RESEARCH BULLETIN 704 JULY, 1959

UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
J. H. LONGWELL, *Director*

Environmental Physiology and Shelter Engineering

With Special Reference to Domestic Animals

LI. EFFECT OF CONSTANT ENVIRONMENTAL TEMPERATURES OF 50° AND 80° F ON OVARIAN ACTIVITY OF BRAHAM, SANTA GERTRUDIS, AND SHORTHORN CALVES WITH A NOTE ON PHYSICAL ACTIVITY

HOMER E. DALE, A. C. RAGSDALE, AND C. S. CHENG
WITH THE TECHNICAL ASSISTANCE OF
G. T. BARROWS, C. W. GROSSE, J. P. MCGINNIS, AND P. L. NICOLETTI

(Publication authorized July 30, 1959)

COLUMBIA, MISSOURI

CONTENTS

ACKNOWLEDGMENTS

This bulletin is a report on the Department of Dairy Husbandry Research Project No. 125, "Climatic Factors." The project is part of a broad cooperative investigation between the Departments of Dairy Husbandry and Agricultural Engineering of the Missouri Agricultural Experiment Station, University of Missouri, and Agricultural Engineering Research Division, Agricultural Research Service, U. S. Department of Agriculture.

Acknowledgments are due to R. G. Yeck and M. M. Jones for cooperation on the engineering phase of the Climatic Laboratory portion of the work; to Harry Ball and Leonard Ayres for care and feeding of animals; to Dennis Hartman, and Vernon H. Viebrock for assistance in taking the measurements; and to Mary Ruth Barrows for her help in assembling the data.

Grateful acknowledgments are made to R. J. Kleberg, Jr., and R. M. Kleberg, Jr., owners of the Santa Gertrudis cattle, King Ranch, Kingsville, Tex.; James W. Box, Sand Springs Farm, Sand Springs, Okla., owner of the Shorthorn cattle; and to the owners of the Brahman cattle: Southern Rice Farms, Carlisle, Ark.; Burke Brothers, Corsicana, Tex.; Whitcombe's Clear Creek Farms, Houston, Tex.; W. S. Gibbs, Huntsville, Tex.; C. Y. Jacobs, Yoakum, Tex.; V. W. Frost, Pecan Acres Ranch, Simonton, Tex.; and R. C. Parker, V-8 Ranch, Center, Tex.

The U. S. Atomic Energy Commission contributed to the support of this research.

SUMMARY

Experimental Brahman, Santa Gertrudis, and Shorthorn heifer calves were raised from approximately one to 12 months of age at constant environmental temperatures of 50° and 80° F with relative humidity of 50 to 70%; they were exposed to equal periods of light and dark. Controls were kept in an open shed and experienced the usual Missouri weather.

Ovarian activity was estimated by rectal palpation; physical activity was measured with a pedometer attached to the forelimb.

One outdoor Brahman did not mature. The remaining outdoor Brahmans and one 50° Brahman were apparently seasonally monestrous. All of the other calves were polyestrous.

Brahmans at 80° F reached puberty at a mean age of 463 days (19% of predicted age at mature weight; mean ages of all other experimental groups at puberty were between 290 and 440 days (11 to 14% of predicted age at mature weight. At puberty 80° F Brahmans had achieved: (1) a mean of 60% of predicted weight (vs. means of 39 to 45% for all other experimental groups); (2) a mean of 95% of predicted mature wither height (vs. means of 80 to 83% for all other experimental groups); and (3) a mean of 84% of predicted mature chest girth (vs. means of 69 to 75% for all other experimental groups).

One 80° Shorthorn was similar to the 80° Brahmans in that she displayed both superior heat tolerance, as indicated by rate of growth, and relatively late puberty.

Mean age at puberty was the same (290 days) for Santa Gertrudis calves raised at controlled environmental temperatures of 50° and 80° F. At puberty the mean ages of Brahman and Shorthorn calves raised at 50° F were less (307 and 303 days) than the mean ages of Brahman and Shorthorn calves raised at 80° F (463 and 440 days)

Persistent multiple follicles that were not accompanied by symptoms of nymphomania were most common on the ovaries of the 80° F Santa Gertrudis calves.

After puberty the incidence of structures (follicle or corpus luteum) on the right ovary was 64%, on the left, 47%.

A difference in hoof growth of 50° and 80° F calves was not correlated with a difference in physical activity. In general 80° F calves were more active than the 50° F calves; Brahmans were more active than either Santa Gertrudis or Shorthorns. All calves doubled or tripled activity when changed from the climatic laboratory to open shed housing conditions.

Environmental Physiology and Shelter Engineering

With Special Reference to Domestic Animals

LI. EFFECT OF CONSTANT ENVIRONMENTAL TEMPERATURES OF 50° AND 80° F ON OVARIAN ACTIVITY OF BRAHMAN, SANTA GERTRUDIS, AND SHORTHORN CALVES WITH A NOTE ON PHYSICAL ACTIVITY

INTRODUCTION

Reproductive activity in plants is intimately related to the climatic environment; germination and flowering are seasonal events, and, at least in some plants, these events represent not the culmination of growth and form but rather an interaction of the organism and climatic factors.[12,15] Reproduction in animals is not so obviously linked to the environment, yet there are seasonal trends that indicate climatic influences.

Birth in many species occurs at a season of favorable temperature and abundant food supply; mating is linked to an event, usually climatic, that preceeds this season by the length of the gestation period. In lower animals there is a fascinating variety of mating stimuli: spring rain, salinity of water, tides, temperatures, food supply, and phases of the moon;[19] in the more highly evolved animals, which have a breeding season, sex activity is related to change in the exposure to light and dark. [4,5,8,14,16,20,25,26]

In animals that do not have a breeding season, i.e., those animals that have estrous cycles at regular intervals throughout the year (usually animals evolved under fairly uniform climatic conditions or domestic animals protected from climatic and nutritional extremes), there are nevertheless, seasonal differences in the incidence of birth.[9,10,13] These are partly economic seasons in domestic animals; they are partly seasonal variations in fertility of both males and females due to the effect of altered nutrition, temperature extremes, and light on pituitary and gonadal activity.[2,3,7,18]

The first appearance of reproductive potential, puberty, is more closely associated with physiologic age, e.g., body length, than with chronologic age.[3,29] Since animals mature sexually at about the same percentage of adult body size, any environmental factor that alters growth rate will affect the calendar age at puberty. Perhaps a slow growth rate is responsible for the delayed appearance of puberty in tropical women.

