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THE UNIVERSITY OF ALBERTA

FACTORS ASSOCIATED WITH CALVING DIFFICULTY AND ITS EFFECT ON CALF PERFORMANCE

BY

MICHAEL ADAM (C)

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled FACTORS ASSOCIATED WITH CALVING DIFFICULTY AND ITS EFFECT ON CALF PERFORMANCE submitted by Michael Adam in partial fulfilment of the requirements for the degree of Master of Science.

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Date ....

ABSTRACT

An investigation was conducted to study the incidence and causes of difficult births in cattle. Breed line differences and factors affecting difficult calvings were examined in 3,783 and 2,596 births recorded by the University of Alberta and the Canadian Charolais Association (CCA). Births were scored for ease of calving on a scale ranging from 0 through 5, 0 being normal and unassisted, and 5 the most difficult cases needing caesarean sectioning for foetal extraction.

No clear pattern of year to year differences in calving difficulty were observed, although percent difficulty did increase over the years as the populations increased in size. Also, perinatal calf mortality rates tended to be high where calving difficulty rates were high.

Preliminary results involving 29 Hereford calves indicated no significant correlation between parturition score and each of head length, head width, body depth, diameter at the shoulders and hips, average circumference of the fore fetlocks and body length.

The main effects of dam age, dam weight, calf birth weight, calf sex, year of calf birth, gestation length and calf breeding (i.e. population line) were significant sources of variation associated with parturition score. The

effects of breed of sire and breed of dam were not significant in the CCA data ($P>0.05$), although Charolais-sired births were somewhat more difficult than those sired by Chianina and Limousin bulls. When parturitions with scores of 2 to 5 were grouped and parturition score tested with breed of sire, however, a significant relationship was obtained between breed of sire and parturition score. Seasonal birth sequence was a significant factor associated with parturition score among the University of Alberta herds.

Age and weight of dam were the most significant sources of variation among the University of Alberta herds, accounting for 17.5% and 13.6% of total variance in parturition score, respectively. In all, the independent variables in this set of data together explained 27.1% of the variability in parturition score.

With the CCA set of data, where calf birth weights were relatively high and where analyses excluded 2-year old heifers and weight of dam as covariables, calf birth weight was the most important factor influencing calving difficulty. It explained 5.1% of total variation in parturition score.

Generally, percent calving difficulty tended to increase with the average birth weights of Charolais, Limousin and Chianina sire progeny groups, with an increase of 1 lb (0.45 kg) in average birth weight resulting in corresponding increases of 0.81, 0.46 and 1.78% difficulty in parturition, respectively. With Hereford and Synthetic hybrid sire progeny groups, however, percent calving difficulty showed a slighlty negative trend with average birth weight, except 2-year-old dams in the Synthetic-hybrid population for which a positive relationship was obtained

A heritability estimate of 9.5 ± 1.8% was obtained for calving difficulty, while mean estimates of 19.2 ± 4.1 and 12.6 ± 4.1% were obtained for repeatability, utilizing 2- and 3-year old dams among the University of Alberta's Hereford and Synthetic-hybrid lines.

Parturition score was observed to have some influence on pre-weaning average daily gain. It did not, however, have any observable relationship to the rib-eye areas of slaughtered steers.

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TABLE OF CONTENTS

LIST OF FIGURES

FIGURE PAGE

1. INTRODUCTION

With rising emphasis on faster growing cattle that yield more milk and leaner carcasses, the utilization of large, lean, exotic sire breeds in crossbreeding programs is rapidly gaining popularity. The use of large sire breeds, however, can result in an increase in the incidence of prolonged and difficult births.

Difficult parturition is an important cause of perinatal calf mortality, particularly from first calf heifers. Such death losses constitute a significant decrease in the potential annual returns to the cow owner and are especially costly as they represent the total production of cows fed and maintained through breeding and gestation. The possibility of an appreciable reduction in re-breeding fertility and milk production of cows that experience difficult births further compounds the problem.

Conditions which prolong parturition or hinder expulsion of the foetus are (a) mechanical (owing to an abnormal presentation of the foetus to the birth canal of the dam or to obstructions of the birth canal), (b) anatomical (owing to abnormalities of the dam's reproductive tract or to calves with disproportionate parts), and (c) functional - when difficulty in parturition is the result of primiparity, incomplete dilation of the cervix, hernias, senility, metabolic disorders, deficiency diseases, or other general infections (Zerobin and Sporri, 1972).

The causes of individual cases of difficult birth can be adequately ascertained if they are anatomical or mechanical, but when they are functional their detection is much more difficult owing to lack of sufficient knowledge of the reproductive process.

Factors associated with calving difficulty may be paternal and/or maternal in origin, or they may be due to some characteristic of the calf. Difficult and prolonged calvings are known to be affected by the dam's age and by the sex and weight of the calf. Also, the breed of the sire and of the dam are important in determining the rate of occurence of difficult and prolonged births in any cattle herd.

The present investigation was conducted to study these and other factors (mainly anatomical and mechanical) that influence calving difficulty, and to elucidate, as much as possible, the effect of difficult calving on the pre-weaning performance of calves and its relationship to carcass conformation at slaughter.

2. REVIEW OF LITERATURE

2.1. Parturition

Parturition, the act of giving birth to young, marks the end of gestation. In the cow the premonitions of birth are the enlargement of the udder which becomes firm and resistant to the touch and yields a milky fluid, the enlargement and swelling of the vulva which discharges an abundant stringy mucus, the drooping of the belly, and the relaxation of the muscles at the sides of the root of the tail so as to leave deep hollows. When the last symptom is seen, calving may be counted on in 24 to 72 hours (Law, 1916).

The hormonal stimulus for the onset of parturition is not clear. Various hypotheses have been advanced to explain the cause of parturition but they all seem inadequate and lack experimental support. Bell et al. (1972) appear to be of the opinion that the oxytocic action of the posterior lobe of the pituitary gland initiates birth, although Smith (1931), after destroying the posterior pituitary in the rat observed normal parturition. According to Dukes (1943), a hypothesis has been advanced, based on the increased action of oxytocin on uterine muscle after oestradiol sensitization, that the synergistic action of these two hormones is instrumental in the onset of parturition.

The course of normal parturition is customarily divided into three stages, each characterised by distinct signs and events. The first stage involves uterine contractions which force the foetal placenta (water-bags) against the cervix thus causing it to dilate so that the foetus can pass through into the pelvis, while the second stage comprises the actual delivery of the foetus and the third stage consists of the expulsion of the placenta (Frandson, 1974).

Dufty (1972), who carried out a detailed study on the sequence of events occuring during normal calving in Hereford heifers in Australia, noticed that no signs of discomfort or restlessness appeared until the cervix had dilated sufficiently to admit a hand, at which time slight dorsal arching was apparent. He observed definite arching bouts only when the chorio-allantois neared the vulva, and these were followed immediately by abdominal muscle contractions which caused the rupture of the chorio allantois, and subsequently by a temporary cessation of abdominal straining which recommenced as the amnion reached the vulva. He also observed a gradual increase in the number of abdominal contractions during each arching bout following the rupture of the amniotic sac with a decrease in resting time, straining sometimes becoming continuous over the last few minutes of parturition. Dufty obtained mean intervals of 1 hour 13 minutes (range 2 minutes to 4 hours 39 minutes) between rupture of the chorio-allantois and amnion, 1 hour 52 minutes (range 17 minutes to 6 hours 13 minutes) between rupture of the amnion and normal calving, and 3 hours 47 minutes (range 1 hour 29 minutes to 7 hours 10 minutes) between birth of the calf and delivery of the placenta.

The total period from the onset of actual labour to normal parturition has been estimated to be about 8 hours in pluriparous cows[1] and a bit longer in primiparous cows[2] (Frandson, 1972), both the dilation and expulsion stages having been reported to be 2 to 5 times longer in primipara (Zerobin and Sporri, 1972).

Law (1916) claims that when there is only one foetus, the natural presentation during parturition is that of the fore feet with the front of the hoofs and knees turned upward toward the tail of the dam and the muzzle lying between the knees, while the natural position of the second in the case of twins is that of the hind feet, the heels and the hocks turned upward toward the cow's tail (Figure 1). In his view, both the posture and presentation take advantage of the natural curvature of the birth canal of the dam. This view is shared by Frandson (1972) who is also of the opinion that a posterior presentation, with the hind feet first and

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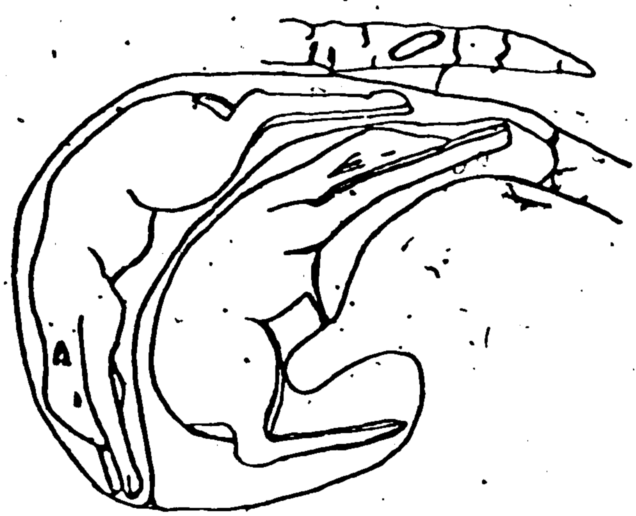
[1]Pluriparous cow: a cow giving birth to her second, or subsequent, calf.
[2]Primiparous cow: a cow giving birth to her first calf.

Figure 1. Twin pregnancy, showing the normal anterior and posterior presentations.



(Source: Law, 1916)

hocks up, occurs frequently enough in cattle to be considered normal.

2.2 Dystocia

With a well-formed dam and a normal presentation of the foetus, parturition is usually prompt, and easy. However, difficult births do often occur in cattle, even under such optimum conditions. Any abnormal situation in which birth of the young is made impossible or unduly difficult and prolonged is termed dystocia (Seiden, 1952; Bellows et al., 1971a; Zerobin and Sporri, 1972) and necessitates intervention which may be in the form of minor hand assistance, a hard pull on the foetus with the hands or by means of a mechanical calf puller, a caesarean section, or a complete dismemberment of the foetus to save the life of the cow (Law, 1916).

Law (1916) identified the major causes of difficult parturition as:

(i) failure of the mouth of the womb to dilate due to fibrous hardening and constriction from previous injuries,

(ii) twisting of the neck of the uterus - favoured by the length of the uterus and the looseness of the ligaments that attach it to the walls of the pelvis,

(iii) tumours in the vagina,

(iv) narrow pelvis due to small size of cow, to callus from a previous facture, or to thickening of the pelvic bone from a previous case of Fragilitas ossium[1] which prevents easy passage of the foetus,

(v) masses of fat upon and within the pelvic region that cause weakness or fatty degradation of muscle, especially in old cows,

(vi) overdistention of the bladder or rectum, or presence of stone in the bladder,

(vii) coagulated blood under the vaginal walls as a result of accidental injury,

(viii) disturbance of a nervous cow by noises,

(ix) constriction of a member by the naval string - the winding of the navel around a limb in early foetal life may retard progress at calving,

(x) dropsy of the calf's abdomen (ascites),

(xi) general dropsy of the calf owing to watery blood or diseases of the liver or kidney which cause a puffed-up and rounded condition of the calf,

(xii) hydrocephallus[2],

(xiii) dead and decomposed foetus that adheres to its membranes and to the wall of the uterus,

(xiv) rigid contractions of muscles which cause anatomical distortions,

---

1 Fragilitas ossium: an abnormal condition of extremely brittle bones (also Osteogenesis imperfecta).
2 Hydrocephallus: a situation in which the head back of the eyes rises into a great rounded ball due to presence of water in the cranial ventricles.

(xv) tumours of the calf which increase the diameter of the body and render progress of the foetus through the pelvic passage impossible,

(xvi) development of monsters (e.g. siamese twins), and

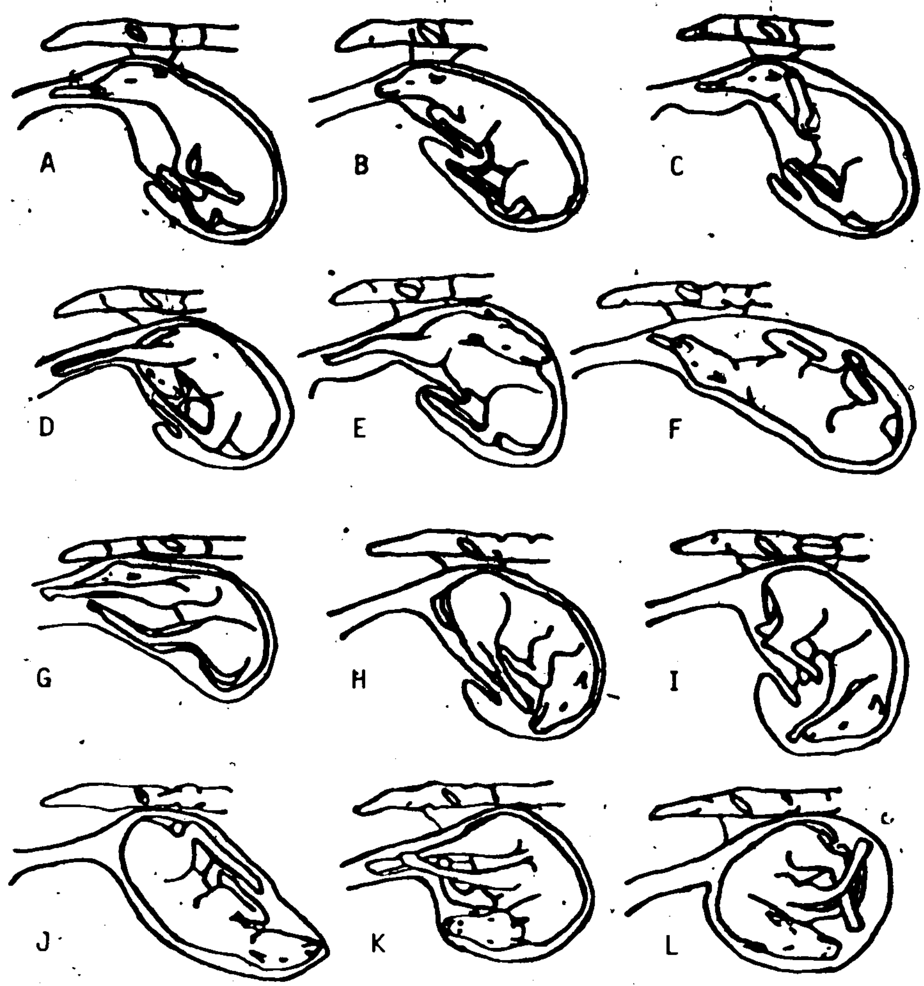
(xvii) abnormal presentations. These have been defined by Frandson (1972) as any deviations from the normal anterior or posterior presentations (Figure 2).

