# THE EFFECTS OF TEMPERATURE AND EXERCISE UPON FERTILIZATION RATE AND EMBRYONIC MORTALITY IN EWES

by

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## INTRODUCTION

The natural mating season of the common breeds of sheep is limited so that a portion of each year is limited with regard to marketable lambs. Lamb must be available in all seasons if the producers expect to keep pace with the changing era of expanding economy and increased population.

Where income is primarily derived from the sale of fat lambs, a late or scattered lamb crop is extremely undesirable. Producers attempt to breed ewes early in the summer so that spring lambs may be marketed at a price advantage and before summer heat retards good pasture. Husbandry problems are increased due to a lack of uniformity of age and size when lambing is scattered.

Concern should be directed to production factors resulting in year-round lamb distribution. Factors needing more intense study are: (1) a more complete understanding of heat-cycle manifestations of breeds and types of sheep, and fertility levels under normal conditions of maintenance, and (2) fundamental knowledge of factors controlling reproduction efficiency is needed so management practices can be altered to accomplish improved breeding efficiency.

This experiment was designed in an effort to determine the effects of temperature and exercise upon fertilization rates and fetal mortality among ewes. One group of ewes was subjected to a lowered environmental temperature by placing them in an air-conditioned room. The control ewes were maintained under normal summer temperatures. One-half of the ewes from both groups were force-exercised on a controlled mechanical exerciser.

## REVIEW OF LITERATURE

### Ovulation and Embryonic Development in Sheep

Reproductive efficiency is governed by numerous sequential steps. These are estrus, ovulation, fertilization, embryonic development and parturition.

Before discussing the effects of climatic factors on these steps, it is only appropriate to discuss the normal processes of reproduction in sheep.

The approximate time of ovulation in the sheep occurs late in the estrus period, as the ewe nears the termination of heat (Clark, 1934 a), (Green and Winters, 1935).

Green (1947) bred ewes at approximately five-hour intervals from zero to 54 hours before the end of estrus. There was no evidence of variation in fertility as related to the time of insemination. It was discovered that ram sperm retain their ability to fertilize the ovum of the ewe after approximately two days' residence in the reproductive tract of the ewe.

The unfertilized sheep ovum resembles other mammalian ova in its morphology (Clark, 1934 b). Allen et al. (1931) identified polar bodies in several sheep ova. These ova were recovered from ewes that had been slaughtered from four to 18 hours post estrus. The life of the unfertilized sheep ovum is probably less than 24 hours (Green and Winters, 1935).

McKenzie and Phillips (1930) found that when ewes were bred later than 14 hours after estrus began, to rams classified of only fair fertility, 70 percent conceived while only 35 percent of the ewes bred before that hour settled. When a highly fertile ram was used the percentages were 100 and 66, respectively. The later part of the heat period appears to be the optimum time to breed.

The number of ova ovulated in the ewe at any single estrous period is apparently not in excess of the usual number of births at the lambing season (Hammond, 1921). Two follicles on the same ovary or on different ovaries do not necessarily ovulate at the same time. Clark (1934 b) and Murphee et al. (1944) observed normal embryos which ranged from two to 16 cells within the same ewe. This reveals further evidence to substantiate the fact that all ova may not be released and/or fertilized simultaneously, thus embryos in the same reproductive tract may be of somewhat different ages.

Green and Winters (1945) and Clark (1934 b) studied prenatal development of sheep ova and reported the time required for each cleavage stage of development to be: (1) two-cell, 39 hours; (2) four-cell, 42 hours;) (3) eight-cell, 42 to 44 hours; (4) 16-cell, three days and seven hours; (5) 32-cell, four days and 17 hours; (6) blastula formation, six days and 17 hours; (7) zona pellucida disappears, end of sixth day and start of seventh day; and (8) spherical blastocoele, eight days, 18 hours. They observed that the ova reached the uterus during the fourth day and, when fertilized, at about the 16 to 32 cell stage. These workers also observed that the blastocyst attached itself to the wall of the uterus on about the tenth day. Attachment was not complete until the 34 day of pregnancy (Green and Winters, 1945). Robertson (1951) found that when pregnant sheep uterus is dissected while submerged in normal saline solution before the 18th day of pregnancy, the embryos invariably float free, indicating that attachment before this stage is extremely loose.

Henning (1939) conducted an extensive study of prenatal and postnatal sex ratios in several breeds of sheep. He found no statistically significant difference between the sex ratios of the live and dead fetuses, or of fetuses deriving from ova from the right or left ovary, or both. There was no evidence of a significantly higher mortality of either sex during the intra-uterine period. The prenatal sex ratio found in sheep is essentially one of equality (50.9% ± 1.60). Henning found ovulation in the ewe to be appreciably more frequent in the right ovary (58.58 ± 1.58%) than in the left.

Robertson (1951) found that after 20 or more days of pregnancy, the liviability of embryos could be accurately determined by gross examinations, whereas under 18 to 20 days this prediction required microscopic study. Robertson found, upon macroscopic and microscopic examination of the embryos from 51 ewes, that all the embryonic mortality had occurred before the end of the fourth week, with only one exception. The peak in mortality rate occurred between 17 and 19 days. Once placentation has proceeded to the extent of the formation of the allantochorion, even though attachment is still rudimentary, the chances of subsequent mortality loss are apparently very small. Robertson found no dead fetuses or fetuses undergoing resorption in ewes during the last half of pregnancy; however, two percent of the ewes aborted.

## Climatic and Topographic Factors Affecting Fertility

It has long been recognized that the reproductive behavior of sheep is influenced very materially by changes in environment. Heape (1899), Clark (1934 a) and Bonfert (1933) reported that environment plays an important part in the fertility of sheep. Heape observed certain seasons to be more conductive to high fertility than others.

Phillips and Spencer (1948) transferred Southdown sheep from Beltsville, Maryland, to Middlebury, Vermont, and another flock from Middlebury to

Beltsville. Both groups were lighter with regard to body weight at Middlebury, and these also produced fewer and lighter lambs at weaning. There were no apparent differences between feeding or management practices at the two stations.

Factors interfering with fertility of sheep and the uniformity and date of lambing are: absence of estrus and/or ovulation, failure of fertilization, resorption of the fetus or abortion (Terrill and Stoehr, 1939). Dutt (1951) slaughtered 90 crossbred yearling ewes three days after breeding and found that all ewes had ovulated. The ovulation rate was 1.47 per ewe and 96.2 percent of the total ova were recovered of which 55.1 percent had been fertilized. At this time 20.5 percent of the fertilized ova were classified as abnormal. In a later experiment, Dutt (1960 a) found that one-third of the fertilized ova failed to develop into full term embryos. He also found the percentage of morphologically abnormal fertilized ova was highest early in the breeding season following the transition from anestrus. Dutt did not observe abnormal cyclic patterns, indicating embryonic mortality occurred at a very early stage of development.

Dutt (1954) designed an experiment to determine the nature of reproductive failures among ewes bred early in the estrual season. He used crossbred, dark-faced, northwestern ewes and bred them during the period from the last week in August through September. Embryonic death loss was considered to be the difference between the observed fertilization rate and actual lambing rate. Other work by Dutt appeared to indicate that failure of ovulation did not represent a major factor in the reproductive efficiency of ewes bred at the beginning of their normal estrual season. Dutt determined fertilization by two or more blastomeres of equal size. Most of the cleaved ova were found to be in the four to eight cell stage of development three days after breeding. There was little difference in the percentage of ewes in which embryonic death occurred (30.0% vs. 30.5%) when semen was divided into two groups on the basis of motility rating: (1) from 20 to 50 percent motile cells; and (2) 60 percent or more motile cells. Ewes which were inseminated with .2 ml of undiluted semen of each motility group represented the two experimental groups. Of all ova recovered (96.2 percent of the total corpora lutea), both cleaved and uncleaved, 20.1 percent were abnormal three days after breeding. Dutt reported the embryonic death loss of fertilized ova to be 24.3 percent, thus, about one of every four cleaved ova failed to develop to full term lambs. Hulet et al. (1956) also studied early-season infertility in sheep. Ova from 77 western ewes were studied. Fertilization failure was 64.3 percent in the ewes bred prior to September 16, and 34.5 percent for ewes bred after September 16 until October 25. Morphologically abnormal ova included 16.7 percent and 2.9 percent for early and late bred ewes respectively. These workers reported embryonic mortality to be 28.6 percent for ewes bred early and 9.9 percent for ewes bred late. Embryonic mortality between the 18th day of pregnancy and lambing date was 9.3 percent.

## Body Temperature and Respiration Rate

The average body temperature for sheep has been reported by numerous workers. Reported values are presented in Table 1.

Variations in body temperature are due to age, sex, season, time of day, environmental temperature, exercise, eating, digestion and by drinking water (Dukes, 1943). Hobday (1896) noted that the location of the thermometer makes an appreciable difference, sometimes as much as one degree. He compared four

Table 1. Normal body temperatures as reported by different authors.

| Author | Temperature - degrees Fahrenheit Average | Range |
|---|---|---|
| Clawson - 1928 | 102.25 | 98.0 - 106.0 |
| U.S.D.A. - 1900 | 103.1 | not reported |
| Lee - 1948 | 102.0 | Upper safe limit - 107.0 - 110.0 |
| Dukes - 1943 | 102.3 | 100.9 - 103.8 |
| Heilbrunn - 1943 | 102.0 - 102.8 | not reported |
| Hobday - 1896 | not reported | 103.4 - 104.4 |
| Smith - 1889 | not reported | 102.2 - 104.0 |
| Smith, F. - 1908 | 102.8 | 101.3 - 105.8 |

inch thermometers with others five or six inches long. The six inch thermometers registered a higher temperature than did the four or five inch thermometers. He also observed that the body temperature increased when excitement or struggling was exhibited by the animal while the temperature was being taken.

