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Range Cattle Production, I

REPRODUCTION

A Literature Review

By

C. B. ROUBICEK, R. T. CLARK, and P. O. STRATTON

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RANGE CATTLE PRODUCTION

A Literature Review

Section I

REPRODUCTION

Carl B. Roubicek
Animal Science Department
University of Arizona

R. T. Clark
Coordinator, Beef Cattle Breeding Research
United States Department of Agriculture
Denver, Colorado

Paul O. Stratton
Animal Production Department
University of Wyoming

INTRODUCTION

Beef Cattle Breeding Research in the Western United States is conducted as a cooperative effort through the Regional Research Project, W-1. This coordinated approach is now being used to consolidate existing research material relative to Range Cattle Production. It is recognized that this initial review is far from complete. It is anticipated, however, that during the next few years additional material will be included to make the review more complete and useful.

The research information has been divided into eight sections under the general heading RANGE CATTLE PRODUCTION:

I. Reproduction
II. Prenatal Development
III. Birth to Weaning
IV. Post-Weaning Performance
V. Carcass and Meat Studies
VI. Maternal Factors
VII. Inheritance
VIII. Effects of Climatic Environment

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RANGE CATTLE PRODUCTION

REPRODUCTION

Reproductive Efficiency

A method of computing reproductive efficiency is described (129). Each calendar month after the heifer reaches breeding age is called a reproductive month. The total number of reproductive months an animal remained in the herd is equal to the time between becoming of breeding age and last parturition. Incomplete breeding cycles are not considered; neither are heifers that failed to conceive.

One hundred percent efficiency by this system of evaluation means that each female of breeding age produces one living calf for each twelve months in the herd. Nine months of pregnancy is counted equivalent to one calf. The difference between the number of months of pregnancy at the beginning of the time computed and at the end of that time was divided by nine. Such periods were counted potential calves from a reproductive standpoint and were added to or subtracted from the number of calves born.

A formula that has been used successfully for estimating the reproductive efficiency of an individual or herd is as follows (143):

$$\frac{C}{S} \times 100 = R$$

C = number of calves born
S = number of services
R = reproductive efficiency

Reproductive efficiency based upon the number of calves born during a twelve-month period is estimated as follows:

$$\frac{C \times 100}{Cr} = R_1$$

C = number of calves born
Cr = number of cows in the herd
R_1 = reproductive efficiency

The percentage calf crop has been stressed as an important factor in economical beef production (124). Cost per calf increases 10 percent for each 10 percent reduction in percentage calf crop.

This has been presented on a dollars basis to show more clearly the importance of high percentage calf crops (240).

If the total cost of keeping each cow for one year is $100, the cost of each weaned calf, depending on the percent calf crop, will be:

Percentage Calf Crop	Cost per calf
100	$100
90	111
80	125
70	143
60	167

If the total annual cost for each cow amounts to $100, the cost per hundred pounds of weaned calf, depending on percent calf crop and the weaned weight of the calf, will be:

Percent calf crop	Average Weaned Weight of calf	Cost of calf per cwt.
100	600	$16.67
	500	20.00
	400	25.00
80	600	20.83
	500	25.00
	400	31.25
60	600	27.78
	500	33.33
	400	41.67

Reproductive efficiency as a part of production cost has been presented as a formula (37):

Death loss (percent) x value of cow = death loss cost + running cost per unit = carrying cost per unit + bull cost per cow = cow maintenance cost ÷ calf crop percent = cost of calf at three months.

The actual percentage calf crop is very difficult to determine. Records will not be available on all females exposed to a bull since many of them will be disposed of for various reasons after the breeding season. If year-round breeding is practiced, some cows may skip two or three years and not be detected, whereas other cows may produce two calves during a single twelve-month period. In a study of the western range area the percentage of calves born to each 100 cows in the herd at breeding time ranged from 40 to 77 percent in different sections, with an average of 63 percent (205). The calf crops on individual ranches included in the study ranged from 25 to 95 percent. In a California survey, the average percentage calf crop ranged from 50.6 to 95.2 (106). In Georgia, the percentage calf crop varied from 75 to 95, with an average of 83 percent. An additional 5 percent died during the year. In a study of dairy Shorthorn calves, the following tabulation of losses was made (35):

Abortions	5.1 percent
Stillbirths	6.3 "
Postnatal	4.8 "

Records were kept on 1000 cows for one year. Over 50 percent of these cows have needed treatment for breeding troubles (96). In Arizona, the calf crop on a large reservation ranged from 40 to 65 percent (157). With artificial insemination in one 10,000-acre pasture, the calf crop was increased to 80 percent. In Utah, 63 percent of the yearlings on the range became pregnant (20). The problem of infertility has also been recognized in other countries. Even under careful management methods, 62 to 92 percent of the cows can be expected to calve (91). In England, careful records over a number of years have shown large differences in relative fertility of adjacent areas or farms (86). Changes occur in the relative fertility on farms and in areas without any apparent reason. These changes have been called "waves of infertility", and the author stresses the need of careful analysis of within-herd fertility to explain these changes.

Similar results are noted in the United States for dairy cattle (77). The correlation between breeding efficiency for consecutive years was 0.084. The predictability of breeding efficiency of herds as units was about the same as that for individual cows. Only 9.3 percent of the "problem herds" were problem herds the next year.

The problem of infertility is difficult to study, and especially so under range conditions where the bulk of the beef cattle are found. Therefore, much of the infertility work is being done with dairy cattle or small numbers of beef cattle under restricted conditions. It is not likely that all information obtained from dairy cattle can be applied directly to beef cattle under range conditions. However, there is much basic information that has been obtained that is worth consideration.

Embryonic Death Loss

A recent study of factors associated with low fertility in beef cattle indicated breed differences could be important (45).

In cows with Brahman breeding

- 9 percent did not show estrus
- 23 percent did not ovulate although estrus occurred
- 5 percent had unilateral pyosalpinx
- 18 percent showed an embryonic death loss between 3 and 34 days

In a group of cows without Brahman breeding

- 5 percent had pyometra accompanied by retained corpus luteum
- 100 percent showed an embryonic death loss between 3 and 34 days

The factor of embryonic death loss has been receiving increased attention recently. As an example, a study was made of 104 cows that had been bred 4 to 13 times without conceiving (242) (243). Of this group, 10.6 percent showed genital abnormalities.

Three days after breeding, fertilized ova were found in 66.1 percent, but in only 23.1 percent 34 days after breeding. This indicates an embryonic death loss of 65.1 percent. The 104 cows would fit into these three main categories:

(a) Failure of fertilization, 39.7 percent
(b) Embryonic death before 34th day, 39.2 percent
(c) Embryos still normal at 34 days, 21.1 percent

A general review of prenatal death as a factor in the fertility of farm animals has been completed (48). The various references indicate an embryonic death rate in the first 90 days as about 30 percent. There are maternal differences in embryonic death rate. This gives emphasis to the study of the maternal environment itself. A factor contributed by the male resulting in early bovine embryonic mortality has also been reported (232). These results indicate early embryonic mortality is associated primarily with the bulls supplying the semen and is highly correlated in a negative direction with the fertility levels of the individual bulls as measured by one-month non-returns to service. Age of the diluted semen appears to have an effect but season does not.

In another detailed study (15), semen from a particular bull gave a very low conception rate, although sperm numbers, sperm density and pH were normal. Examination per rectum of the 42 cows which apparently failed to conceive revealed the presence of corpora lutea. After removal of the corpora lutea, 16 out of 19 animals conceived normally when inseminated with semen from other bulls. Some of the cows which were not treated showed persistent corpora lutea for up to 4-1/2 to 5-1/2 months before normal cycles were resumed. This phenomenon is attributed to conception followed by the death of the embryo at some time subsequent to nidation (10th to 12th day of pregnancy).

Detailed studies were made on 42 Holstein cows that had all been bred at least 4 times without apparent conception (55). They found that fertilization three days after breeding was 88.5 percent and that 34 days after breeding 26.7 percent of the cows had normal embryos. This is an embryonic death rate of 69.8 percent. It has been estimated that approximately 40 percent of all potential young in dairy cattle are lost 60 to 90 days after breeding (141). Their data show that the loss may be estimated as:

3 percent due to genital abnormalities of the cow
9 percent defective ova
12 percent failure of fertilization resulting from undetermined causes
16 percent death of embryo

It is believed that bacteria and nutrition are of minor importance in death and atrophy of the fetus (109). The fact that death of fertilized ova was found in animals under various controlled conditions indicates that it may be associated with anomalies of the later stages of follicle maturation (150). In a recent study of possible causes for physiological sterility in cattle it was found that in cows with apparently normal reproductive tracts, some 30 to 35 percent regularly fail to conceive (112). The following results were indicated as having a possible bearing on this fact:

(a) Injections with large doses of F.S.H., especially in the presence of luteal tissue in the ovary, leads to too rapid passage of the ova down the tubes. Either the ova do not become fertilized, or if fertilized they pass into the uterus before it is in a properly receptive state and degenerate.

(b) Degenerated, fertilized ova and early embryos have been found in heifers with quite normal reproductive tracts.

(c) Ova can be "tube-locked" by excess of estrogen and speeded down the tract by excess progesterone.

Embryonic death loss in sheep appears to be similar to that reported in cattle (79). The embryonic death rate was determined as 32.7 percent by the third day after breeding.

The genetic variation in services per conception and calving interval has been determined in dairy cattle (158).

(a) Heritability of services per conception = 0.026
intra-cow repeatability = 0

(b) Heritability of calving interval = 0
repeatability = 0.133

Estrous Cycle

There is considerable variation in the length of the estrous cycle of cattle. A cycle length of 18 to 22 days is accepted (178) (66) (72) (12), although variations from 17 to 27 days are also reported (74) (251). In a study of cycle length in identical twins, no genetic variation and no individuality could be detected in either this character or the number of services per conception (74). An analysis has been made of some of the component phases of the variation in the sexual cycle in cattle.(50). Some of the observations made were:

(a) With increasing age of the females there is a slight increase in mean cycle length, but not in variation.