In an article reported in Cattlemen (1974) and based principally on evidence obtained from various research centres in the United States, it was noted that the most difficult parturitions occured when the foetuses were excessively large in relation to the birth canal of the dam. In such cases, extremely hard pulls or surgical (Caesarean) operations are the only means of calf extraction.

2.3 Factors associated with dystocia in cattle

Since calving difficulty is most apt to occur when the calf is too large to move easily through the dam's birth canal, any factor that increases calf size and/or decreases birth canal size could result in a more difficult and prolonged parturition. Consequently, variations in dystocia scores are due in the most part to factors attributable to the dam and the calf (Bellows *et al.*, 1969; Rice and Wiltbank, 1970; Bellows *et al.* 1971a) and to the sire inasmuch as he contributes toward the characteristics of the calf.

Figure 2. Abnormal presentations of the calf for delivery.



(Source: Frandson, 1975)

Figure 2 (contd.)

A. Anterior presentation - one foreleg retained

B. Anterior presentation - forelegs bent at knees

C. Anterior presentation - forelegs crossed over neck

D. Anterior presentation - downward deviation of head

E. Anterior presentation - upward deviation of head

F. Anterior presentation - with back down

G. Anterior presentation - with hind feet in pelvis

H. Croup and thigh presentation

I. Croup and hock presentation

J. Posterior presentation - the foetus on its back

K. All feet presented

L. Dorsolumber presentation

2.3.1 Sire effects:

Researches involving the use of various sire breeds have provided, and continue to provide, information on their relative calving ease.

Long and Gregory (1974) observed that calves sired by Hereford bulls were 1.4 kg heavier at birth and experienced significantly more dystocia (9.3%) than did Angus-sired calves. A similar observation has been reported by Gregory et al. (1965) on Hereford- and Angus-sired calves from Hereford, Angus and Shorthorn dams, and by Laster et al. (1973) who carried out a comprehensive investigation at the Meat Animal Research Center at Clay Center, Nebraska. They found that Charolais, Simmental, Limousin and South Devon bulls produced significantly more difficult calvings when they were bred to Hereford and Angus cows than did Hereford, Angus and Jersey bulls. Sagebiel et al. (1969) obtained significant differences between sire breeds only in male births, and not in female births, when they bred Angus, Hereford and Charolais cattle reciprocally, but Nelson and Huber (1971) found that breed of sire was not a significant source of variation in dystocia when Hereford heifers were bred to Hereford, Angus, Brown Swiss and Charolais bulls.

It has been observed that sires of the same breed do differ in the ease of birth of their progeny. Accordingly, it has been the experience of the American Breeders Service that bulls tend to rank approximately the same when used together in several herds and that differences among them diminish when many progeny are evaluated (Cattlemen, [illegible]).

2.3.2 Effects of the dam:

2.3.2.1 Breed

Available literature on the influence of breed of dam on calving difficulty is quite scanty, probably because researchers have in the past felt that producers are limited in the choice of dam breeds. However, the few studies that have compared ease of calving between various breeds of dam are almost unanimous in their findings that dam breeds do differ in the amounts of difficulty experienced during parturition.

Notably, Sagebiel <u>et al</u>. (1969) found that breed of dam was a significant source of variation in dystocia in male births but not in female births, while in their experiment Laster <u>et al</u>. (1973) obtained results which indicated a significantly higher calving difficulty in Hereford than in Angus cows for both male and female births, with means of 34.78% and 27.02% for Hereford and Angus cows, respectively.

There are suggestions that the influence of breed of dam on dystocia is due largely to differences in the birth weights of calves (Berg, 1973a). In fact, both Gregory <u>et al</u>

. (1965) and Pahnish et al. (1969) found that breed of dam significantly influenced calf birth weight, and Laster and his colleagues (1973) obtained a mean difference of 2.5 kg between the birth weights of Hereford- and Angus-born calves which would explain some portion of the difference in calving difficulty between the two dam breeds.

2.3.2.2 Age and pelvic size

It is a well-established and documented fact that first-calf heifers have a higher percentage of difficult calvings than do mature cows, particularly so in the case of heifers which calve first as 2-year-olds (Berg, 1973a). Age of dam was a major source of variation associated with calving difficulty in the reports of Gregory et al. (1965), Sagebiel et al. (1969) and Turner and McDonald (1969). Laster et al. (1973) observed that dystocia in 2-year-old cows was 36.0% higher than in 3-year-olds and 44.62% higher than in 4- and 5-year-olds. Indications are that age of dam effects may be confounded by the effects of year to year variations (Laster et al., 1973; Long and Gregory, 1974).

Bellows (1971), according to Laster et al. (1973), has shown that the cross-sectional area of the dam's pelvic opening is a major reason for the differences in calving difficulty among different age groups of dams. Dufty (1972) measured the pre-calving transverse (T) and sacro-pubic (V) diameters of the anterior openings of primiparous Hereford heifers that had been bred to calve at 22 months of age from which he calculated the areas of the openings using the formula (TxV) $\pi/4$. He obtained a mean area of 265 sq. cm. Significantly, the heifer that turned in the least figure (191 sq. cm.) not only experienced a difficult parturition but also delivered a stillborn foetus.

Bellows et al. (1971a) reported a value of 249.6 sq. cm. for pre-calving pelvic area in a group of Hereford heifers bred to calve as 2-year-olds while Bellows et al. (1971b) obtained a mean of 292 sq. cm. for primiparous Hereford heifers bred to calve at 3 years of age, thus indicating that a measurable increase in pelvic size occurs between 2 and 3-year-old heifers which should account for some of the difference in the amounts of dystocia experienced by the two age groups.

In their work, Bellows and his co-workers (1971b) also revealed that of all body measurements, including rump length, hip width, pelvic height, and pelvic width, body weight was the best indication of pelvic size, accounting for 32% of the variation in pelvic area. This singles out the body weight of the dam as a very important parameter in ease of calving studies in the absence of pelvic measurements.

2.3.3 Calf characteristics:

2.3.3.1 Birth weight and gestation length

The birth weight of the calf is one of the most important factors that influence calving difficulty (Cattlemen, 1974). Indeed, the results of many experiments are consistent with this observation (Sagebiel et al., 1969; Nelson and Huber, 1971; Bellows et al. 1971a; Burfening et al., 1973; Long and Gregory, 1974). When, Laster et al. (1973) held birth weight constant in their analysis, dam age was the only other factor that significantly affected dystocia.

Laster et al. (1973) found that calving difficulty increased 2.30 ± 0.21% for each kilogram increase in average birth weight. The Cattlemen (1974) article claimed a similar increase (2.42%) in pluriparous cows and a much higher increase in 2-year-old heifers (7.40%).

Burris and Blunn (1952) reported a positive regression of birth weight on gestation length, and Brakel et al. (1952) found a positive correlation between gestation length and calf birth weight. This suggests that longer gestation periods will result in bigger calves and possibly more difficult births.

There may be instances where percent calving difficulty of a progeny group is high although the dams may have appreciably large pelvic openings and calf birth weights may be appreciably low. In such cases, the important factors determining ease of calving could be the calves' physical measurements. Double-muscled calves, for example, reportedly produce very difficult calvings despite moderate birth weights (Cattlemen, 1974). Ward (1973) did not, however, observe any significant effect of heart girth, width at shoulders, circumference of the hocks, and thigh measurements of the calf on percent dystocia.

2.3.3.2 Sex and crossbreeding

Male calves are on the average heavier at birth than female calves (Koch et al., 1959; Lasley et al., 1961; Ellis et al., 1965; Joandet et al., 1973). It has been estimated that male calves average about 2.3 to 3.2 kg more at birth and are involved in about 66% of all difficult births (Cattlemen, 1974). In the work of Long and Gregory (1974), male calves were 1.9 kg heavier at birth and exhibited 14.5% more difficult births ($P<0.01$).

Laster et al. (1973) obtained differences for male over female calves of 3.02 kg and 11.42% for birth weight and dystocia, respectively ($P<0.005$). Also, they found that calving difficulty in parturitions involving male calves were 4.09% higher in reciprocal crosses than in straightbred Hereford and Angus calves, while in parturitions involving female calves dystocia was 6.9% higher ($P<0.10$) in straightbreds than in reciprocal crosses. The combined male and female figures revealed 1.42% more dystocia cases in straightbreds than in reciprocal crosses, leading the authors to the conclusion that heterosis did not have a significant effect on calving difficulty. Sagebiel *et al.* (1969) reported similar results for male births, but their results for female births were in direct contrast to that reported by Laster and his co-workers (1973), while Long and Gregory (1974) observed no significant differences between straightbreds and crossbreds for percent dystocia.

2.3.4 Nutrition:

The dam's feeding regime, especially in late pregnancy, does not appear to have any direct significance on the incidence of dystocia. Broster (1971), reviewing the literature on the subject, concluded that very generous feeding in the latter stages of pregnancy does not have any effect on dystocia, despite the popular belief in this direction.

Scarth and Dorton (1972), working in Georgia, assigned heifers and cows randomly to two treatment groups (a moderate stocking rate and a high stocking rate) three months prior to the beginning of the calving season in mid-January. They observed no significant differences between the two groups with respect to calving difficulty.

Insignificant influences of winter cow gain on calving difficulty have also been reported by Ward (1973) and by

Nelson and Huber (1971) who obtained no significant relationships between dam'S condition score and calving difficulty in first- and second-calf Hereford dams.

Evidence points to indirect influences of the dam's nutritional plane on such other factors as calf weight, calf body measurements, and the size of the foetal membranes, rather than directly on calving difficulty. This is particularly the case when she is subjected to a severe nutritional restriction. Ridler et al. (1963) and Gardner (1969) found from brief surveys of the literature that severe undernutrition in pregnancy could result in a reduction in the birth weight of the calf and the size of the foetal membranes, but that more normal variations would only produce very little effect. Young (1970) conducted a trial in Australia in which one of two groups of Angus heifers that had been bred as yearlings was subject to a low plane of nutrition during the latter stages of pregnancy while the other was maintained on a high nutritional plane over the same period. The high-plane group produced significantly heavier male and female calves than the low plane group.

2.4 Association of dystocia with subsequent productivity

Tests have shown that cows experiencing difficulty at parturition tend to have a lower rebreeding fertility than do those that experience normal births.

Comparative data on reproductive performance and subsequent calf weight for 2-year-old Hereford heifers requiring assistance at birth and those not requiring any assistance have been presented by Brinks et al. (1973). Heifers that experienced difficult births at 2 years of age weaned 11% fewer first calves and 14% fewer second calves per cow exposed than their herd mates who delivered without difficulty. Also, second calves were born 13 days later and were on an average 21 kg lighter at weaning if the cow experienced difficulty with the birth of her first calf.

Laster et al. (1973) reported a significant negative influence of calving difficulty on the percentage of cows detected in oestrus during a 45-day artificial insemination period and on the conception rate during the breeding period, but they did not observe any significant relationship between ease of calving and other reproductive parameters such as interval from calving to first breeding and interval from calving to conception. Brinks et al. (1973), however, found that the suppressing effects of suckling and lactation on oestrous cycle activity was less in the group that experienced calving difficulty owing to a higher calf mortality rate in this group.

Of 1538 cows that had exhibited dystocia in an earlier calving, Konermann et al. (1969) rebred 917 and obtained a conception rate of 76.4%, a level of fertility 10 to 15% lower than the rate they obtained for cows that had experienced normal births. On the other hand, milk production did not, according to them, appear to have been affected by type of birth. Clearly, more research is required in this direction to firmly establish the effects of dystocia on the performance of both the cow and her calf.

3. OBJECTIVES

The purpose of the present study was to investigate the incidence and causes of difficult parturition in cattle from the genetic and breeding management standpoint.

More specifically, the objectives were to:

1. examine the inter- and intra-breed sire effects on calving difficulty,
2. determine the influence of factors related to the dam on the difficulty of birth of her progeny,
3. determine the effects of sex and calf size on calving difficulty,
4. obtain heritability and repeatability estimates for calving difficulty,
5. evaluate the effects of difficult birth on calf performance prior to weaning and on carcass conformation, and
6. suggest methods for alleviating difficulties in parturient cattle.

4. MATERIALS AND METHODS

4.1 Experimental data - sources and history

The records used in the first part of this study were accumulated on the cattle herds maintained at the University of Alberta ranch located at Kinsella, Alberta over a 14-year period, from 1961 to 1974.

Initially, this population consisted of two lines, a purebred Hereford (HE) line and a Synthetic-hybrid (HY) line obtained by crossing among three breeds - Angus, Charolais and Galloway. During later years, a dairy (DY) population, primarily composed of Holstein and Brown Swiss breeding was established, together with several other smaller populations which were established for specific purposes (Berg, 1975). These include a Heavily-muscled (DM) population and a Crossbred (XB) population obtained by crossing with Limousin, Simmental, Holstein, Brown Swiss, Hereford and Synthetic hybrid bulls. The number of births in each population as at the end of the 1974 calving season is presented in Table 1.