Clawson (1928) recorded 8,526 rectal temperatures of 514 normal sheep at an altitude of 8,000 feet in Utah under summer conditions. Ewes and wethers of grade Rambouillet, Cotswold and Lincoln breeding were used in this study to determine the effects of sex, age, and confinement on the body temperature. Rectal temperatures were recorded with a mercury thermometer at a depth from three to four inches. The mean temperature was 102.3$^{\circ}$ F. with a standard deviation of 1.0$^{\circ}$ F. Clawson reported that sheep under observation for the first time required a week or more for the temperature readings to reach a fairly constant level. He also reported the body temperature of the sheep decreased with age, confinement, and a change from green feed to dry lot. Nervousness or fear also caused an increase in body temperature. The lowest temperature reported by Clawson was 98° F. and the highest was 106.7° F.

Riek et al. (1950) observed that Merino ewes were more heat tolerant than Corriedales. Increased feed intake caused both breeds to become more heat sensitive. Miller and Monge (1946) also reported differences in body temperatures due to breeds among sheep. Average temperatures recorded for the various breeds in southeast Texas were: Southdown, 103.0° F.; Hampshire, 102.8° F.; Merino, 101.9° F.; and Rambouillet, 102.0° F. All breeds showed significant increases in body temperature concurrent with increases in ambient temperature; however, when exposed to comparable environments, the mutton breeds exhibited earlier and more pronounced rises in body temperatures than the fine wool breeds.

Lee (1950) compared sheep with other quadrapeds and observed that sheep were more tolerant to the effects of body temperature rise than the cow, dog, pig, cat, or rabbit. Lee found that when body temperature was 103.0° F., sheep were in a state of rapid respiration. At 106.0° F. they were in a state of panting. A rectal temperature of 108.0° F. caused extreme agitation and at 109.0° F. gasping ensued. At 110.0° F. they began to stagger.

Sheep do not seem to differ from other mammals in their ability to withstand cooling and have been reported to have a minimum live body temperature of 60 to 70° F. (Lee, 1948). Under natural conditions, with moderate wool growth, sheep can thrive in the open at an environment of -40° F. (Lee, 1950). This tolerance of extreme cold is at least partially due to the insulating properties of wool.

Heilbrunn (1943) found that temperature has a marked effect on the rate of respiratory exchange, both in cold-blooded and in warm-blooded animals. Respiratory exchange is due to the mechanism of heat regulation. At very high body temperatures this regulation breaks down and the respiratory exchange increases with body temperature.

Regan and Richardson (1938) studied the reaction of dairy cows with regard to changes in environmental temperature. They found that as environmental temperature increases there is a rise in the respiration rate and a decline in the pulse rate. The rectal temperature, however, remains constant until an environmental temperature of 70.0° F. is reached, after which, it also rises. These workers found that when the environmental temperature rises above 80° F., there is a definite change in the amount and chemical composition of milk produced. Gaalaas (1945) also reported a relationship between the body temperature and environmental air temperature for Jersey cows. The average body temperature varied from 101.0° F. at an average environmental air temperature of 50° F. to 103.2° F. at an average environmental air temperature of 95° F. As the ambient temperature increased, so did the respiration rate.

Heitman and Hughes (1949) found that swine, maintained in a psychrometric room, displayed increased body temperatures and respiration rates as the air temperature was increased.

Dukes (1943) reported the normal respiration rate to be 12 to 20 respirations per minute for sheep at rest. He indicated variation in respiration rate due to: body size, age, exercise, excitement, environmental temperature, pregnancy, and degree of fill of the digestive tract. Heilbrunn (1943) reported a corresponding respiration rate of 10 to 30 per minute. The United States Department of Agriculture Yearbook (1900) indicated 20 to

30 respirations per minute. Average respiration rate per minute for ewes maintained at $88^{+o}$ F. is reported to be 150 per minute as compared to 28 per minute for ewes maintained in a cooled room (Dutt and Bush, 1955). Increased respiration rate is apparently a response by the ewes to maintain normal body temperature by heat dissipation through expelled air.

### Temperature - Its Effects on the Estrus Cycle, Embryonic Death and Lambing Performance

The exact role of environmental temperature in seasonal variations in fertility of cattle, sheep, swine, and laboratory animals is unknown. In regions where high environmental temperatures persist over prolonged periods, it appears that the general level of fertility declines during mid-summer in most farm animals. There have been numerous investigations of the cause for reproductive failures in different species as related to seasonal variations.

Johnson (1924) found the breeding season of ewes to be delayed by hot weather. When unbred ewes were gathered in the spring and sent to the mountain ranges, where a decreased environmental temperature is brought about by high elevation, most of the unbred ewes appeared to breed and conceive. Seath and Staples (1941), studied the breeding records of two North Louisiana dairy herds, and found that hot weather was detrimental in reproductive efficiency. They found seasonal differences in the rate of conception for both herds. In each herd the summer months required more services per conception, the best season for conception rates occurred during the winter months.

Fertility in sheep has been found to be affected by altitude, which is probably associated with ambient temperature. Sheep acclimatized to high altitudes since the seventeenth century have nearly 100 percent fertility (Monge, 1943). Fertility in these ewes was reduced to 30 percent when mated to purebred imported rams from near sea level regions. Fertility was increased to 60 or 70 percent with the progressive acclimation imported rams, but rarely exceeded this level.

The effect of temperature on the onset of estrus in anestrous ewes has been studied (Dutt and Bush, 1955). They found that onset of the breeding season was hastened by placing anestrual ewes in a cool environment. Previous work reported by McKenzie and Phillips (1933) indicated no relationship between temperature and the onset of the breeding season; however, artificially cooled ewes were maintained in an iced room for only the first ten days of August. The effect of low temperature imposed on ewes earlier in the summer was not included in the study. Woody, et al. (1959) found little difference in the number of anestrual ewes exhibiting estrus during the first 18 days after a group of ewes was placed in an air conditioned room (65° F.) compared to control ewes maintained outside during July and August.

Dutt et al. (1959) exposed ewes to a 90° F. environmental temperature on the twelfth day of the estrus cycle and found the fertilization rate of these to be significantly lower ($P < 0.01$) than for control ewes during October. The heat treatment was observed to increase in the percentage of abnormal ova. Only 3.7 percent of ova from control ewes examined three days after breeding were classified as morphologically abnormal, compared to 44.2 percent for those from ewes subjected to the heated room. Dutt also observed that embryonic mortality expressed as the percent of fertilized ova that failed to survive to be significantly higher among ewes exposed to the 90° temperatures before breeding compared to the control ewes. For control ewes, the estimated embryonic mortality was 4.0 percent compared to 91.7 percent for ewes exposed to the heat treatment before breeding. He also noted that rectal temperatures and pulse rates of the ewes in the heated room were significantly higher ($P > 0.01$) than control ewes. The shorn ewes in the heated room had lower average rectal temperature and pulse rates than the unshorn ewes. Dutt found that shorn ewes exposed to heat displayed higher fertility and lower embryonic death loss than unshorn ewes. Stress conditions seemed to impair fertility and caused an increase in early embryonic mortality.

Alliston and Ulberg (1959) studied the influence of ambient temperature on early embryonic mortality by techniques involving embryo transfer. Five days prior to predicted estrus, all ewes were randomly allotted to and placed in environmental chambers maintained at either 70° or 90° F. with approximately 65 percent relative humidity. The higher of the two environmental temperatures caused a significant increase in rectal temperature (104.4° F. vs. 103.0° F.) and respiration rate (136/minute vs. 66/minute). Thirty-four corpora lutea with 24 transferable embryos were produced in 26 donor ewes maintained at 70° F. contrasted to 22 corpora lutea and 9 transferable embryos produced in 16 ewes maintained at 90° F. When both donor and recipient ewes were maintained at 70° F., 5 of 11 transferred embryos resulted in successful pregnancies as compared with 6 of 13 when donor and recipient were maintained at 70 and 90° F., respectively. No successful pregnancies resulted from 9 transfers in which donor and recipient were held at temperatures of 90 and 70° F., respectively.

Yeates (1953), experimenting with Romney Marsh ewes, found that ewes subjected to a temperature of 92° F. during the fall and winter months produced lambs which were highly significantly lighter in weight than control ewes. He concluded that although high temperature is apparently without effect on the incidence of estrus in ewes, it is inimical to optimum gestation. Heitman et al. (1951) studied the effects of elevated ambient temperature on pregnant sows. The sows were at the 85th day of gestation when placed in a temperature chamber at 70° F. and a relative humidity of 50 percent. Temperature was increased until there was a definite body (rectal) temperature increase among the sows. They were maintained at that environmental temperature for 24 to 72 hours. These workers found that the respiration rate and body temperature of the pregnant sows increased markedly concurrent with an increase in ambient temperature. Of 13 treated pregnant sows, 11 farrowed normal pigs, one sow died from heat prostration while carrying a litter which was apparently normal, and one sow aborted.