(b) There is no apparent seasonal effect on cycle length.

(c) There is an indication of an average increase in the duration of estrus with increasing age.

(d) There is no definite seasonal effect on the duration of estrus.

(e) There does appear to be some correlation between the length of the estrous cycle and the duration of the subsequent estrous period.

The estrous (heat) period varies from 12 to 18 hours, with the average being reported as 13-1/2 hours (66) and 16 hours (178).

An attempt has been made to provide a more complete basis from which to interpret reproductive phenomena in the cow (268). Oviducts, uteri, and placentas removed at slaughter from reproductively normal cows in known stages of the estrous cycle and gestation were studied histologically. In addition, the tissues were examined histochemically for type of connective tissue, alkaline phosphatase, lipid and glycogen.

The oviducts are active during the follicular phase of the cycle, as evidenced by the high level of alkaline phosphatase activity and the concentrated cytoplasmic basophilia. Indications of regression are seen during the luteal phase. The mucosal epithelium shows increased pseudostratification, goblet-like cells, and extruding nuclei during early diestrus. Glycogen and small amounts of lipid accumulate during the luteal phase. The oviducts seen during gestation resemble the oviducts of diestrus.

Changes which occur in the uterus during the estrous cycle are not marked. Progestational proliferation and glandular activity continue throughout diestrus as shown by intense alkaline phosphatase activity in the epithelium at this time. Very little epithelial lipid or glycogen is seen during the luteal phase. The uterine surface shows localized desquamation during estrus or metestrus, and blood becomes trapped in the stratum compactum during this regressive stage.

It has been known for a considerable period that there is no fixed anatomical state or condition for any part of the genitalia; instead, constant changes, cyclic in character, are occurring (186).

Studies were made upon excised uterine muscle of cattle killed at known stages of the estrous cycle (67):

(a) 1 day proestrum; slow, even contractions of great amplitude at intervals of about 1-1/2 minutes.

(b) Estrus: slow contractions at 1-1/2-minute intervals, tending to staircase and become tonically contracted.

(c) 1 day postestrum: large, even, slow contractions at about 2-minute intervals with superimposed, small, more rapid contractions.

(d) 2 days postestrum: low, even contractions at 2-minute intervals with superimposed, small, rapid contractions and a tendency to long, regular changes in tone.

(e) 4 days postestrum: regular, long changes of tonus with short, somewhat irregular changes at intervals of about 3/4 minute.

(f) 8 days postestrum: not much spontaneous activity, a tendency toward short, irregular contractions.

(g) 12 days postestrum: no spontaneous activity.

(h) 16 days postestrum: little or no spontaneous activity.

(i) 2 days proestrum: slight spontaneous activity.

(j) Spontaneous motility is greatest during proestrum and estrus, becomes irregular during metestrum and dies down during diestrum.

(k) The motility consists of two types of wave, strong contractions of great amplitude at intervals of 1-1/2 to 2 minutes and small contractions at 20- to 30-second intervals. The latter increase in importance during metestrum and are a large factor in the production of the irregularity. In early diestrum, long rhythmic changes of tone also occur.

(l) The muscle cells of the uterus grow in length during the estrogenic phase and decrease in length during the rest of the cycle. The growth impulse starts at the apices of the uterine horn and travels caudally. It is over at the apices earlier than it is in the rest of the tract.

Studies of uterine motility were also made using the balloon-menometer method (89). They found very marked activity at estrus and for 1 to 2 days postestrus. This spontaneous activity decreased until 11 to 16 days after ovulation. From the 16th day to the 21st (estrus) the uterus becomes more active spontaneously and at estrus again shows very marked motility. They reported that ovariectomy abolished any motility of the uterus of the cow.

The histology of metrorrhagia was studied in 22 clinically normal virgin heifers (267):

(a) Endometrial edema began during early proestrus and reached a maximum during the 1st day postestrus near time of ovulation. The edema consisted of a distention of lymphatic lacunae with plasma.

(b) Pronounced capillary distention was observed principally in the caruncular areas after the end of estrus.

(c) Mitotic activity began during the 1st day postestrus prior to ovulation and continued through the bleeding period.

Variations in the total N, dry matter, viscosity and flow elasticity of bovine cervical mucus have been studied during the estrous cycle (236). A method of determining flow-elasticity in the field is described. The test is easily carried out, takes no more than two minutes to complete, and is very accurate. It was found that total N, dry matter and viscosity reach maximum values at about the time of estrus. Flow-elasticity shows a marked maximum. Variations in total N in the secretions are enough to serve as the basis for the diagnosis of estrus. It seems that soon after the onset of estrus, nitrogenous substances enter the secretion. In contrast to the mucus viscosity values found here, another investigator has reported that the viscosity of cervical and vaginal mucus was lowest during the first 6 hours of estrus and gradually increased as estrus was prolonged (128). They believe the penetrability of the mucus by spermatozoa was highest during the first 6 to 10 hours of heat. A study has been made of the cytological changes in the cervical mucosa of the cow throughout the estrous cycle (130). A summary of this study stresses the following points:

(a) Mucus is constantly secreted by the columnar epithelial cells of the cervix but the volume varies with the stage of the cycle.

(b) The maximum fullness of mucus-producing cells occurs just at estrus.

(c) The luminal ends of the cells rupture at estrus and discharge their cytoplasm (mucus) into the lumen of the cervix. The cells on the apexes and sides of the primary, secondary, tertiary, and even the quaternary folds are most likely to empty during estrus, while the cells in the crypts remain filled and empty at irregular times.

(d) During estrus, the intercellular substance increases in amount in the mucosa and submucosa, producing edema and enlargement of the cells, which accounts for the relaxation of the cervix at that time.

(e) During estrus the mucus is abundant, clear, adhesive, and contains considerable cellular debris. During metestrus the mucus is less abundant, tinged with blood from the uterus, and is adhesive in character containing a moderate amount of cellular debris. During diestrus mucus is minimal, cohesive, and contains very little cellular debris. In the proestrus stage there is a gradual increase in mucus secretion which is cohesive-adhesive and contains a minimal amount of cellular debris.

A record of 400 examinations on 38 cows showed a rather constant pH value of the vagina of between 6.5 and 7.5 (43). In the region of the external os, the vaginal mucosa is characterized by a superficial layer of mucus-secreting, columnar-type cells with a varied thickness of stratified squamous-type cells beneath. The epithelium thickens during estrus and becomes thinner during the interestrual period; the low point is reached one to two days prior to the onset of estrus. At estrus, the thickening results from the greatly increased height of the columnar-type cells of the superficial layer rather than from an increase in the number of layers of the squamous epithelium.

In another study of vaginal-cervical secretions, mucus was grouped into four fairly definite types with regard to sperm penetration (230). The average penetration rate in mucus collected during estrus was 2.81 mm. per minute; the range was 0 to 6 mm. per minute. Color reactions were obtained from mucus that were characteristic of glycogen, peptide linkage, and the amino acids tyrosine, cystine, tryptophan, and phenylalanine. The color tests were faintest during early heat and tended to become more intense as ovulation approached. The pH of the mucus varied during the estrual cycle. The lowest pH usually was observed in early estrus. It was also noted that vaginal temperatures and heart rates were slightly higher during estrus than during diestrus and pregnancy.

Estrus mucin has 1 to 1.5 percent dry matter, diestrus mucin has 2 to 3 percent dry matter and pregnancy mucin 4 to 5 percent dry matter (33).

A summary of the pH values of various fluids of the cow has been reported (154):

	Range	Average
Vaginal douches (anestrus)	6.0 - 6.7	6.4
Cervical fluid	7.6 - 8.9	8.3
Uterine wash	6.6 - 7.2	6.8

The corpus luteum of the ox ovary has been studied in relation to the estrous cycle (180).

(a) The time and manner of follicular development varies greatly in the same individual and between individuals. The majority of the follicles reach a diameter of 16 to 19 mm. before rupture but they may rupture as small as 10 mm.

(b) The color of the corpus luteum of estrum is at first a light brown; about the seventh day an old gold; by the 14th day a bright golden yellow; by the 20th day an orange or yellowish orange, eventually changing to a bright brick-red. This color change is associated with the quantity and character of the lipoid in the lutein cells.

Bovine follicular fluid has been analysed for chemical composition (162). The pH ranges from 7.5 - 7.7 with a mean value of 7.6 (Substantiated by Lardy et al, 1940) (154).

The content, in mg./100 ml., of some constituents of bovine follicular fluid:

Na	252
K	32
Ca	8.6
Mg	1.6
Chloride	39
Inorganic P	5.8
Total N	750 - 900

(equals 4.65 - 5.60 protein)

Non-protein N	0.5
NH_3N	0.5
Amide - N	negligible
Lactic acid	73 - 95
Ascorbic acid	0.8 - 3.0
Citric acid	3.2
Cholesterol	26.6
Acetylcholine	0

Carbohydrate:

Anthrone - reactive	52
Glucose	43
Carbohydrate other than glucose	10

Ovulation

There is evidence to indicate that the right ovary is functionally more active than the left ovary. The right ovary has been reported as being functional 60 to 74 percent of the time (218), 58 percent of the time (59), and 57 percent (127), 68 percent (182), 56.5 percent (40). There is less apparent agreement concerning the actual time of ovulation.

(a) Ovulation occurred 7.7 hours after estrus if serviced by a vasectomized bull, 9.9 hours when not serviced (174).

(b) Ovulation occurred an average of 13.57 hours from the end of estrus (38).

(c) Ovulation occurred approximately 14 hours after the end of estrus (189) (66).