One major purpose of this investigation was to determine the effect of environmental temperatures of 50° and 80° F on the appearance of puberty in beef calves. Although such an effect might result from body temperature differences on hypothalamic-hypophyseal function, it is more in accord with the preceding discussion to relate differences in the appearance of puberty to differences in feed consumption and growth rate.

The subject of environmental and nutritional influences on endocrine and reproductive activities is complicated and imperfectly understood; there are several reviews[1,6,17,23,27,30] of the pertinent literature.

EXPERIMENTAL DESIGN AND PROCEDURES

Santa Gertrudis, Brahman, and Shorthorn calves were raised from about one month of age at constant environmental temperatures of 50° and 80° F. A third group of calves was kept under the usual Missouri housing conditions with daily exposure to Missouri weather. Details of the Climatic Laboratory, the calves, and the feeding and management practices have been published.[21]

The ovaries and internal genitalia of the calves were examined by rectal palpation;[24] most of the examinations were performed by four senior students in the Missouri School of Veterinary Medicine. The original intention was to have each calf examined by two students every other day, a frequency not always maintained.

After each examination the palpators discussed their results, frequently reexamined individuals where discrepancies were noted, and completed the form shown in Figure 1 in the Appendix.

Physical activity was estimated with a pedometer (New Haven Watch Company) attached to alternate forelimbs for a period of one week.[11] The pedometers were calibrated weekly by placing the carrier with the enclosed pedometer upright in a large container and then bouncing the container and enclosed pedometers 10,000 times. Readings, as miles on the pedometer dial, before and after the calibration bouncing, were used to convert miles to steps or bounces.

RESULTS AND DISCUSSION

Two objectives of the ovarian examinations were to determine the time of puberty and the regularity of the ovarian cycles.

Puberty is the time when reproduction can first occur; in a heifer calf it would be the date of conception of a viable fetus while the heifer is in constant association with mature males. This criterion, as well as the detection of the first overt estrus by a vasectomized male, was impractical in this experiment.

Lacking the usual index of puberty, ovarian activity was evaluated by the size and persistence of structures on the surface of the ovary. The calves were assumed to have reached puberty when an ovarian follicle grew to mature size (as contrasted to the atretic follicles on the ovary before puberty), ruptured, and

was followed by a corpus luteum which persisted long enough to indicate luteal function. In addition, puberty was evaluated by the degree of ovarian activity; it was assumed that prior to puberty an occasional follicle might approach mature size but that for most of the time, structures on the ovary would not be of functional size. It was assumed that after the time of puberty one ovary should have structures of mature size on it most of the time. It was expected that frequency or regularity of cycles could be established by a wave of follicular growth paralleled by regression of a corpus luteum.

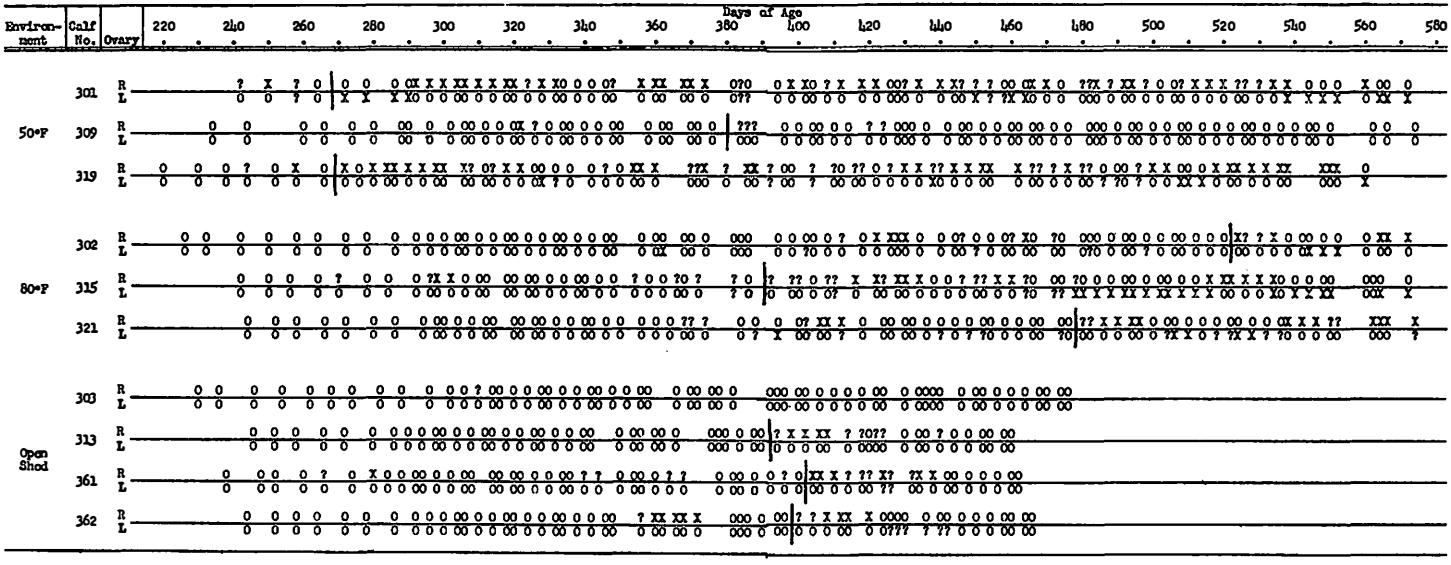
The ovarian data from the examination cards are summarized in Tables 1 to 3. In these tables the right ovary is represented by the top of the line; the left ovary, by the bottom. Each examination is indicated by symbols above and below the line under the appropriate days of age. Structures on the ovary, other than small atretic follicles which gave the ovary a granular feeling even before puberty, were of two classes: those definitely identified as follicles or corpora lutea, indicated by "X" on the tables; and those which were not identified, indicated by "?" on the tables. What was identified as a functional follicle or corpus luteum was represented by a common symbol because differentiation is a matter of interpretation of what is palpated through the wall of the rectum. It was felt that while the nature of the structure, i.e., follicle or corpus luteum, might be debatable, the presence of the structure (the size and persistence of which invited the debate) was indisputable. When the structure was not identified as a follicle or a corpus luteum or when the size of the structure was less than usual, the symbol "?" was used in Tables 1 to 3.