Wilson et al. (1959) studied environmental factors which they believed might influence lambing rate among Rambouillet ewes. These workers simulated various seasonal conditions characteristic of the month of October during the actual months of May and June and found the most favorable treatment situation, toward ewe fertility, was one including both October's temperature and length of day. The second highest lambing group was one subjected only to a temperature comparable to October. Percentage of ewes lambing in the control group was by far the lowest of all groups studied. Woody et al. (1959) found no difference in the number of ewes lambing from an air conditioned group and a control group of ewes during summer months. There was, however, a difference in the average number of services required per conception, 1.73 and 1.24 for the air conditioned as contrasted to 2.33 and 1.94 for the control ewes in 1958 and 1959, respectively.

Inkster (1959) found that the shearing of ewes increased the chance of survival for the fertilized eggs. A higher percentage of the shorn ewes reared lambs (81.6 vs 60.2%). He also slaughtered shorn and unshorn ewes on two to four days after breeding and found that the percentage of ewes with fertilized eggs, on the basis of first and second services, much higher among the shorn ewes.

The inability of the ram to produce viable fertile sperm in quantity has been believed to be a primary reason for ewes failing to conceive readily during the summer breeding season. Dutt (1960 b) obtained data on ewes slaughtered three days after breeding and found that 50 percent of the ova had not been fertilized.

Dutt (1954) studied environmental temperature in relation to fertility of Southdown rams early in the breeding season. He found that the fertility of rams maintained in air conditioned rooms (45 to 48° F.) greatly improved over that of controls. Fertilization rates were 26.0 percent for ewes bred to control rams and 64.2 percent for ewes bred to treated or cooled rams. Lambing percentages were 14.3 percent and 50 percent respectively. Dutt estimated embryonic mortality to be 69.2 percent for ewes bred to control rams and 41.2 percent for ewes bred to rams kept in an air conditioned room. Similar results were found by Simpson et al. (1959). Rams which were subjected to an air conditioned room were more fertile than rams which were treated similarly but did not have access to a cooled room. These workers found highly significant differences due to treatment in ejaculate volume, percent motile sperm, sperm concentration, and percentage of abnormal spermatazoa when weekly semen collections were studied.

Nelson (1958) found that rams which were in active breeding service and subjected to daytime cooling generally exhibited a greater improvement of fertility during the summer than did treatment groups which were not cooled. High summer temperatures caused adverse effects on semen quality as measured by semen motility, ejaculate volume, sperm concentration and percentage of abnormal spermatazoa. He also observed seasonal changes in semen quality, as evaluated by semen quality studies of rams undergoing semen collection during the fall, winter, and spring months. Results indicated that medium to high fertility prevails in rams from September through the first two weeks in December. From January until the middle of April the rams appeared to possess low fertility.

Dutt and Hamm (1957) studied the effects of elevated environmental temperature and shearing on semen quality and fertility of rams by placing rams in a heated room (90° F.) for a one week period in January. Motility of sperm was affected adversely, by heat treatment, especially in the unshorn group, which actually produced the lowest percentage of motile cells during the fifth week after treatment. Volume of semen was apparently not affected. Percentage of abnormal spermatazoa increased in both experimental groups during the study. They found sperm concentration decreased more appreciably in the unshorn than in the shorn rams. Semen quality after heat treatment appeared to return to normal in eight weeks. In a similar study, Young (1927) found that by running water, heated to 115° F., over the guinea pig scrotum for 30 minutes caused an immediate degeneration of the germinal epithelium. The effect prevailed for twelve days. He found most spermatids lost their viability within a few hours after the heat treatment. The most pronounced effect on reproductive capacity was the increase in sterile matings, which reached a peak between the forty-fourth and seventy-fifth day after treatment. No effect on the libido of the males was observed. Ogle (1934) found that white mice subjected to a warm humid environment displayed lowered fertility in three ways: (1) a lower percentage of matings that resulted in pregnancy; (2) smaller litter size; and (3) reduced viability of offspring. He insisted that the most efficient reproduction resulted from a cool environment and that the onset of puberty and reproductive maturity was earlier among individuals in this same environment.

Even though the reasons for the differences observed in these studies remain somewhat obscure, the results suggest the importance of variations in adaptability to environment in sheep production and emphasize the need for much greater attention to problems of this nature in animal husbandry research.

## Light

Natural light exposure or day length is closely associated with seasonal temperature changes. "Since maximum temperatures and maximum day length coincide, the separation of these two factors under normal conditions of livestock management is not possible." (Andrews, 1953)

The onset of reproductive activity in the ewe is believed to be engendered by a light-sensitive retino-pituitary mechanism (Yeates, 1949). Yeates regarded the anterior pituitary as the organ activated by the light stimulus. Light impulses are received by the eye, from which they are probably passed to the hypothalamus along neural pathways, final transmission to the pituitary being possibly by humoral means via the hypophysial portal vessels. He reported the onset of the breeding season to be a response to decreasing daily amounts of day light exposure and occurs 13 to 16 weeks after the change from increasing to decreasing day length. In the same sheep the cessation of the breeding season is a response to increasing daily amounts of light and occurs 14 to 19 weeks after the change from decreasing to increasing day length. Yeates believed that the intensity of artificial light employed for the experimental modification of the breeding season of the ewe is unimportant once a certain, relatively low, candle-power is reached.

It has been demonstrated by Bissonnette (1932) that the anterior pituitary exercises a direct control over the development and activity of the gonads, and that the pituitary is necessary to the light-gonadal response. Hill and Parkes (1934) found that hypophysectomized female ferrets were incapable of reacting to the stimulus of additional illumination. These investigators assumed that the response to light treatment is caused by stimulation of the anterior pituitary which in turn activates the reproductive organs. Whitaker (1940) found that white footed mice blinded by the removal of eyes, no longer exhibited the normal tendency for cyclic breeding activity. Nalbandov (1958) reported that ferrets maintained in complete darkness and blinded ferrets exhibited estrus during the same season as control animals kept under normal light conditions. Nalbandov also reported that cows which were blind because their optic nerves were completely atrophied, as a result of vitamin A deficiency, showed normal reproductive cycles, including normal rates of ovulation and fertilization.

Baker and Ranson (1932) found that shortening the daily exposure of light from 15 to 9 hours caused a near cessation of reproduction in the field mouse. Bissonette (1932) induced complete estrus in female ferrets several months prior to the normal breeding season by subjecting the animals to six additional hours of artificial light exposure beyond the normal day-light hours during the winter.

The reversal of the normal seasonal breeding pattern of sheep and deer was observed by Marshall (1937) after these animals had been transported from one hemisphere to another. He concluded that the initiation of the breeding cycle was associated with a progressive decrease in day length and other environmental factors. Yeates (1949) also discussed the phenomenon of the reversal of normal breeding season of grade Suffolk ewes subjected to a modification of natural light exposure.

These original investigations led to later experimentation with a variety of species. It has been demonstrated that the majority of animal species possessing a seasonal breeding behavior show sexual response to seasonal changes in the length of day and night. The literature concerning the initial investigations of light and its effects on reproduction in animals was reviewed by Dutt (1960 b).

Experimental evidence indicates that the breeding behavior of goats is controlled by changes in natural light exposure. The natural diminution of light exposure is important in inducing sexual activity in the female goat (Bissonnette, 1941). Female goats were subjected to artificially increased light exposure from January until April and decreased light exposure from April until July. Following this treatment they were returned to natural light exposure and mated with males which had been similarly treated. Young were born to these treated goats in December, two months before parturition occurred in untreated, control females.

Rowan (1925) suggested that seasonal changes of reproduction in birds was not related to temperature but instead to light changes. In succeeding experimentation, Panquite and Thompson (1940) reported that the use of artificial light in poultry houses during winter would successfully alter the normal pattern of egg production in fowls. It is the general consensus that seasonal trends in egg production, rather than increase in total production, is affected by artificial alteration of light. Nalbandov (1958) agreed that in chickens there is a definite correlation between the rate of egg production and the amount of daily light exposure. Whetham (1933) summarized data relating variations in length of day light exposure at different geographied latitudes on egg production in fowls. He postulated that the pituitary gland appears to be stimulated by changes in light-dark ratio rather than by quantity of daily light. Hafez (1952), in experiments with sheep, also found that the ratio of darkness and artificial light could produce the onset of estrus or anestrum. Hammond (1952) studied the effects of various schedules of completely artificial light, of constant intensity, on incidence and maintenance of estrus and on pelt changes in ferrets. These experiments were conducted from October 20 to November 8. He found that when ferrets were subjected to a single continuous daily period of light exposure, estrus terminated and the animals moulted into a winter pelt.

The effect of artificial light exposure on reproduction in seasonally breeding animals has been demonstrated. Season variations in ram fertility and spermatogenesis also appears to be controlled by the light environment (Yeates, 1949). He reported that the summer decline in ram libido and semen quality, which occurs under natural condition, may be converted to a period of high fertility by an artificial reversal of seasonal light conditions.