(d) Ovulation occurs about 24 hours after the cessation of heat (274).

(e) The time of ovulation in females in which copulation is not permitted is 30 to 65 hours after the onset of heat (180).

(f) Ovulation occurred within 24 to 36 hours after the onset of heat (43).

(g) Ovulation occurs 24 - 40 hours after estrus begins (178).

There are a number of factors which apparently influence time of ovulation:

(a) Heifers ovulated an average of 3.64 hours sooner than cows that had calved (39) (38).

(b) Time of day and breed of cattle had no effect on ovulation (39).

(c) Ovulation occurred sooner if female was serviced by a bull (174) (10).

(d) The subcutaneous injection of small doses (5 to 10 mg.) of progesterone at the beginning of estrus hastens the ovulatory process in heifers. Both the length of estrus and the time from end of estrus to ovulation are significantly reduced.

The ova which have migrated into the oviduct are surrounded by a sphere of follicular cells (90). After ovulation the corpora lutea develop rapidly and can be distinguished as early as three days after estrus. Development continues until the 9th to 11th day after estrus, when maximum size is reached. The corpora lutea can be palpated through 2 or 3 succeeding cycles (43). The length of the functioning life of the corpus luteum in the absence of pregnancy is considered as being approximately 16 to 18 days (254).

Superovulation

Anterior pituitary injections can produce follicular development in the calf as early as the first week after birth (170). Ovulation can occur spontaneously in the calf at less than three weeks after birth, provided the follicles have been stimulated by gonadotrophic treatment. Thirty-two calves varying in weight between 90 to 180 pounds were subjected to a series of subcutaneous injections of gonadotrophic extracts predominantly of follicle-stimulating activity, followed by intravenous injection of luteinizing extract and artificial insemination (22). Moderate to extreme follicular stimulation was induced but corpora lutea were formed in only 50 percent of the calves. Thirty-five ova were recovered from ten calves but only seven showed evidence of fertilization. For the production of viable ova, processed P.M.S., whole P.M.S., and freeze-dried P.M.S., were compared. Whole P.M.S. was the best (40). With the injection of 3600 to 4500 i.u., of whole P.M.S. an average of 26 follicles were produced (231).

The young calf, unlike most mammals, can respond to injections of pituitary gonadotrophins from birth (171). Ovulation can occur spontaneously following F.S.H. treatment before the end of the first month of postnatal life. The ova are capable of fertilization although the percentage becoming fertilized is low. This ovulation in the calf up to 8 or 9 months of age is unaccompanied by estrus. In an actual trial (170), ovulation was induced in 55 percent of 7-day to 44-week old heifers injected subcutaneously twice daily for 3 to 4 days with anterior pituitary extract high in F.S.H., and 48 hours later injected intravenously with human chorionic gonadotrophin. Multiple ovulations of the majority of the follicles stimulated by the first treatment were induced by repeating the treatment after 15 days.

Superovulation in the cow has received consideration as a part of ova transplantation (111), (272), (76). If more than three eggs are fertilized in a cow they will invariably abort at about 5 months (113). Two procedures of inducing superovulation in the cow will be described as representative of still other variations that may be used. In the first method (76), 100 mg. of horse anterior pituitary extract is injected subcutaneously for three days following the follicular phase of the cycle. He also describes a method of collecting ova by washing out the uterine horn. The second method (152) consists of the injection of P.M.S. immediately following enucleation of the midcycle corpus luteum. To increase to a maximum the number of viable ova, an intravenous injection of 2,000 i.u., of L.H., should be given about the end of the heat period.

Attempts at nonsurgical transfer of bovine ova have not been generally successful in terms of resulting pregnancies (80).

Semen

Marked development of the germinal epithelium was first noted at 84 days of age in the ram, 142 days in the bull, and 84 days in the boar. Spermatozoa first appeared in the normal series at 147 days in the ram, 224 days in the bull, and 147 days in the boar (206).

Characteristics of Semen (178)

Animal	Volume per ejaculate	Sperm concentration (per cu. mm.)	pH
Stallion	40-320(75-150)	30,000 - 800,000 (60,000)	7.0 - 7.8
Bull	2.0 - 14.0 (3.0 - 4.0)	300,000 - 800,000 2,000,000	6.5 - 7.5
Ram	0.5 - 2.0 (0.8)	500,000 - 1,000,000 6,000,000	6.2 - 6.8
Boar	125-500-(200)	25,000 - 100,000 1,000,000	6.8 - 7.2

Underlined figures indicate most common levels.

Ratio of testis weight to mature body weight (255):

Ram	1:180
Boar	1:1250
Bull	1:2500
Stallion	1:3000

An excellent electron microscopic study of ram spermatozoa has been made (277). It shows the axial fibrils of the spermatozoa are continuous from the head through the neck to the midpiece. There are 9 fibrils up to the head-neck junction. Bovine spermatozoa have also been described in detail (217). It was stated that the protoplasmic drops associated with spermatozoa are normal and probably serve as nutritional factors in early sperm development.

Sperm are ejaculated into an environment with a slightly alkaline reaction. The pH in the uterus (6.8) is optimum for bull sperm storage (154).

Hyaluronidase has been studied as a factor in semen fertility. This material may be a factor in dispersing follicular cells surrounding ova (90). In humans the origin of hyaluronidase seems to be the spermatogenic elements in all stages of maturation. Direct correlation was noted between testicular weight, tubular size, tubular cellularity, the degree of mature spermatogenesis, and hyaluronidase concentration (201).

As a preface to the study of the possible association of hyaluronidase activity in bull semen with fertility certain factors were determined.(135):

(a) Hyaluronidase is found in seminal plasma immediately after ejaculation.

(b) Seminal plasma completely cleared of spermatozoa shows no increase in hyaluronidase when stored.

(c) Seminal plasma from semen which has been stored does show increase.

(d) Bacteria present in semen may produce hyaluronidase.

Castration causes the disappearance of fructose and citric acid from seminal plasma, but the formation of both of these substances is re-established on administration of testosterone (168). There is a quantitative relation between the amount of testosterone administered and the production of fructose and citric acid. Thus, the assay of these substances can be used as a "hormone indicator test."

There have been many studies of semen evaluation. A recent review of the problem of testing fertility in bulls describes the Rothchild spermometer which is used to measure the rate of impedance change (65). The determination of rate of impedance changes in freshly ejaculated bull semen provides the most practical method for routine daily semen appraisal.

Long-term storage of bull semen frozen at very low temperatures is discussed in detail (210) (211). A summary of the procedure is as follows:

(a) Dilute semen at 5°C., with a citrate buffer containing glycerol to give a concentration of 10 percent in the semen.

(b) Equilibrate the semen and diluent for 12 to 20 hours at 5°C., before freezing.

(c) Cool the semen slowly at a rate not exceeding 2° per minute between 5°C. and 15°C.

(d) Up to 80 percent of the spermatozoa may resume motility after freezing and thawing to 40°C.

(e) Semen does not appear to have normal fertilizing power.

The hydrogen ion concentration of the preputial cavity of the bull has been determined (269).

Posterior preputial cavity	6.68 (6.3 - 7.4)
Middle preputial cavity	7.42 (6.8 - 8.0)
Anterior end of penis	7.15 (6.7 - 7.7)

Fertilization

Mammalian ova which have migrated into the oviduct are surrounded by a sphere of follicular cells. The mechanism whereby the ovum is freed from these cells to promote fertilization is quite obscure (90). Preparations rich in hyaluronidase, such as testicles, have a very pronounced effect in dispersing the follicular cells surrounding the ova. It appears that hyaluronidase itself is responsible for this effect, an indispensable step in fertilization. The free ovum remains capable of fertilization for approximately 12 to 20 hours in the cow. Sperm can survive about 24 hours (66). Sperm are ejaculated into an environment with a slightly alkaline reaction. The pH in the uterus (6.8) is optimum for bull sperm (154).

There is some disagreement as to just how long sperm require to reach the oviducts:

(a) 6 - 9 hours for mature cows; 4 to 7 hours for heifers (39).

(b) 3 to 4 minutes (10).

(c) 2.5 to 4 minutes (250).

An egg in the two-celled stage was recovered 52 hours after copulation (274).

In a study of the physiological responses in the cow during mating and artificial insemination, sperm travel was the same for both estrous and postestrous cows and with motile and non-motile sperm (250). Mounting and copulation caused a definite release of oxytocin which in turn caused uterine contractions and aided sperm travel. There are investigators, however, who consider the cervical mucus as an important factor in sperm travel. In a study with humans, it was found that semen and cervical mucus are virtually immiscible (17). It is believed that fecundation depends on the ability of the sperms to penetrate the interface between mucus and semen.

The difference in penetrability of the mucus by spermatozoa has been studied in some detail (230). The average penetration rate in mucus collected during estrus was 2.81 mm. per minute, the range was 0 to 6 mm. per minute. When incubated at 37° to 39° C., sperm motility was maintained an average of 3.30 hours longer in a semen-mucus mixture than in control semen samples. Sperm motility survival was maximal in mucus collected during full and late heat. It was suggested that an *in vitro* technique for testing mucus for sperm penetrability and survival time may be useful in the evaluation of semen and in the evaluation of mucus in cases of unexplained "sterility" in cattle. A method of determining flow-elasticity of cervical mucus in the field has been described which appears to be relatively easy and requires only two minutes to complete (236).

Infertility

Endocrine Effects

Since there are many different hormones influencing the various phases of the normal reproductive pattern, it is difficult to visualize an infertility problem that is not in some way concerned with an endocrine role. The placental anastomosis of a male and female bovine embryo results in the well-known freemartin (273). This anastomosis may be present for other multiple births besides twins (196). The freemartin is said to occur in approximately 91 percent of bisexed twins (99). The abnormal development consists of an underdevelopment of the Mullerian ducts and an overdevelopment of the parts arising from the Wolffian ducts. Therapy has not been successful with freemartins (9).