A vertical line was drawn for each calf on Tables 1 through 3 to indicate the estimated time of puberty. This line was drawn after a consideration of the data presented in the table, the palpation reports of each calf (see Figure 1 in Appendix), and the opinions of the palpators.

The palpators were asked to express their opinions as to the nature of the ovarian activity of the calves at frequent intervals during the experiment. They were asked to state the time when the first structure of mature size appeared on the surface of the ovary and to give their opinion as to when the calf first had a complete cycle (follicle of mature size followed by mature corpus luteum).

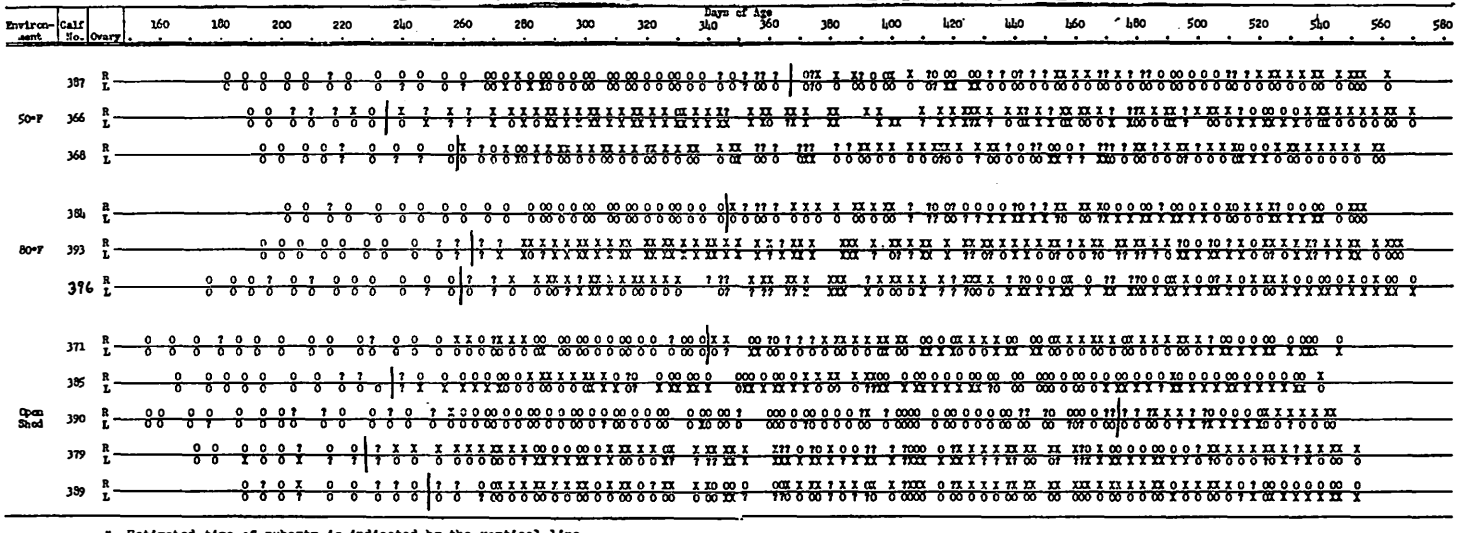
Table 4 presents the last opinion of the palpators. This table was prepared (G.T.B. and P.L.N.) in January 1956 without access to, or knowledge of, Tables 1 through 3. The opinions expressed in Table 4 were considered in drawing the lines indicating puberty on Tables 1 to 3. In general, there is good agreement between estimated times of puberty as stated on Table 4 and as shown by the vertical lines on Tables 1 to 3. Major differences are seen in the case of calves 384 and 393 where persistent multiple follicles were a complicating factor and in calves 321, 387, 371, and 354 where an initial burst of ovarian activity was followed by a period of quiescence. In the case of 387, 371, and 354 the reader will better understand why a later date of puberty was selected if he will draw lines indicating days of age at first cycle from Table 4 on Tables 1 to 3. In the case

TABLE 1--OVARIAN ACTIVITY OF BRAHMAN CALVES*



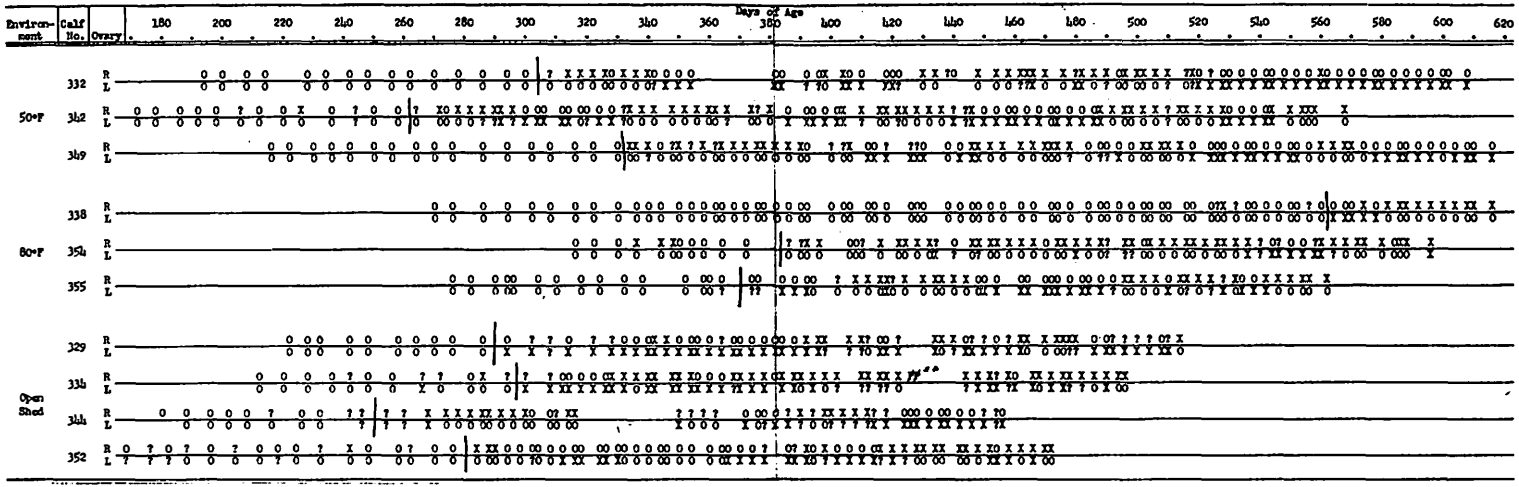
* Estimated time of puberty is indicated by the vertical line.