Except in the XB population, bulls used on the ranch were mostly home-grown and were selected on the basis of their own performance. In addition to these, a few more, selected on individual performance and/or progeny test records were introduced from other sources by artificial

TABLE 1. NUMBER OF BIRTHS BY POPULATION

(University of Alberta Ranch, 1961-1974)

Breeding Group	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	TOTALS
Heifers															
HE	15	16	6	13	2	6	15	14	17	23	35	29	38	24	253
HY	10	5	21	18	10	16	24	33	17	23	43	43	67	47	377
XB	-	-	-	11	12	19	77	68	48	-	-	14	12	18	279
DM	-	-	-	-	-	-	-	-	-	14	15	8	17	11	65
DY	-	-	-	-	-	-	-	-	2	5	8	10	12	6	43
Cows															
HE	16	42	59	48	39	35	76	72	73	60	74	65	56	57	772
HY	43	62	67	67	46	63	89	87	105	100	134	122	106	139	1230
XB	-	-	-	39	80	68	34	68	34	48	40	35	57	44	547
DM	-	-	-	-	-	-	1	13	9	19	13	12	15	16	98
DY	-	-	-	-	-	-	-	5	19	15	18	13	23	26	119
TOTALS	84	125	153	196	189	207	316	360	324	307	380	351	403	388	3785

[a] Breed codes: DM, Heavily-muscled; DY, Dairy; HE, Hereford; HY, Synthetic-hybrids and XB, Crossbred.

Dashes mean no records available.

insemination. Normally, one bull was bred to 20 to 25 cows randomly alloted within a breeding population.

The second part of the study was based on information recorded by the Canadian Charolais Association (CCA) for its Conception to Consumer beef improvement program. This program, which began in 1968, involved only purebred Charolais (CH) bulls in the beginning but Chianina (CI) and Limousin (LI) bulls were used in the 1972-74 phase.

Under the program, bulls were artificially bred at random to cows of various breedings and ages in co-operating commercial herds. Virgin heifers were excluded. Semen from the selected bulls was distributed by the Association to the farms according to the number of cows available on each farm during each breeding season. In the early stages of the program the co-operating herds were located only in Alberta but during the 1971-73 phase herds in the Province of Saskatchewan were added to obtain a broader base and more diversified management conditions.

For the purpose of the present experiment, all births involving Angus (AN), Hereford (HE), Charolais-Angus (CA) and Charolais-Hereford (CE) cows on which complete calving data had been recorded were compiled for analysis. The total number of births from 1969 through 1973 that were included in this study are presented in Table 2.

TABLE 2. NUMBER OF CALVINGS BY YEAR OF BIRTH (CCA)[a]

Breed of Sire	Breed of Dam	YEAR 1969	1970	1971	1972	1973	OVERALL
CH	AN	33	78	93	52	57	313
	HE	372	564	470	193	237	1836
	CA	-	16	12	7	17	52
	CE	21	29	33	93	54	230
CI	AN	-	-	-	-	25	25
	HE	-	-	-	-	65	65
	CA	-	-	-	-	4	4
	CE	-	-	-	-	19	19
LI	AN	-	-	-	-	14	14
	HE	-	-	-	-	30	30
	CA	-	-	-	-	-	-
	CE	-	-	-	-	8	8
OVERALL		426	687	608	345	530	2596

[a]Breed codes: AN, Angus; CA, Charolais x Angus; CE, Charolais x Hereford; CH, Charolais; CI, Chianina; HE, Hereford; and LI, Limousin.

Dashes mean no records available.

4.2 Feeding and breeding management

The general management of the University of Alberta herd has been outlined in detail in a series of articles by Berg (1971, 1973b and 1975).

Traditionally, the management program on the ranch has consisted of the exposure of cows to bulls on pasture from late June to late August so that calves were dropped in the spring (late March through May) and weaned in October. Separate breeding pastures were used for each bull and group of cows except for the DY population where multiple sires were used and the XB population where A.I. was used followed by single-sire pickup.

During winter the cow herds were generally maintained in two groups, with cows three years old and older constituting one group and yearling and 2-year-old heifers the other. The feeding regimes during this period (December to March) have been comprehensively outlined by Berg (1975).

Cows dropped their calves in the open, or in an emergency shelter when necessary, while in-calf 2-year-old heifers were kept in a feedlot over the calving period where closer attention was paid them at calving. Beginning in the summer of 1966 lactating heifers were fed supplementary grain diets 4 weeks prior to breeding as a flushing ration. Since 1970 this flushing period has been extended from shortly after calving to breeding.

The management practices on the co-operating commercial farms of the CCA's Conception to Consumer program were generally similar to those practised at the University of Alberta ranch, i.e. breeding in summer, calving in spring, weaning in the fall, and year-round maintenance of herds on range with some supplementary feeding in winter.

4.3 Records and statistical analyses

When calving appeared imminent, cows were observed for calving difficulty. Parturition scores were assigned to indicate the degree of difficulty or ease involved in the birth process. The system of classification adopted is presented in Table 3. With the CCA records, the scoring system that was used combined both score 0 and score 1 into one category thus making it impossible to distinguish between those two classes of birth.

A preliminary analysis of the assembled data was carried out in accordance with the procedures described by Nie et al. (1970) for two-way to n-way crosstabulations involving two or more variables to determine the individual effects of several factors on type of birth. Subsequently, the data was analysed by stepwise multiple regression technique (Cohen, 1968) using the least squares linear model:

TABLE 3. CALVING DIFFICULTY SCORING SYSTEM

Score	Degree of difficulty/ease
0	No assistance (normal birth)
1	Slight assistance given
2	Fetal extractor used - easy
3	Fetal extractor used - hard pull
4	Veterinarian required
5	Fetus removed by caesarean section

$$Yi = Bo + BkXki + Ei$$

where Yi=the dependent variable, Bo=the Y intercept, Bk=the regression coefficient, Xk=the kth independent variable of X1, X2, X3, ..., Xk, and Ei=a random disturbance term of Yi (Jeffery and Berg, 1971). The dependent variables that went into the equation were parturition score, and pre-weaning average daily gain (ADG) to 200 days of age (adjusted for age of dam[1]) and rib eye area (REA) of slaughtered steers among the CCA lot. The latter two were adopted as indexes of calf performance and of conformation, respectively.

The independent variables included

(a) year of birth of calf,

(b) month of birth of calf,

(c) breed of sire and dam (CCA), or breeding group (i.e. population line) of calf (University of Alberta),

(d) sex of calf,

(e) weight of calf (taken within 72 hours of birth),

(f) post-partum weight of dam,

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[1]Adjustment of pre-weaning ADG for age of dam:
2-year-old dams=ADG x 1.15
3-year-old dams=ADG x 1.10
4-year-old dams=ADG x 1.05

(g) gestation length, and

(h) age of dam at birth of calf.

Combined effects of all the independent variables on ease of calving were studied by allowing the variables to enter the equation according to the highest partial correlation coefficient with parturition score. Independent effects were subsequently ascertained by removing the effects of other variables, selected on *a priori* reasoning and on information from preliminary crosstabulation analyses, by forcing their entry into the regression equation to precede the variable(s) of interest. As noted by Jeffery *et al.* (1971), these procedures are important in isolating those independent variables that contribute an essential part of explained variance.

The individual effects of sire of calf on ease of calving were ascertained by regressing the percentages of assisted births of sire progeny groups on the respective average birth weights of the groups.

Heritability estimates of calving difficulty were calculated from the sire components of variance for each age category of dam using the University of Alberta data. The relevant formula is $h^2=4t$ where h^2 is the heritability estimate, and t (the intra-sire correlation) = s/(s+ w), with s and w representing the between and within sire components of variance, respectively. This procedure is a slight modification of that used by Davenport et al. (1965) and Brinks et al. (1973) who estimated heritability according to the formula $h^2 = (1/R)t$, R being the average coefficient of relationship among paternal sibs. The multiplication of the intra-sire correlation (t) by 4 to obtain estimates of heritability in the present study was based upon the assumption that sire components of variance constitute one-quarter of the additive genetic variance among paternal half-sibs (Pirchner, 1969).

Repeatability estimates of calving difficulty were obtained, in accordance with the method described by Brinks et al. (1973), from the University of Alberta data utilizing only those HE and HY heifers that calved both as 2- and 3-year olds. The heifers were classified as 1 for difficulty (parturition scores of 1 through 5) and 0 for normal unassisted births (parturition score of 0) for each calving season. The differences in percent calving difficulty between those two classes in each subsequent season were adopted as measures of repeatability.

No attempt was made in the analyses to separate multiple births from single births because the incidence of multiple births was too low in both the University of Alberta and CCA sets of data to merit any special consideration.

Mostly, analyses and other computations were done in the Fortran IV programming language on an IBM 360/67 computer system.

5. RESULTS AND DISCUSSION

5.1 Incidence and pattern of dystocia

Calving difficulty rates among the University of Alberta's population lines, obtained by grouping parturitions with scores of 1 through 5 and expressing them as percentages of the respective numbers of births recorded, increased over the years among both 2-year-old first-calf heifers and mature cows but showed no clear patterns of year to year variations (Figure 3). Such year to year fluctuations may be due partly to changes in personnel and management practices, and to actual year differences (Brinks et al., 1973).

Table 4 represents the yearly rates of assisted births and of perinatal calf mortality for heifers and for mature cows on the ranch. In each line, heifers experienced more difficult parturitions over the years than did their mature counterparts. During the 14-year period studied, fully 51.9% of the parturitions involving HE heifers were assisted to effect delivery of the calf. This far exceeded the assistance required by first-calf heifers in the DY (43.2%), XB (39.4%) and HY (37.4%) populations, but the most difficulty was experienced by DM heifers (52.4%). This observation was consistent with the results obtained for the mature cows (i.e. pluripara), where the DM population again experienced the most difficulty (16.0%) compared with the DY

Figure 3. Calving difficulty patterns (University of Alberta populations) 1962 to 1974.

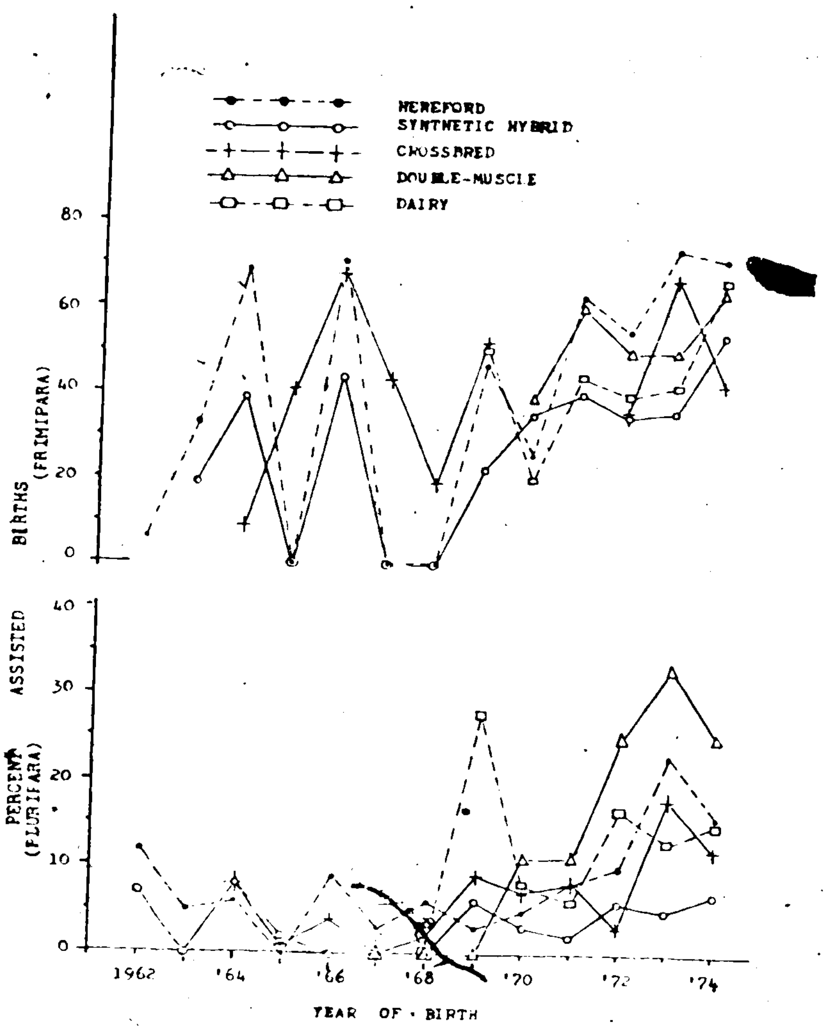

TABLE 4. PERCENT ASSISTED BIRTHS AT THE UNIVERSITY OF ALBERTA RANCH, 1961-1974 (WITH PERCENT DEAD AT BIRTH IN BRACKETS)[a]

Breeding group	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	OVERALL
Helfers															
HE	6.7 (0.0)	6.3 (12.5)	33.3 (0.0)	69.1 (30.7)	0.0 (0.0)	71.4 (16.7)	0.0 (0.0)	0.0 (0.0)	47.1 (0.0)	26.1 (0.0)	62.9 (2.9)	55.2 (10.3)	73.7 (2.6)	71.8 (12.5)	51.9 (6.3)
HY	0.0 (0.0)	- (-)	19.0 (0.0)	38.9 (5.6)	0.0 (0.0)	44.4 (12.5)	0.0 (0.0)	0.0 (3.0)	22.2 (0.0)	34.8 (8.7)	39.5 (0.0)	34.8 (4.6)	35.8 (4.5)	54.2 (12.8)	37.4 (4.0)
XB	- (-)	- (-)	- (-)	9.1 (0.0)	41.2 (0.0)	68.4 (10.5)	42.9 (9.1)	18.6 (2.9)	52.1 (4.2)	- (-)	- (-)	35.7 (0.0)	66.7 (8.3)	42.1 (27.8)	39.4 (7.0)
DM	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	38.5 (7.1)	60.0 (6.7)	50.0 (0.0)	50.0 (5.9)	63.6 (0.0)	52.4 (3.9)
DY	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	50.0 (0.0)	20.0 (20.0)	44.4 (12.5)	40.0 (0.0)	41.7 (0.0)	66.7 (16.7)	43.2 (8.2)
Cows															
HE	5.9 (6.3)	11.9 (2.4)	5.1 (5.1)	6.2 (0.0)	0.0 (2.7)	8.8 (2.8)	2.6 (9.2)	5.6 (0.0)	2.7 (4.1)	5.0 (0.0)	8.1 (1.4)	9.7 (10.3)	23.2 (0.0)	15.8 (1.8)	7.8 (3.7)
HY	0.0 (2.3)	6.6 (4.8)	0.0 (3.0)	7.5 (0.0)	2.2 (13.0)	0.0 (0.0)	0.0 (1.1)	0.0 (2.3)	5.8 (5.7)	2.9 (0.0)	1.5 (1.0)	5.7 (4.6)	4.7 (1.8)	6.5 (2.9)	3.4 (3.0)
XB	- (-)	- (-)	- (-)	7.5 (0.0)	1.2 (3.8)	4.4 (4.4)	0.0 (2.9)	1.5 (2.9)	8.8 (14.7)	6.7 (2.1)	7.5 (5.0)	2.8 (0.0)	17.5 (1.8)	11.6 (0.0)	6.1 (3.4)
DM	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	0.0 (0.0)	0.0 (7.7)	0.0 (0.0)	10.5 (0.0)	11.1 (0.0)	25.0 (0.0)	33.3 (13.3)	25.0 (12.5)	16.0 (4.2)
DY	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	0.0 (0.0)	27.8 (0.0)	7.7 (0.0)	5.9 (11.1)	16.7 (0.0)	13.8 (4.3)	15.4 (0.0)	14.0 (2.2)

[a]Dashes mean no records available.

