | 97 | 83 | 69 | 132 |
| | | A M | 92 | 79 | 82 | 74 | 135 |
| 57 | | R P | 101 | 82 | 92 | 65 | 139 |
| | | A M | 101 | N R | 91 | 68 | 141 |
| 64 | | R P | 101 | 80 | 91 | 70 | 137 |
| | | A M | 105 | 80 | 92 | 72 | 138 |
| 63 | | R P | 113 | 75 | 85 | 76 | 145 |
| | | A M | 112 | 63 | 85 | 79 | 146 |
| | Mean | R P | 101.2 | 78.1 | 89.6 | 66.0 | 138.7 |
| | | A M | 101.4 | 71.6 | 89.8 | 69.1 | 140.4 |
| | Correlation (r) | | 0.97 | 0.68 | 0.97 | 0.84 | 0.99 |

N R Not recorded
CD Conjugate diameter of the pelvic inlet
TD Transverse diameter of the pelvic inlet
PPI Distance between the posterior promontories of the ischium
LIT Distance between the lateral ischial tuberosities
R P Radiographic pelvimetry
A M Actual measurement

of the pelvic outlet in the non-pregnant animal. In addition difficulties in relating this diameter in the non-pregnant animal to that at parturition are created by individual variations in fusion of the sacral vertebrae and the mobility of the sacro-iliac joint (Bassett, 1955; Bassett and Phillips, 1955 a). For these reasons estimates of the outlet diameter were omitted from subsequent between group comparisons.

## V.4.2. Between group and between age comparisons of pelvic measurements

### V.4.2.1. Results

The pelvic measurements and body weights for the three groups of mature ewes, together with analyses testing for differences in group means, are shown in Tables V (ii) and V (iii). Of particular note is the significantly greater estimated area of the pelvic inlet in the group II and III ewes as compared with the group I ewes. In Table V (iv) mean area of the pelvic inlet is related to mean birth weight of lambs for each of the three groups. Both groups of ewes with histories of freedom from dystocia (groups II and III) have larger pelvic inlet areas both in terms of absolute size and in relation to the mean birth weight of lambs sampled for each group. The correlations between the various parameters measured are shown in Table V (v). Because of cut-off of the image by the focused grid or lack of contrast at certain planes, some of the parameters were not recorded from all the radiographs, explaining the variation in group numbers. Similarly, body weights were not recorded for all of the ewes, either because the ewe had not reared a lamb (see V.3.2), or had not been weighed.

The mean number of fused sacral vertebrae did not appear to differ between the three groups of mature ewes, although it was often difficult to distinguish between sacral and coccygeal vertebrae and in some cases, between sacral and lumbar vertebrae from the radiographs. A number of ewes in group I exhibited radiographic evidence of partial luxation of the sacro-iliac joint. This was always unilateral and was presumed to have resulted from dystocia. It was not observed in the groups

TABLE V (ii): MEAN PELVIC DIMENSIONS AND BODY WEIGHTS OF GROUPS I, II AND III EWES (MATURE EWES)

| Measurement[1] | Group | Mean | S D | n |
|---|---|---|---|---|
| CD (mm) | I | 100.31 | 7.5 | 32 |
| | II | 103.81 | 7.0 | 26 |
| | III | 106.68 | 7.0 | 22 |
| TD (mm) | I | 90.66 | 4.4 | 32 |
| | II | 96.42 | 3.7 | 26 |
| | III | 91.32 | 3.7 | 22 |
| TC (mm) | I | 178.00 | 7.8 | 24 |
| | II | 182.45 | 7.5 | 22 |
| | III | 165.40 | 8.5 | 15 |
| AC (mm) | I | 70.72 | 4.1 | 32 |
| | II | 73.76 | 5.0 | 26 |
| | III | 69.68 | 3.1 | 22 |
| PPI (mm) | I | 69.27 | 6.8 | 30 |
| | II | 66.00 | 7.9 | 18 |
| | III | 62.85 | 5.0 | 13 |
| LIT (mm) | I | 141.41 | 8.2 | 32 |
| | II | 143.96 | 8.3 | 26 |
| | III | 128.18 | 6.8 | 22 |
| Area ($mm^2$) (CD x TD) | I | 9,088 | 726 | 32 |
| | II | 10,010 | 774 | 26 |
| | III | 9,734 | 638 | 22 |
| Pelvic shape (CD/TD) | I | 1.11 | 0.1 | 32 |
| | II | 1.08 | 0.1 | 26 |
| | III | 1.17 | 0.1 | 22 |
| Body weight (kg) | I | 54.8 | 4.6 | 14 |
| | II | 59.0 | 4.0 | 26 |
| | III | 41.5 | 4.2 | 21 |