TABLE 2--OVARIAN ACTIVITY OF SANTA GERTRUDIS CALVES*



* Estimated time of puberty is indicated by the vertical line.

TABLE 3--OVARIAN ACTIVITY OF SHORTHORN CALVES*



* Estimated time of puberty is indicated by the vertical line.

* Termination of accidental pregnancy by expression of corpus luteum.

TABLE 4--OPINION OF THE PALPATORS REGARDING THE ONSET AND NATURE OF OVARIAN ACTIVITY IN THREE BREEDS OF BEEF CALVES UNDER DIFFERENT ENVIRONMENTAL CONDITIONS

Breed	Calf No.	Days of Age at First Activity	Days of Age at First Cycle	Remarks[1]
		Chamber I (East) - 50°F		
Brahman	301	242	271	Cycles stopped in Jan.
	309	180		Irregularities - No cycle yet
	319	272	278	Irregular cycle
Santa Gertrudis	387	274	274	
	366	240	240	Irregular cycles - mult. follicle
	368	259	259	Highly irregular
Shorthorn	332	307	307	Regular
	342	271	271	Fairly regular
	349	329	329	Regular
		Chamber II (West) - 80°F		
Brahman	302	523		No cycle yet
	315	381	381	Regular now
	321	481	552	Now in cycle
Santa Gertrudis	384	348	402	Regular
	393	272	475	Multiple follicles
	396	262	262	Irregular cycle
Shorthorn	338	504	560	Regular now
	354	336	336	Irregular (12/21/55 Regular)
	355	376	376	Regular
		Open Shed		
Brahman	313	398	394	Cycles stopped Nov. 24, 1955
	361	403		Stopped Dec. 6, 1955
	362	355	400	Stopped now (Dec. 6)
	303			No activity
Santa Gertrudis	371	258	258	Irregular
	385	232	232	Multiple follicles
	390	494	501	Irregular
	379	232	232	Regular
	389	232	232	Irregular
Shorthorn	334	286	300	Irregular
	344	241	241	Regular
	352	283	283	Irregular
	329	293	293	Regular

[1] Regular and irregular express an opinion as to the length of the cycle.

of 321 the earlier date of puberty (compare Tables 1 and 4) represents the opinion of the senior author.

Time of Puberty.

A change in the nature of the structure on the ovary was apparent at the time of puberty. Prior to this time the ovary presented the granular feeling of numerous underdeveloped or atretic follicles; after this time one or more structures appeared on the surface of the ovary, large and persistent enough to indicate a mature follicle or corpus luteum.

The exceptions to this were one 50° F Brahman (309) and the open shed Brahmans (all except calf 303), in which, after one or two ovarian cycles in the fall (September and October), the ovaries again presented a surface without structures large enough to be functional. This period of ovarian activity, although followed by an estrus, was regarded as the time of puberty in these calves.

As shown in Figure 2, age and body weight were more variable at the time of puberty than wither height and chest girth. This variability is partly due to the fact that wither height and chest girth at the start of the experiment were closer to mature values than were age and body weight. Tables 6 and 7 show that wither height at puberty averaged only 142% of the starting value and yet, 82% of the predicted mature value; chest girth at puberty averaged 271% of the starting value and 72% of the predicted mature value; while weight at puberty was 486% of the starting value and only 43% of the predicted mature value. These comparisons give emphasis to the fact that in growing to maturity there

TABLE 5--AVERAGE VALUES AT PUBERTY

Breed	Brahman			Santa Gertrudis			Shorthorn		
Environment	50°F	80°F	Shed	50°F	80°F	Shed	50°F	80°F	Shed
Age (days)	307	463	397	290	290	306	303	440	280
Body Weight (kg)	261	357	296	295	269	243	263	267	219
Wither Height (cm)	114	118	118	112	109	110	111	111	108
Chest Girth (cm)	154	171	156	153	148	145	152	152	137

These animals were raised at 50° and 80°F and then exposed to the various temperatures (65°-105°F)

TABLE 6--VALUE AT PUBERTY AS A PERCENT OF STARTING VALUE

Breed	Brahman			Santa Gertrudis			Shorthorn		
Environment	50°F	80°F	Shed	50°F	80°F	Shed	50°F	80°F	Shed
Age	593	886	759	630	577	993	532	625	534
Body Weight	434	570	654	403	436	514	458	517	387
Wither Height	137	147	151	141	132	143	139	145	140
Chest Girth	212	228	243	220	203	220	213	220	193