Yeates (1956) found that the breeding season of Merino sheep could be reversed by artificially reversing the seasonal trend of daylight duration. He also observed ewes to undergo normal reproduction as a result of an altered breeding season. Sykes and Cole (1944) gradually decreased the daily light exposure environment of a group of ewes beginning in the latter part of March and extending through April and early May until a total deficiency of six hours of daylight was created. They found that most of the treated ewes exhibited estrus and were bred at least once and possibly twice during May and early June. All ewes that conceived gave birth to lambs in the early part of November, or at a time four to five months earlier than normally expected.

A gradually decreasing plane of light and increasing plane of darkness is not an essential factor for stimulating the onset of estrus in sheep according to Hart (1950). Hart found that a standard and regularly maintained rhythm of short-light and long-dark will stimulate the onset of estrus. A ratio of one part light to two parts or more of dark is sufficient to simulate the effect. He found that the induced estrus cycles conformed to those of the normal breeding season. The induced estrus was also associated with the ovulation of normal ova. He reported no apparent depressing effects on milk yield associated with the artificial light-dark induced lactation.

The most important role of light in governing reproductive functions may lie in its ability to synchronize reproductive events in all the members of a local population, causing them to be in similar reproductive states at any time of the year (Nalbandov, 1958). Without the synchronizing effect of light, reproductive rhythms would still be possible, but reproductive efficiency would be greatly impaired, for the periods of reproductive readiness in different individuals would be out of phase, and their coincidence would be purely a result of chance.

## Exercise

Environmental factors other than air temperature affecting the body temperature of sheep were observed by Quinlan and Mare (1932), who reported that body temperature of the Merino ewes increased 0.9° F. following a short period of fright, and approximately 0.1° F. for each 200 yards they were forced to walk at a rate of 0.3 to 0.4 miles per hour. They also found that the body temperature of the Merino ewe exhibited diurnal variation, being highest at night and lowest in the early morning. The effects of exercise, excitement, and confinement on the body temperature of sheep have also been reported by Dukes (1943), Hobday (1896) and Clawson (1928). Hobday (1896) found that the rapid driving of sheep around loose in an open pen for one minute caused a rise in body temperature. Forced driving for five minutes increased the body temperature 1.7° F. and the animals sweat profusely around the tail and anal region. At the end of a 30 minute exercising period, the body temperature rose 1.9° F. Hobday frightened and violently pulled sheep about individually for three minutes and found an average body temperature rise of 1.6° F. seven minutes after the treatment was terminated.

The effect of exercise on the quantity and quality of semen produced by dairy bulls was studied by Lepard (1941). Four bulls were exercised during a 12 week period on a mechanical exerciser for 40 minutes each day. The average ejaculate volume was slightly, but insignificantly, higher for exercised bulls than control bulls. No significant differences were noted between the semen of two groups with regard to sperm morphology, concentration of sperm cells, and viability of the sperm at 40° F. Conception rates obtained through use of the semen of the two groups of bulls also followed the same general trend.

Dowling (1956) studied heat tolerance among cattle and found that Shorthorn bulls which had heavy hair coats could withstand exercise much better than bulls with a thin hair coat. Bulls with a heavy hair coat had an average body temperature of 106.0° F. following 30 minutes of exercising. The bulls which reached the higher temperatures appeared to have nearly reached their physiological limits.

## MATERIALS AND METHODS

Forty-eight western ewes of predominately Rambouillet breeding were allotted at random into eight treatment groups during the summer of 1960 (Table 2).

All ewes were sheared prior to the initiation of the experiment. They were grazed on brome pasture and fed one-half pound of grain sorghum per head daily until they were placed in either an air conditioned room or a control pen. Throughout the remainder of the experiment all groups were given equal quantities of a grain mixture and all the alfalfa hay they would consume. No body weights or other measures of nutritional status were taken, however, the ewes appeared to gain in weight during the experimental period.

Twenty-four control ewes were maintained under a normal outdoor environment and twenty-four were placed in an air conditioned room on the seventh day of the second detected estrous cycle of the experimental period. Temperature in the air conditioned room was maintained at 60° to 64° F. Twelve ewes from each group were force exercised on a mechanical exerciser for thirty minutes each day, starting on the tenth day of the second estrous cycle. Exercised ewes were forced to walk 1.43 miles during the 30 minute period. This rate of speed compelled the ewes to walk at a fairly rapid gait but they were not forced into a trot.

Rectal temperature and respiration rate were recorded immediately before and after exercising. Temperature was taken with a four inch rectal thermometer inserted its full length for each reading. Respiration rate was determined by counting the number of flank movements per minute. Temperature and respiration rate were taken periodically on the ewes not exercised.

All ewes were bred on the second exhibited estrous which was the first estrous after being placed in the respective treatment groups. Ewes were mated to two Hampshire rams which were maintained in a cooled room beginning three weeks prior to first breeding service occurring in the experiment. Rams were alternately allowed to serve ewes and each ram usually served each ewe two or more times. Six ewes from each of the four treatment groups were slaughtered three days after breeding. The remaining twenty-four ewes were allowed to lamb. Thirty-five day non-return rates were used as a measure of expected lambing.

Air conditioning and exercising were maintained until the day of slaughter in the case of the twenty-four ewes killed at three days post breeding. Other ewes remained in the air conditioned room until the twenty-fifth day of gestation and were exercised until the twentieth day. On the twenty-fifth day of gestation all remaining twenty-four experimental ewes were placed together.

Reproductive tracts of ewes slaughtered at the third day post breeding were removed and the corpora lutea counted. The method described by Robertson (1951) was used for collecting the ova. The fallopian tubes were dissected from the mesosalpinx, straightened by careful removal of all connective tissue, and detached from the uterus at the cornual junction. The oviducts were flushed with physiological saline solution. Ova were studied at 40-X, 400-X, and 1000-X through the use of a binocular microscope.

Ova which were unfertilized or having a cracked zona pellucida or abnormal cell numbers, or degenerate cytoplasm or nucleus were considered abnormal. Cleaved ova in the two to sixteen-plus cell stages were recovered. There was a wide variation in the number of sperm present in the zona pellucida.

Ewes were checked for estrus at approximately twelve hour intervals with a vasectomized teaser ram throughout the experiment until the thirty-fifth day of gestation.

The air conditioned room was cooled by one two-ton and one one-ton refrigerated air conditioners. The floor of the insulated cooled room was 26 feet long and 11.5 feet wide. The ceiling height was 8 feet. Humidity was not controlled and probably varied considerably although no measure of it was taken. Natual light conditions were maintained as closely as possible through three unshaded windows. One was located on the east and two on the south exposures. Artificial light was also provided by a 300 watt electrical bulb in the cooled room from sunrise to sunset. The temperature increased for short periods of time during the cleaning of the room and moving of the mechanical exerciser in and out. At other times the temperature ranged from $60^{\circ}$ to $64^{\circ}$ F. The room lacked adequate ventilation and ammonia from the urine was a problem.

The control pen was approximately the same size as the air conditioned room. This pen was located in the barn near the air conditioned room. The east side of it was open and drop ventilation doors located on the west side were kept open in order to provide adequate ventilation and air movement. No artificial light was used in the control pen.

EXPERIMENTAL RESULTS AND DISCUSSION

The earliest date of breeding in the experiment occurred on July 24 and the latest date was September 2. The average date of breeding was August 12. Due to the randomness with which ewes come in heat, it was impossible to handle the ewes in the experiment simultaneously; however, treatment varied very little throughout the experimental period.

Ewes were allotted to one of eight treatment groups as indicated in Table 2.

Temperature in the air conditioned room was maintained at 60° to 64° F. Summer temperatures were fairly constant with little variance throughout the experimental period. Average summer temperatures, under which the non-cooled ewes were maintained, are given in Table 3. Higher summer temperatures would have been more desirable for the purposes of this study and might have caused a more pronounced difference between the cooled and non-cooled ewes.

Ovulation Rate. All ewes slaughtered, with one exception, had ovulated, as evidenced by the presence of at least one recently formed corpus luteum on an ovary. Dutt (1951) slaughtered 90 cross-bred yearling ewes three days after breeding and found that all ewes had ovulated. Other work by Dutt (1954) also appears to indicate that failure to ovulate does not represent a major factor in the reproductive efficiency in ewes bred at the beginning of their normal breeding season.

The ovulation rates for the slaughtered ewes are summarized in Table 4. There were no significant differences among groups. A total of 29 ova were recovered from the 24 ewes, which represented 96.7 percent of the corpora lutea. Average ovulation rate was 1.30 per ewe.

Fertilization Rate. Fertilization rate for the slaughtered ewes was

Table 2. Experimental design.*

| non-cooled | | | | cooled | | | |
|---|---|---|---|---|---|---|---|
| exercised | | non-exercised | | exercised | | non-exercised | |
| slaughtered 3 days post breeding | not slaughtered | slaughtered 3 days post breeding | not slaughtered | slaughtered 3 days post breeding | not slaughtered | slaughtered 3 days post breeding | not slaughtered |

*Experiment included six ewes in each of the eight treatment groups.