(14.0%), HE (7.8%), XB (6.1%) and HY (3.4%) populations.

Perinatal calf mortality, like calving difficulty, generally occured at higher rates among heifer calvings than among mature cow calvings on the ranch (Table 4). However, no distinct relationships were observed between calving difficulty and calf mortality. In several instances over the years, though, mortality rates tended to be high when the corresponding calving difficulty rates were high. Overall, calf mortality ranged from 3.9% to 8.2% and from 2.2% to 4.2% among heifer and mature cow populations, respectively. The average incidence of stillbirths has been reported to range between 5 and 7% (Arthur, 1966; Rasbech, 1967). Although the exact nature of such deaths is not usually ascertained, most occur at parturition, mainly as a result of drought (in tropical areas), brucellosis and dystocia (Young, 1970).

Calving difficulty and calf mortality rates obtained from the CCA data are given by years in Table 5 for the various breed of sire and breed of dam combinations. Here, calving difficulty rates were obtained by expressing parturitions with scores of 2 through 5 as percentages of the total numbers of births recorded. The rates of dystocia among the parturitions sired by CH bulls, the only set that covered the entire 5-year period studied, fluctuated over the years without displaying any clear year to year

TABLE 5. PERCENT ASSISTED BIRTHS (CCA)[a]

Breed of sire	Breed of dam	YEAR 1969	1970	1971	1972	1973
CH	AN	12.1 (6.1)	10.3 (0.0)	8.6 (0.0)	11.5 (1.9)	4.5 (1.8)
	HE	8.1 (1.3)	11.0 (0.9)	10.2 (0.4)	6.7 (0.5)	10.5 (2.5)
	CA	- -	6.2 (0.0)	8.3 (0.0)	28.6 (0.0)	6.2 (5.9)
	CE	9.5 (0.0)	0.0 (3.4)	0.0 (0.0)	5.4 (1.1)	9.3 (0.0)
CI	AN	- -	- -	- -	- -	0.0 (0.0)
	HE	- -	- -	- -	- -	0.0 (0.0)
	CA	- -	- -	- -	- -	0.0 (0.0)
	CE	- -	- -	- -	- -	0.0 (0.0)
LI	AN	- -	- -	- -	- -	7.1 (0.0)
	HE	- -	- -	- -	- -	3.2 (3.2)
	CA	- -	- -	- -	- -	- -
	CE	- -	- -	- -	- -	0.0 (0.0)

[a]Figures in brackets represent perinatal calf mortality rates.

Dashes mean no records available.

variations. Also, there were no noticeable relationships between the dead-on-arrival and dystocia figures.

The incidence of dystocia as a direct consequence of abnormal presentation was found to be very low in the present study. 2.8% of the parturitions analysed from the CCA records involved some kind of presentation other than the normal anterior and posterior presentations (see Figures 1 and 2). This is within the range of 1 to 5% reported in Cattlemen (1974). Posterior presentations resulting in difficult birth were observed in approximately 0.8 and 1.7% instances in the University of Alberta and CCA records, respectively. Laster et al. (1973) reported 0.9% cases of posterior presentation in 1,889 parturitions. Generally, posterior presentations appear to occur at very low frequencies in all cattle herds.

5.2 Factors influencing calving difficulty

5.2.1 Simple effects:

This portion of the present investigation was aimed at determining the separate influences of sire, dam, calf and related factors on calving difficulty. To achieve this objective, the effects of individual sires within breed and of calf anatomy were analysed by regression and correlation techniques, respectively. All other factors were appraised through their chi-square distributions in relation to parturition score in accordance with the cross-tabulation procedures described by Nie *et al*. (1970). Essentially, the chi-square method tested the null hypothesis that there were no real differences between the various categories considered under each factor with respect to the proportions of births classified under each parturition score.

5.2.1.1 Breed of sire

The differences between the percentage distributions of parturition score among the various sire breeds investigated in the CCA data were non-significant at a 5% level of probability (Table 6a). Nelson and Huber (1971) found that the breed of sire of the calf was not significantly related to calving difficulty but Long and Gregory (1974) reported significant effects of breed of sire on percent dystocia.

There is a likelihood that lack of significant differences in the present data was due to the lack of sufficient births from Limousin and Chianina sires. As evidenced by the results presented in Table 6, calvings sired by CI bulls were the easiest of the three sire breeds studied, as all the calvings in this group were either unassisted or needed only minor hand assistance for foetal extraction (score 0-1). With LI and CH bulls, parturitions scored under the same category constituted 96.1% and 90.8% of the respective numbers recorded.

A further analysis was carried out with parturition

TABLE [illegible] PERCENT PARTURITION SCORE
BREED OF SIRE (CCA)

Parturition score	Breed of sire		
	CH	LI	CI
0-1	90.8	96.1	100.0
2	1.7	2.0	0.0
3	7.3	2.0	0.0
4	0.0	0.0	0.0
5	0.1	0.0	0.0
Total count	2,431	52	113

Degrees of freedom = 8

Chi-square = 13.73

Test = non-significant ($P>0.05$)

TABLE 6b. PERCENT PARTURITION SCORE BY BREED OF SIRE (WITH SCORES OF 2-5 GROUPED INTO ONE CATEGORY)

Parturitior score	Breed of Sire		
	CH	LI	CI
0-1	90.8	96.1	100.0
2-5	9.2	3.9	0.0

Degrees of freedom = 2

Chi-square = 13.15

Test = Significant (P<0.01)

scores of 2-5 grouped into one category with the result that parturition score varied significantly with breed of sire (Table 6b). Thus it can be concluded that breed of sire had a significant influence on the proportion of calves requiring assistance in calving in the CCA data.

5.2.1.2 Breed of dam

The breeds of dam that were investigated in the present study consisted of two purebred groups (HE and AN) and their respective crosses with CH bulls, i.e. CE and CA. Data are given in Table 7 to show the parturition score distribution of each. In all the breeds, the incidence of severe cases of dystocia, i.e. those that called for veterinary intervention (scores of 4 and 5), was very low at less than 1%. While the distribution of parturition score did not differ between the breeds (P>0.05), births involving CE dams appeared to be somewhat easier than were those involving the other three breeds; 95% of CE calvings were classified under the 0-1 parturition score category, compared with 91.7, 90.9 and 90.7% for AN, CA and HE calvings.

Higher rates of dystocia have been reported by Laster et al. (1973) for HE over AN dams and for straightbred over crossbred dams. Except for the AN-CA pair, the results obtained in the present study tended to be consistent with these reports.

TABLE 7. PERCENT PARTURITION SCORE BY BREED OF DAM (CCA)

Parturition score	Breed of dam			
	HE	AN	CE	CA
0-1	90.7	91.7	95.3	90.9
2	1.6	1.9	1.2	5.5
3	7.7	6.1	3.1	3.6
4	0.1	0.0	0.0	0.0
5	0.1	0.3	0.4	0.0
Total count	1932	362	256	55

Degrees of freedom = 12

Chi-square = 1[illegible]

Test = non-significant (P>0.05)

Berg (1973a) suggested that the differences in the amounts of calving difficulty experienced by different dam breeds were due largely to differences in the birth weights of their progeny. This was observed to be true among the purebred HF and AN dams in the present investigation where higher rates of dystocia among HE dams corresponded with higher calf birth weights (41.54 kg against 38.72 kg). With the crossbred groups, however, the results that were obtained were contrary to expectation. While births involving CE dams were less difficult, their calves were on an average heavier at birth than were the calves from CA dams (44.06 kg against 41.37 kg). It is hence possible that other factors, most probably dam age and size, are confounded with dam breed in determining the degree of difficulty that the cow experiences at parturition.

5.2.1.3 Age of dam

The age of the dam at birth of her calf proved to be a major factor influencing calving difficulty among both the University of Alberta herds and the CCA's co-operating herds. In both cases, age of dam was a highly significant (P<0.01) source of variation associated with parturition score (Table 8). This agrees with Gregory et al. (1965), Sagebiel et al. (1969), Turner and McDonald (1969) and Laster et al. (1973).

With the University of Alberta herds, dystocia rate

TABLE 8. PERCENT PARTURITION SCORE BY AGE OF DAM

Parturition score	Age of dam			
	2-years	3 years	4-10 years	Above 10 years
University of Alberta				
0	58.4	87.1	96.3	95.8
1	12.8	5.2	1.8	4.2
2	17.2	5.1	1.2	0.0
3	7.4	1.6	0.6	0.0
4	0.8	0.3	0.1	0.0
5	3.4	0.7	0.2	0.0
Total count	948	689	1992	72
CCA				
0-1	-	85.9	91.8	92.2
2	-	2.0	1.5	3.9
3	-	11.2	6.7	3.2
4	-	0.0	0.0	0.0
5	-	0.8	0.0	0.6
Total count	-	249	2202	154

University of Alberta

Degrees of freedom = 15

Chi-square = 740.86

Test = significant (P<0.01)

CCA

Degrees of freedom = 8

Chi-square = 32.86

Test = significant (P<0.01)

(i.e. 100% less the percentage of unassisted births) was highest among 2-year-old dams at 41.60%, followed by 3- , above-10- and 4-10-year-olds in that order with 12.90%, 4.20% and 3.70%, respectively. There was thus a general trend of decreasing rate of dystocia with an increase in age of dam. Brinks et al. (1973) reported a higher rate of dystocia among very old cows (above 9 years of age) than among 5-9-year-old cows. The situation with senile cows could be that the contractability of their uterine muscles may have declined with age (Law, 1916), thus resulting in more difficult births than would otherwise be observed.

The 3-year-old dams in the CCA set of data, the youngest group in that set, had 14.0% of their births classified under the parturition score range of 2 to 5. These were followed by the 4-10-year-olds with 8.2% in the same parturition score range, and finally by the above 10-year-olds with 7.7%. Corresponding figures for the University of Alberta lot were 28.8%, 7.7%, 2.1% and 0.0% for the 2- , 3-, 4-10- and above-10-year-old dam categories, respectively. Both sets of results suggest an inverse relationship between age of dam and the proportion of dams that experience very serious problems at parturition.

5.2.1.4 Weight of dam

Weight of dam in the present investigation referred to the dam's weight as measured within 72 hours of the birth of her calf. To facilitate comparison, the weights were grouped into categories, each covering a range of 100 lb (or 45.45kg). The percentage distribution of parturition score for each category is given in Table 9. Dams that weighed below 500 lb (227.27 kg) numbered only 3. They were therefore deemed atypical and were excluded from the analysis.

There was a definite trend in the variation of percent assistance with weight of dam. The smallest dams, i.e. those that weighed between 500 and 599 lb, had the highest percentage of assisted births (scores 1-5) at 88.2. From this maximum, the percentage of assisted births decreased steadily with weight to a low of around 2% among the dams that weighed between 1,000 and 1,099 lb. Beyond this, a further increase in dam weight was associated with an increase in the percentage of assisted births. Also, a look at the percentages of caesarean sections performed (score 5) revealed that the highest rate was among the small cows. In all, the parturition score distributions did differ significantly (P<0.01) between the weight of dam categories, thus suggesting a significant relationship between calving difficulty and weight of dam.

It is relevant to note that weight of dam varied directly with age (see Table 10). Hence, dams in the lighter weight ranges were mostly the younger 2- and 3-year-olds

TABLE 9. PERCENT PARTURITION SCORE BY WEIGHT OF DAM

(University of Alberta)

Parturition score	Weight of dam category (lb)[a]								
	500-599 (227-272)	600-699 (273-317)	700-799 (318-363)	800-899 (364-408)	900-999 (409-454)	1,000-1,099 (455-499)	1,100-1,199 (500-545)	1,200-1,299 (546-590)	>1,300 (≥ 591)
0	11.8	44.9	65.7	81.4	92.6	98.1	98.0	90.0	88.9
1	23.5	13.4	13.3	8.4	3.8	1.1	2.0	6.7	11.1
2	11.8	22.8	11.1	7.2	2.2	0.8	0.0	3.3	0.0
3	0.0	12.6	6.5	2.5	1.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.7	0.2	0.0	0.0	0.0	0.0	0.0
5	52.9	6.3	2.7	0.2	0.5	0.0	0.0	0.0	0.0
Total count	17	127	414	404	417	265	99	30	9

Degrees of freedom = 40

Chi-square = 595.76

Test = significant (P<0.01)

[a] Figures in brackets represent the approximate weight equivalents in kilograms.