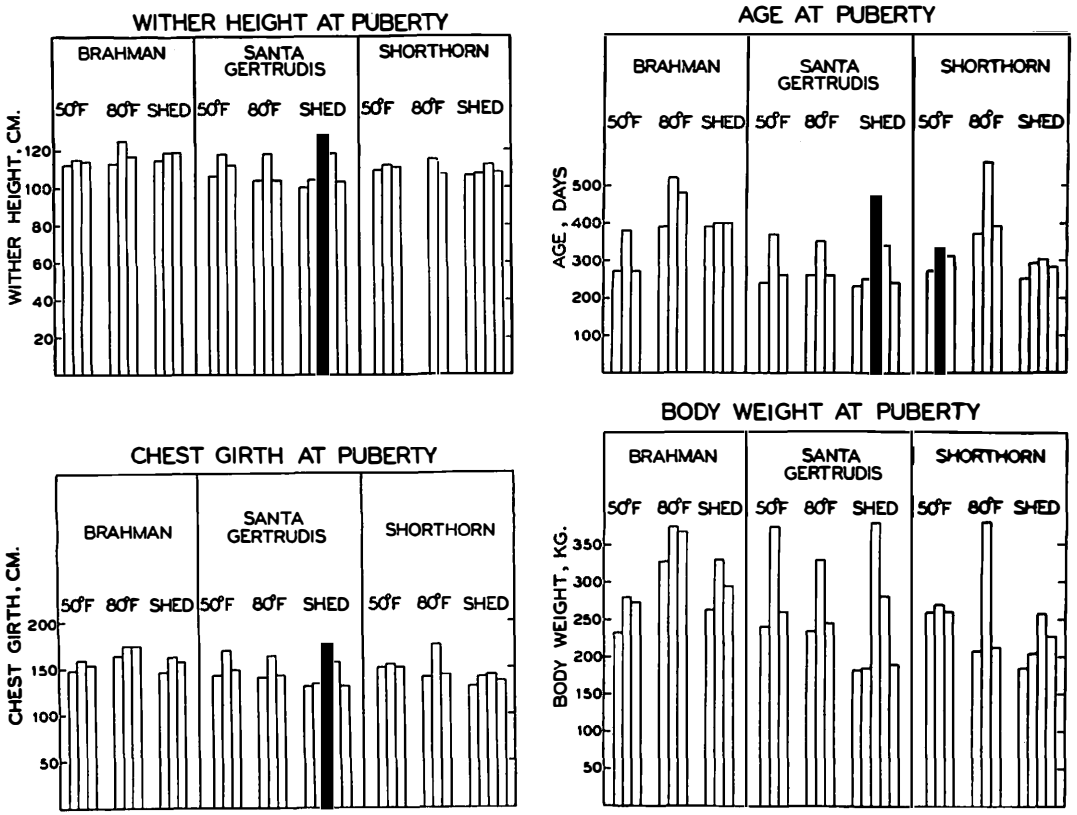


Fig. 2—Physical measurements at the time of puberty.

TABLE 7--VALUE AT PUBERTY AS A PERCENT OF PREDICTED MATURE VALUE

Breed	Brahman			Santa Gertrudis			Shorthorn		
Environment	50°F	80°F	Shed	50°F	80°F	Shed	50°F	80°F	Shed
Age	12	19	17	13	11	12	11	14	9
Body Weight	44	60	50	43	39	36	39	45	32
Wither Height	83	95	86	82	80	77	80	81	75
Chest Girth	74	84	77	71	69	66	69	75	63

is relatively more change in body weight (and age) than in wither height and chest girth. Nonetheless the data indicate that while the calves at puberty were close to the same stature (wither height and chest girth), they reached this stature at quite different ages and with considerable variation in the amount of soft tissue. The effect of temperature on sexual maturity is, to some degree, the result of altered nutrition and growth rate.

Calves grow at different rates and ultimately reach different sizes. An informative relationship is shown in Table 7 where the mean value at puberty (Table 5) is expressed as percent of the predicted mature value.[21] Disregarding for a moment the open shed calves of all breeds, it is apparent that in terms of percent of predicted mature value puberty was delayed in the 80° F Brahmans, a breed in which growth was more rapid at 80° than at 50° F. In the Shorthorns the effect was similar but not as pronounced. The Shorthorn data are distorted by calf 338 at 80° F; 338 was about 100 pounds heavier than the other 80° F Shorthorns at similar age, yet she did not reach puberty until 560 days of age compared to 370 and 380 days of age for the other 80° F Shorthorn calves. In both the 80° F Brahmans and the 80°F Shorthorn 338, where heat tolerance was indicated by a rapid growth rate, puberty was delayed, compared to calves of the same breed at 50° F or to the two heat intolerant Shorthorns at 80° F. In this case the effect of environmental temperature on puberty was not the result of altered nutrition and growth rate but apparently a temperature effect on hypothalamic-hypophyseal activity.

The open shed Brahmans appeared to have a breeding season in September and October. Here puberty was presumably the result of an interaction between body size and the environment;[3, 19, 20] however, calf 303, which did not mature, was one of the largest calves in this group.

The Shorthorns reached puberty at an earlier age and smaller size in the open shed than at either 50° or 80° F; this is apparent both in absolute values (Table 5) and as a percent of the predicted mature value (Table 7). Time of puberty in the Santa Gertrudis calves did not seem to be affected much by climatic conditions.

Regularity of Cycles.

The day of ovulation was not determined; as a consequence no information is available concerning the length or regularity of the estrous cycles beyond that which can be gained from Tables 1 to 3. The opinion was expressed by the pal-

pators, however, that all of the calves except the open shed Brahmans and some Santa Gertrudis did have ovarian cycles in the sense that an ovarian follicle was followed by a corpus luteum but that in many instances (Table 4) the length of the cycle, especially the persistence of the corpus luteum, was not uniform.

As noted in the previous section, the open shed Brahmans and one 50° F Brahman were apparently seasonal in their ovarian activity. Several Santa Gertrudis calves had multiple follicles on the ovary which persisted for long periods of time, in one instance up to 150 days. Table 8 shows the age in days when the words "multiple follicles" appeared on the record cards. In some cases, e.g.,

TABLE 8--DAYS OF AGE WHEN MULTIPLE FOLLICLES WERE PALPATED ON THE OVARIES

Temp.	Calf	Days of Age
		Brahman
50°	301:	
	309:	
	319:	
80°	302:	
	315:	533
	321:	
Shed	303:	
	313:	
	361:	
	362:	
		Santa Gertrudis
50°	387:	
	366:	269, 287-396, 455-458, 542
	368:	
80°	384:	449, 487, 501, 523
	393:	272-279, 293-454, 465-475, 493, 513, 531-538
	396:	316-329, 346, 357, 365, 384-391, 409-420, 492-496, 510, 528, 549
Shed	371:	
	385:	288-306, 491
	390:	
	379:	363, 380, 391, 399, 437-440
	389:	
		Shorthorn
50°	332:	466, 538, 559-562
	342:	355, 404, 423, 446, 467, 487, 527, 544
	349:	427, 570
80°	338:	616
	354:	480, 539, 560, 579
	355:	418
Shed	329:	368, 377
	334:	328, 339-374, 443, 465, 489
	344:	309, 449
	352:	419

Shorthorn 342, multiple follicles apparently were part of the normal cycle; in others, e.g., Santa Gertrudis 366 and 393, their persistence precluded cyclic ovarian activity. None of the calves showed symptoms of nymphomania.