[1]
CD Conjugate diameter of the pelvic inlet
TD Transverse diameter of the pelvic inlet
TC Distance between the tubera coxarum
AC Distance between the acetabula
PPI Distance between the posterior promontories of the ischium
LIT Distance between the lateral tuberosities of the ischium

TABLE V (iii): SIGNIFICANCE OF DIFFERENCES IN MEANS BETWEEN GROUPS I, II AND III EWES

| Measurement | Group I vs Group II | Group I vs Group III | Group II vs Group III |
|---|---|---|---|
| CD | N S | ** | N S |
| TD | *** | N S | *** |
| TC | N S | *** | *** |
| PPI | * | ** | ** |
| LIT | N S | *** | *** |
| AC | * | N S | ** |
| TD x CD | *** | ** | N S |
| CD/TD | N S | * | * |
| Body weight | ** | *** | *** |

CD Conjugate diameter of the pelvic inlet
TD Transverse diameter of the pelvic inlet
TC Distance between the tubera coxarum
PPI Distance between the posterior promontories of the ischium
LIT Distance between the lateral ischial tuberosities
AC Distance between the acetabula
TD x CD Estimate of area of the pelvic inlet
CD/TD Estimate of internal pelvic shape
N S $(p>0.05)$
* $(p<0.05)$
** $(p<0.01)$
*** $(p<0.001)$

TABLE V (iv): THE RELATIONSHIP BETWEEN PELVIC AREA AND BIRTH WEIGHT OF THE LAMB IN THE THREE GROUPS OF MATURE EWES

| Measurement | Group I | Group II | Group III |
|---|---|---|---|
| Pelvic area ($mm^2$) (CD x TD) | 9,088$^{b}$ | 10,010 | 9,734 |
| Mean birth weight of lambs in sample (kg) $\pm$ S D | $5.33 \pm 0.68$ | $5.22 \pm 0.78$ | $4.76^{*} \pm 0.36$ |
| Number of lambs in sample | 18 | 18 | 15 |
| Ratio of pelvic area to lamb weight ($\times 20^{-1}$) | 850 | 960 | 1,022 |

b Mean estimated pelvic area of Group I ewes less than that of either Groups II or III ewes $(p<0.01)$

* Mean lamb weight of Group III ewes less than that of Groups II and I ewes $(p<0.01)$

TABLE V (v): CORRELATIONS BETWEEN PELVIC DIMENSIONS OF GROUPS I, II AND III EWES (MATURE EWES)

| Measurement [1] | Group | CD | TD | CD x TD |
|---|---|---|---|---|
| TC | I | 0.29 | 0.41 * | 0.52 ** |
| | II | 0.26 | 0.59 ** | 0.48 * |
| | III | 0.34 | 0.36 | 0.53 * |
| | CE | 0.29 * | 0.47 *** | 0.55 *** |
| PPI | I | 0.09 | - 0.12 | 0.01 |
| | II | 0.2 | 0.50 * | 0.41 |
| | III | 0.2 | 0.22 | 0.38 |
| | CE | 0.14 | N A | 0.21 |
| LIT | I | 0.02 | 0.28 | 0.44 * |
| | II | 0.28 | 0.62 *** | 0.55 ** |
| | III | 0.65 ** | 0.09 | 0.70 *** |
| | CE | N A | N A | 0.55 *** |
| TD | I | - 0.21 | - | 0.41 * |
| | II | + 0.00 | - | 0.54 ** |
| | III | - 0.02 | - | 0.29 |
| | CE | - 0.09 | - | 0.42 *** |
| CD | I | - | - 0.21 | 0.80 *** |
| | II | - | + 0.00 | 0.86 *** |
| | III | - | - 0.02 | 0.81 *** |
| | CE | - | - 0.09 | 0.82 *** |
| Body weight | I | 0.18 | 0.00 | 0.22 |
| | II | - 0.08 | 0.61 *** | 0.07 |
| | III | 0.36 | 0.3 | 0.56 ** |
| | CE | 0.13 | N A | 0.22 |

N A Groups not combined since 'r' differed between groups ($p<0.05$)

C E Combined estimate of 'r'

[1]
TC Distance between the tubera coxarum
PPI Distance separating the posterior promontories of the ischium
LIT Distance separating the lateral ischial tuberosities
TD Transverse diameter of the pelvic inlet
CD Conjugate diameter of the pelvic inlet
CD x TD Estimate of pelvic area
* ($p<0.05$)
** ($p<0.01$)
*** ($p<0.001$)

II, III, IV or V ewes.

