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J. H. LONGWELL, Director

Environmental Physiology and Shelter Engineering

With Special Reference to Domestic Animals

LIII. TEMPERATURE EFFECTS ON THYROID I^{131} RELEASE RATE OF DAIRY CALVES

H. D. JOHNSON AND A. C. RAGSDALE
WITH TECHNICAL ASSISTANCE OF
DELANO ROBERTSON

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SUMMARY

Thyroid activity, an endocrine function, is believed to be clearly associated with the production potential of cattle. Since thyroid I^{131} activity is generally known to be influenced by climate or the environment, the following studies were initiated.

This bulletin is a report of thyroid I^{131} release rate data obtained over a period of a year and one half. Part I is a growth study on changes in thyroid activity I^{131} of 18 Holstein, Brown Swiss, and Jersey calves maintained at either 50°F or 80°F, from a few days to approximately one year of age. Part II is a continuation of studies on the same animals. It describes the effects of rising environmental temperature (35°-95°F) on the thyroid I^{131} activity of calves acclimated to either 50° or 80°F during growth.

Studies of the effect of age, body weight, and temperature on thyroid I^{131} release rate of growing calves were conducted under controlled environmental conditions in the climatic laboratory.

Throughout the growth study thyroid I^{131} release rates of Jersey calves were approximately twice as great as those of Holsteins and Brown Swiss.

At both temperatures and for all calves, thyroid I^{131} activity increased with age; thyroid I^{131} activity per unit weight decreased with age. The rate of increase in thyroid I^{131} activity with body weight (and age) was significantly higher in the Jerseys than in either the Brown Swiss or the Holsteins.

Thyroid I^{131} activity per unit surface area showed no effect of temperature, but did increase slightly with increments in both age and temperature.

Rising environmental temperature (35°-95°F) caused a gradual decrease in thyroid I^{131} release rate of all calves—particularly above 80°F. Significant negative correlations were obtained between rising environmental temperature and thyroid I^{131} release rate.

PART I. CHANGES IN THYROID I^{131} RELEASE RATE DURING GROWTH IN HOLSTEIN, BROWN SWISS AND JERSEY CALVES AT CONSTANT ENVIRONMENTAL TEMPERATURE (50° AND 80°F)

Thyroid I^{131} activity, believed to be an important factor in growth and milk production, was measured on growing dairy calves the effects of 50° and 80° F constant environmental temperature on the changes in thyroid activity during growth (1-12 months).

The studies of Johnson *et al.* (6) (8) on rabbits showed that relatively high constant environmental temperatures depressed thyroid I^{131} release rate. Blincoe (2) demonstrated a similar effect upon beef cattle and Brown-Grant (3) provided evidence that cold environmental temperatures increased the thyroid I^{131} rate of rats.

CONDITIONS AND METHODS

These studies were conducted under controlled environmental conditions in the Missouri climatic laboratory. The laboratory consists of two independently controlled chambers; one chamber was maintained at a constant temperature of 50° F, the other at a constant temperature of 80° F. Humidity, air velocity, and illumination remained constant.

Holstein, Brown Swiss, and Jersey heifer calves were used in these studies. Three calves of each breed were placed in pens in each chamber at about two weeks to one month of age and were maintained there until the end of the experiment (about 12 months of age). Feed composition and management were the same for each chamber.

Calves were fed alfalfa hay *ad libitum* and grain according to a program similar to that suggested by Herman (4).

Experimental Procedures: Approximately every six weeks the calves were injected intravenously with carrier-free Na I^{131} The dose level was 100 uc until the calves were six months old, then 200 uc throughout the remainder of the experiment.