Table 3. Average summer temperatures.

| Month | Average Maximum | Average Minimum | Average Temperature | Average at Exercise Period |
|---|---|---|---|---|
| June | 83.7 | 62.3 | 73.0 | 77.8 |
| July | 87.5 | 76.1 | 76.1 | 83.3 |
| August | 90.0 | 66.7 | 78.3 | 84.9 |

66.7 percent (Table 4). Twenty out of 29 ova were normally cleaved. Fertility in the cooled ewes was significantly higher ($P > .05$) than for the non-cooled ewes when the data were tested by the method of Fisher's Exact Probability (Fisher, 1934). Eighty percent (12 of 15) of the ova from the cooled ewes were fertilized and 57.1 percent of the ova (8 of 14) from the non-cooled ewes were fertilized. These results are in agreement with those of Johnson (1924) and Seath and Staples (1941) who found hot temperatures detrimental to dairy cattle fertility. Dutt et al. (1959), Alliston and Ulberg (1959), Wilson et al. (1959), Inkster (1959), and Yeates (1953) also found that high ambient temperatures have adverse effects on ewe fertility.

Exercised ewes had a significantly lower fertilization rate ($P > .05$) than non-exercised ewes as indicated in Table 4. Fifty-seven percent (8 of 14) of the ova of exercised ewes were fertilized while 80 percent of the ova from non-exercised ewes were fertilized. No record of experimental work conducted on the effects of exercise on fertility of sheep was found in the review of literature.

Abnormal Ova. Part of the failure of ewe reproduction appears to be due to an increase in morphologically abnormal ova in non-cooled ewes maintained under Kansas summer temperatures. Ova with cracked zona pellucida, degenerated

Table 4. Ovulation rate, fertilization rate, and abnormal ova in slaughtered ewes.

| Item | Non-cooled Exer. Sl. | Non-cooled Non-ex. Sl. | Cooled Exer. Sl. | Cooled Non-ex. Sl. | Total | Percentage |
|---|---|---|---|---|---|---|
| No. of ewes | 6 | 6 | 5[a] | 6 | 23 | |
| No. of ovulations | 6 | 8 | 8 | 8 | 30 | |
| No. of ova recovered | 6 | 8 | 8 | 7 | 29 | 96.7 |
| No. of fertilized ova | 3 | 5 | 5 | 7 | 20 | 66.7 |
| No. of abnormal ova | 3 | 3 | 3 | 0 | 9 | 30.0 |
| Fert. in cooled ewes | | | 5 | 7 | 12[b]* | 80.0 |
| Fert. in non-cooled ewes | 3 | 5 | | | 8 | 57.1 |
| Fert. in exercised ewes | 3 | | 5 | | 8 | 57.1 |
| Fert. in non-exercised ewes | | 5 | | 7 | 12[c]* | 80.0 |
| Abnormal ova, cooled ewes | | | 3 | 0 | 3 | 20.0 |
| Abnormal ova, non-cooled ewes | 3 | 3 | | | 6[d]* | 42.9 |
| Abnormal ova, exercised ewes | 3 | | 3 | | 6[e]* | 42.9 |
| Abnormal ova, non-exercised ewes | | 3 | | 0 | 3 | 20.0 |

[a]One ewe had not ovulated, a persistent follicle was found on one ovary.

[b]Significantly different from the non-cooled ewes at the 5% level.

[c]Significantly different from the exercised ewes at the 5% level.

[d]Significantly different from the abnormal ova of the cooled ewes at the 5% level.

[e]Significantly different from the non-exercised ewes at the 5% level.

cytoplasm or creanated nuclei, abnormal cell numbers, and apparently normal ova that were not fertilized, were classified as abnormal when examined under the microscope. Photomicrographs of various types of abnormalities observed in sheep ova were presented by Dutt (1954). In the summarized data (Table 4) no distinction was made between abnormal and apparently normal but unfertilized ova; however, in Table 5, ovum characteristics are described. Twenty percent (3 of 15) of the ova from the air conditioned ewes were classified as abnormal. Dutt (1954) reported that 20.1 percent of all ova recovered, both cleaved and uncleaved, were abnormal three days after breeding when ewes were maintained under warm summer temperatures. Abnormal ova from the non-cooled ewes represented 42.9 percent (6 of 14) of the total ova. This difference was significant ($P > .05$) when analyzed by the method of Fisher's Exact Probability Test. These results are in agreement with those by Dutt (1959), who exposed ewes to a $90^{\circ}$ F. temperature in October and found the fertilization rate among control ewes to be significantly lower ($P > .01$) than among heated ewes. Dutt also found that morphologically abnormal ova comprised 44.2 percent of the total ova from the hot room ewes.

Exercised ewes had a significantly higher ($P > .05$) number of abnormal ova (6 of 14) than did non-exercised ewes (3 of 15). Thirty-seven percent (3 of 8) of the ova were abnormal from the cooled, exercised ewes contrasted to 50 percent (3 of 6) from the non-cooled, exercised ewes.

Even though there is a significant difference in the percent of abnormal ova from exercised ewes compared to non-exercised ewes, the ambient temperature appeared to have a more pronounced detrimental effect on ova normality. Only three abnormal ova were observed in the cooled ewes while there were six in the non-cooled ewes. Exercise had no effect on the occurrence of abnormal

Table 5. Ova data from slaughtered ewes.

| Group | No. of ovulations | Ovulating ovary | Nature of ovum | Unfertilized or abnormal | Type of abnormality | Cleavage stage |
|---|---|---|---|---|---|---|
| 6 ewes (outside ) (no exercise) | 8 | 5-left<br>3-right | 5-fertilized and normal | 1-unfertilized<br>2-abnormal | 1-apparently normal<br>1-abnormal cell number<br>1-creanated nucleus | 3 2-cell<br>1 8-cell<br>1 16-cell |
| 6 ewes (outside ) (exercised) | 6 | 2-left<br>4-right | 3-fertilized and normal | 3-abnormal | 3-ruptured zona pelludica | 1 4-cell<br>1 8-cell<br>1 16-cell |
| 6 ewes (cooled) (non-exercise) | 8 | 3-left<br>5-right | 7-fertilized and normal<br>1-not recovered | | | 2 2-cell<br>2 4-cell<br>2 8-cell<br>1 16-cell |
| 5 ewes* (cooled ) (exercised) | 8 | 5-left<br>3-right | 5-fertilized and normal | 1-unfertilized<br>2-abnormal | 1-apparently normal<br>1-abnormal cell number<br>1-degenerated cytoplasm | 1 2-cell<br>1 8-cell<br>1 16-cell<br>2 beyond 16 cells |

*One ewe had not ovulated, a persistent follicle was found on one ovary.

ova in the non-cooled ewes. Three abnormal ova were recovered from both the exercised and non-exercised, non-cooled ewes. However, exercise did appear to influence the production of abnormal ova in the cooled ewes. Thirty-seven percent (3 of 8) were abnormal in the case of the cooled, exercised group contrasted to 0 percent (none) in the non-exercised, cooled ewes.

Thirty-five-Day Non-Returns. The 24 ewes allotted to retention for lambing were checked daily for estrus from the time of breeding until 35 days post-breeding. Embryonic survival and/or abnormal ova production were assumed to be the cause of repeated estrus in the event it occurred. Lambing data were not available at the time the experimental data were summarized. Thirty-five day non-return ewes were used as a measure of normal fertility and embryo development. Non-return rate for the air conditioned ewes (none of 12) was significantly higher ($P > .01$) than for the non-cooled ewes (6 of 12, as indicated in Table 6. There was no apparent difference in the number of ewes returning to heat from the exercised (3 of 6) and non-exercised ewes (3 of 6) within the non-cooled treatment groups. Neither the ewes from the exercised, cooled, nor non-exercised, cooled groups exhibited estrus after being bred. Exercise, therefore, had no significant influence upon non-return rates of the cooled ewes.

The Border $X^2$ Test (Snedecor, 1956) was used to test the "Reproductive Performance" (fertilization rate + embryo survival) of all treatment groups. On this basis, air conditioned or cooled groups had highly significantly ($P > .01$) increased "Reproductive Performance" over non-cooled groups. Exercised groups were not significantly different from non-exercised groups.

Rectal Temperature and Respiration Rates. Average rectal temperature and respiration rates for the four exercised groups of ewes are summarized

Table 6. Thirty-five day non-return rates.

| Item | Returns | Non-returns | Total | Percent |
|---|---|---|---|---|
| Cooled | 0 | 12 | 12 | 100 |
| Non-cooled | 6 | 6 | 12 | 50** |
| Exercised | 3 | 9 | 12 | 83.3 |
| Non-exercised | 3 | 9 | 12 | 83.3 |
| Exercised, non-cooled | 3 | 3 | 6 | 50.0 |
| Non-exercised, non-cooled | 3 | 3 | 6 | 50.0 |

**Highly significantly different from the cooled ewes at the 1% level.

in Table 7. Rectal temperatures prior to exercise were significantly different ($P > .01$) among the four groups, the cooled ewes had the lower average. These data were analyzed by analyses of variance which are presented in Table 8. Respiration rate per minute, prior to exercise, was also significantly lower ($P > .01$) for the ewes maintained in the cooled room. These results are in complete agreement with those of Dutt (1954), Dutt et al. (1959), Alliston and Ulberg (1959) and others who have reported that both body temperature and respiration rate increase with elevated ambient temperatures. Rectal temperature post exercise increased significantly more in the non-cooled ewes than in the cooled ewes as evidenced by a highly significant ($P > .01$) difference in the temperature rise. The difference in pre and post exercise was also significantly higher ($P > .05$) in the non-cooled than cooled groups. Since it has been shown by many workers that body temperature of the ewe is influenced by the environment and various other stress factors, it is only natural that exercise affects heat production or dissipation and causes variations in body temperature and respiration rate.