Persistent multiple (cystic) follicles have been recognized as a disease of domestication, close confinement, and high production[24]; certainly conditions that prevailed in this experiment.

Right vs Left Ovary.

The two ovaries do not function alternately. In cows it has been demonstrated that ovulation occurs more frequently from the right ovary than from the left.[22]

Table 9 shows the total number of rectal examinations after puberty and expresses as percent the frequency with which structures were palpated on each ovary. With random sampling (rectal examinations) of equally distributed (between right and left) ovulations, the two frequencies should be approximately equal. The observed results, an incidence of 64% for the right ovary and 47% for the left ovary, would occur about four times in 100 as a result of chance (Chi Square).

TABLE 9--FREQUENCY OF STRUCTURES ON RIGHT AND LEFT OVARIES

Temp.	Calf	Examined (No. times)	Right Ovary: No. of "X"	Right Ovary: No. of "?"	Right Ovary: Total X+?	Right Ovary: Frequency (X+?/Exam.)	Left Ovary: No. of "X"	Left Ovary: No. of "?"	Left Ovary: Total X+?	Left Ovary: Frequency (X+?/Exam.)
					Brahman					
50°	301	78	36	16	52	.67	14	4	18	.23
	309	50	0	5	5	.10	0	0	0	.00
	319	76	37	20	57	.75	6	6	12	.16
80°	302	13	5	2	7	.54	3	0	3	.23
	315	49	13	11	24	.49	19	4	23	.47
	321	26	11	4	15	.58	4	6	10	.38
Shed	303	0	0	0	0	.00	0	0	0	.00
	313	20	4	6	10	.50	0	0	0	.00
	361	18	6	5	11	.61	0	2	2	.11
	362	20	4	2	6	.30	0	6	6	.30
					Santa Gertrudis					
50°	387	53	22	16	38	.72	4	2	6	.11
	366	83	65	10	75	.90	48	7	55	.66
	368	81	51	20	71	.88	12	5	17	.21
80°	384	57	23	12	35	.61	22	7	29	.51
	393	81	69	8	77	.95	45	19	64	.79
	396	78	43	15	58	.74	45	10	55	.71
Shed	371	57	28	5	33	.58	25	1	26	.46
	385	81	17	2	19	.23	50	6	56	.69
	390	20	10	5	15	.75	6	3	9	.45
	379	86	49	12	61	.71	43	16	59	.69
	389	82	51	8	59	.72	12	8	20	.24
					Shorthorn					
50°	332	73	29	5	34	.47	38	9	47	.64
	342	81	45	6	51	.63	33	10	43	.53
	349	76	32	8	40	.53	31	4	35	.46

TABLE 9--CONTINUED

Temp.	Calf	Examined (No. times)	Right Ovary				Left Ovary			
			No. of "X"	No. of "?"	Total X+?	Frequency (X+?/Exam.)	No. of "X"	No. of "?"	Total X+?	Frequency (X+?/Exam.)
					Shorthorn (cont.)					
80°	338	15	11	0	11	.73	5	0	5	.33
	354	57	40	8	48	.84	10	7	17	.30
	355	50	25	3	28	.56	20	5	25	.50
Shed	329	56	18	15	33	.59	42	7	49	.88
	334	52	37	3	40	.77	31	10	41	.79
	344	45	17	13	30	.67	17	9	26	.58
	352	53	21	2	23	.43	22	4	26	.49
	Total	1667			1066	.64			784	.47

Physical Activity.

The physicial activity of cows has been correlated with ovarian activity.[11] Partly to confirm the results of palpation findings and also because of a difference in hoof growth, pedometers were used to estimate physical activity.

A difference of hoof growth between 50° and 80° F calves was marked at six months of age (Figure 3). Overgrowth of hooves was most apparent in the 80° F Brahmans; it was apparent but less obvious in the 50° F Shorthorns.

It is usually assumed that the hooves wear off with walking and that an overgrowth is associated with inactivity. This assumption may explain the difference in hoof growth of the 50° and 80° F Shorthorn calves; however, as shown in Table 10 and Figure 4, the 80° F Brahmans were more active than the Brahmans at 50° F. Some other factor, perhaps the moisture content and consequently the abrasive qualities of the bedding, may be responsible for the difference. Starting July 15, 1955, the hooves were trimmed about every 30 days in all calves where overgrowth was apparent.

TABLE 10--PHYSICAL ACTIVITY AS STEPS PER WEEK OF BRAHMAN, SANTA GERTRUDIS, AND SHORTHORN CALVES AT 50° AND 80°F. FROM MAY 26, 1955 TO DECEMBER 16, 1955

	Steps per Week*			
Temp.	Brahman	Santa Gertrudis	Shorthorn	Mean
50°	31,500	32,800	25,500	29,900
80°	36,500	29,100	34,300	33,300
Mean	34,000	30,900	29,900	

* Average (to nearest 100) of three calves of each breed.