A great deal of information has been published concerning the therapeutic value of hormones in various cases of infertility. In general, the practical use of hormones for therapy is limited and the results are uncertain (123) (132). The gonadotrophins may be of some help, although their use often has been disappointing since the ova from gonadotrophic-treated animals are not always fertile (4). Pituitary gonadotrophins do appear to decrease the mean time from the end of estrus to actual ovulation (173).

The product E.C.P. is reported to have some value in the treatment of anestrus and retained corpus luteum, although a relatively high incidence of persistent heat has been observed following intramuscular injections of E.C.P. (83). Follicle-stimulating hormone has been recommended in conjunction with massage and other treatments (9).

Six cows with typical symptoms of nymphomania were compared with normal, spayed, and stilbestrol-implanted cows (265):

Plasma Constituents

	Normal	Spayed	Nymphomania
Hemoglobin, gm.%	11.35	11.85	11.40
Plasma calcium, mg.%	9.3	10.3	9.5
Plasma inorganic phosphorus, mg.%	6.34	6.03	4.56
Plasma protein, gm.%	7.98-8.77	7.92-8.91	9.14-9.77

Partition of Plasma Proteins

	Normal	Nymphomania
Total plasma protein	7.61	9.23
Plasma albumin	3.05	2.81
Total globulin	4.56	6.41
Alpha globulin	.65	.73
Beta globulin	1.57	1.95
Gamma globulin	2.34	3.73

A 23.5 lb. granulosa cell tumor was removed from a heifer that exhibited signs of nymphomania (153).

Since progesterone will speed up the travel of the ova and estrogen functions to "tube-lock" the ova, it has been suggested that in many cows there is a slight abnormality in the estrogen-progesterone level in the blood which causes difficulties in conception (112).

The thyroid plays a very important role in general fertility (221). A study of the thyrotropic hormone content of beef and dairy cattle pituitaries showed that lactating non-pregnant dairy cattle contained 30 percent more; lactating and pregnant 17 percent more; and dry, non-pregnant 60 percent more than the corresponding classes of beef cattle (246). The adrenal cortex may also be involved in certain types of sterility (63). The growth effects of estrogen in ruminants are indirect, being dependent upon an increased secretion of androgen by the adrenals which, in turn, is stimulated by an increased secretion of ACTH by the pituitary. Mounting and copulation cause a release of oxytocin which is important in causing uterine contraction as an aid to sperm travel (250). Some cows may be inherently lacking in this release of oxytocin in mating. The caruncular arterioles of normal cows are extremely coiled. The endometrial arterioles of 13- to 16-month-old heifers are essentially straight, while similar arterioles in the uteri of mature cows are more numerous and more highly coiled. These facts appear significant in relation to the lower conception rate encountered in heifers and in relation to more frequent occurrence of metestrous bleeding in heifers (118).

The feces of cows in various stages of gestation and of unbred heifers, when dried and fed to chicks as a supplement to their diet, stimulated comb growth. The development of the testes and the ovaries was retarded when chicks were fed material containing the active factor. These effects indicate the presence of one or more androgenic principles.

Feces from mature bulls were without effect on either comb growth or gonadal development (227).

Iodinated protein has proved beneficial in improving libido and fertility in sluggish and inactive bulls, and may provide a means of extending the period of usefulness of some herd sires (27).

Nutrition Effects

Reduced food intake has been shown to delay sexual maturity and inhibit estrous cycles in all mammalian species studied (181) (220). Calves receiving 70 percent of the recommended allowances for growing calves were delayed 12 to 14 weeks in sexual maturity compared to calves receiving recommended allowances (93). Undernutrition has its most pronounced effect first on the less essential portions of the body. The skeleton and essential organs continue to grow at the expense of muscular fat and tissue (133). Quantitative and qualitative requirements for reproduction do not exceed those for growth of young animals or those for adequate maintenance of mature animals (220). Inadequate nutrition is recognized as an important causal factor in infertility (213)(147). Any deficiency that affects appetite affects reproduction through coincident general undernutrition (103). In an early classical experiment (121), it was found that restriction to the wheat plant as a source of "balanced" nutrients (wheat grain plus wheat straw) did sustain growth with Holstein heifers. These animals failed to show estrus and could not be bred. Similar results were obtained with sows (122). Since then, many nutrients essential to reproduction have been identified.

Vitamin A: A lack of vitamin A has been cited as probably one of the outstanding causes of nutritional sterility among farm animals (202). Although there are many manifestations of vitamin A deficiency, under range conditions the symptoms are commonly limited to reproductive failure (104)(125). Degeneration of germinal epithelium may be one of the primary causes of sterility (103), although there is evidence to show that the damage to germinal epithelium is not always permanent (164). Lack of vitamin A is most common in females. The male appears to be more resistant to vitamin A deficiency than the female (220). A deficiency in bulls is characterized by a rapid decrease in sexual activity. Semen samples collected as the depletion progressed showed a marked increase in the percentage of abnormal spermatozoa and cellular debris with a progressive decline in motility (166).

Cystic pituitary glands have been found in young beef and dairy cattle suffering either from vitamin A deficiency or with a history of early severe vitamin A depletion. No evidence of repair in a cystic pituitary was found in an animal that was vitamin A-deficient early in life but later fed adequate amounts of carotene, suggesting that the injury of the gland may be permanent (167). The accumulation of vitamin A in the body tends to increase with age (225). In order to support normal gestation, the carotene level of first-calf heifers must be considerably higher than for aged Hereford cows (198)(126)(161). Yearlings on an A-deficient diet required 128 to 266 days to show deficiency symptoms.

The chances of producing a normal living calf were poor when the plasma vitamin A level of the cow was below 18 µg. per 100 ml. (165)(71). The carotene blood plasma level of first-calf range heifers must be at least 117 µg. per 100 ml. for normal reproduction (198). Values for aged cows may be considerably less. The normal vitamin A content of the maternal liver is about 200 I.U. per gm. (36). The daily requirement of carotene for cattle is about 26 to 33 µg. per kg. live weight (105). However, if the animals have been on a deficient diet they may require higher levels (165).

It is possible that vitamin A deficiency has been held to blame for reproductive failures that are due to other causes. Heifers kept on a vitamin A-deficient diet for 181 days showed no abnormalities in weight or appearance of ovaries and uterus (175). In a long-range study of supplementation, two groups of grade Hereford cows were grazed on dormant range typical of southern New Mexico and given a supplemental feed during the precalving and calving periods. The energy and digestible protein of the supplemental feed were approximately the same for both groups, but one group received additional carotene from dehydrated alfalfa meal. Feeding the alfalfa meal did not raise the plasma carotene level over that of the cows fed no extra carotene. There was no significant difference in the plasma carotene and vitamin A levels for the two groups (262). The blood carotene of these cows when compared to existing statements of requirements indicates that a vitamin A deficiency might occur only in case of prolonged drouth or extremely abnormal conditions (260)(261)(263). In a careful study of sterility cases a deficiency of vitamin A was not evident (117). The thought has been expressed that a protein supplement may be a more critical factor in reproduction than vitamin A (257).

The thyroid helps regulate the conversion of carotene to vitamin A. In view of the importance of vitamin A in reproduction, the possibility must be considered that a hypothyroid state combined with a low intake of vitamin A could result in abortion or dead or weak offspring. Thyroid function can be depressed by goitrogenic substances in the diet. Plants of the family Brassicaceae appear to be outstanding in this respect, although many other foods have not yet been tested (181).

In studies with the rat, an excessive intake of vitamin A has reduced fertility (62). Of 74 offspring produced, 34 exhibited a gross anomaly in the development of the skull and brain. The anomaly is an extrusion of the brain.

Minerals: Phosphorus. Of the mineral elements generally considered essential to animal life (calcium, phosphorus, magnesium, sodium, chlorine, iodine, iron, copper, manganese, sulphur, zinc, potassium, and cobalt), phosphorus is most likely to be incriminated in reproductive trouble (9)(87) (187). Marked inhibition of estrum was observed with animals on phosphorus-deficient feeds (84). The fact that a phosphorus deficiency causes a decrease in appetite and consequent inanition is also very important (103).

The concentration of inorganic phosphate in the blood plasma in cattle aphosphorosis is an important index of the severity of the disease. Large fluctuations in the concentration of inorganic phosphate in the blood plasma of cattle may occur from day to day (85). Good reproductive results were obtained with cattle on New Mexico range when the average inorganic blood plasma phosphorus level varied from 2.11 mg. during the winter to 5.37 mg. during summer and fall months (259). Inorganic phosphorus levels of 3 to 4.5 mg. per 100 cc. of blood plasma may be near optimum for mature range cows (144)(161). Minimum value of inorganic phosphorus in the blood of cattle has been placed at 4 mg. per 100 cc. of whole blood (25). Average plasma-carotene levels have been found generally higher in phosphorus-deficient cows (244)(245). Under normal range conditions, cows receiving a phosphorus intake of over 10 gm. per head daily were able to maintain an adequate blood phosphorus level (144)(190a). Inorganic phosphorus in the blood appears to be closely related to phosphorus intake (r= .6102)(144).

There are a number of very excellent experiments showing the value of adequate phosphorus for range cattle. There is a distinct tendency for cows on a phosphorus-deficient ration to reproduce once each two years (85). In a well-conducted experiment on New Mexico range, additional phosphorus fed to cows resulted in more and heavier calves and in better health of all animals (144)(145)(146)(258).

Effect of Mineral Supplements on Weight and Production of Range Cattle (results of 7 years).