Table 7. Effect of exercise on rectal temperature and respiration rates per minute.

| Treatment group | Temperature | | Respiration | | Unit Increase | |
|---|---|---|---|---|---|---|
| All exercised | Before | After | Before | After | Temp. | Resp. |
| Non-cooled lambed | 102.6 | 104.4 | 66.0 | 141.0 | 1.7 | 74.1 |
| Non-cooled slaughtered | 102.4 | 104.6 | 63.5 | 156.7 | 2.2 | 95.3 |
| Average | 102.5 | 104.5 | 64.8 | 148.9 | 2.0 | 84.7 |
| Cooled lambed | 102.3 | 103.8 | 32.6 | 94.7 | 1.5 | 61.4 |
| Cooled slaughtered | 102.5 | 104.3 | 34.1 | 132.0 | 1.9 | 96.0 |
| Average | 102.4** | 104.0** | 33.4** | 112.8** | 1.6* | 78.7* |

*Significantly different from the non-cooled ewes at the 5% level.
**Significantly different from the non-cooled ewes at the 1% level.

Rectal temperature and respiration rate data, prior to exercise, for the eight treatment groups is summarized in Table 9. The observed increase in rectal temperature and respiration rates incurred by exercise dissipated prior to the subsequent treatment. Respiration was observed to decline within a short period after completion of exercise. However, rectal temperature did not start a decline to normality until approximately two hours thirty minutes post exercise. This decline was very gradual, varying with the gradient of increase, and did not reach normal until approximately five to six hours post exercise. The exercised ewes were not apparently stressed beyond their physiological limit. However, as has been previously mentioned, exercise had a significant effect on the incidence of abnormal ova. There was little difference in body temperature and respiration rate between the exercised and non-exercised groups within the non-cooled and air conditioned ewes.

Regression analysis revealed that, with body temperature being the

Table 8. Effect of cooling and exercise on rectal temperature and respiration rates.
Analysis of Variance

| Source | Degrees of freedom | Sums of squares | Mean square | F |
|---|---|---|---|---|
| | | Rectal temperature prior to exercise | | |
| Groups | 3 | 9.97 | | |
| Ewes:groups | 20 | 13.4781 | .6739 | |
| Observations:ewes | 468 | 83.1719 | .1777 | 3.7923** |
| | | Respiration rate prior to exercise | | |
| Groups | 3 | 122102.02 | | |
| Ewes:groups | 20 | 19685.38 | 984.269 | |
| Observations:ewes | 468 | 145689.00 | 311.301 | 3.16179** |
| | | Difference-pre and post exercise, rectal temperature | | |
| Groups | 3 | 26.9298 | | |
| Ewes:groups | 20 | 41.4261 | 2.0713 | |
| Observations:ewes | 468 | 294.767 | .6298 | 3.2888** |
| | | Difference-pre and post exercise, respiration rates | | |
| Groups | 3 | 87091.9 | | |
| Ewes:groups | 20 | 40532.13 | 2026.6065 | |
| Observations:ewes | 468 | 553823.97 | 1183.3845 | 1.7126* |

*Significantly different at the 5% level.
**Significantly different at the 1% level.

Table 9. Averages of rectal temperature and respiration rates for all treatment groups prior to exercise.

| Treatment* | No. of ewes | Temperature | Respiration |
|---|---|---|---|
| Lambed, cooled, exercised | 6 | 102.28 | 32.61 |
| Lambed, cooled, no exercise | 6 | 102.28 | 34.62 |
| Lambed, outside, exercised | 6 | 102.61 | 66.02 |
| Lambed, outside, no exercise | 6 | 102.46 | 59.67 |
| Slaughtered, cooled, exercised | 6 | 102.47 | 34.10 |
| Slaughtered, cooled, no exercise | 6 | 102.16 | 29.65 |
| Slaughtered, outside, exercised | 6 | 102.40 | 63.48 |
| Slaughtered, outside, no exercise | 6 | 102.51 | 72.20 |
| Outside, exercised | 12 | 102.51 | 64.75 |
| Outside, no exercise | 12 | 102.48 | 65.93 |
| Cooled, exercised | 12 | 102.37 | 33.36 |
| Cooled, no exercise | 12 | 102.22 | 32.13 |
| All outside | 24 | 102.49 | 65.34 |
| All cooled | 24 | 102.23 | 32.74 |

*For significant values refer to Tables 4, 6, 7 and 8.

independent variable and respiration rates the dependent variable, respiration rate increases per minute were not constant in the different exercised treatment groups. The unit increase in respiration rate per minute for each unit increase in rectal temperature was apparently associated with the number of days exercised rather than ambient temperature. Ewes which were exercised seven days prior to and three days post breeding (approximately 10 days) had a lower regression coefficient than ewes which were exercised to 20 days post breeding (approximately 27 days), as given in Table 10.

Table 10. Regression coefficients of rectal temperature and respiration rates for the exercised ewes.

| Exercised group | Days exercised | No. of ewes | Reg. coeff. |
|---|---|---|---|
| Non-cooled, slaughtered | 10 | 6 | 11.2525 |
| Non-cooled, lambed | 27 | 6 | 17.1398 |
| Cooled, slaughtered | 10 | 6 | 5.8138 |
| Cooled, lambed | 27 | 6 | 24.2760 |

## GENERAL DISCUSSION

Other research work, as well as this study, has shown that environmental temperature is highly correlated with fertilization rate, production of abnormal ova and embryonic mortality. However, few workers have made postulations as to why these phenomena occur. Rectal temperature and respiration rate of cooled ewes were found to be significantly lower than non-cooled ewes in this study. Other work reported by Dutt (1954), Dutt et al. (1959), Yeates (1953) and others verify these observations. The thermoregulator in the brain (Magoun and Harrison, 1938) evidently can not regulate body temperature under stressful conditions at ambient temperatures of 90° F. or above. Ewes can tolerate a higher ambient temperature if the relative humidity is low (Lee, 1950 and others). A high temperature causes more stress when accompanied by high relative humidity. The thermoregulator mechanism may also have other interrelationships with various organs of the body. For example, in mammals a drop in body temperature is accompanied by a decrease in blood pressure (Prosser et al., 1950). It is not known if variation in blood pressure is related in any way to development of normal ova or early embryonic development.

Within the ewe changes in metabolism genetic differences and estrual activity also cause different levels of body temperature. These factors must be associated with the thermoregulator mechanism. Alterations of body temperature during estrual activity may be due to the influence of endocrines on the thermoregulator. Lowered body temperatures may affect the production and/or release of follicle stimulating hormone (F. S. H.) and luteinizing hormone (L. H.). Kammlade et al. (1952) suggested that L. H. production is increased by lowered ambient temperatures. It is possible that the drop in body temperature before estrus stimulates gonadotrophins production. Christian (1959) noted a drop in temperature approximately two days prior to onset of estrus, followed by a gradual rise in temperature with a peak at mid-cycle. The characteristic increase in body temperature of the cow during estrus as reported by Wrenn et al. (1959) was not observed in the ewe. Wrenn et al. (1959) observed 2.0° F. rises in temperature when progesterone was administered intraperitoneally in the cow. However, Christian (1959) did not observe rises in temperature when ewes were given presumed physiological levels of gonadal hormones. Although gonadal hormones may not have a thermogenic response in the ewe, as is characteristic of the cow, it is still conceivable that quantities of progesterone may be produced by the follicle, prior to ovulation and corpus luteum formation, which might possibly trigger the production of L. H. or effect the quantity released. This theory could be verified by conducting a biological assay of progesterone content of follicular fluid and of the ovary prior to maturation of the ovarian follicle. Elevated body temperature may in some way alter this mechanism.

Another explanation for the association between environmental temperature and fertility is that the ewes' sensitivity to gonadal hormones might be increased or decreased with a lowered body temperature. To test this theory injections of gonadal hormones could be given ewes which were kept in a cooled environment. Estrual activity, fertilization rate and abnormal ova production could be compared with ewes which were not injected. Another possibility would be to inject ovariectomized ewes with gonadal hormones at intervals and check estrual response.

The cause of fluctuation in the ewes' temperature before ovulation is not known, but the possibility remains that this temperature fluctuation may be an inherent part of the normal estrual cycle and ovulation. Fertility of both the ovum and sperm may be improved in a lowered temperature of intra-fallopian environment. Uterine environment may be more favorable for the normal growth and development of the embryo (Alliston and Ulberg, 1959).

The significant number of abnormal ova in exercised ewes vs. non-exercised ewes most likely occurred as the result of elevated body temperatures caused by stress of exercise. Apparently body temperature rose to a degree which was incompatible to the normality and life of the ovum (Alliston and Ulberg, 1959, and Dutt, 1960 a).

Results of this experimental work could be applied in practical sheep production. Ewes should be maintained under as cool an environment as possible, especially during the breeding season. Although construction of a cool room may not be practical for breeding ewes, the sheepman could follow the principle involved. Shades could be provided and air circulating fans installed in barns and sheds. Ewes probably should be bred only in the cool of night, if feasible in a particular production program. Rams should be maintained under the coolest conditions available to insure maximum fertility. Stress under high ambient temperatures and relative humidities should be avoided. Ewes probably should not be driven long distances during the breeding season, particularly in the heat of the day. Shearing both ewes and rams just prior to breeding season has proved to be very beneficial for improvement of fertility and uniformity of lamb crop.