Because the distance between the posterior promontories of the ischium in the hill country ewes (groups III, IV, V) was difficult to measure confidently, particularly in the younger ewes, because of poor contrast at this plane, it has been omitted from the age comparisons. The mean pelvic measurements and body weights for the groups III, IV and V ewes, together with the analyses testing for differences in group means, are shown in Tables V (vi) and V (vii). Correlations between the various pelvic diameters are shown in Table V (viii).

Ventro-dorsal radiographs from a eutocous and a dystocous ewe are shown in Plates V. 7 & 8.

TABLE V (vi): MEAN PELVIC DIMENSIONS AND BODY WEIGHTS OF GROUPS III, IV AND V EWES

| Measurement[1] | Group of ewe | Mean | S D | n |
|---|---|---|---|---|
| CD (mm) | III | 106.68 | 7.0 | 22 |
| | IV | 103.93 | 7.3 | 29 |
| | V | 102.85 | 6.2 | 20 |
| TD (mm) | III | 91.32 | 3.7 | 22 |
| | IV | 89.41 | 5.1 | 29 |
| | V | 88.35 | 3.6 | 20 |
| TC (mm) | III | 165.40 | 8.5 | 15 |
| | IV | 161.11 | 8.5 | 26 |
| | V | 160.33 | 9.0 | 12 |
| AC (mm) | III | 69.68 | 3.1 | 22 |
| | IV | 67.34 | 4.4 | 29 |
| | V | 66.00 | 3.5 | 20 |
| LIT (mm) | III | 128.18 | 6.8 | 22 |
| | IV | 125.83 | 7.7 | 29 |
| | V | 125.15 | 7.4 | 20 |
| TD x CD ($mm^2$) | III | 9,734 | 638 | 22 |
| | IV | 9,288 | 786 | 29 |
| | V | 8,968 | 743 | 20 |
| CD/TD | III | 1.17 | 0.1 | 22 |
| | IV | 1.17 | 0.1 | 29 |
| | V | 1.17 | 0.1 | 20 |
| Body weight (kg) | III | 41.47 | 4.2 | 21 |
| | IV | 37.42 | 3.4 | 28 |
| | V | 36.92 | 3.2 | 20 |

1
- CD Conjugate diameter of the pelvic inlet
- TD Transverse diameter of the pelvic inlet
- TC Distance between the tubera coxarum
- AC Distance between the acetabula
- LIT Distance separating the lateral ischial tuberosities
- TD x CD Estimated pelvic inlet area
- CD/TD Estimate of pelvic shape

TABLE V (vii): SIGNIFICANCE OF DIFFERENCES IN MEANS BETWEEN GROUPS III, IV AND V EWES

| Measurement | Group III vs Group IV | Group III vs Group V | Group IV vs Group V |
|---|---|---|---|
| CD | N S | N S | N S |
| TD | N S | N S | N S |
| TC | N S | N S | N S |
| LIT | N S | N S | N S |
| TD x CD | * | *** | N S |
| AC | * | *** | N S |
| CD/TD | N S | N S | N S |
| Body weight | *** | *** | N S |

CD Conjugate diameter of the pelvic inlet
TD Transverse diameter of the pelvic inlet
TC Distance between the tubera coxarum
LIT Distance between the lateral ischial tuberosities
TD x CD Estimate of area of the pelvic inlet
AC Distance between the acetabula
CD/TD Estimate of internal pelvic shape
N S ($p>0.05$)
* ($p<0.05$)
*** ($p<0.001$)