Measure of Production		Cows not Fed Minerals	Cows Fed Minerals	Gain from Mineral Feeding
Cows calving	percent	90.4	92.2	1.8
Calves died	"	10.8	2.7	8.1
Cows weaning calves	"	80.7	89.7	9.0
Average weight of calves	lbs.	408	442	34
Average production per cow	"	336	389	53
Gain of yearling steers	"	321	353	32
Gain of 2-year-old heifers	"	202	278	76

The results of an experiment on Texas range show a cumulative effect of phosphorus deficiency when calf crops during 4 successive years are: 91 percent, 88 percent, 74 percent, and 22 percent (25). The actual difference in percentage calf crop between the control and treated lots was 20 percent in favor of the treated (24). The addition of superphosphate to depleted soil did not show any results in bone ash or serum phosphate or reproductive performance of experimental animals grazing on the land (266). Some advantage in overall performance using pasture fertilized with triple superphosphate has been noted (223).

Animals on a low phosphorus and low protein diet were more seriously affected than on low protein alone (126). Protein and phosphorus both tend to be deficient in range plants during the winter months (98)(144). Animals receiving cottonseed cake on the range showed a marked increase in plasma organic phosphorus during the winter months despite the lower phosphorus content of the roughage (161).

In the United States, blood phosphorus levels showed no obvious relation to breed (161). In South Africa it has been noted that in the cattle raising areas that are generally phosphorus and protein-deficient, native cattle do not show deficiency symptoms as do imported cattle and their progeny (213).

Calcium. The calcium content of blood plasma varies between 10 and 12.2 mg. per 100 ml. (161). It does not appear to be correlated with season, breed or age. Calcium does not appear to be deficient in any of the range grasses and is actually in excess in many samples (98). Studies with radio-calcium indicate age and nutritional status to be the major factors influencing the physiological behavior of calcium. Pregnancy and stage of gestation, dwarfism, source of dietary calcium, and current calcium intake were of less effect (115).

Cobalt, copper, iodine, and manganese may be important in some areas (2)(202)(116)(103). Studies of the "Grand Traverse disease" in Michigan showed that "affected" hay had 0.03 to 0.06 ppm. of cobalt while "healthy" hay had a cobalt content of 0.12 ppm. (2). They suggest that the minimum cobalt requirements are met with about 0.1 ppm. in the feed, or an intake of about 1.0 mg. daily by adult cattle.

Pastures containing less than 7.5 ppm. of copper are probably deficient (2). They describe the syndrome of a copper deficiency as including (a) loss of appetite, (b) stunted growth, (c) rough coat, (d) anemia, and (e) suppressed estrus. Young calves may have straight pasterns and may tend to stand on their toes. A deficiency of manganese will cause congenital debility and testicular atrophy (103) but does not appear to affect the estrous cycle. An amount adequate for growth was inadequate for good quality semen production in bulls (202).

Protein: The protein requirements for reproduction in ruminants are not exacting since they can synthesize amino acids (202). There is evidence of irregularity of estrus in cattle due to a low protein intake (103)(187). Blood analysis of cattle in India has shown red cells, white cells, cell volume, sugar, hemoglobin, iron, total cholesterol, calcium, inorganic phosphorus, magnesium, non-protein nitrogen, and the protein fractions were decreased in protein-deficient animals (138). A direct relationship between phosphorus and protein has also been demonstrated. Animals on low protein and phosphorus were more seriously affected than animals on low protein alone (126). Also, animals receiving cottonseed cake on the range showed a marked increase in plasma organic phosphorus during the winter months despite the lower phosphorus content of the forage (161). The analysis of range forages in northwest Texas indicates that two percent of the young plants were protein-deficient for range animals while 73 percent of the mature plants were deficient (98). During November almost all plants showed a deficiency of protein. The protein content did not appear to be closely related to the total nitrogen in the soil. Studies at the U. S. Range Livestock Experiment Station, Miles City, Montana, (23) indicate that cottonseed cake is a valuable supplement on native range but for greatest economy its use should be limited to seasons in which winter range conditions are severe.

The practice of self-feeding cottonseed meal to range cattle by mixing the meal with salt is being used on many southwest ranges (46). Feeding of large amounts of salt to cows during pregnancy and subsequent lactation had no apparent harmful effects. The intake of one to two pounds of salt per day did not alter calcium, phosphorus, chlorides, or hemoglobin content of the animal blood as compared to controls (233). There was no detrimental effect on the cows or their calves (191), and a digestion trial indicated a beneficial effect of high salt intake upon digestibility of all nutrients, particularly protein, crude fiber, and nitrogen-free extract (226). It is generally agreed that the cows should become gradually adjusted to the high salt intake and have an abundant supply of water at all times (46)(233)(191)(226). Cattle fed salt-meal mixtures during the winter consumed more than twice as much water as controls.

In a series of experiments with rats, it was found that a deficiency of lysine is responsible for a cessation of the estrous cycle (199)(200). It appears that the nutritive demands for growth may be satisfied before those for the estrous cycle.

Vitamin E: Although there has been considerable controversy regarding the value of vitamin E in normal reproduction of ruminants, it is now generally concluded that the need in cattle nutrition is not important (202)(103)(107). In dairy cattle normal tocopherol levels in the blood are 582 to 685 µg. per 100 ml. (137). These levels are apparently provided in ordinary feeds (220)(26). A cow that eats 100 pounds of fresh grass daily in the summer will have an intake of between 2.7 and 12.6 gm. of tocopherols. The intake during the winter will not be greater than about 1 gm.

Blood levels of less than 100 µg. per 100 ml. were accompanied by cardiac abnormalities (137). Another characteristic of a vitamin E deficiency in farm animals is a hyaline degeneration of the skeletal and cardiac musculature and, under some conditions, there may be abnormalities of the fatty deposits (26). A low vitamin E ration did not impair the utilization of carotene and vitamin A (137). A study with rats indicates that estrogenic, androgenic, and gonadotrophic activity can be demonstrated with wheat germ oil, solvent-extracted at low temperatures. These effects were not found in rancid wheat germ oil (159).

Vitamin C: Subcutaneous injection of ascorbic acid resulted in the restoration of fertilizing capacity of certain impotent bulls (204). They found that potent bull semen normally contained 3.0 to 8.0 mg. of ascorbic acid per 100 cc. of fresh semen. Values below 2 mg. were associated with impotency. Subcutaneous ascorbic acid therapy of "hard to settle" cows resulted in a positive response in 60 percent of the cases treated (203). It was concluded that vitamin C was closely related to successful reproduction. It apparently stimulated the production of high quality semen and was necessary in ample amounts for certain early phases of pregnancy (202). Attempts to duplicate these beneficial results with ascorbic acid therapy have not been generally successful (57). Injections of ascorbic acid failed to stimulate sexual activity or modify the quality of semen produced by vitamin A-deficient bulls (166).

Vitamin D: Although a deficiency of vitamin D is not probable in range cattle production it has been associated with productivity, and reproductive efficiency and may be a factor in certain climates or when animals are kept indoors for long periods of time (1).

General Nutrition Level: Heifers that have been kept on a low nutritional plane showed a delayed puberty of 221 days (136). In a study of the possibility of breeding cattle for increased adaptability to tropical and subtropical environments it was found that chronic undernourishment in the unadapted types could be detected even in newly born calves (29). All the animals whose growth had been considerably retarded revealed depressed sexual activity. Clinical examinations as well as slaughter tests proved the sexual organs of the animals, particularly the ovaries and wombs, to be infantile.

Females that received only enough meadow hay to maintain a healthy condition dropped 15 percent fewer calves than females that had all the meadow hay they could clean up in a 24-hour period (134).

Flushing ewes will lead to a higher ovulation rate provided the ewes are not in high condition to start with (60). It has also been recommended that breeding cows that are very thin at the start of winter be fed so as to gain weight to be in strong breeding condition in the spring (7).

In a study of the effect of underfeeding on the genital functions of a bull the food intake was reduced so that the bull lost about 15 pounds per week (169). The volume and density of semen and motility and morphology of the spermatozoa were not significantly changed. The secretory effect, however, was markedly affected by underfeeding. The concentration of fructose and citric acid in semen decreased 30 and 60 percent, respectively. During the recovery period the fructose and citric acid returned to normal.

In terms of output, the testes exert no special demands upon the general economy of the body and no exceptional substances are formed. We may expect that if the animal received a nutrition adequate to maintain body health the needs of the testes will be adequately met (255).

High condition often has been considered a cause of sterility (177)(187). It was stated that the derangement of the estrous cycle in fat animals was caused by a disturbance of the ovarian metabolism as manifested especially by a considerable deposition of pigmented fat or lipochrome in the interstitial tissue. This process was said to be accompanied by an unusually extensive degeneration of follicles which may lead to a prolonged state of sterility (177). Anestrus has been frequently observed in highly conditioned heifers, in heifers and young cows during late winter and early spring, and in those animals in a state of low nutrition. Ovarian, follicular cysts were also observed in some well-conditioned beef cattle (254).

Some experimental results indicate that high condition alone does not have an adverse effect on fertility (216)(197). In fact, it has been stated that obesity is caused by sterility rather than that sterility results from obesity (120). This apparent conflict as to the importance of obesity in fertility may be due to different management factors. Starting at 15 months of age, heifers have been kept in high condition, with very restricted exercise, in a darkened stall for 3-1/2 years. They bred as well as control cattle provided they were regularly bred (213). Other cattle kept under similar conditions but bred for the first time when they were four or five years old became difficult breeders or hopelessly sterile.

Essential Fatty Acids: A deficiency of essential fatty acids results in large, pale ovaries showing vacuolization. Testicular atrophy has also been noted (103).