TABLE 10. POST-PARTUM DAM WEIGHT BY AGE
(University of Alberta)

Age (yr.)	Average weight (kg)
2	350.1±1.9
3	366.8±2.4
4 - 10	440.6±1.9
Above 10	462.7±6.2
Overall	402.1±1.6

while the more mature dams fell within the higher ranges. Those cows that weighed above 1,200 lb were mostly senile, i.e. above 10 years of age. In the light of this, the results reported here appear to be reasonable.

5.2.1.5 Calf birth weight

Birth weight of calf was a highly significant ($P<0.01$) source of variation associated with parturition score in both the University of Alberta and CCA groups of herds (Table 11). These results are consistent with the findings of Sagebiel et al. (1969), Laster et al. (1973) and Long and Gregory (1974) indicating important influences of birth weight of calf on parturition score. As expected, the highest rates of assistance and caesarean sections in both sets of data were recorded among the heaviest weight category (above 100 lb). However, there was a clear pattern of decreasing rates of 0-1 parturition scores with increasing birth weight within the CCA group that was not evident among the University of Alberta herds probably because no primipara were included in the CCA's Conception to Consumer beef improvement program. This rather significant omission largely eliminated the confounding influence of dam age that undoubtedly affected the results obtained for the University of Alberta herds.

The percentages of assisted births and means for calf birth weight are listed by breeding group in Table 12 to

TABLE 11. PERCENT PARTURITION SCORE BY CALF BIRTH WEIGHT

Parturition score	Birth weight category (lb)[a] <60 (<27.3)	60-<80 (27.3-<36.4)	80-<100 (36.4-<45.5)	>100 (>45.5)
University of Alberta				
0	83.2	84.7	86.0	77.8
1	7.6	5.0	4.9	8.6
2	4.4	6.9	4.9	6.2
3	1.9	2.3	2.9	3.7
4	0.6	0.1	0.5	0.0
5	2.2	0.9	0.8	3.7
Total count	316	2010	1298	81
CCA				
0-1	100.0	97.2	93.1	78.9
2	0.0	1.0	1.6	2.5
3	0.0	1.8	5.2	18.2
4	0.0	0.0	0.0	0.2
5	0.0	0.0	0.1	0.2
Total count	8	500	1613	484

University of Alberta	CCA
Degrees of freedom = 15	Degrees of freedom = 12
Chi-square = 30.17	Chi-square = 133.98
Test = significant (P<0.01)	Test = significant (P<0.01)

[a]Figures in brackets represent weights in kilograms

show the relationship between them among the University of Alberta herds. With the HY, XB and DY populations which represented various levels of outbreeding and crossbreeding, percent assistance increased with calf birth weight, ranging from 10.0% (HY) to 21.6% (DY) and from 34.76 ± 1.86 kg (HY) to 37.55 ± 2.47 kg (DY), respectively. The XB population was intermediate between the HY and DY populations in both calf birth weight and percent assisted births.

Purebred HE calves were relatively lighter at birth than were HY and XB calves but a higher percentage of their dams needed assistance at parturition than did the dams of HY and XB calves. Thus, although heterosis may influence calf birth weight, it does not necessarily result in higher rates of dystocia. This result is similar to that of Laster <u>et al</u>. (1973) who observed more dystocia in straightbreds and higher birth weights in reciprocal crosses.

DM calves were the lightest of all the breeding groups at birth, weighing about 1.94 kg lighter than the overall mean weight. However, their dams experienced the greatest difficulty at parturition, registering 15.65% more assistance than the overall assistance required by the entire lot. Since the main difference between these calves and the calves from the other populations is their excessively muscular nature, these results reflect calf anatomy as a probable important factor, although the

TABLE 12. MEAN BIRTH WEIGHT AND PERCENT ASSISTED BIRTHS (University of Alberta)

Breeding group	Mean birth wt., kg	Assisted births, %
HE	33.15±1.10	17.60
HY	34.76±1.86	10.00
XB	35.33±1.68	17.50
DM	32.51±2.14	30.60
DY	37.55±2.47	21.60
Overall	34.45±1.61	14.95

possible confounding influence of the dam's age, weight and pelvic size can not be overlooked.

The overall mean weight at birth of the CCA calves compared to that of the University of Alberta herds was extremely high (41.39 ± 1.97 kg against 34.45 ± 1.61 kg). Calf birth weight and percent assisted births in this set appeared to depend on the system of crossbreeding practised in that backcrosses were heavier at birth and were associated with more difficult parturitions than were three-way crosses (Table 13). CA and CE backcrosses with CH bulls were heavier than the F1 CHxAN and CHxHE crosses, indicating some degree of progress toward the CH breed through backcrossing. Crossbred CE dams on the whole had easier calvings than purebred HE dams despite heavier foetuses, but parturitions involving crossbred CA dams were more difficult than were those involving purebred AN cows. This indicates that CE cows, probably because of increased mature size through crossbreeding, were more capable of accomodating their foetuses than were their purebred counterparts. In the case of CA cows, it is possible that increased dam size through crossing was not enough to offset the increase in foetal size through backcrossing.

Laster <u>et al</u>. (1973) reported heavier calves and higher dystocia rates for HE cows than for AN cows. Both agree with the findings of the present work. In the present study mean

TABLE 13. MEAN BIRTH WEIGHT AND PERCENT ASSISTED BIRTHS (CCA)[a]

Breed of sire	Breed of dam	Mean birth wt., kg	Assisted births, %
CH	AN	38.76±2.26	9.40
	HE	41.52±1.99	9.30
	CA	41.51±2.01	12.30
	CE	44.17±2.05	4.80
CI	AN	39.31±0.86	0.00
	HE	42.47±0.55	0.00
	CA	38.53±1.46	0.00
	CE	42.30±3.25	0.00
LI	AN	35.15±1.85	7.10
	HE	37.85±2.30	3.20
	CA	-	-
	CE	37.05±3.53	0.00
Overall		41.39±1.97	8.75

[a]Dashes mean no records available

calf birth weight and dystocia rate were 40.61 ± 1.41 kg and 9.3% and 37.74 ± 1.31 kg and 8.3% for HE and AN dams, respectively across breed of sire.

Intra-breed sire effects on calving difficulty and calf birth weight were evaluated by regressing the percentages of assisted births of sire progeny groups within the University of Alberta's HE and HY populations and the CCA's bull breeds on their average birth weights. The exercise was limited to only those sires that had 5 or more progeny in the University of Alberta herds while the progeny groups of the CCA bulls consisted of 20 or more calves. To remove year effects, the regressions were performed for each year from which pooled coefficients were obtained. However, because of the inadequacy of data in some years regression analyses could not be carried out on the records accumulated in those years.

Table 14 shows the results that were obtained for the University of Alberta's HE population. The regression coefficients for the various years among 2-year-old dams varied significantly (P<0.05), with a pooled coefficient of -0.41. Similarly, the coefficients for all dams, including 2-year-olds, varied significantly over the years and had a negative pooled coefficient of -1.23. With the HY population, a pooled regression coefficient of 2.17 was obtained for 2-year-old dams, but the pooled coefficient for

TABLE 14. REGRESSION OF % ASSISTED BIRTHS ON AVERAGE BIRTH WEIGHT OF HEREFORD SIRE PROGENY GROUPS[a]

(University of Alberta)

Year	N	R^2x100	B	S	EMS	F
		2-year-old dams				
1970	3	92.74	-3.16	0.88	32.82	12.77
1971	5	34.26	1.96	1.57	300.50	1.56
1973	6	41.22	-2.63	1.57	81.79	2.81
1974	3	95.96	-2.58	0.53	12.87	23.74*
Pooled	17	1.48	-0.41	0.95	221.53	9.77*
		All dams				
1961	3	24.95	-1.45	2.52	84.49	0.33
1962	3	6.49	-0.28	1.06	52.74	0.07
1963	5	49.98	-0.92	0.53	34.81	3.00
1964	5	37.21	-2.13	1.59	223.05	1.78
1966	3	31.19	-0.78	1.16	45.87	0.45
1967	4	72.72	-2.02	0.88	6.77	5.33
1968	5	1.03	-0.16	0.95	134.71	0.03
1969	7	85.94	-2.65	0.48	51.99	30.57**
1970	8	9.22	-0.40	0.51	102.02	0.61
1971	6	16.04	0.91	1.04	89.00	0.76
1972	7	17.61	-1.12	1.08	159.47	1.07
1973	7	56.14	-2.55	1.01	216.78	6.40*
1974	6	31.93	-2.77	2.03	234.07	1.88
Pooled	69	24.55	-1.23	0.29	133.49	15.27**

[a] N, number of progeny groups; R, correlation coefficient; B, regression coefficient; S, standard deviation of B; EMS, error mean square; and F, variance ratio.

** = P<0.01, * = P<0.05 and no asterick means not significantly different from zero (P>0.05).

all dams revealed an inverse relationship between calving difficulty and average birth weight (Table 15).

The results obtained for the CCA's bull breeds are shown in Table 16. The exclusion of virgin heifers and the larger sizes of the progeny groups in this set of data compounded to yield more consistent results. All the regression coefficients obtained over the years for CH bulls were positive, although there was a significant variation in the magnitudes of the coefficients ($P<0.05$). The pooled coefficient was 0.81. For the LI and CI breeds only one coefficient each was obtained, both indicating a positive relationship between percent assisted births and average birth weight.

Laster et al. (1973) reported an increase of 2.3 ± 0.2% assistance for each kilogram increase in average birth weight while Berg (1973a) obtained a regression coefficient that indicated an increase of 1.6% calving difficulty per pound increase in calf birth weight when he regressed the average birth weights of 21 sire progeny groups from the CCA's Conception to Consumer program against their respective percentages of assisted births.

The atypical pooled coefficients that were obtained for the University of Alberta's HE and HY lines in the present study were probably due to the smallness in numbers in the

TABLE 15. REGRESSION OF % ASSISTED BIRTHS ON AVERAGE BIRTH WEIGHT OF SYNTHETIC-HYBRID SIRE PROGENY GROUPS[a]

(University of Alberta)

Year	N	R^2x100	B	S	EMS	F
		2-year-old dams				
1971	5	17.92	2.10	2.63	741.64	0.64
1972	6	43.59	4.37	2.49	505.17	3.09
1973	8	13.88	1.35	1.37	423.89	0.97
1974	7	60.76	2.21	0.79	253.02	7.74*
Pooled	26	30.92	2.17	0.71	409.88	1.24
		All dams				
1962	6	7.89	0.23	0.39	81.50	0.34
1963	5	37.01	-0.47	0.35	26.37	1.76
1964	7	10.57	-0.46	0.60	128.16	0.59
1966	6	21.32	-1.64	1.58	449.93	1.08
1969	8	42.00	-0.74	0.35	49.92	4.35
1970	8	61.99	-5.59	1.79	120.12	9.78*
1971	10	8.67	0.73	0.84	92.27	0.76
1972	9	14.22	0.66	0.62	176.58	1.16
1973	8	0.30	0.07	0.56	64.78	0.01
1974	8	48.40	1.63	0.69	40.61	5.63*
Pooled	75	0.45	-0.12	0.23	140.13	20.48**

[a]N, number of progeny groups; R, correlation coefficient; B, regression coefficient; S, standard deviation of B; EMS, error mean square; and F, variance ratio.

** = P<0.01, * = P<0.05 and no asterik means not significantly different from zero (P>0.05).

TABLE 16. REGRESSION OF % ASSISTED BIRTHS ON AVERAGE BIRTH WEIGHT (CCA)[a]

Year	N	R^2x100	B	S	EMS	F
		Charolais bulls				
1969	20	20.82	0.92	0.42	46.98	4.73*
1970	22	12.76	-0.63	0.37	44.35	2.93
1971	21	48.13	1.58	0.38	30.97	17.63**
1972	37	25.53	0.82	0.24	37.59	11.99**
1973	31	41.47	0.89	0.20	25.45	20.54**
1974	23	20.88	0.48	0.21	26.14	5.28*
Pooled	154	25.91	0.81	0.11	34.94	6.10*
		Limousin bulls				
1973	6	13.27	0.46	0.58	17.53	13.27*
		Chianina bulls				
1974	6	76.97	1.78	0.49	14.27	13.37*

[a]N, number of progeny groups; R, correlation coefficient; B, regression coefficient; S, standard deviation of B; EMS, error mean square; and F, variance ratio.

** = P<0.01, * = P<0.05 and no asterik means not significantly different from zero (P>0.05).

progeny groups, and to the influence of dam age. Lighter calves in the two populations came from 2- and 3-year-old dams and were consequently associated with more calving problems than were heavier calves which were predominantly from older and more mature cows.

Figure 4 represents the scatter diagram for the sire progeny groups with the University of Alberta's HY line in 1974, with percent assisted births as the dependent variable and average birth weight as the independent variable. In the manner of Berg (1973a), each progeny group has been coded with a number according to the percent assisted births of the group. Despite the overall tendency for percent assistance to increase with average birth weight, there were instances where, on the one hand, percent assisted births of groups with low average birth weights were relatively high, and on the other, percent assisted births were low although average birth weights were high (progeny groups 1 and 3, respectively). In such exceptional circumstances, other calf factors, such as calf anatomy are suspect.

5.2.1.6 Calf sex

Sex of calf was a highly significant (P<0.01) source of variation affecting parturition score in the University of Alberta and CCA lots. The percentage distribution of parturition score for male and female births are given in Table 17, while Table 18 shows the relationships between the

Figure 4. Average birth weights of sire progeny groups and percent assisted births of Synthetic-hybrid population (University of Alberta, 1974).