## SUMMARY

Forty-eight western ewes were randomly allotted in eight treatment groups. Twenty-four ewes were maintained under Kansas summer temperature and 24 were placed in an air conditioned room on the seventh day of the second detected estrus cycle. Twelve ewes from each group were exercised on a mechanical exerciser for 30 minutes each day, starting on the tenth day of the second estrous cycle. They were forced to walk 1.43 miles.

Rectal temperature and respiration rates were recorded immediately before and after exercise. Temperature and respiration rates were taken periodically of the ewes which were not exercised.

All ewes were bred during the second exhibited estrus which was the first estrus after being placed in the respective treatment groups. Six ewes from each of the four treatment groups were slaughtered three days after breeding. Ova were recovered from the reproductive tracts of the slaughtered ewes, studied under a microscope and classified as fertile or abnormal. The remaining twenty-four ewes were retained for the opportunity to produce lambs.

Air conditioning and exercise were maintained until the time of slaughter for the twenty-four slaughtered ewes. Slaughtered ewes were maintained in their respective treatment groups for 12 to 14 days, varying with length of

estrus. They were exercised for 9 to 12 days, accordingly. Ewes which lambed were kept in the cooled room until the twenty-fifth day of gestation (34 to 36 days) and were exercised until the twentieth day of gestation (26 to 28 days).

Ewes were checked for heat at approximately twelve hour intervals with a vasectomized teaser ram throughout the experiment until the thirty-fifth day of gestation.

Statistical analysis of the fertilization data showed a significant difference ($P > .05$) between cooled and non-cooled ewes. Eighty percent of the ova from cooled ewes were fertilized compared with 57.1 percent from the non-cooled ewes. Exercised ewes also had a significantly lower fertilization rate ($P > .05$) than non-exercised ewes. Fertilization rate for all slaughtered ewes was 66.7 percent (20 of 29). All ewes slaughtered, with one exception, had ovulated.

Abnormal ova recovered from the non-cooled ewes, 42.9 percent, was significantly higher ($P > .05$) than for the cooled ewes, 20.0 percent. Exercised ewes also had a significantly higher ($P > .05$) number of abnormal ova than did non-exercised ewes.

Thirty-five day non-return rate for the air conditioned ewes (none of 12) was highly significantly different ($P > .01$) than for the non-cooled ewes (6 of 12). Exercise had no significant influence upon non-return estrus rates among the cooled ewes.

Air conditioned groups had a highly significant ($P > .01$) increased "Reproductive Performance" (fertilization rate + embryo survival) over the non-cooled ewes. However, exercised groups were not significantly different from non-exercised groups in their combined fertilization rate and embryo survival.

Rectal temperature and respiration rates per minute were significantly lower (P> .01) in the cooled ewes. Post exercise rectal temperature and respiration rates were also significantly lower (P> .01) in the cooled groups of ewes. Exercise, however, did increase rectal temperature and respiration rate as indicated by significant increase in post exercise temperatures and respiration rates over pre exercise reading.

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LITERATURE CITED

Allen, E., F. F. McKenzie, J. W. Kennedy and W. F. Beare.
Oestrous periods, ovarian changes, and tubal ova in the sheep. Anatomical Record 48:9. 1931. (Abstract)

Alliston, C. W., and L. C. Ulberg.
The influence of ambient temperature on early pregnancy loss as determinted by embryo transfer. J. Animal Sci. 18:1550. 1959. (Abstract)

Andrews, F. N.
The influence of the environment on reproduction in female farm animals. Iowa State Journal Sci. 28:9. 1953.

Austin, C. R.
The fragmentation of eggs following induced ovulation in immature rats. J. of Endocrinology. 6:104. 1949.

Bissonnette, T. H.
Modification of mammalian sexual cycles. Reactions of ferrets of both Sexes to electric light after dark in November and December. Proc. Roy. Soc. B110:322. 1932.

Bissonnette, T. H.
Experimental modification of breeding cycles in goats. Physiological Zoology. 14:379. 1941.

Bonfert, A.
Contribution to the study of the sexual life of sheep. Animal Breeding Abstracts. 2:114. (Bulet. Assoc. Gen. Med. Vet. Romania. 45:215-233) 1933. (Abstract)

Christian, J. C.
The effects of stage of the estrual cycle, environment and exogenous hormones on the vaginal temperature of the ewe. Unpublished Master's Thesis, University of Kentucky. 1959.

Clark, Richard T.
Studies on the physiology of reproduction in the sheep. Anatomical Record. 60:125. 1934a.

Clark, Richard T.
Studies on the physiology of reproduction in the sheep. Anatomical Record. 60:135. 1934b.

Clawson, A. B.
Normal rectal temperatures of sheep. American J. of Physiology. 85:251. 1928.

Dowling, D. F.
An experimental study of heat tolerance of cattle. Australian J. of Agricultural Research. 7:469. 1956.

Dukes, H. H.
The physiology of domestic animals. Comstock Publishing Co. 5th ed. Ithaca, N. Y., 1943.

Dutt, R. H.
Fertility rate and embryonic death loss in ewes early in the breeding season. J. Animal Sci. 10:1075. 1951.

Dutt, R. H.
Fertilization rate and embryonic death loss in ewes early in the breeding season. J. Animal Sci. 13:464. 1954.

Dutt, R. H.
Effect of temperature on ram and ewe fertility. Thirteenth Annual Ohio Sheep Day. Ohio Agri. Exp. Sta. Animal Sci. Mimeo. Series No. 118. 1960a.

Dutt, R. H.
Temperature and light as factors in reproduction among farm animals. Supplement to J. Dairy Sci. 43:123. 1960b.

Dutt, R. H., and Leon E. Bush.
The effect of low environmental temperature on initiation of the breeding season and fertility in sheep. J. Animal Sci. 14:885. 1955.

Dutt, R. H., Earl F. Ellington and William W. Carlton.
Fertilization rate and early embryo survival in sheared and unsheared ewes following exposure to elevated air temperature. J. of Animal Sci. 18:1308. 1959.

Dutt, R. H., and Paul T. Hamm.
Effect of exposure to high environmental temperature and shearing on semen production of rams in winter. J. Animal Sci. 16:328. 1957.

Dutt, R. H., and E. C. Simpson.
Environmental temperature and fertility of Southdown rams early in the breeding season. J. Animal Sci. 13:1019. 1954.

Dziuk, Philip.
Frequency of spontaneous fragmentation of ova in unbred gilts. Proceedings of Soc. for Exp. Bio. and Med. 103:91. 1960.

Fisher, R. A.
Statistical methods for research workers. Fifth ed. Edinburg. Oliver and Boyd. 1934.

Gaalaas, R. F.
Effect of atmospheric temperature on body temperature and respiration rate of Jersey cattle. J. Dairy Sci. 28:555. 1945.

Green, W. W.
Duration of sperm fertility in the ewe. American J. Vet. Res. 8:299. 1947.

Green, W. W., and L. M. Winters.
Studies on the physiology of reproduction in the sheep. III. The time of ovulation and rate of sperm travel. Anat. Record. 61:457. 1935.

Green, W. W., and L. M. Winters.
Prenatal development of the sheep. Tech. Bul. Minn. Agri. Exp. Sta. No. 169. 1945.

Hafez, E. S. E.
Studies on the breeding season and reproduction of the ewe. I. The breeding season in different environments. J. Agri. Sci. 42:189. 1952.

Hammond, J. Jr.
Control of reproductive and pelt changes in ferrets: some experiments with animals kept entirely upon artificial light. J. Agri. Sci. 42: 293. 1952.

Hammond, John
Further observations on the factors controlling fertility and foetal atrophy. J. Agri. Sci. 11:337. 1921.

Hart, D. S.
Photoperiodicity in Suffolk sheep. J. Agri. Sci. 40:143. 1950.

Heape, W.
Abortion, barrenness and fertility in sheep. J. R. Agri. Soc. 60:217. 1899.

Heilbrunn, L. V.
An outline of general physiology. W. B. Saunders Company. Second ed. Philadelphia. 263. 1943.

Heitman, H. Jr., and E. H. Hughes.
The effects of air temperature and relative humidity on the physiological well being of swine. J. Animal Sci. 8:171. 1949.

Heitman, H. Jr., E. H. Hughes and C. F. Kelly.
Effects of elevated ambient temperature on pregnant sows. J. Animal Sci. 10:907. 1951.

Henning, William Lewis.
Prenatal and postnatal sex ratio in sheep. J. Agri. Res. 58:565. 1939.

Hill, M. and A. S. Parkes.
Effect of absence of light on the breeding season of the ferret. Proc. Roy. Soc. B115:14. 1934.

Hobday, F.
Temperature and exercise. J. Comp. Path. and Therop. 9:286. 1896.

Hulet, C. V., H. P. Voigthander Jr., A. L. Pope and L. E. Casida. The nature of early-season infertility in sheep. J. Animal Sci. 15:607. 1956.

Inkster, I. J. A study of fertilization in sheep. Effect of pre-mating shearing on two-tooth lambing performance. Sheep Farming Annual. pp. 9-16. 1959.

Johnson, Everett L. Relation of sheep to climate. J. Agri. Res. 29:491. 1924.

Kammlade, W. G. Jr., J. A. Welch, A. V. Nalbandor and H. W. Norton. Pituitary activity of sheep in relation to the breeding season. J. Animal Sci. 11:646. 1952.