TABLE V (viii): CORRELATIONS BETWEEN PELVIC DIMENSIONS OF GROUPS III, IV AND V EWES

| Measurement | Group | CD | TD | TD x CD |
|---|---|---|---|---|
| TC | III | 0.34 | 0.36 | 0.53 * |
| | IV | 0.07 | 0.63 *** | 0.48 * |
| | V | 0.28 | 0.41 | 0.66 * |
| | CE | 0.21 | 0.5 *** | 0.55 *** |
| LIT | III | 0.65 ** | 0.09 | 0.70 *** |
| | IV | - 0.09 | 0.63 *** | 0.53 ** |
| | V | - 0.02 | 0.43 | 0.29 |
| | CE | N A | 0.41 *** | N A |
| TD | III | - 0.02 | - | 0.29 |
| | IV | - 0.13 | - | 0.56 ** |
| | V | - 0.21 | - | 0.46 |
| | CE | - 0.12 | - | 0.46 *** |
| CD | III | - | - 0.02 | 0.81 *** |
| | IV | - | - 0.13 | 0.75 *** |
| | V | - | - 0.21 | 0.47 |
| | CE | - | - 0.12 | 0.70 *** |
| Body weight | III | - | - | 0.56 ** |
| | IV | - | - | 0.64 *** |
| | V | - | - | 0.24 |
| | CE | - | - | N A |

| | |
|---|---|
| N A | Groups not combined since 'r' differed between groups ($p<0.05$) |
| CD | Conjugate diameter of the pelvic inlet |
| TD | Transverse diameter of the pelvic inlet |
| TD x CD | Estimate of pelvic area |
| LIT | Distance between the lateral tuberosities of the ischium |
| TC | Distance between the tubera coxarum |
| CE | Combined estimate |
| * | ($p<0.05$) |
| ** | ($p<0.01$) |
| *** | ($p<0.001$) |

Plate V.7. Ventro-dorsal radiograph of pelvis of a eutocous 3 year old ewe from group IV.

| | |
|---|---|
| Conjugate diameter - | 109mm |
| Transverse diameter - | 91mm |
| Acetabular diameter - | 72mm |
| Lateral ischial diameter - | 124mm |
| Distance between the posterior promontories of the ischium - | 57mm |
| CD x TD - | 9919mm$^2$ |

Plate V.8. Ventro-dorsal radiograph of pelvis of a dystocous Romney stud ewe from group I.

| | |
|---|---|
| Conjugate diameter - | 109mm |
| Transverse diameter - | 85mm |
| Acetabular diameter - | 68mm |
| Lateral ischial diameter - | 139mm |
| Distance between the posterior promontories of the ischium - | 79mm |
| CD x TD - | 9265mm$^2$ |

7

8

## V.4.2.2. Discussion

The pelvic dimensions recorded from the five groups of ewes in this study are in general agreement with those previously reported by Bassett (1955) and Quinlivan (1971) for New Zealand Romney ewes (Table V (ix) ).

TABLE V (ix): PELVIC MEASUREMENTS OF NEW ZEALAND ROMNEY EWES

| Author | | Details | Pelvic measurement<br>CD[1] (mm) | TD (mm) | TD x CD ($mm^2$) | LIT (mm) | PPI (mm) | TC (mm) |
|---|---|---|---|---|---|---|---|---|
| Bassett (1955) | | 3 year old | 105 | 89 | 9,280 | 136 | - | 175 |
| | | 4 year old | 108 | 92 | 9,907 | 136 | - | 181 |
| | | Mature | 107 | 94 | 9,993 | 144 | - | 187 |
| Quinlivan (1971) | | Dystocous | 90 | 95 | 8,536 | 141 | 73 | - |
| | | Eutocous | 105 | 92 | 9,739 | 148 | 79 | - |
| Present Study | | 2 year old (GpV) | 103 | 88 | 8,968 | 125 | - | 160 |
| | | 3 year old (GpIV) | 104 | 89 | 9,288 | 126 | - | 161 |
| | Mature ewes | Eutocous (GpIII) | 107 | 91 | 9,734 | 128 | 63 | 165 |
| | | Eutocous (GpII) | 104 | 96 | 10,010 | 144 | 66 | 182 |
| | | Dystocous (GpI) | 100 | 91 | 9,088 | 141 | 69 | 178 |

CD[1] Conjugate diameter of the pelvic inlet
TD Transverse diameter of the pelvic inlet
TD x CD Estimated area of the pelvic inlet
LIT Distance between the lateral ischial tuberosities
PPI Distance between the posterior promontories of the ischium
TC Distance between the tubera coxarum