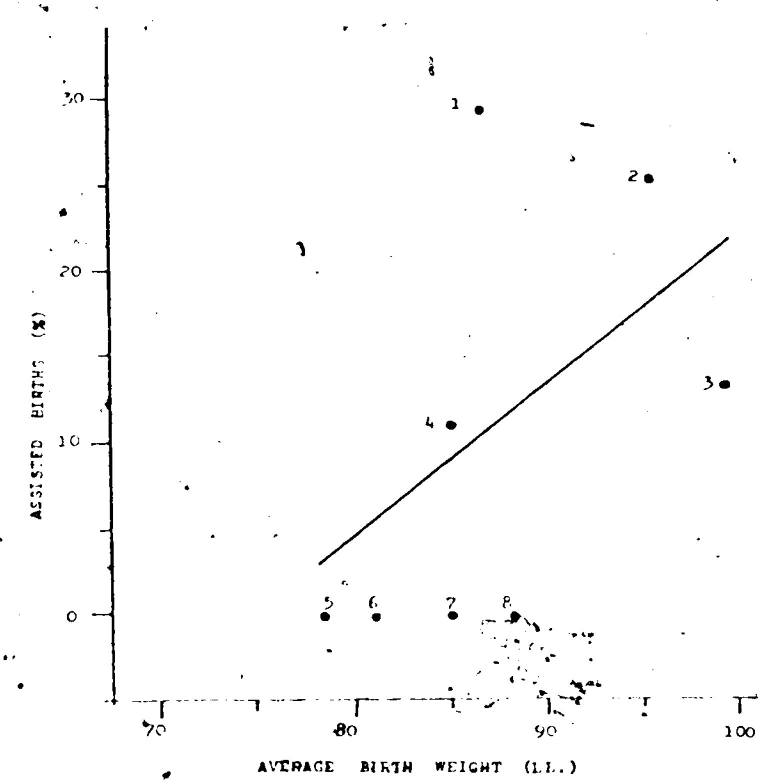

TABLE 17. PERCENT PARTURITION SCORE BY SEX OF CALF

Parturition score	Sex: Male	Sex: Female
University of Alberta		
0	82.7	87.4
1	5.5	5.0
2	6.9	5.1
3	3.0	1.7
4	0.4	0.2
5	1.5	0.6
Total count	1875	1776
CCA		
0-1	88.4	94.4
2	1.8	1.5
3	9.5	4.1
4	0.1	0.0
5	0.2	0.0
Total count	1365	1240

University of Alberta	CCA
Degrees of freedom = 5	Degrees of freedom = 4
Chi-square = 21.82	Chi-square = 33.72
Test = significant (P<0.01)	Test = significant (P<0.01)

TABLE 18. MEAN BIRTH WEIGHT AND PERCENT ASSISTED BIRTHS BY CALF SEX

Sex of calf	Mean birth wt., kg	Assisted births, %
University of Alberta		
Male	35.59±0.13	17.30
Female	33.31±0.12	12.60
CCA		
Male	42.72±0.15	11.60
Female	39.93±0.14	5.60

respective percentages of assisted births and mean birth weights. Male calves were 2.28 ± 1.14 kg heavier at birth and were involved in 4.70% more dystocia than were the female calves among the University of Alberta herds. Corresponding figures for the CCA lot were 2.79 ± 1.39 kg and 6.0% respectively for bull calves over heifer calves.

The influence of calf sex on birth weight has been well documented by Koch et al. (1959), Lasley et al. (1961), Bradley et al. (1966) and Karren (1969) while the influence of sex on dystocia has been reported by Sagebiel et al. (1969), Nelson and Huber (1971), Laster et al. (1973) and Brinks et al. (1973).

5.2.1.7 Calf anatomy

To ascertain the effect of the anatomy of the calf on calving difficulty, several physical measurements, including head length, head width, hip and shoulder diameters, body length, body depth and the average circumference at the fore fetlocks of 29 Hereford calves of which 7 had been born with difficulty were appraised in relation to parturition score. Head length was measured from the top of the poll to the tip of the muzzle and head width from the outside of the left eye to the outside of the right eye. The diameters at the shoulders and hips were taken as the distance from the left extremity to the right extremity at the shoulders and hips, respectively. Body length was measured from the tail head to the poll of the head with the head held in normal position, while body depth was taken as the vertical distance from the top of the withers to the tip of the brisket. All measurements were made within 48 hours of birth with the calf in a standing position.

Table 19 gives the means for each of the parameters along with mean birth weight according to parturition score. In each case, the differences between the means were not significant (P>0.05). Also, correlation analyses revealed no significant relationship between parturition score and any of the parameters considered (Table 20). These findings are, however, not very conclusive since the number of calves involved is so small. Nevertheless, they seem to be in general agreement with Ward (1973) who reported non-significant effects of heart girth, width at the shoulders, circumference of the hocks and thigh measurements of the calf on percent dystocia. It is suggested that larger numbers and the inclusion of other physical measurements might yield more conclusive results.

5.2.1.8 Gestation length

Gestation length, the duration from insemination to parturition, was not known for certain among the University of Alberta herds as cows were mainly bred by natural service on the ranch. Hence, only the CCA records, where all inseminations were by artificial means, were analysed for

TABLE 19. MEANS FOR ANATOMICAL MEASUREMENTS AND BIRTH WEIGHTS OF HEREFORD CALVES[a]

Parameter	Parturition score		
	0	1	2
Length of head	20.44(0.18)	20.57(0.25)	20.96(0.64)
Width of head	12.18(0.22)	11.94(0.31)	12.70(0.00)
Diameter of shoulders	17.26(0.32)	16.76(0.48)	17.78(1.27)
Diameter at hips	18.01(0.30)	18.03(0.25)	17.78(1.27)
Body length	72.91(0.91)	73.91(1.16)	73.03(3.18)
Ave. circumference at fore fetlocks	17.32(0.21)	17.02(0.31)	17.78(1.27)
Body depth	28.23(0.34)	28.70(1.03)	27.94(1.27)
Birth weight	34.94(0.84)	32.64(2.25)	34.09(0.00)
Count	22	5	2

[a]Numbers in brackets indicate the standard errors of the means. Anatomical measurements are in centimeters and birth weight is in kilograms.

TABLE 20. COEFFICIENTS OF CORRELATION BETWEEN ANATOMICAL MEASUREMENTS AND PARTURITION SCORE IN HEREFORDS (University of Alberta Ranch - 1974)

		No. of variable corresponding to left column						
No.	Variable	1	2	3	4	5	6	7
1	Length of head							
2	Width of head	0.58**						
3	Diameter of shoulders	0.44*	0.37*					
4	Diameter at hips	0.52**	0.39*	0.33				
5	Body length	0.30	0.07	0.47**	0.00			
6	Ave. circumference at fore fetlocks	0.47**	0.53**	0.50**	0.50**	0.43*		
7	Body depth	0.16	0.12	0.37	-0.36	0.60**	0.17	
8	Parturition score	0.16	0.06	0.00	-0.03	0.06	0.03	0.02

** Significant (P<0.01)

* Significant (P<0.05)

No asterisk means not significant (P>0.05) the relationship of the duration of pregnancy with parturition score.

The average length of gestation tended to differ only slightly among the various breed combinations in the herds. This fact notwithstanding, gestation length did prove to have a highly significant influence on parturition score (see Table 21). There was generally a low incidence of caesarean sections and a definite trend of increasing rates of serious dystocia cases (scores 2-5) with gestation length, rising to a high of 13.7% in the gestation length range of 290 to 299 days. This trend in dystocia with regard to increases in the duration of gestation is probably a function of calf birth weight. Indeed, calf birth weight has been reported to have positive correlation (Brakel et al., 1952) and regression (Burris and Blunn, 1952) coefficients with gestation length, implying that higher birth weights are associated with longer gestation periods.

The overall mean gestation length was 286.5 ± 0.9 days. This is well within the range reported for various breeds of cattle by Burris and Blunn (1952), Wheat and Briggs (1952) and Lasley et al. (1961).

5.2.1.9 Seasonal birth sequence

Indications from the available literature are that the cow's feeding regime during late pregnancy does not have any

TABLE 21. PERCENT PARTURITION SCORE BY GESTATION LENGTH (CCA)

Parturition score	Gestation length (days)				
	<270	270-279	280-289	290-299	≥300
0-1	100.0	95.4	92.9	86.3	89.7
2	0.0	1.4	1.4	2.4	0.0
3	0.0	2.3	5.6	11.2	10.3
4	0.0	0.0	0.0	0.1	0.0
5	0.0	0.9	0.1	0.0	0.0
Total count	7	216	1651	699	29

Degrees of freedom = 16

Chi-square = 52.97

Test = significant ($P<0.01$)

direct significance on the ease of birth of her calf (Broster, 1971; Nelson and Huber, 1971; Scarth and Dorton, 1972; Ward, 1973). Parturitions were classified in the present work among the University of Alberta records to reflect the quality and quantity of available pasture during the latter stages of gestation. Three groups were thus obtained, in accordance with the sequence in which the parturitions occured over a calving period that mainly covered the months of April, May and June, i.e. first third (little or no new grass), middle third (some new grass) and last third (much new grass). Owing to a wide spread in parturition dates and, more importantly, the differences in management on the CCA's co-operating farms, no such analysis was carried out on that set of data.

The results obtained showed birth sequence to be highly significantly related to parturition score ($P<0.01$). Thus, the cow's nutritional plane in the latter stages of pregnancy may have significantly influenced calving difficulty among the herds. As revealed by the figures presented in Table 22, there was a distinct tendency for the rate of assisted births (scores 1-5) to decrease as fresh pasture became more abundant.

5.2.2 Combined effects

The calving difficulty response variable, parturition score, was regressed on the independent variables age of

TABLE 22. PERCENT PARTURITION SCORE BY CALF BIRTH SEQUENCE

Parturition score	Birth sequence category		
	First third	Middle third	Last third
University of Alberta			
0	79.1	84.8	90.5
1	7.3	4.8	3.9
2	7.9	6.4	3.6
3	4.0	2.5	1.0
4	0.6	0.1	0.3
5	1.1	1.4	0.7
Total count	1132	1385	1176

Degrees of freedom = 10

Chi-square = 72.54

Test = significant ($P<0.01$)

dam, weight of dam, birth weight of calf, sex of calf, population line (breeding group), gestation length, and year and month of birth of the calf to ascertain the joint effects of these variables on calving difficulty among the University of Alberta herds. The additional effects of lesser factors were also tested to assess their level of importance over and above more major factors. A summary of the results obtained is presented in Table 23, in such a way that the total variance explained by the independent variable(s) that went into the regression equation at each stage are in an increasing order of magnitude.

The main contributing factor in explaining total variance in parturition score was dam age, followed by dam weight. By itself, dam age explained 17.5% of the variation in parturition score. Together with dam weight, it explained 20.6%, dam weight accounting for a highly significant ($P<0.01$) additional variance (3.1%) over and above dam age. When these two factors were omitted from the regression model, all the other factors together explained only 7.9% of total variance. Dam effects would therefore appear to be very critical considerations in any attempts at minimizing the frequency of dystocia in cattle herds.

Differences between populations accounted for 3.3% of total variance but additional variance due to these differences over and above dam age and weight was small

TABLE 23. EFFECTS OF VARIABLES ON PARTURITION SCORE

(University of Alberta)

Variable(s) held constant	Total variance (R^2x100)	Last Variable(s) in equation, L	Additional variance due to L (%)	P
a	17.5	-	-	-
a	20.6	b	3.1	**
a,b	21.5	e	0.9	**
a,b,e	26.2	c,f	4.7	**
a,b,e,c,f	27.1	d,g,h	0.9	**

P is the level of significance associated with the last variable(s) to enter the regression equation (** = $P<0.01$).
Code: a, age of dam; b, weight of dam; c, birth weight of calf; d, year of birth of calf; e, breeding (population) group of calf; f, sex of calf; g, gestation length; and h, month of birth of calf.
A dash means not applicable.
Variables were held constant by forcing them into the equation to precede the variable(s) of interest.

(0.9%), though highly significant (P<0.01). Upon the introduction of calf factors (sex and weight), an additional highly significant (P<0.01) 4.7% of total variance was accounted for over and above the effects of cow factors and population differences. All considered, the independent factors together explained 27.1% of total variance, with gestation length and year and month of calf birth accounting for a highly significant (P<0.01) 0.9% of total variance over and above the other variables. Thus, factors other than those included in this study would explain 72.9% of the variability associated with dystocia on the University of Alberta ranch. As indicated by the results of Bellows *et al.* (1971a), Bellows *et al.* (1971b) and Dufty (1972), and by the importance of dam effects as shown in the present investigation, the pelvic size of the cow could be a possible critical consideration.

The independent variables considered from the CCA records, i.e. breed of dam, breed of sire, age of dam, sex of calf, birth weight of calf, gestation length, and year and month of calf birth did not reveal much, as altogether they only explained 8.4% of the total variance associated with parturition score. This was due partly to the method of scoring used (i.e. the grouping of parturition scores of 0 and 1 into one category), the omission of dam weight as a covariable, and most importantly the exclusion of virgin heifers which considerably toned down the effects of dam age. Nevertheless, there were significant influences of factors over and above others (see Table 24).

When Brinks et al. (1973) considered calving difficulty as a trait of the dam and of the calf, year, sex, age of dam, calf inbreeding, dam inbreeding, line of sire, sire effects, day of year of calf birth, and sex x age of dam and age of dam x inbreeding of dam interactions together accounted for only 16.1 and 17.0%, respectively, of the variation in parturition score.

5.3 Heritability and repeatability estimates

Since preliminary analyses had revealed age of dam to be the most important factor associated with dystocia on the University of Alberta ranch, an estimate of heritability was computed for each age of dam category across populations, with the exception of above-10-year olds where a reliable estimate could not be made owing to the relatively small number of births recorded. The computations were carried out within year and breeding population to remove the effects of those variables. With repeatability, separate computations for age of dam categories were not possible because of the method of estimation adopted.