Lee, D. H. K. Heat and cold. Ann. Rev. of Physiol. 10:365. 1948.

Lee, D. H. K. Studies on heat regulation in the sheep with special reference to the Merino. Australian J. Agri. Res. 1:200. 1950.

Lepard, O. L., C. Edmund Shuart and Arden Foster. The effect of exercise on the amount and quality of a dairy bull's semen. J. Dairy Sci. 24:509. 1941. (Abstract)

Magoun, H. W. and F. Harrison. Localization of the heat center in the brain. J. of Neurophysiology. 1:100. 1938.

Marshall, F. H. A. On the change-over in the oestrus cycle in animals after transference across the equator, with further observations on the incidence of the breeding seasons and the factors controlling sexual periodicity. Proc. Roy. Soc. B122:413. 1937.

McKenzie, F. F., and R. W. Phillips. Some observations on the estrual cycle in sheep. Proc. American Soc. Animal Prod. pp. 138-142. 1930.

McKenzie, F. F., and R. W. Phillips. The effects of temperature and diet on the onset of the breeding season (estrus) in sheep. Mo. Agr. Exp. Sta. Bul. 328 1933.

McKenzie, F. F., and Clair E. Terrill. Estrus, ovulation, and related phenomena in the ewe. Mo. Agr. Exp. Sta. Res. Bul. No. 264. 1937.

Miller, J. C. and L. Monge. Body temperature and respiration rate, and their relation to adaptability in sheep. J. Animal Sci. 5:147. 1946.

Monge, Carlos.
Chronic mountain sickness. Physiol. Rev. 23:166. 1943.

Murphee, R. L., E. J. Warwick, L. E. Casida and W. H. McShan.
Potential fertility of ova from ewes treated with gonadotrhpins. J. Animal Sci. 3:12. 1944.

Nalbandov, A. V.
Reproductive physiology. W. H. Freeman and Co., San Francisco. pp. 68. 1958.

Nelson, Edward Almon.
Factors influencing semen quality and reproductive efficiency in rams. Dissertation. Kansas State College of Agriculture and Applied Science, 1958.

Ogle, Cordelia.
Adaptation of sexual activity to environmental stimulation. American J. Physiology. 107:628. 1934.

Panquite, Robert, and R. B. Thompson.
Results of a ten-year study on the influence of artificial light on egg production. Poultry Science. 19:358. 1940 (Abstract).

Phillips, Ralph W., and Damon A. Spencer.
Reactions of Southdown sheep to two environments. J. Animal Sci. 7:40. 1948.

Prosser, C. L., D. W. Bidhop, F. A. Brown, T. L. Jojn and V. J. Wueff.
Comparative animal physiology. W. B. Saunders Co., Philadelphia. 1950.

Quinlan, J., and G. S. Mare.
The normal temperature of Merino sheep during January in the Karee, and how it is influenced by exercise. Union of South Africa. 18th Report to the Director of Veterinary Service and Animal Industries. pp. 1037. 1932.

Regan, W. M., and G. A. Richardson.
Reactions of the dairy cow to changes in environmental temperature. J. Dairy Sci. 31:73. 1938.

Riek, R. F., M. H. Hardy, D. H. K. Lee and R. B. Carter.
The effect of the dietary plane upon the reactions of two breeds of sheep during short exposures to hot environments. Australian J. Agri. Res. 1:217. 1950.

Robertson, T. J.
The control of fertility in sheep. J. Agri. Sci. 42:6. 1951.

Rowan, William.
Relation of light to bird migration and developmental changes. Nature. 115:494. 1925.

Schott, R. C., R. W. Phillips and D. A. Spencer.
The occurrence of estrus in sheep and its relation to extra-seasonal production of lambs. Proc. Am. Soc. An. Prod. 32:347. 1939.

Seath, D. M., and C. H. Staples.
Some factors influencing the reproductive efficiency of Louisiana herds. J. Dairy Sci. 24:510. 1941. (Abstract)

Simpson, E. C., H. C. Rice, D. G. Steele and R. H. Dutt.
Summer semen characteristics of rams having free access to a plastic air-conditioned room. J. Animal Sci. 18:1157. 1959. (Abstract)

Smith, F.
A manual of veterinary physiology. Third ed. 1908.

Smith, Robert M.
The physiology of the domestic animals. 1889.

Snedecor, George W.
Statistical methods. Iowa State College Press. Fifth ed. 1956.

Sykes, J. F., and C. L. Cole.
Modification of mating season in sheep by light treatment. Mich. State Univ. Agr. Exp. Sta. Quart. Bul. 26:250. 1944.

Terrill, C. E., and John A. Stoehr.
Reproduction in range sheep. Proc. An. Soc. An. Prod. 32:369. 1939.

United States Department of Agriculture.
Agriculture Yearbook. p. 741. 1900.

Whetham, E. O.
Factors modifying egg production with special reference to seasonal changes. J. Agri. Sci. 23:383. 1933.

Whitaker, W. L.
Some effects of artificial illumination or reproduction in the white-footed mouse. J. Exp. Zool., 83:33-60. 1940.

Wilson, R. L., W. C. Godley and Victor Hurst.
Some factors affecting breeding performance and early lambing in sheep. J. Animal Sci. 18:1157. 1959. (Abstract)

Wrenn, T. R., J. Bitman and J. D. Sykes.
The thermogenic influence of progesterone in ovariectomized cows. Endocrinology 65:317. 1959.

Woody, C. O., Bryan Baker Jr., and C. W. Alliston.
Effect of environmental temperature and progesterone-PMS treatment on the reproductive performance of ewes. J. An. Sci. 18:1156. 1959. (Abstract)

Yeates, N. T. M.
The breeding season of the sheep with particular reference to its modification by artificial means using light. J. Agri. Sci. 39:1. 1949.

Yeates, N. T. M.
The effect of high air temperature on reproduction in the ewe. J. Agri. Sci. 43:199. 1953.

Yeates, N. T. M.
The effect of high air temperature on pregnancy and birth weight in Merino sheep. Australian J. Agri. Res. 7:435. 1955.

Yeates, N. T. M.
The effect of light on the breeding season gestation, and birth weight of Merino sheep. Australian J. Agri. Res. 7:440. 1956.

Young, W. C.
The influence of high temperature on the guinea pig testes. J. Exp. Zool. 49:459. 1927.

THE EFFECTS OF TEMPERATURE AND EXERCISE UPON
FERTILIZATION RATE AND EMBRYONIC
MORTALITY IN EWES

by

SAMUEL PAYTON SCOTT

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AN ABSTRACT OF A THESIS

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Sheep have been used in studies to determine the effects of high ambient temperature upon fertilization rate and reproductive performance of ewes. Results obtained indicate that high environmental temperatures cause highly significantly lowered fertilization rates and reproductive performances. This study was designed in an effort to determine the effects of temperature and exercise upon fertilization rates and fetal mortality among ewes.

Forty-eight western ewes were randomly allotted in eight treatment groups. Twenty-four ewes were maintained under Kansas summer temperature and 24 were placed in an air conditioned room on the seventh day of the second detected estrus cycle. Twelve ewes from each group were exercised on a mechanical exerciser for 30 minutes each day, starting on the tenth day of the second estrous cycle. They were forced to walk 1.43 miles. Rectal temperature and respiration rates were recorded immediately before and after exercise. Temperature and respiration rates were taken periodically of the ewes which were not exercised.

All ewes were bred during the second exhibited estrus. Six ewes from each of the four treatment groups were slaughtered three days after breeding. The ova were recovered and studied under a microscope. The remaining 24 ewes were retained for the opportunity to produce lambs.

Air conditioning and exercise were maintained until the time of slaughter for the 24 slaughtered ewes. Ewes which lambed were kept in the cooled room until the twenty-fifth day of gestation and were exercised until the twentieth day of gestation.

Statistical analysis of the fertilization data showed a significant difference ($P > .05$) between cooled and non-cooled ewes. Eighty percent of the ova from cooled ewes were fertilized compared with 57.1 percent from the non-cooled ewes. Exercised ewes also had a significantly lower fertilization rate ($P > .05$) than non-exercised ewes. Fertilization rate for all slaughtered ewes was 66.7 percent (20 of 29 ova).

Abnormal ova recovered from the non-cooled ewes, 42.9 percent was significantly higher ($P > .05$) than for the cooled ewes, 20.0 percent. Exercised ewes also had a significantly higher ($P > .05$) number of abnormal ova than did non-exercised ewes.

Thirty-five day non-return rate for the air conditioned ewes (none of 12) was highly significantly different ($P > .01$) than for non-cooled ewes (6 of 12). Exercise had no significant influence upon non-return estrus rates among the cooled ewes.

Air conditioned groups had a highly significant ($P > .01$) increased "Reproductive Performance" (fertilization rate + embryo survival) over the non-cooled ewes. However, exercised groups were not significantly different from non-exercised groups in their combined fertilization rate and embryo survival.

Rectal temperature and respiration rates per minute were significantly lower ($P > .01$) in the cooled ewes. Post exercise rectal temperature and respiration rates were also significantly lower ($P > .01$) in the cooled groups of ewes. Exercise, however, did increase rectal temperature and respiration rate as indicated by significant increase in post exercise temperatures and respiration rates over pre exercise readings.