A comparison of pelvic dimensions of ewes with histories of eutocia and dystocia would ideally be undertaken on a within flock basis. Since this was not possible in the present study it could not be assumed that the birth weights of lambs from the different groups constituted a homogeneous set. It seemed reasonable therefore, to examine the relationship between lamb size and pelvic size within each of the three groups and to make comparisons on this basis. In terms of absolute area, the size of the pelvic inlet of the eutocous ewes in groups II and III was clearly greater than that of the dystocous ewes in group I. Of more importance, when the area of the pelvic inlet is related to the mean birth weight of the lambs for the different groups, large differences were again apparent between the eutocous and the dystocous ewes. These differences in the relationship of lamb size to pelvic size are considered to be largely responsible for the differences in the recorded incidence of dystocia between the groups. Similar differences in the relationship of lamb weight to pelvic area have been demonstrated between eutocous and dystocous ewes by other authors. Naaktgeboren et al. (1971) concluded from their study that the higher incidence of dystocia in the Texel ewes, as compared with the Heath ewes, was attributable to the high lamb weight at birth and the inadequate size of the pelvic inlet of the ewe. In a more recent study Fogarty and Thompson (1974) demonstrated that the area of the pelvic inlet of Border Leicester ewes was significantly greater than that of Dorset Horn ewes yet birth weights from the two breeds were reported to be similar. They concluded that the relatively greater pelvic inlet area of the Border Leicester ewes was associated with the low incidence of dystocia noted in this breed.

The relatively large pelvic area of the group III ewes could be attributable to natural selection which, over many years, may have resulted in an increase in pelvic dimensions, a decrease in lamb weight at birth, or both through the death of lambs and ewes experiencing dystocia.

Differences in the area of the pelvic inlet between the ewes in groups I and III were largely ascribable to differences in the conjugate diameter of the inlet, since the transverse diameter did not differ between the two groups (Table V (iii)). As a consequence the shape of the pelvic inlet was significantly different between these two groups, a finding which agrees with the results reported by Fogarty and Thompson (1974):

as in the present study, the ewes with the low incidence of dystocia (Border Leicester) were shown to have longer, narrower pelvic inlets than ewes with a high incidence of dystocia (Dorset Horn). This did not apply in the case of the group I and II ewes; the difference in pelvic area between these two groups was attributable more to a difference in transverse diameter than conjugate diameter, although shape of the pelvic inlet did not differ significantly (Table V (iii)).

The conjugate diameter of the pelvic inlet accounted for 67% of the variation in estimated pelvic area over the three groups of mature ewes compared with only 18% accounted for by the transverse diameter. This result agrees well with the 68% and 15% reported by Fogarty and Thompson (1974) for these respective measurements.

Estimates of correlations between external and internal pelvic dimensions are in general agreement with the findings of Bassett (1955) and Fogarty and Thompson (1974), and as these authors have pointed out, none of the correlations are sufficiently high to be of use in predicting pelvic area.

Width between the lateral tuberosities of the ischium was correlated with conjugate diameter in group III ewes but not correlated with the transverse diameter. In contrast, in the group II ewes the reverse was true, while in group I ewes width between the lateral tuberosities of the ischium was correlated with neither conjugate nor transverse diameters (Table V (v)). Such within breed differences would need to be taken into account if external pelvic measurements are to be used to estimate internal pelvic dimensions.

With two exceptions body weight was not significantly related to the internal measurements of the pelvis. The first was the relatively high correlation (0.61) demonstrated between transverse diameter of the pelvic inlet and body weight in the group II ewes and the second was the correlation between body weight and estimated pelvic area in the group III ewes (Table V (v)). The explanation for the former relationship is not apparent; however, it is noteworthy that despite this relationship, the correlation between body weight and pelvic area was close to zero in this group. Fogarty and Thompson (1974) demonstrated a similar relationship ($r = 0.44$) between body weight and transverse diameter of the pelvic inlet in Dorset Horn ewes. The relationship between body weight of the group III ewes and estimated pelvic area could be explained by the low level of nutrition of these hill country ewes which may have restricted pelvic growth. As noted in section V2.3.2., the pelvis has been shown to increase relatively rapidly in weight after birth and because of this could be expected to be more strongly influenced by under-nutrition than slower growing parts of the skeleton. Certainly stocking rate on this property has been considered relatively high for this class of country up to 1973, when it was reduced. This change in management may be reflected in the absence of a significant correlation between body weight and area of the pelvic inlet in the group V ewes (2 years of age) (Table V (viii) ).

Internal pelvic shape showed no tendency to alter with age in the present study in contradistinction to the findings of Bassett (1955) which, although not statistically significant, indicated that the inlet becomes rounder with age. The groups III, IV and V ewes may not be representative of the Romney breed in this respect however, because of the type of environment in which they have been bred.