Figure 1 indicates the method of determination of the thyroid I^{131} release rate. The restraining stall and head-holder is portable and the wheels are removed during counting procedures. The counting stall was moved into the temperature chambers and counts were made daily. Animals readily became accustomed to the procedure. An NRD scintillation detector (1″ crystal) with a

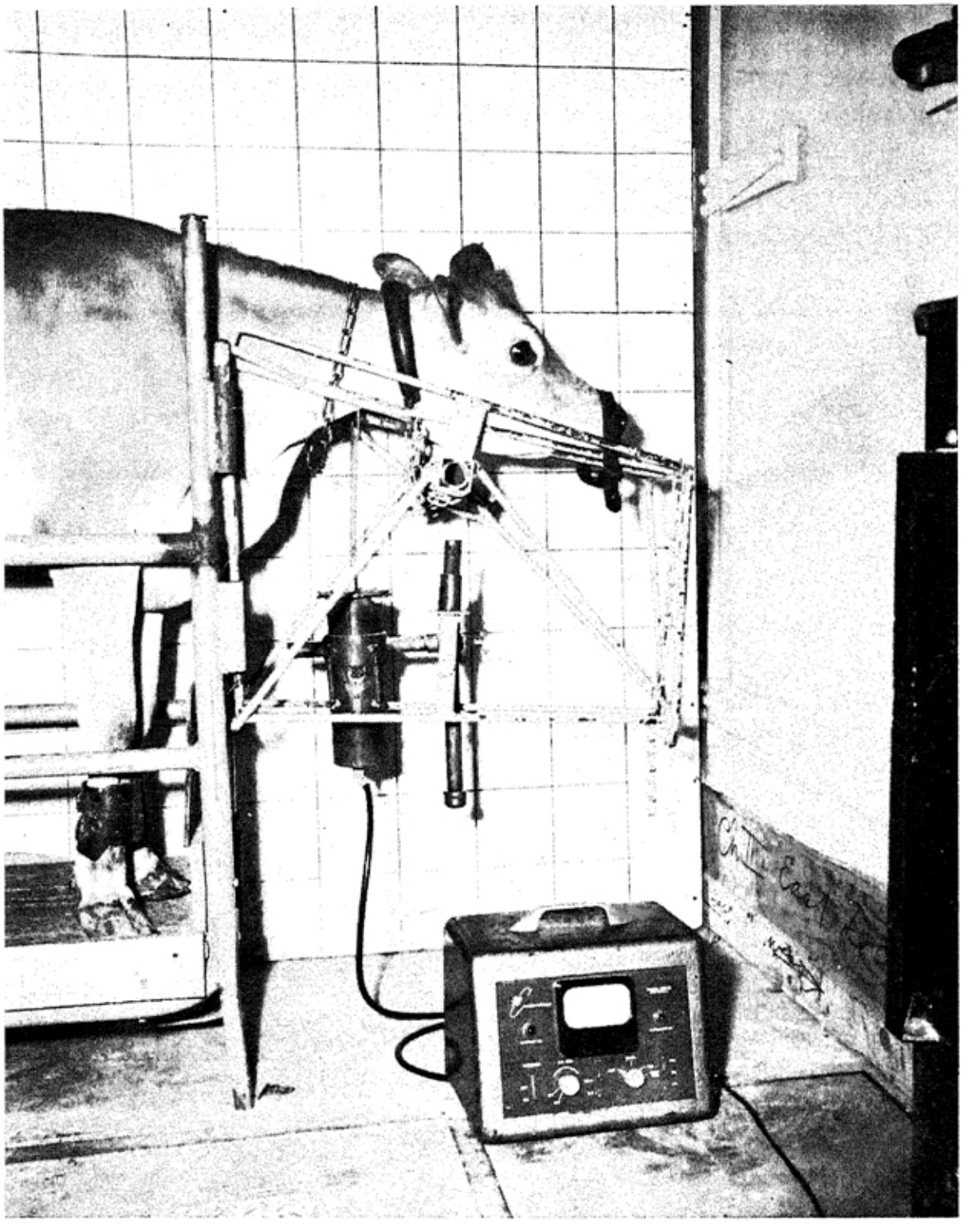

Fig. 1—Thyroid I^{131} activity counting apparatus. The stall is portable; the wheels are removed during the counting procedure.

30 cm. spacer was used for counting. Maximum counts per minute were recorded by a nuclear Chicago rate meter. The standard activity was determined (a known amount, actually ½ of the dose given the animal) at a distance approximately equal to that of the thyroid from the detector. Counts were made of the thyroid region; after correction for the standard dilution factor and room background level, these data were expressed as percentage of standard dose. Counts were made at the statistical error level of 0.01. Duplicate readings were taken and values averaged.