Analysis of Variance[28]

Source	D.F.	Sum of Square	Variance (s^2)	F
Breeds	2	1,000,289,952	500,144,976	6.6**
Temperature	1	922,640,706	922,640,706	12.3**
Weeks	17	3,716,955,252	218,644,427	2.9**
Breed-temperature	2	2,211,673,950	1,105,836,975	14.7**
Breed-weeks	34	2,704,843,242	79,554,213	1.1
Temperature-weeks	17	1,776,293,919	104,487,878	1.4
Breed-temp.-weeks	34	1,878,271,442	55,243,278	.7
Residual	217	16,340,011,955	75,299,594	

** Significant .01

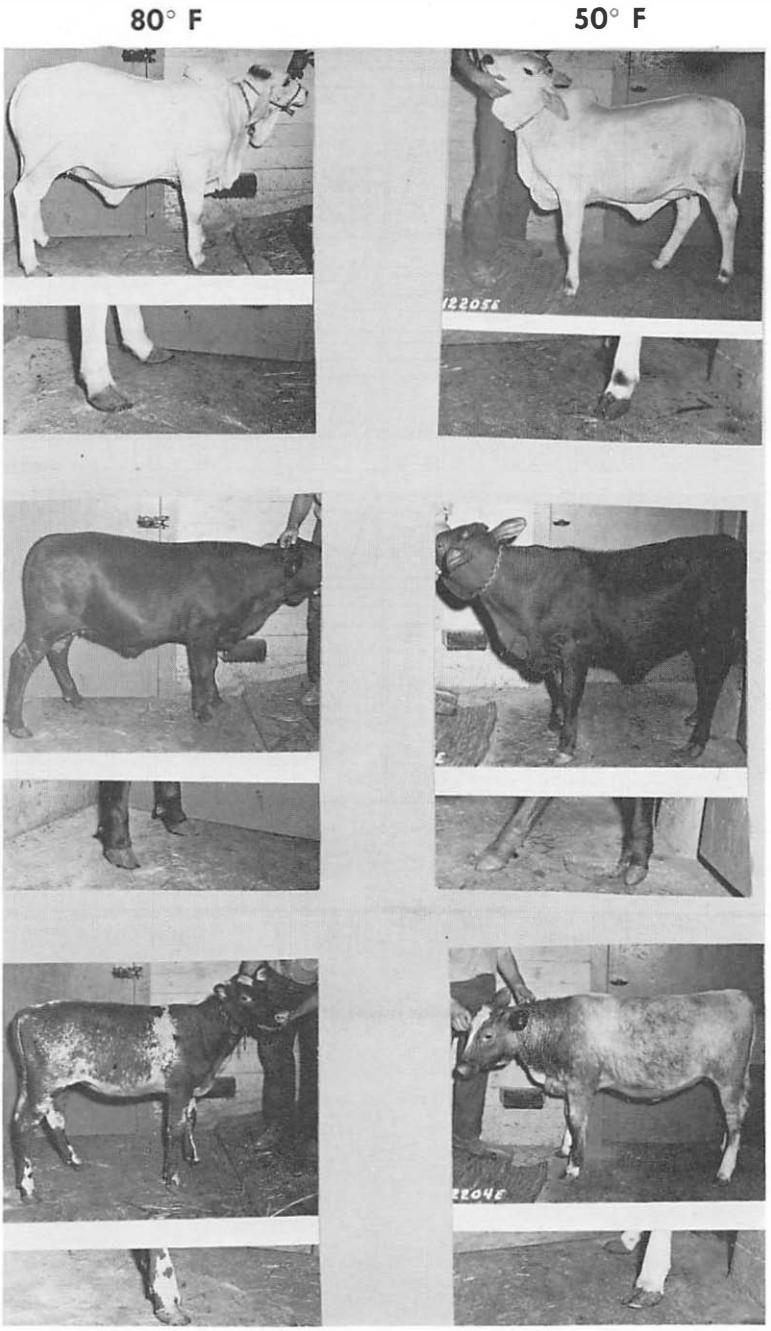


Fig. 3—Appearance of calves' feet in May, 1955, after approximately six months in the climatic laboratory.

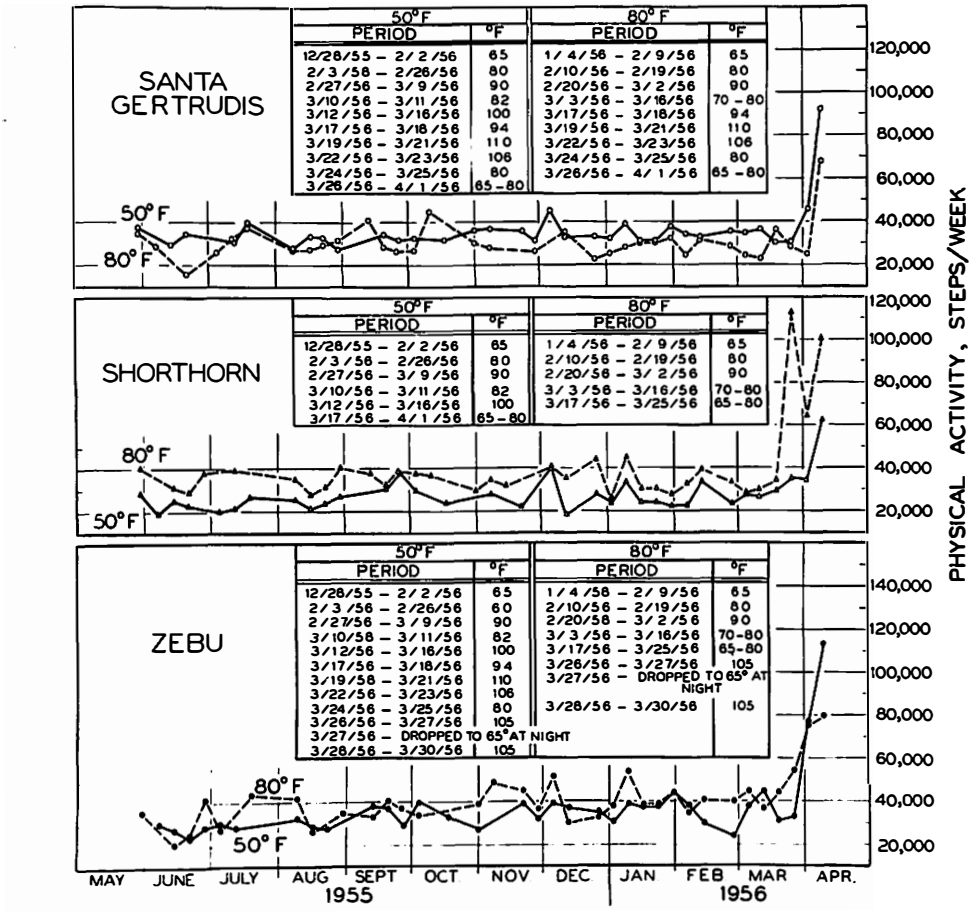


Fig. 4—Physical activity as steps per week for calves at 50° and 80° F. Each line represents the average of three calves.