5.3.1 Heritability

The heritability estimates that were obtained for the

TABLE 24. EFFECTS OF VARIABLES ON

PARTURITION SCORE (CCA)

Variable(s) held constant	Total variance (R^2x100)	Last variable(s) in equation 'L'	Additional variance due to L (%)	P
c	5.1		-	-
c	5.4	f	0.3	**
c,f	6.8	m,n	1.2	**
c,f,m,n	7.2	d,g,h	0.6	*
c,f,m,n,d,g,h	8.4	a	1.2	**

P represents the significance level associated with the last variable entering the regression equation. * = $P<0.05$ and ** = [illegible]. Code: a, age of dam; c, birth weight of calf; d, year of birth of calf; [illegible] of calf; g, gestation length; h, month of birth of calf; m, breed of sire; [illegible]eed of dam.

A dash means not applicable.

Variables were held constant by forcing th[illegible]he equation to precede the variable(s) of interest.

different age of dam categories are given in Table 25. All estimates were moderately low, i.e. 8.4 ± 2.0%, 9.8 ± 2.2% and 14.8 ± 2.5% for the 2-, 3- and 4-10-year-old dam groups, respectively, with an overall estimate of 9.5 ± 1.8% for the entire herd. From a review of the few studies that have been reported on the subject, it was concluded in Cattlemen (1974) that calving difficulty is lowly heritable (10% or less). Brinks et al. (1973), however, obtained an estimate of 13.4% when they considered dystocia as a trait of the dam, but when they considered it as a trait of the calf they obtained a lowly figure of 6.9%. Inconsistencies in the magnitude of heritability estimates of calving difficulty are therefore due, at least partially, to differences in the methods of estimation employed, as well as to overall herd differences.

Nevertheless, the estimates obtained in the present study seem to indicate that of the sire's genotype is quite important in determining the degree of difficulty in the birth of his progeny. Hence, moderate reductions in calving difficulty may be expected if bulls who have a history of exceptionally high frequencies of difficult calvings are excluded from breeding programs.

5.3.2 Repeatability:

Estimates of repeatability were obtained utilizing those HE and HY line dams among the University of Alberta

TABLE 25. HERITABILITY ESTIMATES[a]

Age of dam category	K	Between sire M.S.	Within sire M.S.	σ^2_S	Heritability estimate (%)
2 years	5.99	2.08	1.86	0.04	8.4±2.0
3 years	3.68	0.84	0.76	0.02	9.8±2.2
4-10 years	6.90	0.34	0.26	0.01	14.8±2.5
Overall	5.63	0.94	0.82	0.02	9.5±1.8

[a]Heritability estimate = $4\sigma^2_S/(\sigma^2_S + \text{Within sire M.S.})$

where σ^2_S = (Between sire M.S. − Within sire M.S.)/K

K = $(N-\Sigma ni^2/N)$s-1 where s = no. of sires

N = total no. of progeny from s sires

ni = no. o[f] progeny of the i^{th} sire

i = 1, ----, S

herds that had calves both as 2- and 3-year-olds. These estimates are given in Table 26 for each pair of years from 1961 to 1974, with the exception of those cases where lack of sufficient information made estimation impossible. Also presented in Table 26 are the respective numbers of births from which each estimate was calculated.

There were wide variations in the magnitudes of the estimates within both lines, with ranges of 8.3 to 37.5% and 0.0 to 33.3% in the HE and HY lines, respectively. These variations are likely due to year to year differences, and to the differences in the numbers of calvings involved, although no definite relationships were observed between these numbers and the repeatability estimates.

Brinks et al. (1973) estimated the repeatability of calving difficulty at 4.5% using similar procedures as adopted in the present work. This would make the overall mean estimates of 19.2 ± 4.1% (HE) and 12.6 ± 4.1% (HY) obtained in the present study appear too high. However, since adequate research in this area is lacking, these results can not be justifiably regarded as inconsistent.

5.4 Calf performance

The indexes of calf performance that were analysed in the present study included average daily weight gain from birth to weaning, corrected for age of dam, and rib-eye area

TABLE 26. REPEATABILITY ESTIMATES (%)[a]

Year	HE	HY
1961-62	8.3(13)	16.7(6)
1962-63	11.1(10)	-
1963-64	-	33.3(14)
1964-65	-	0.0(10)
1965-66	-	-
1966-67	-	0.0(15)
1967-68	-	-
1968-69	-	-
1969-70	20.0(8)	22.2(9)
1970-71	12.3(18)	9.1(18)
1971-72	15.0(18)	25.0(29)
1972-73	37.5(16)	3.8(26)
1973-74	30.4(22)	2.9(46)
Mean	19.2±4.1	12.6±4.1

[a]Figures in brackets indicate number of calvings. Dashes mean no estimates made.

of steers at slaughter.

Male calves, which were the heavier of the two sexes at birth, made more weight gains per day prior to weaning than their female counterparts within each population and age of dam category, with the exception of calves born to very old dams where both sexes made almost equal amounts of gain. Overall, female calves weighed 2.30 kg less at birth, gained 0.06 kg less per day prior to weaning, and hence were on an average about 14.3 kg lighter when weaned at 200 days of age.

When pre-weaning average daily gain, as a calf performance response variable, was regressed on calf birth weight, calf sex and parturition score, calf birth weight yielded the most significant result, explaining 12.9% of the variation in average daily gain. Parturition score on the other hand proved to be quite inconsequential as it only explained 0.2% of total variance in average daily gain over and above birth weight and calf sex (see Table 27).

Results of the regression of calf birth weight, pre-weaning average daily gain, age at slaughter and parturition score on the rib-eye areas of steers appear in Table 24. While age at slaughter explained 4.3% of total variance, understandably the most significant factor was average daily gain which accounted for 7.0% of the variation in rib-eye

TABLE 27. CALF PERFORMANCE

Dependent variable	Independent variable(s) held constant	Total variance (R^2 x100)	Last variable in equation 'L'	Additional variance due to L (%)	P
	University of Alberta				
d	a	12.9	-	-	-
	a	13.6	b	0.7	**
	a,b	13.8	c	0.2	**
	CCA				
e	c	0.0	-	-	-
	f	4.3	-	-	-
	d	7.0	-	-	-
	d	8.5	a	1.5	**

P is the significance level associated with the last variable to enter the regression equation (* = P<0.01). Codes: a, birth weight of calf; b, sex of calf; c, parturition score; d, average daily gain (pre-weaning); e, rib eye area at slaughter; and f, age at slaughter. A dash means not applicable.

area, with birth weight explaining an additional 1.5% of total variance over and above average daily gain. Parturition score, however, had absolutely no bearing on rib-eye area, as it failed to explain any portion of total variance.

From these findings, it could be inferred that [illegible]ia may have some influence on early life weight gains [illegible]at this influence is not expressed in the conformati[illegible] the carcass at slaughter.

6. SUMMARY AND CONCLUSIONS

The use of large, lean bulls in breeding programs in an attempt to increase growth rate and cutability can result in an increase in the frequency of difficult births in cattle.

The present study was conducted to investigate the incidence and causes of calving difficulty. Accordingly, differences between the frequencies of difficult calvings among different cattle breed-lines were assessed, and the separate and combined influences of selected factors on these frequencies duly ascertained through crosstabulation and stepwise multiple regression analyses. Heritability and repeatability estimates of dystocia were obtained, and the effects of calving difficulty on calf performance investigated.

Records analysed were from the University of Alberta ranch at Kinsella, Alberta, supplemented with data obtained from the Canadian Charolais Association. In all, 3,783 births recorded over a 14-year period and 2,596 births accumulated in 5 years were considered from the University of Alberta and the Canadian Charolais Association sets of data, respectively. Ease of calving was classified on a 6-point scoring system ranging from 0 to 5, 0 being normal and unassisted, and 5 needing surgery for foetal extraction.

There was a highly significant difference ($P<0.01$)

between the University of Alberta population lines with respect to the incidence of difficult births but no clear year to year trends were observed. However, percent calving difficulty tended to increase over the years as the populations increased in size, and, as percent calving difficulty increased, so did percent dead-on-arrivals.

A preliminary investigation on calf physical measurements did not reveal any significant correlation between the anatomical features studied and parturition score. This result was attributed to the smallness of the number of calves appraised, even though it was consistent with other reports in the literature.

Male calves were on the average heavier at birth and were involved in significantly more dystocia ($P<0.01$) than were female calves in both the University of Alberta and CCA data. Age of dam, weight of dam, birth weight of calf, sex of calf, gestation length and year of calf birth were the significant sources of variation associated with calving difficulty. In the CCA records, the effects of sire and dam breed were not significant ($P>0.05$), although Charolais-sired calvings were somewhat more difficult than were either Chianina- or Limousin-sired calvings. When parturitions with scores of 2 to 5 were grouped and parturition score tested with breed of sire a significant relationship was obtained between breed of sire and parturition score. Also, seasonal birth sequence was a significant (P<0.01) factor associated with parturition score among the University of Alberta herds, thus indicating that the nutritional plane of the dam during the latter stages of pregnancy was important in determining the ease or difficulty of calf birth on the ranch.

Age and weight of dam were the two most important factors influencing dystocia in the University of Alberta group of herds; 17.5% and 13.6% of total variance in parturition score was explained by each. Assistance was greatest with 2-year-old first-calf heifers which experienced 41.6% difficulty. Also, sex differences were most pronounced among these. With the CCA set of data, which excluded 2-year-old heifers and where calf birth weights were very high, the most important factor was birth weight which accounted for 5.1% of total variance. This suggests a confounding influence of calf weight on dam age. Where calf birth weights are high, calf weight could take precedence over dam age. This is especially true in cases where large bull breeds are crossed with relatively smaller dam breeds, in particular when the dams are young.

Age and weight of dam together explained 20.6% of the total variation in parturition score among the University of Alberta data while all the factors put together explained 27.1% of total variance. These results stress the importance of cow factors in ease of calving studies.

Regression of percent assisted births on the respective average birth weights of sire progeny groups indicated a general trend of increasing difficulty with birth weight among the CCA's CH, LI and CI breeds, a 1 lb (0.45 kg) increase in average birth weight resulting in increases of 0.81, 0.46 and 1.78% difficulty, respectively. Among the University of Alberta's HE and HY lines, however, percent assisted births turned out to be inversely related to average birth weight, with the exception of 2-year-old heifers in the HY population for which a positive relationship was obtained.

Heritability estimates, calculated by the paternal half-sib method, were moderately low in all cases. Indications are that the exclusion of bulls noted for calving difficulty from breeding programs could result in some amount of progress being made in reducing the frequency of difficult births in cattle.

Mean repeatability estimates of 19.2 ± 4.1 and 12.6 ± 4.3% were obtained for calving difficulty utilizing 2-, and 3-year-olds among the University of Alberta's HE and HY lines, from which it was concluded that the judicious breeding of cows, especially very young ones, to bulls carefully selected for easy calving would be a worthwhile practice.

Parturition score was observed to influence pre-weaning average daily gain but had no effect on the rib-eye areas of steers at slaughter. It was therefore inferred that the effect of calving difficulty on the pre-weaning performance of cattle is not reflected in the conformation of the carcass at slaughter.

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8. APPENDIX

TABLE 1. CALF MEASUREMENTS (cm)

Serial No.	Head length	Head width	Shoulder width	Hip width	Body length	Circumference at fore fetlocks	Body depth	Parturition score
1	20.32	12.70	19.05	16.51	76.20	16.51	29.21	2
2	20.32	11.43	17.78	19.05	71.12	16.61	25.40	1
3	20.32	12.70	15.24	17.78	71.12	16.51	23.94	0
4	21.59	12.70	17.78	17.78	71.12	16.51	31.75	1
5	20.32	10.16	15.24	17.78	76.20	16.51	26.67	0
6	20.32	12.70	17.78	22.86	66.04	17.78	24.13	0
7	21.59	12.70	19.05	19.05	78.74	17.78	29.21	0
8	20.32	11.43	15.24	17.78	76.20	16.51	27.94	1
9	19.05	10.16	16.51	16.51	71.12	16.51	27.94	0
10	20.32	12.70	19.05	17.78	76.20	17.78	27.94	0
11	20.32	11.43	17.78	17.78	72.39	16.51	29.21	0
12	20.32	12.70	16.51	17.78	76.20	17.78	29.21	1
13	19.05	11.43	17.78	16.51	69.85	16.51	27.94	0
14	20.32	11.43	16.51	17.78	74.93	17.78	29.21	1
15	20.32	12.70	17.78	17.78	72.39	17.78	29.21	0
16	20.32	12.70	16.51	17.78	74.93	17.78	29.21	0
17	20.32	12.70	16.51	17.78	74.93	17.78	29.21	0
18	21.59	11.43	20.32	19.05	81.28	19.05	30.48	0
19	19.05	10.16	15.24	16.51	71.12	16.51	29.21	0
20	21.59	13.97	16.51	19.05	68.58	17.78	25.40	0
21	21.59	13.97	20.32	19.05	78.74	19.05	30.48	0
22	20.32	12.70	17.78	17.78	72.39	19.05	27.94	0
23	20.32	12.70	16.51	17.78	73.66	17.78	27.94	[illegible]
24	20.32	11.43	15.24	16.51	62.23	15.24	25.40	0
25	21.59	12.70	17.78	17.78	73.66	16.51	29.21	0
26	21.59	12.70	16.51	19.05	69.85	19.05	26.67	2
27	19.05	11.43	16.51	16.51	69.85	16.51	29.21	0
28	21.59	12.70	17.78	19.05	73.66	17.78	29.21	0
29	20.32	11.43	16.51	17.78	74.93	16.51	27.94	0

TABLE II. MEAN BIRTH WEIGHT OF CALVES (kg)[a]

(University of Alberta)

Population	Age Group of Dam: 2 years Male	2 years Female	3 years Male	3 years Female	4-10 years Male	4-10 years Female	Above 10 years Male	Above 10 years Female	Overall Male	Overall Female
HE	31.20 (0.41)	29.71 (0.40)	32.81 0.39)	31.27 (0.49)	35.31 (0.27)	33.62 (0.24)	36.61 (1.29)	37.33 (1.94)	33.94 (3.15)	32.36 (4.51)
HY	33.11 (0.36)	31.21 (0.40)	35.58 (0.41)	31.80 (0.40)	37.32 (0.24)	34.81 (0.22)	38.93 (1.71)	34.29 (1.02)	36.07 (3.99)	33.44 (2.61)
XB	32.54 (0.35)	31.17 (0.38)	35.31 (0.68)	32.03 (0.78)	39.39 (0.36)	36.84 (0.33)	38.57 (2.00)	36.18 (1.02)	36.51 (4.73)	34.14 (3.15)
DM	30.07 (0.63)	28.52 (0.66)	34.00 (1.51)	33.28 (1.51)	36.60 (.080)	32.82 (1.44)	39.09 (0.00)	41.36 (0.00)	34.02 (4.02)	30.99 (4.76)
DY	34.55 (0.88)	34.19 (0.72)	38.26 (1.36)	35.35 (0.91)	41.72 (0.79)	37.11 (0.97)	-	-	(3.97)	(3.31)
Overall	32.33 (0.20)	30.84 (0.22)	34.79 (0.27)	31.96 (0.28)	37.33 (0.16)	34.9[illegible] (0.15)	37.83 (0.88)	35.65 (0.74)	35.59 (0.13)	33.31 (0.12)

[a] Numbers in parenthesis are standard errors for the respective means.