Of practical importance was the finding that the relationship between the distance separating the lateral ischial tuberosities and the estimated area of the pelvic inlet differed significantly between the three age groups of hill country ewes (groups III, IV and V). Clearly if external pelvic measurements are to be used to predict internal pelvic dimensions, with a view to selecting ewes with larger pelvic areas, the effect of age on the relationship between the two will need to be examined further.

## V.5. Conclusion

Radiographic pelvimetry has been evaluated and is found to be a useful research technique for measuring the pelvic dimensions of live sheep. The relatively high incidence of dystocia in the stud ewes is considered to have been caused by an incompatibility in size between the maternal pelvis and the lamb at birth. Use of external pelvic measurements in predicting internal pelvic dimensions seems impracticable because of the low degree of correlation between the two and because of the within breed variations that exist in these relationships.

## VI: FINAL DISCUSSION AND CONCLUSION

Evidence from each of the three studies described in Chapters III, IV and V points to a causal relationship between dystocia and a disparity in size between the maternal pelvic inlet and the lamb at birth. Weak expulsive effort was only implicated as a primary cause of dystocia in one ewe that developed uterine inertia in the study described in Chapter IV. However, relatively low abdominal bearing down effort, associated with posterior presentation of the foetus, is thought to have contributed to the lack of progress during parturition in three ewes in the same study.

Further work is required to determine the cause of foetal maldispositions at birth. However, the results suggest that rather than being a primary cause of dystocia, foetal maldisposition may be related to dystocia through a common cause, for example, a disproportion between the lamb and the maternal pelvis. There was a suggestion from the studies that this may not be the case with lambs presented posteriorly, but this could not be verified.

The hypothesis is therefore advanced that dystocia in Romney stud ewes is commonly caused either by the relatively small size of the pelvic inlet of the ewe, or the relatively large size of the lamb at birth, or both.

The decrease in the incidence of dystocia achieved by selection and the high repeatability of the condition in the stud flock (Chapter III), together with the low incidence in the flock that had been naturally selected against dystocia (Chapter V), provides evidence of a genetic basis for dystocia in sheep. This is supported by the results achieved through selection against this condition by Parker (1974) (Table VI (i) ). On the basis of these findings it is suggested that the high incidence of dystocia in some Romney stud flocks has resulted, over a number of years, from a reduction in the selection pressure against this trait, brought about by intensive shepherding, sparing lambs and ewes experiencing dystocia. Further work is required to estimate the heritability of this condition in sheep to determine whether selection against dystocia could provide a practical means of reducing the incidence in flocks.

TABLE VI (i): DECREASE IN THE INCIDENCE OF DYSTOCIA ACHIEVED BY SELECTION (Parker, 1974).

| Year | % Ewes assisted at lambing |
|---|---|
| 1956 | 12.3 |
| 1957 | 8.6 |
| 1958 | 5.3 |
| 1959 | 7.0 |
| 1960 | 2.3 |
| 1961 | 12.3 |
| 1962 | 9.2 |
| 1963 | 4.0 |
| 1964 | 7.0 |
| 1965 | 2.9 |
| 1966 | 2.4 |
| 1967 | 2.6 |
| 1968 | 2.6 |
| 1969 | 1.3 |
| 1970 | 0.5 |
| 1971 | 0.9 |
| 1972 | 0.5 |
| 1973 | 1.4 |

Although the present studies have shown the importance in parturition of the physical relationship at birth between the lamb and the maternal pelvis, they have not indicated the relative contribution of each to the problem of dystocia. It therefore seems important that a definitive study be undertaken to determine the relative contribution of lamb birth weight and the area of the pelvic inlet of the ewe to dystocia. Only when this has been carried out will it be clear how best a reduction in the incidence of dystocia may be achieved by the use of these measurements. It is likely that further work would then be necessary to identify clearly those factors which influence lamb birth weight, pelvic area, or both, so that the latter can be altered by selection or management to achieve the desired result.

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# APPENDICES

## Appendix I Definitions

(i) Dystocia. Parturition which directly or indirectly results in injury to the ewe or the lamb.

(ii) Disposition of the lamb. This term is used in this thesis to describe the presentation, position and posture of the lamb at birth. Normal disposition being anterior presentation, dorso-sacral position, extended posture. Maldisposition refers to any deviation in presentation, position, or posture from normal.