The physical activity showed no correlation with ovarian activity; time of ovulation and estrus were not precisely determined; pedometers were read at weekly intervals, and the activity of one calf tended to increase the activity of all of the calves in a pen. Greater "physical activity" at the higher temperature is, in the opinion of the authors, primarily a restless-type movement rather than a vigorous energy-consuming type of activity.

From January to March, 1956, both the 50° and 80° F calves were exposed to changing (generally rising) environmental temperatures. The pedometers, read at weekly intervals, did not measure physical activity during exposure to any one temperature; for example, the pedometer reading for one week may have included three days exposure to 80° F and four days exposure to 90° F. However, the general trend of the temperatures was up, and there was no similar trend apparent in physical activity. The abrupt rise in physical activity at the last of March and first of April came when the calves were changed from the Climatic Laboratory to open shed housing conditions.

REFERENCES

1. Andrews, F. N., The influence of the environment on reproduction in female farm animals. Iowa State College J. of Sci., 28:9-18, 1953.
2. Asdell, S. A., Factors involved in sterility of farm animals. Iowa State College J. of Sci., 28:127-132, 1953.
3. Asdell, S. A., *Patterns of mammalian reproduction.* Ithaca, N. Y.: The Comstock Publishing Co., 1946. 437pp.
4. Bissonnette, T. H., Experimental modification of breeding cycles in goats. Physiol. Zool., 14:379-383, 1941.
5. Bissonnette, T. H., and E. E. Bailey, Litters from ferrets in January induced by increased exposure to light after nightfall. Amer. Nat., 70:454-458, 1936.
6. Cowie, A. T., and S. J. Folley, Physiology of the gonadotropins and the lactogenic hormone. *The hormones. Vol. III,* Pincus, G., and K. V. Thimann (Editors). New York: The Academic Press, 1955. 1012pp.
7. Dutt, R. H., E. F. Ellingon, and W. W. Carlton, Effect of shearing and exposure to elevated air temperatures on fertility and early embryo survival in ewes. J. Animal Sci. 15:1307, 1956.
8. Eaton, O. N., and V. L. Semmons, Inducing extraseasonal breeding in goats and sheep by controlled lighting. U.S.D.A. Circ. 933, 1953, 16pp.
9. Edwards, J., Season and rate of conception. Nature, 142:357, 1938.
10. Erb, R. E., and D. R. Waldo, Seasonal changes in fertility of dairy bulls in northwestern Washington. J. Dairy Sci., 35:245-249, 1952.
11. Farris, E. J., Activity of dairy cows during estrus. J. Amer. Vet. Med. Assoc., 125: 117-120, 1954.
12. Garner, W. W., and H. A. Allard, Effect of the relative length of day and night and other factors of the environment on growth and reproduction in plants. J. Ag. Res., 18:553-606, 1920.
13. Hammond, J., *The physiology of reproduction in the cow.* Cambridge Univ. Press, 1927. 226pp.
14. Hammond, J., Jr., Light regulation of hormone secretion. Vitamins and Hormones, 12:157-206, 1954.
15. Leopold, A. C., Photoperiodism in plants. Quart. Rev. Biol., 26: 247-263, 1951.
16. Marshall, F. H. A., Exteroceptive factors in sexual periodicity. Biol. Rev., 17:68-90, 1942.
17. Mites, J., Relation of nutrition to endocrine-reproductive functions. Iowa State College J. of Sci., 28:19-44, 1953.
18. Mercier, E., and G. W. Salisbury, Seasonal variations in hours of daylight associated with fertility level of cattle under natural breeding conditions. J. Dairy Sci., 30: 747-756, 1947.
19. Parkes, A. S., *Marshall's physiology of reproduction. Vol. I, Part One,* Third edition, London: Spottiswoode, Ballantyne and Co. Ltd., 1956, 688pp.
20. Parkes, A. S., *Marshall's physiology of reproduction. Vol. II.,* Third edition, London: Longman's, Green and Co., 1952. 880pp.

21. Ragsdale, A. C., C. S. Cheng, and H. D. Johnson, Environmental physiology and shelter engineering. XLII. Effects of constant environmental temperatures of 50° F and 80° F on the growth responses of Brahman, Santa Gertrudis, and Shorthorn calves. Mo. Agr. Exp. Sta. Res. Bul. 642, 1957. 32pp.
22. Reece, R. P., and C. W. Turner, The functional activity of the right and left bovine ovary. J. Dairy Sci., 21:37-39, 1938.
23. Reid, J. T., Relationship of nutrition to fertility in animals. J. Amer. Vet. Med. Assoc., 114:158-164, 242-250, 1949.
24. Roberts, S. J., *Veterinary obstetrics and genital diseases.* Ithaca, N. Y., Published by the author; distributed by Edwards Bros. Inc., Ann Arbor, Michigan, 1956, 551pp.
25. Rowan, W., Relation of light to bird migration and developmental changes. Nature, 115:494-495, 1925.
26. Rowan, W., Light and seasonal reproduction in animals. Biol. Rev., 13: 374-402, 1938.
27. Samuels, L. T., The relation of the anterior pituitary hormones to nutrition. Recent progress in hormone reseach, 1:147-170, 1945.
28. Snedecor, G. W., *Statistical methods applied to experiments in agriculture and biology.* Fourth edition, Ames, Iowa Iowa State College Press, 1946. 485pp.
29. Sorensen, A. M., Jr., *et. al.* The growth and sexual development of young Holstein heifers as influenced by three levels of nutrition. J. Animal Sci., 13:1031-1032, 1954.
30. Zuckerman, S., Pathways in the environmental stimulation of the pituitary. J. Endocrinology, 5:15-17, 1946.

APPENDIX

Gynecological Examination

Calf No._____ Operator_____ Date_____

Right ovary:

size:

follicle:

corpus luteum:

Left ovary:

size:

follicle:

corpus luteum:

Uterus:

size:

position:

tone:

Remarks:

Fig. 1