TABLE III. MEAN BIRTH WEIGHT OF CALVES (kg)[a]

(Canadian Charolais Association)

	Hereford Dams							
	3-year olds		4-10 yr. olds		Above 10 yrs.		Overall	
Sire Breed	Male	Female	Male	Female	Male	Female	Male	Female
Charolais	39.80 (0.68)	38.82 (0.48)	43.19 (0.19)	40.25 (0.17)	42.76 (0.58)	39.96 (0.62)	42.92 (0.91)	40.11 (0.80)
Limousin	40.91 (0.00)	-	38.86 (1.18)	35.73 (1.48)	-	-	39.97 (1.18)	35.73 (1.48)
Chianina	40.00 (0.00)	-	42.33 (0.91)	42.99 (0.83)	39.09 (4.55)	42.53 (1.74)	42.08 (4.64)	42.85 (1.93)

[a]Numbers in parenthesis are standard errors for the respective means.

TABLE III. (Contd.)

MEAN BIRTH WEIGHT OF CALVES (kg)[a]

(Canadian Charolais Association)

	Angus Dams							
	3-year olds		4-10 yr. olds		Above 10 yrs.		Overall	
Sire Breed	Male	Female	Male	Female	Male	Female	Male	Female
Charolais	39.38 (0.87)	35.41 (1.43)	40.40 (0.44)	37.27 (0.42)	40.99 (1.23)	37.68 (0.63)	40.36 (1.57)	37.16 (3.55)
Limousin	84.09 (0.00)	-	37.27 (3.18)	34.15 (0.66)	36.82 (0.45)	31.36 (0.00)	36.45 (3.08)	33.84 (0.66)
Chianina	-	34.09 (0.00)	40.25 (1.92)	39.50 (1.74)	36.36 (0.00)	36.59 (0.32)	39.92 (1.92)	38.70 (1.76)

[a]Numbers in parenthesis are standard errors for the respective means.

TABLE III. (Contd.)

MEAN BIRTH WEIGHT OF CALVES (kg)[a]

(Canadian Charolais Association)

	Charolais x Hereford Dams							
	3-year olds		4-10 yr. olds		Above 10 yrs.		Overall	
Sire Breed	Male	Female	Male	Female	Male	Female	Male	Female
Charolais	43.64 (0.82)	41.82 (1.23)	46.38 (0.48)	43.37 (0.56)	45.00 (7.25)	38.33 (2.72)	45.62 (7.31)	42.72 (3.04)
Limousin	40.91 (0.00)	34.55 (0.00)	39.20 (2.52)	-	-	-	39.55 (2.52)	34.55 (0.00)
Chianina	-	34.55 (0.00)	44.59 (1.61)	40.68 (2.73)	-	-	44.59 (1.61)	40.00 (2.73)

[a]Numbers in parenthesis are standard errors for the respective means.

A dash means no observations made.

TABLE III. (Contd.)

MEAN BIRTH WEIGHT OF CALVES (kg)[a]

(Canadian Charolais Association)

Sire Breed	Charolais x Angus Dams							
	3-year olds		4-10 yr. olds		Above 10 yrs.		Overall	
	Male	Female	Male	Female	Male	Female	Male	Female
Charolais	44.25 (1.92)	38.86 (1.23)	42.32 (1.34)	40.97 (1.25)	43.18 (0.00)	-	42.93 (2.35)	40.09 (1.75)
Limousin	-	-	-	-	-	-	-	-
Chianina	37.73 (0.00)	39.09 (0.00)	37.27 (0.00)	40.00 (0.00)	-	-	37.50 (0.23)	39.56 (0.46)

[a]Numbers in parenthesis are standard errors for the respective means.

A dash means no observations made.

TABLE IV. MEAN GESTATION LENGTH (Days)[a]

(Canadian Charolais Association)

	Breed of Dam							
	Hereford							
	3-yr. olds		4-10 yr. olds		Above 10 yrs.		Overall	
Sire Breed	Male	Female	Male	Female	Male	Female	Male	Female
Charolais	286.1 (0.6)	285.0 (0.6)	287.8 (0.2)	286.0 (0.2)	288.3 (0.8)	286.5 (0.8)	287.7 (1.0)	285.9 (1.0)
Limousin	290.0 (0.0)	-	289.7 (1.2)	288.1 (0.7)	-	-	289.7 (1.2)	288.1 (0.7)
Chianina	279.0 (0.0)	-	282.7 (4.5)	284.6 (5.1)	292.0 (2.0)	289.4 (0.7)	283.1 (4.9)	286.0 (5.1)

[a]Numbers in brackets are standard errors for the respective means.

TABLE IV. (Contd.)

MEAN GESTATION LENGTH (Days)[a]

(Canadian Charolais Association)

Sire Breed	Breed of Dam: Angus							
	3-yr. olds		4-10 yr. olds		Above 10 yrs.		Overall	
	Male	Female	Male	Female	Male	Female	Male	Female
Charolais	285.2 (1.2)	282.3 (1.0)	286.8 (0.7)	284.6 (0.5)	284.4 (1.6)	286.0 (1.1)	286.5 (1.6)	284.5 (1.6)
Limousin	280.0 (0.0)	-	285.0 (4.0)	281.4 (1.2)	289.5 (1.5)	283.0 (0.0)	285.8 (1.7)	281.6 (1.2)
Chianina	-	294.0 (0.0)	287.7 (1.2)	286.7 (1.3)	295.0 (0.0)	286.0 (2.0)	283.0 (1.2)	287.1 (2.4)

[a]Numbers in brackets are standard errors for the respective means.

TABLE IV. (Contd.)

MEAN GESTATION LENGTH (Days)[a]

(Canadian Charolais Association)

Sire Breed	Breed of Dam: Charolais x Hereford — 3-year olds Male	3-year olds Female	4-10 yr. olds Male	4-10 yr. olds Female	Above 10 yrs. Male	Above 10 yrs. Female	Overall Male	Overall Female
Charolais	285.5 (1.1)	286.0 (1.4)	286.7 (0.5)	285.2 (0.7)	287.3 (1.7)	282.2 (1.2)	286.4 (2.1)	285.2 (2.0)
Limousin	288.0 (0.0)	283.0 (0.0)	284.5 (2.1)	-	-	-	285.2 (2.1)	283.0 (0.0)
Chianina	-	286.0 (0.0)	292.3 (2.0)	285.5 (1.2)	-	-	292.3 (2.0)	285.6 (1.2)

[a]Figures in brackets are standard errors for the respective means.

TABLE IV. (Contd.)

MEAN GESTATION LENGTH (Days)[a]

(Canadian Charolais Association)

Sire Breed	Breed of Dam							
	Charolais x Angus							
	3-year olds		4-10 yr. olds		Above 10 yrs.		Overall	
	Male	Female	Male	Female	Male	Female	Male	Female
Charolais	287.6 (3.0)	280.5 (1.3)	283.8 (0.7)	284.3 (1.6)	282.0 (0.0)	-	284.9 (3.1)	282.7 (2.1)
Limousin	-	-	-	-	-	-	-	-
Chianina	289.0 (0.0)	290.0 (0.0)	286.0 (0.0)	285.0 (0.0)	-	-	287.5 (1.5)	287.5 (2.5)

[a]Figures in brackets are standard errors for the respective means.

TABLE V. MEAN DAM WEIGHT (kg) BY AGE CATEGORY BY POPULATION

(University of Alberta)

Population	Age Category			
	2 years	3 years	4-10 years	Above 10 years
Hereford	327.8±3.4	350.2±4.2	424.0±3.7	473.1±14.7
Hybrid	366.9±2.5	379.4±3.1	445.9±2.6	465.5±9.0
Crossbred	359.6±5.7	360.5±5.7	446.8±4.0	450.1±10.5
Dairy	372.5±5.6	391.7±9.6	475.0±7.0	-
Double-muscle	319.8±5.6	327.0±9.2	397.9±11.5	451.1±1.2
Overall	350.1±1.9	366.8±2.4	440.6±1.9	462.7±6.2

TABLE VI. MEAN AVERAGE DAILY GAIN (PRE-WEANING) WITH STANDARD ERRORS IN PARENTHESIS (kg)

(University of Alberta)

Population	Age of Dam									
	2 years		3 years		4-10 years		Above 10 years		Overall	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
HE	0.84 (0.02)	0.78 (0.02)	0.79 (0.02)	0.81 (0.02)	0.85 (0.01)	0.81 (0.01)	0.77 (0.04)	0.78 (0.05)	0.83 (0.10)	0.80 (0.08)
HY	1.01 (0.02)	0.97 (0.01)	1.03 (0.01)	0.97 (0.01)	1.03 (0.01)	0.95 (0.01)	1.12 (0.05)	0.98 (0.03)	1.03 (0.12)	0.96 (0.05)
XB	0.88 (0.02)	0.83 (0.01)	0.98 (0.03)	0.93 (0.02)	0.96 (0.01)	0.91 (0.01)	0.96 (0.80)	0.93 (0.05)	0.94 (0.08)	0.89 (0.05)
DM	0.89 (0.02)	0.88 (0.03)	0.93 (0.04)	0.90 (0.04)	0.99 (0.02)	0.85 (0.02)	0.82 (0.00)	1.06 (0.00)	0.94 (0.12)	0.87 (0.04)
DY	1.17 (0.04)	1.06 (0.02)	1.17 (0.04)	1.05 (0.03)	1.16 (0.03)	1.03 (0.02)	-	[illegible]	1.16 (0.09)	1.04 (0.10)
Mean	0.93 (0.01)	0.88 (0.01)	0.96 (0.04)	0.92 (0.01)	0.97 (0.1)	0.90 (0.01)	0.91 (0.04)	0.92 (0.03)	0.96 (0.09)	0.90 (0.07)

TABLE VII. MEAN AVERAGE DAILY GAIN (PRE-WEANING)

OF MALE CALVES (kg)

(Canadian Charolais Association)

	Breed of Dam							
	Hereford				Angus			
Sire Breed	3-year olds	4-10 yr. olds	Above 10 yrs.	Overall	3-year olds	4-10 yr. olds	Above 10 yrs.	Overall
Charolais	0.84±0.02	0.93±0.01	0.89±0.02	0.92±0.03	1.01±0.07	0.97±0.01	0.90±0.04	0.97±0.05
Limousin	0.69±0.00	0.84±0.01	-	0.82±0.01	0.63±0.00	0.81±0.00	0.83±0.01	0.78±0.21
Chianina	0.75±0.00	0.83±0.03	0.70±0.00	0.82±0.03	-	0.91±0.04	0.88±0.08	0.91±0.04

TABLE VII. (Contd.)

MEAN AVERAGE DAILY GAIN (PRE-WEANING)

OF MALE CALVES (kg)

(Canadian Charolais Association)

Sire Breed	Breed of Dam							
	Charolais x Hereford				Charolais x Angus			
	3-year olds	4-10 yr. olds	Above 10 yrs.	Overall	3-year olds	4-10 yr. olds	Above 10 yrs.	Overall
Charolais	0.99±0.03	1.12±0.02	1.08±0.12	1.08±0.15	0.96±0.12	0.99±0.04	0.90±0.00	0.97±0.03
Limousin	1.08±0.00	1.07±0.04	-	1.08±0.04	-	-	-	-
Chianina	-	1.13±0.04	-	1.13±0.04	0.97±0.00	0.90±0.00	-	0.94±0.03

TABLE VIII. MEAN RIB EYE AREA OF SLAUGHTERED STEERS (sq. cm.)
(Canadian Charolais Association)

	Breed of Dam							
	Hereford				Angus			
Sire Breed	3-year olds	4-10 year olds	Above 10 yrs.	Overall	3-year olds	4-10 year olds	Above 10 yrs.	Overall
Charolais	37.92±1.21	76.80±0.39	75.78±1.45	76.81±0.30	75.21±2.12	77.10±0.80	76.42±2.62	76.93±0.54
Limousin	69.36±0.00	81.24±2.59	-	80.25±5.94	79.04±0.00	87.10±0.00	79.04±0.00	81.85±2.69
Chianina	79.04±0.00	78.46±1.03	75.81±0.00	78.38±1.03	-	84.95±2.05	69.36±0.00	83.39±7.79

TABLE VIII. (contd.)

MEAN RIB EYE AREA OF SLAUGHTERED

STEERS (sq. cm.)

(Canadian Charolais Association)

	Breed of Dam							
	Charolais x Hereford				Charolais x Angus			
Sire Breed	3-yr. olds	4-10 yr. olds	Above 10 yrs.	Overall	3-yr. olds	4-10 yr. olds	Above 10 yrs.	Overall
Charolais	83.81±1.37	88.06±1.17	87.49±9.29	86.76±1.47	88.70±1.63	85.42±3.68	64.52±0.0	85.17±7.57
Limousin	75.81±0.00	84.41±3.76	-	82.26±4.30	-	-	-	-
Chianina	-	87.51±1.82	-	87.51±1.82	70.97±0.00	66.13±0.00	-	68.55±2.42