(iii) Presentation describes the orientation of the longitudinal axis of the foetus. In cattle and sheep malpresentation refers to posterior and transverse presentations.

(iv) Primipara. An animal that has had one parturition.

(v) Secundipara. An animal that has had two parturitions.

(vi) Multipara. An animal that has had more than two parturitions.

(vii) Montevideo unit. Average frequency of contractions in ten minutes x Average amplitude of contractions within the same time period examined.

(viii) Pascalian system. An enclosed pressure system in which pressure is uniform at all points.

(ix) Tocometry. Measurement of parturient uterine activity.

## Appendix II Mating harness and crayon

Sire Sine harness and Sire Sine crayons (mild and cold), Mannings Ltd., Hamilton, N.Z.

## Appendix III Aerosol stock marker.

Spray Mark. Crown Chemical Company Ltd., U.K.

## Appendix IV Pregnancy diagnosis and pelvimetry

(a) X-ray machine. Elema-Schonander Triplex Optimatic 1023.

The X-ray installation is based around a three phase 1000 ma. generator which has a near d.c. output due to the 12 pulse high tension curve per mains cycle. There is a continuous KV adjustment from 40-200 KV and the X-ray exposures are switched by six thyratron valves which are controlled by an electronic timer capable of switching from 0.003 to 8 seconds in 32 steps. This tube is equipped with a conventional light indicating collimator and also an optical range finder is fitted so that the correct tube-film distance can be achieved simply and rapidly in any situation.

(b) Kodak cassette with Kodak high speed screens.

(c) RP/X-OMAT film processed in a Kodak RP/X-OMAT automatic processor.

(d) Grid ratio 12:1, 100 lines/inch, focused at 1 m.

(e) Exposure factors

A. Pregnancy diagnosis 75 mas, 80 KV.

B. Pelvimetry (i) Ventro-dorsal exposure 80 mas, 80 KV.

(ii) Lateral exposure 85 mas, 100 KV

Appendix V Plastic catheters

Vinyl catheters I.D. 1.5 mm, O.D. 2.7 mm (SV 116). Dural Plastics and Engineering Pty. Ltd., Dural, N.S.W., Australia.

Appendix VI Stainless probe

Made from stainless steel orthopaedic pin (Zimmer) 2.78 mm diameter, 10 cm long.

Appendix VII Anaesthetic machine

Commonwealth Industrial Gases twin cannister circle absorber.

Appendix VIII Tocometry

(a) Transducers

(i) Intra-uterine pressure
Statham P23 BB, range $\pm$ 50 mm Hg,
displacement 3.1 $mm^3$/100 mm Hg.

(ii) Intra-abdominal pressure
Sanborn 267B, range -100 mm Hg - +400 mm Hg, displacement 0.05 $mm^3$/100 mm Hg

(b) Amplifiers

(i) Intra-uterine pressure
Devices DC.2C pre-amplifier

(ii) Intra-abdominal pressure
Sanborn 350 - 1100 C carrier pre-amplifier

(c) Recorders

(i) Four channel direct writing recorder. Constructed by the Instrument Workshops, D.S.I.R., Palmerston North

(ii) Two channel recorder. Devices M2 two channel direct writing recorder

(d) Damping

(i) Intra-uterine pressure
T.C. 3 seconds

(ii) Intra-abdominal pressure
T.C. 1 second

(e) Calibration

(i) Intra-uterine pressure
For this purpose the outputs of the DC.2C pre-amplifiers could be displayed on a meter (Fig. IV(ii) ). By switching a calibration resistor into the wheatstone bridge circuit of the transducer the gain of the pre-amplifier could be adjusted to give a full scale deflection on the meter and the chart recorders of 25 mm Hg. During parturition the range could be doubled by adjusting the range setting on the pre-amplifier controls.

(ii) Intra-abdominal pressure
Calibration of these transducers was checked by connecting them with water manometers after the sheep had lambed.

Appendix IX Personal communications cited in the thesis

(1) A.N. Bruere, Veterinary Clinical Science Department, Massey University

(2) R. Buchanan, Lockwood Romney Stud, Otamauri, Hawke Bay

(3) G.C. Liggins, National Women's Hospital, Auckland

(4) W.B. Currie,
Protein and Polypeptide Hormone Laboratory,
Department of Physiology,
Faculty of Medicine, University of Manitoba,
Winnipeg, Canada.