Natural Estrogenic Substances: The extraction of clover and alfalfa hays revealed the presence of biologically active estrogenic substances (51)(69)(52)(279)(95). Although only isolated cases of the importance of this material on fertility have been reported, it may be an important factor under some conditions (95). Genistein, an isoflavone derivative, is one of the active estrogenic substances in subterranean clover. The estrogenic potency of these isoflavone compounds is low when compared with that of diethylstilbestrol; nevertheless, when one considers the large amounts of feed such as legume hay and soybean-oil meal that are consumed by farm animals, enough estrogenic substances may be present in these feeds to exert an important influence upon their physiological functions (53). An unknown factor or fraction in soybean hay has been shown to impair reproduction (139).

Green clover is potent in the estrogenic material while dry clover has little potency (21).

Genetic Effects

"White heifer disease" is usually considered as an inherited condition (99)(222)(32)(8). The term is actually nondescriptive although it is commonest in white heifers of the Shorthorn breed. It has been reported in roan and red Shorthorns and in colored animals of other breeds. White daughters of a white bull seem more susceptible than white daughters of a roan bull. The condition is a form of sterility characterized by a developmental deficiency of the Mullerian ducts. It is also referred to as "imperforate hymen." The characteristics are listed as follows:

(a) Closed hymen or hymen persisting in varying degrees.

(b) Distention of one or both uterine horns, the uterine body being present in rudimentary form.

(c) Complete absence of cervix and anterior vagina.

(d) Prominence of Wolffian ducts.

(e) Presence of longitudinal submucous channels in the vagina.

(f) Aplasia of one uterine horn.

Conception may occur but parturition in those cases is very difficult.

Normally, about 90 to 94 percent of the heifers born twin to a bull are sterile (99)(14)(8). The abnormal development consists of an underdevelopment of the Mullerian ducts and an overdevelopment of the parts arising from the Wolffian ducts (99). There is a list of characteristics used to identify the freemartin (241).

(a) Retarded udder development

(b) Atypical udder development

(c) Enlarged clitoris

(d) Fold of skin extending along median plane of body, part or all of the way from the rear attachment of the udder to the navel

There is evidence in a Jersey herd that the fertility of a heifer twin to a male may be controlled by heredity (14). Two cows, full sisters, were born less than a year apart, each twin with bull, and each fertile.

A genetic condition in the Swedish Highland breed known as "ovarian hypoplasia" has been described in considerable detail (147)(148)(149). This condition affected 17.5 percent of the cattle examined in 1936. The incidence was very high in the proximity of the breeding center where the first known cases were found, the incidence decreasing with distance from this center (148). An all-out campaign to reduce the incidence was undertaken with governmental financial assistance, and by 1948 the incidence had been reduced to 9.4 percent (149).

The condition is characterized by underdevelopment of the epithelium layers of the seminal ducts and follicles of the ovaries (88). The hypoplasia may be single-sided or double-sided. The double-sided hypoplasts in both sexes are sterile, although sexual instinct and copulation are normal. One-sided hypoplasts may have irregular reproduction from good to sterile. It has been postulated that two separate genes are involved. When separate they cause single-sided hypoplasia and together they produce double hypoplasia.

A gene-controlled sterility has been studied in Holstein-Friesian bulls (75)(114)(238). The condition is characterized by abnormal formation of the acrosome and is called "knobbed." It does not appear to have a counterpart in female sterility and so is considered as due to an autosomal sex-linked gene (75). The semen of the affected bulls shows normal metabolic activity and the diagnosis of this form of sterility is based on microscopical examination. In a careful study of the abnormality (238), it was concluded that the formation of vacuoles in the developing spermheads may be related to some unknown changes in the nucleic acid metabolism of the spermhead. The absence of any chromosomal aberration, whether of quantitative or structural nature, may lead to the conclusion that the changes are due to a gene mutation.

In a study of six totally sterile bulls, the testes were found to contain gross and microscopic changes, including atrophy, calcification, degeneration of seminiferous tubules, and varying degrees of fibrosis (92). It was concluded that the hereditary influences were important but the exact mode of inheritance was not known.

So-called "female infertility", particularly when associated with persistent corpora lutea, is believed to be due to an inherited factor from the sire that causes fetal death (15).

It is known that the proportion of abnormal spermatozoa does not differ significantly at various levels of the reproductive tract, leading to the conclusion that the testes are the original source of morphologically abnormal spermatozoa (34).

Some additional factors which influence male fertility:

(a) In Holstein males, infertility is conditioned by a recessive autosomal gene that is different from the gene conditioning female sterility (101).

(b) Inability of the male to copulate because of failure of sigmoid curve of the penis to straighten during coitus due to an autosomal recessive gene (99).

(c) Umbilical hernia which is associated with breeding efficiency. Probably due to a sex limited dominant gene of low penetrance (99).

(d) Sperm that are abnormal with respect to their tails, which are turned back past the head. The mode of inheritance has not been determined (99).

(e) The failure of spermatogenesis due to excessive temperature within the testicles. The inheritance seems to be for the large testicle of the European parent and the small scrotal sac from the other parent as noted in crosses of (a) bison x European cattle, (b) yak x European cattle, and (c) yak x Zebu (99).

(f) The sperm production capacity of bulls is determined mainly by heredity (28)(147). This is apparently true also for the bulls' readiness and ability to serve.

A single autosomal sex-limited gene has been shown to effect female sterility in the Jersey and Holstein breeds (102)(101). The cause of the failure is probably due to zygote abortion in late cleavage or early blastocyst state. It has been further suggested that in this type of sterility, cows which produce only one calf might be genetically sterile (142).

The greater number of services required per conception for females of some breeds indicates inherited factors (99). Individual variation may also be gene-conditioned. The Simmenthal, Telemark and Swedish Highland breeds have very intense heat. Other breeds show very weak heat and may be undetected. Individuals in the Swedish Highland breed have also been shown to have an inherited tendency for cystic ovaries, but the exact mode of inheritance is not known (147). Infantile ovaries are also considered as gene-influenced, although this condition often follows malnutrition early in life (9). An autosomal dominant gene is believed responsible for a gonadless condition in females (99). While constricted vulva and cervix, as well as excessive fat surrounding the genitals, are believed to be genetically influenced, the mode of inheritance is not known.

Crosses of bison and domestic cattle have produced all sterile male hybrids (160).

A study of the relationship between level of milk production and breeding efficiency of 519 cows in 29 dairy herds showed a correlation of -0.04 between milk production and the number of services for conception (30). The repeatability of fertility as measured by nonreturns to first service in a population of half sisters within the same herd of dairy cattle was 0.027. The heritability of nonreturns to first service is 0.004 (73). In another study the heritability of services per conception in dairy cattle was 0.026. The heritability of calving interval was 0 (158). In a study of fertility in a beef cattle herd, over 50 percent of the shy-breeding cows could be identified by the time they reached 4 years of age and approximately 80 percent by 6 years of age (16).

Disease Effects

Disease long has been recognized as an important factor in infertility. Infectious systemic diseases such as brucellosis and bovine tuberculosis have received a great deal of attention in this country. Some of the infectious coital diseases such as contagious granular vaginitis, contagious vesicular vaginitis, trichomoniasis, and Vibrio fetus, are also important but not as well known (253). Estimates of losses in the United States due to brucellosis and vibriosis place the loss in 1953 at $45,000,000 and $137,734,000, respectively (249).

There is evidence that the temporary or yearly variation in bull fertility is due to some disease (94)(264)(147)(109)(213). However, there is also general agreement that disease alone is not the most important factor in many cases. Bacteriological studies of ovaries and reproductive tracts indicate that in all cases of infection about the genital tract, multiple cystic degeneration of medium sized Graafian follicles is an almost constant finding (19). The uterus under the influence of the corpus luteum is much more susceptible to infection than when under the influence of estrogen.

Progesterone promotes conditions in the uterus favorable for bacterial development of infection. This may be allied to the role of progesterone in promoting conditions in the uterus suitable for the developing zygote.

Exogenous estrogen helped to prevent bacterial development. This may explain why cows conceive more readily if allowed two to three months before postpartum service, by which time the heat periods would ensire that any infection introduced at parturition is eliminated (151).

Brucellosis: Sterility is four times more frequent in suspects and eight times more frequent in reactors than in negative animals (192).

In a study of dairy cattle, evidences of vaginitis were observed in 10.2 percent of the cows inseminated. Breeding efficiency for animals exhibiting symptoms of vaginitis was 60 percent compared to 66 percent for those free from this disease. Data available on a limited number of cows indicated brucellosis was an important factor affecting breeding efficiency. Animals in brucellosis-free herds required 1.77 services per conception compared to 2.10 for cows in infected herds (197).

The yearly variation in breeding efficiency indicates that there is a tendency for the years of lowest efficiency to follow years when the percentage of abortion was highest (131).

Vibrio Fetus: Vibrio fetus can be transmitted through artificial insemination and by contact (82). Abortion has been caused experimentally in cattle by injections of Vibrio fetus (70). This disease not only causes abortions during the first six months of pregnancy but also causes poor conception rate (192).

Vibriosis may impair the breeding efficiency of a herd by lowering the conception rate and causing the sale of cows because of sterility as well as by causing abortions.

During the first year following the appearance of infection in a representative herd the incidence of positive reactors and clinical evidence of vibriosis appeared to be greatest and equally distributed in different age groups (209).

Bovine Venereal Trichomoniasis: A study has shown one percent of slaughtered cows positive for trichomoniasis. The disease is characterized by temporary sterility, early abortions, and antepartum pyometra (192). The addition of immune bovine sera to semen did not prevent transmission of trichomoniasis to females and very materially lowered the fertility of the semen (185).

Microorganisms in Bull Semen: It has been suggested that over-all breeding efficiency may possibly be raised by eliminating semen ejaculates of high bacterial plate count (275). *E. coli* has a depressing effect on spermatozoan motility in semen of dairy bulls, rams and rabbits. This effect appears to be chiefly due to an accumulation of hydrogen peroxide in semen - *E. coli* suspensions (276).