The values were plotted on semilogarithmic paper. Slopes were determined from daily data taken three to approximately 30-35 days after injection of Na I^{131}.* The slopes or loss of activity in the thyroid region were determined by the method of least squares to express the rate of thyroid release of I^{131} activity. This slope or K is equal to K_4 as reported by Blincoe and Brody (1).

In addition to thyroid I^{131} activity, many physical and physiological factors were measured on the growing dairy calves. Measurements included: body weight—twice weekly; heart girth and wither height—bi-monthly; surface area (surface integrator method), hair density ("beta gauge"), hair length, and color —every six weeks; rectal temperature, skin temperature, respiration, pulse rate, and feed and water consumption—daily; heat production, respiratory, surface (capsule), and total vaporization—weekly; and red-cell volume (Cr^{51}), butanol soluble I^{131}, and blood glutathione (GSH)—every six weeks.

DATA AND DISCUSSION

Changes in Thyroid I^{131} Activity Versus Age

The thyroid I^{131} release rate of the three breeds differed as shown in Figure 2 and Table 1.

TABLE 1--ANALYSIS OF VARIANCE OF THYROID I^{131} ACTIVITY

Source of Variation	Df	Mean Square	F	P
Temperatures	1	8.07	2.12	ns
Ages	6	36.83	9.69	.01
Breeds	2	75.40	22.47	.01
Temperatures x Ages	6	3.71	.90	ns
Temperatures x Breeds	2	13.22	3.48	.05
Ages x Breeds	12	3.08	.90	ns
Temperatures x Ages x Breeds	12	.51	.01	ns
Within	84	3.80	.01	ns
Total	125			

Both the breed differences and the breed and temperature interaction differences are significant, the former with a probability of less than 0.01 and the latter with one of 0.05. The change of thyroid I^{131} with age is significant at the

*Reutilization correction factors were not used since accurate values for calves of various ages and environmental temperature conditions were not available.