Environmental Effects

Season:

(a) Infantile ovaries seem to be more frequent in northern latitudes. Sunlight may be a factor (9).

(b) Season does not have an effect on male fertility (232).

(c) With respect to fertility level, cattle of various ages responded differently and consistently to seasons of the year, the younger and very old cattle being influenced more readily than mature cattle (183).

(d) Winter was the poorest breeding season of the year (183).

(e) Fertility level of the bulls was significantly correlated with length of daylight, their being a lag of 1 to 2 months before the effect of daylight reached its maximum (183).

(f) Highest percentage of fertile matings occurred in April and the lowest in August (208).

(g) In cows, highest fertility was obtained in December, lowest in August or September (192).

(h) The most noticeable effect of season on breeding efficiency was the relatively large number of services required for conception during midsummer, followed by a sharp decrease in the fall (131).

(i) Certain climatic conditions, including temperature and sunshine, appear to affect bull semen. If maximum temperatures are not too high, the high temperature is associated with better semen (3).

(j) Highly significant individual and monthly differences were noted for density and motility of sperm and pH of semen (3).

(k) In Canada, lowest percent of successful services was obtained during winter and spring and highest during summer and fall (184)

(l) The average monthly conception rate was significantly correlated with the monthly average length of daylight, there being a lag of approximately 1 to 2 months before the maximum effect was reached (184).

(m) Temperature changes had no measurable direct effect on the fertility level in Canada (184).

(n) Breeding efficiency of dairy cattle does decline in summer. It is difficult to separate the effect of temperature and light (5).

(o) There is no experimental evidence of an effect of light on cattle fertility (5).

(p) In rabbits, high environmental temperatures do reduce fertility, continuous heat being more detrimental to fertility than intermittent high and low temperatures (194).

(q) In sheep, there is a relationship between the duration of the breeding season and the latitude and altitude of the breed (108).

(r) Romney Marsh ewes were exposed daily to temperatures averaging 105°F for two months prior to start of breeding season. All ewes experienced estrus at the same time as non-heated controls but most of the heated ewes did not lamb (278).

(s) There is some possibility that the degeneration in size and fertility of successive generations of European cattle bred under the hot conditions of the tropics is due to the effects of high air temperatures causing increased body temperature and inhibition of the development of the anterior-pituitary gland in the young animal.

Though succulent or green feeds increase the volume of the semen, they do not increase the number of spermatozoa or their viability.

The number and viability of the sperm in bull semen is in direct proportion to the amount of protein in the ration (110).

(t) Animals kept out of sunlight as long as the 5th generation showed no adverse effects on reproduction (195).

(u) Shorthorn bulls showed the highest percentage of fertile matings in April and the lowest in August (208).

(v) There was no seasonal effect in length of estrous cycle (50).

(w) No definite seasonal effect on duration of estrus was shown (50).

(x) There was a striking difference in the age of sexual maturity of the heifers born in different years. The influence of rainfall on sexual maturity was not significant (215).

(y) Time of day had no effect on ovulation (39).

(z) Breeding efficiency based on 94,935 first services was studied by months and seasons for a period of one year. The mean conception rate was highest in June and lowest in August and February. When the data were summarized by seasons, the average percentage nonreturns was highest in spring, with summer, fall, and winter showing little difference (197).

(1) The percentage of bulls producing inferior quality semen was lowest during the summer months, with fall and winter being intermediate (197).

(2) The over-all conception rate varies with season, the highest conception rates being attained during spring months and the lowest during summer months (234).

(3) Research work indicates that a neurohumoral mechanism is involved in the release of L.H. from the hypophysis and in ovulation in dairy cattle (116).

Age:

(a) Heifers 21 to 24 months of age had a higher conception rate than younger heifers (193).

(b) The highest conception rate was obtained with cows at their 4th or 5th pregnancy (193).

(c) Peak in calf production was reached with 6- and 7-year-old cows. After cows became 9 years of age a sharp drop in calf production was noted (44).

(d) As age of cow increased beyond 7 years, there was an increase in the number of conceptions that occurred later in the pasture breeding season (44).

(e) There were no significant differences in fertility of rams of different ages, and no trend in fertility with increasing age (271).

(f) Bulls under 2 years usually have higher efficiency than bulls 3 to 12 years of age (64).

(g) Fertility was lowest in 2-year-old heifers, highest in cows 5 to 7 years of age, and declined again in cows 9 to 10 years of age (155).

(h) The effect of age of cow on fertility is not significant (16).

(i) Age of bull did not have a significant effect on calf crop percentage (16).

(j) No material difference in the rate of conception for heifers and cows was noted (224).

(k) Cows appear to have the highest fertility at 4 to 6 years of age (192).

(l) After the first gestation, age had little apparent effect upon the breeding efficiency of cows (131).

(m) Heifers being bred for the first time required more services than the older cows (131).

(n) Bulls over 5 years of age showed a distinctly higher number of services per conception than did young bulls when bred to heifers being bred for their first gestation (131).

(o) Young bulls that were bred exclusively to virgin heifers proved more efficient than the whole group of young bulls (131).

(p) With increasing age there is a slight increase in mean cycle length but not in variation (50).

(q) With increasing age there is an average increase in the duration of estrus (50).

(r) Heifers ovulated an average of 3.64 hours sooner than cows that had calved (39).

(s) The percentage nonreturns for 507 virgin heifers was 68, compared to 67 for 2,070 young cows and 69 for 2,768 mature cows. These small differences in conception rate do not indicate heifers are any more difficult to breed than cows that have had one or more calves (197).

(t) Semen showed a steady decline in fertility with advancing age (197).

(u) Average number of services required to establish pregnancy decreased with 2nd, 3rd and 4th calvings (72).

Days after Parturition:

(a) There is a significant effect of date of calving upon interval from calving to postpartum estrus. A cow had 4.6-day shorter interval from calving to estrus for each ten days later in the season that she calved (256).

(b) There was no effect on fertility of interval from parturition to calving or of sequence of heat period at which the cows were bred (256).

(c) The fertility of cows bred following cycles below the average was significantly lowered (251).

(d) A minimum interval of 50 days from calving to first insemination was required for satisfactory fertility (237).

(e) Fertility level increased with length of the post partum to first service interval up to 100 to 120 days (252).

(f) Nearly 2.6 services per conception were required on the average for cows bred within 40 days after calving and 1.7 services per conception when first bred 100 to 120 days after parturition. After 200 days the number of services per conception again increased (252).

(g) There is a definite association between the average length of the return-interval and the fertility of the return cows at second service, long return-intervals being associated with low fertility (54).

(h) Effect of days after parturition on conception (193).

Days after Parturition	Conception Rate (%)
less than 35	29
50-75	55
more than 120	49

(i) Average cows came into heat thirty days after calving (193).

(j) Interval from calving to first estrus averaged 80 days (155).

(k) Dry cows were harder to settle than lactating cows (155).

(l) Rate of conception during a controlled breeding season (224).

Days of Breeding Season	% Cows Pregnant
20	52
40	80
60	90
120	100

(m) Breeding efficiency of cows was not appreciably affected by the length of calving interval (131).

(n) A significant upward trend in breeding efficiency was observed where cows were inseminated at increasing intervals up to 135 days after parturition. A gradual decline in conception rate occurred for those serviced at later intervals. Only 57 percent of the cows inseminated less than 37 days after calving conceived from one service, compared to 76 percent for those bred 106 to 135 days post partum (197).

Conditions of Reproductive Tract:

(a) In a study of 33 normal and 52 difficult-breeding females, the difficult-breeding females showed the following characteristics (229):

(1) Larger ovaries

(2) More acid vaginal and cervical pH

(3) 28.8 percent had obstructions that would interfere with sperm and ova transport

(4) 25 percent had uterine mucosa and cotyledons so seriously eroded that normal fetal attachment could not occur

(b) Poor semen quality may be due to a degree of toxicity of accessory gland secretions (99).

(c) Hemoglobin, glucose, calcium, inorganic phosphorus, lipid phosphorus, and cholesterol in the blood of sterile cows were found to be within the normal range of variation (13).

(d) There is no apparent correlation between the failure to conceive and pH of the vagina (43). The pH of the vagina was quite constant, 86 percent of the readings being between 6.7 and 7.5.

(e) Total N, dry matter, and viscosity of the bovine cervical mucus reach maximum values at about the time of estrus (236).

(f) The vaginal pH varied with the estrous cycle, being high during diestrum and estrus and low during metestrum. The pH varied from 7.0 to 8.9 with an average of 7.9. Vaginal acidity is not an important factor in sterility of cattle (239).

(g) Vaginal temperatures and heart rates were slightly higher during estrus than during diestrus and pregnancy (230).

(h) The pH of mucus varied during the estrual cycle; the lowest pH usually was observed in early estrus (230).

(i) The viscosity of cervical and vaginal mucus was lowest during the first 6 hours of estrus and gradually increased as estrus was prolonged. Penetrability of the mucus by spermatozoa was highest during the first 6 to 10 hours of heat (128).

(j) Survival of bull spermatozoa is dependent primarily upon a variable physiological factor which influences their resistance to adverse environmental conditions. Bulls from Arizona showed less resistance than bulls from Missouri (156).

Management:

(a) In China, bulls in service are fed eggs. In some areas the cow is given wine after service in the belief she is more apt to conceive (207).

(b) In comparing high and low levels of wintering breeding females, the following observations were made (212):

(1) The total number of calves dropped favors the low wintering.

(2) There is a tendency for cows wintered at the low level to calve later than those wintered at medium or high levels.

(c) There is no evidence that inseminating with semen from bulls of another breed is beneficial in increasing conception rate in repeat-breeder cows (56).

(d) No specific injurious effects upon the ability of the animals to reproduce were noted due to feeding heifers alfalfa hay exclusively from 6 months of age through two lactation periods (219).

(e) In a review of animal breeding research in the U.S.S.R., it was reported that female fertility was increased when they were mated to males of two different breeds at 5- to 15-minute intervals (228).

(f) Delayed breeding resulted in an increased number of services for conception (72). It was suggested that delayed breeding, with consequent noninterruption of sexual cycles over a period of years, led to a state of "fatigue" or exhaustion of the anterior pituitary function, with failure of the organ to produce and secrete lutenizing hormone. This is shown by the histological appearance of the acidophilic cells.

(g) Single-bull herds had approximately 6 percent more calves than multiple-bull herds (16).

(h) Time of day and breed of cattle had no effect on ovulation (39).

(i) Of animals weighing above the mean within an age group, 88.2 percent became pregnant. Of those weighing less than the mean, 47.4 percent became pregnant (247).

(j) Starting at 15 months of age, heifers have been kept in high condition, with very restricted exercise, in a darkened stall for 3-1/2 years. They still bred as well as control cattle provided they were regularly bred. Other cattle kept under similar conditions but bred for the first time when they were 4 or 5 years old became difficult breeders or hopelessly sterile (213)(216).

(k) In Africa, native cattle are far less likely to be infertile than imported cattle and their progeny (213).

(l) Large differences in relative fertility of adjacent areas or farms occur. Changes in relative fertility in farms and areas occur without any apparent reason. These are reported as "waves of infertility." More information is needed on the variations of within-herd fertility (86).

(m) Heifers born from cows having access to unlimited sunlight and exercise showed first estrus on an average of 133 days earlier than heifers whose mothers were kept with a minimum of sunlight and exercise (215).

(n) At altitudes of 12,000 to 16,000 feet, only 18 of 50 rams were found to have reasonably good semen (179).

(o) Certain bulls used at first service may affect the conception rate of bulls later used on the return cows (54).

(p) A study was made of the effect of the site of insemination in the reproductive tract on reproductive efficiency of 5,422 dairy cows in Louisiana artificial breeding associations. Sixteen cooperating technicians assisted in the study. Semen from 49 bulls was used. Records compiled by the Louisiana Artificial Breeding Cooperative, Inc., were used in computing breeding efficiencies. Efficiency of reproduction was based on the percentage 60- to 90-day nonreturns to first service (197).

   (1) The nonreturns for the four sites of insemination studied were as follows: combination cervix and body of uterus, 66 percent; middle of cervix, 66 percent; body of uterus, 68 percent; and horns of uterus, 67 percent. These differences were negligible and indicate that no increases in breeding efficiency may be expected by depositing semen beyond the mid-point of the cervix.

   (2) However, when semen was used the third day after collection, breeding efficiencies for intracervical, intrauterine, and intracornual inseminations were 64, 65, and 69 percent, respectively. A significant increase of 5 percentage points in breeding efficiency was observed for cornual as compared to cervical semen depositions when three-day-old semen was used.

(3) A large majority of the cows studied were inseminated during the 2nd, and 3rd six-hour periods after estrus was observed. First service nonreturns for the 1st, 2nd, 3rd, and 4th six-hour intervals after estrus was observed were 69, 65, 68, and 66 percent, respectively. These differences do not indicate any important relation between time of insemination and breeding efficiency for cows serviced within 24 hours after the beginning of estrus.

(4) Due to the small number of services made during the 1st six-hour interval, the average breeding efficiency for cows serviced during the 3rd interval (12 to 18 hours after estrus observed) was considered highest, with those inseminated during the 3rd and 4th intervals only slightly lower.

Application:

(a) The average expectancy of normal cows settling in one service is about 70 percent as far as the cow is concerned (64).

(b) Over 50 percent of the shy breeders could be identified by the time they reached 4 years of age, and approximately 80 percent by 6 years of age (16).

(c) There was a tendency for cows to repeat their breeding performance. A record of the breeding performance over a period of two years should be sufficient for the elimination of poor breeding cows (155).

(d) The correlation between breeding efficiency for consecutive years was 0.084. The predictability of breeding efficiency of herds as units was about the same as that for cows (77)(78).

(e) Only 9.3 percent of the "problem herds" were problem herds the next year (77)(78).

(f) In a large range beef cattle (Angus) herd the heritability of calving interval was (41)(42):

(1) Paternal half sib = 0

(2) Intra-sire daughter-dam regression = -.18

(3) Repeatability = 0

Components of environmental influence of calving interval:

Sequence = 17.5% of total variance
Years = 6.7%

Treatments

Freemartin: Therapy not successful (9).

Infantile Ovaries: Injection of follicle stimulator followed by injection of lutenizer (9).

Hypoplastic Ovaries in Adult: Injection of follicle stimulator reinforced by massage treatment (9).

Subestrum (animals do not come in heat, and small follicles are present in the ovaries but no corpora lutea): Injection of follicle stimulator plus massage (9).

Persistent Corpora Lutea: Squeeze corpora lutea from the ovary (9). Injection of E.C.P. (81)(83). Pressure plus hormone (18). Fresh ovarian extract (73)(97).

Nymphomania: Intravenous injection of pituitary for a lutenizing effect (9).

Repeat Breeder Cows (no diagnosed pathological condition): No rational therapy (9). No rational therapy (132). Ascorbic acid therapy (203)(204).

The use of hormone therapy in sterility is definitely limited and the results are uncertain (123). Gonadotrophins may be of some value, but the ova from gonadotrophic-treated animals are not always fertile and often the results are disappointing (4). A relatively high incidence of persistent heat has been observed following intramuscular injections of E.C.P. (83). Actually, it is extremely difficult to evaluate the results of a treatment because of the many related and confounding conditions present (123).

The average level of estradiol benzoate required to bring ovariectomized heifers into heat is 600 rat units daily for 3 days. The duration of heat is usually less than one day even though the injections are continued. This low threshold is probably reached early in the development of the Graffian follicle in the normal cow. "Estrous block", apparently in the central nervous system, then sets in, so that the cow is out of heat before ovulation (11).

The mean dose of stilbestrol needed to bring the ovariectomized heifer in heat is 0.255 mg. Implanted diethylstilbestrol pellets cause hypertrophy of the putuitary and adrenal glands in both steers and heifers (61). In a test with Holstein cows, the effect of diethylstilbestrol dipropionate was studied in relation to postpartum changes (49).

The injection of 20 mg. of the hormone failed to produce a demonstrable effect on the intervals from calving until:

(a) Involution of the uterus

(b) First succeeding ovulation

(c) First succeeding estrus

There was no effect of treatment on the occurrence of cystic ovaries or percentage of cows conceiving upon first service.

Estrogenic substances will tube-lock ova if used at the time of fertilization (270). Large amounts are necessary if injections are delayed.

"Difficult to settle" cows were divided into three groups for therapy comparison (59):

Group I

Given douches of physiological saline during estrus, a short time before breeding.

Cows and heifers treated	41
Average number of times bred before treatment	4.6
Average number of times bred after treatment	1.9
Cows becoming pregnant	38
Cows failing to conceive	3

Group II

Treated by ovarian massage. Included cows and heifers which did not show recognizable lesions of tubular genitalia or ovaries, but whose ovaries did not show evidence of recent function. Some of the younger animals in this group had never been observed in heat, though all were past customary breeding age.

Cows and heifers treated	15
Average number of times bred before treatment	1.9
Failed to conceive (bred twice)	14

Group III

Animals showed no lesions of genitalia. Most of the cases had been previously treated with saline douche or ovarian massage without apparent benefit.

Tissue extract was commercial product said to be obtained from ovaries after removal of corpus luteum. Animal injected with 10 cc. shortly before being bred.

Animals treated	17
Average number of times bred previous to treatment	4.5
Cows which conceived following treatment	10
Average number of times bred	1.6
Cows which failed to conceive following treatment but later conceived	6
Permanently sterile	1

Douches of physiological saline solution and ovarian massage were of value in treating some cases of so-called functional sterility.

Hemoglobin, glucose, calcium, inorganic phosphorus, lipid phosphorus, and cholesterol in the blood of sterile cows were found to be within the normal range of variation (13).

The extensive use of artificial insemination in range cattle awaits a means of synchronizing the unrelated estrous cycles without excessive labor cost or daily treatment with hormones (190). Progesterone has been used in an attempt to achieve this synchronization. Injections of progesterone prevented estrus and ovulation during injection period of 14 to 19 days (248). Individuals which were slaughtered within ten days posttreatment showed recent ovulations.

The subcutaneous injection of small doses (5 to 10 mg.) of progesterone at the beginning of estrus hastens the ovulatory process in dairy heifers.

Both the length of estrus and the time from end of estrus to ovulation are significantly reduced. These results and histological changes occurring in the ovary at estrus suggest that progesterone produced by the ovary before ovulation normally plays a role in luteinizing hormone release and ovulation in the cow. These facts may be significant in an understanding of the deranged physiology of the nymphomaniac cow and in other types of infertility in farm animals (119).

Single applications of progesterone in varied dosage indicate that follicular development is inhibited for at least 11 to 13 days postinjection, at which time the inhibitory level of exogenous progesterone is absent and normal follicular development occurs (190).

In general, it appears that accurate breeding records should be kept for all females and if a cow does not conceive after three services a thorough examination should be made (6).

In a study of sterility in the bull, the masculine characteristics are of themselves no criterion of the breeding efficiency of the animal (176). A practical method of electric ejaculation has been developed which can be used routinely for the collection of semen (172). The determination of rate of impedance changes in freshly ejaculated bull semen provides the most practical method for routine daily semen appraisal (65).

Weekly injections of 100 to 200 mg. of testosterone cyclopentylpropionate had no effect on semen characteristics or sexual behavior of beef bulls (188). Cortisone and hydrocortisone did increase the concentration and decrease the percentage of abnormal spermatozoa of two bulls with poor quality semen (68).

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