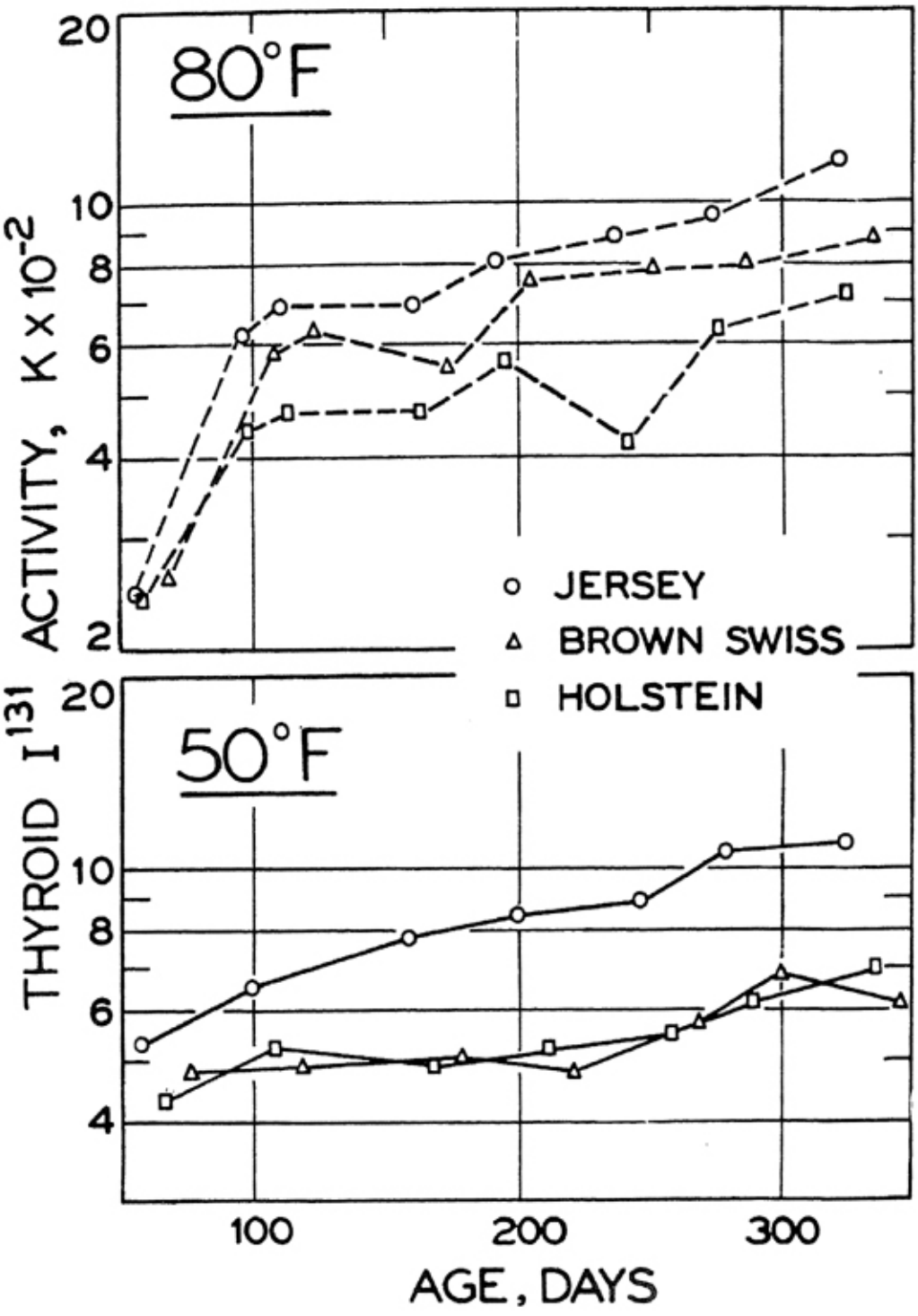

Fig. 2—Thyroid I^{131} activity of Jersey, Brown Swiss, and Holstein calves during growth at 50° and 80° F.

0.01 level of probability. Thyroid I^{131} activity appears to increase more with age at 80° F than at 50° F; however, the early data points greatly influence this trend and there is no statistically significant difference. The early data points for the calves in the 50° F room may have been high because the animals were experiencing considerable constant cold exposure for their relatively small body

size. The initially high thyroid I^{131} activity may have been a reflection of their extra heat requirements due to greater surface area per unit weight. It is also probable that the animals in the 80° F chamber were more heat-stressed during the early growth period and consequently depressed in their thyroid activity. As the animals became "adjusted" to the two temperature conditions, the 50° F and 80° F differences in thyroid activity became less. However, observations of short-period exposures, made by Johnson (7) at the conclusion of the growth experiment, indicated significant 80°-50° F differences. The present similarity in thyroid I^{131} activity is believed due to the relatively much longer period of "acclimation" or adaptation of the growing animal to the environment. The exact mechanism of "acclimation" in cattle is unknown at present.

Hoesslin (5) observed a similar adaptation phenomenon from results of studies on two litter mate dogs, one raised at 32° C and the other at 5° C. Though there was an enormous temperature difference between the body and the air, the metabolism of the dog reared at 5° C was only 12 percent higher. However, the cold-reared dog's fur was three times heavier than that of the 32° C animal. Dairy calves in the current experiment appeared to have compensated by this as well as by other physiological factors as indicated by unpublished hair density data on these calves. For example, the average hair densities for the 50° and 80° F dairy calves were 12.3 mg/cm and 9.2 mg/cm, respectively.

Individual Animal Differences in Thyroid I^{131} Activity

Striking individual differences were apparent in the 50° F Holsteins and the 80° F Jerseys as indicated graphically in Figure 3. Note the lower levels of thyroid I^{131} activity of Holstein 847 and Jersey 637. These within-breed differences were consistent throughout the growth study. Relationship of these individual differences to heat tolerance of level of production (growth) will be reported later. Despite this individual variability, however, the differences mentioned, i.e., breed and age, were highly significant (Table 1).

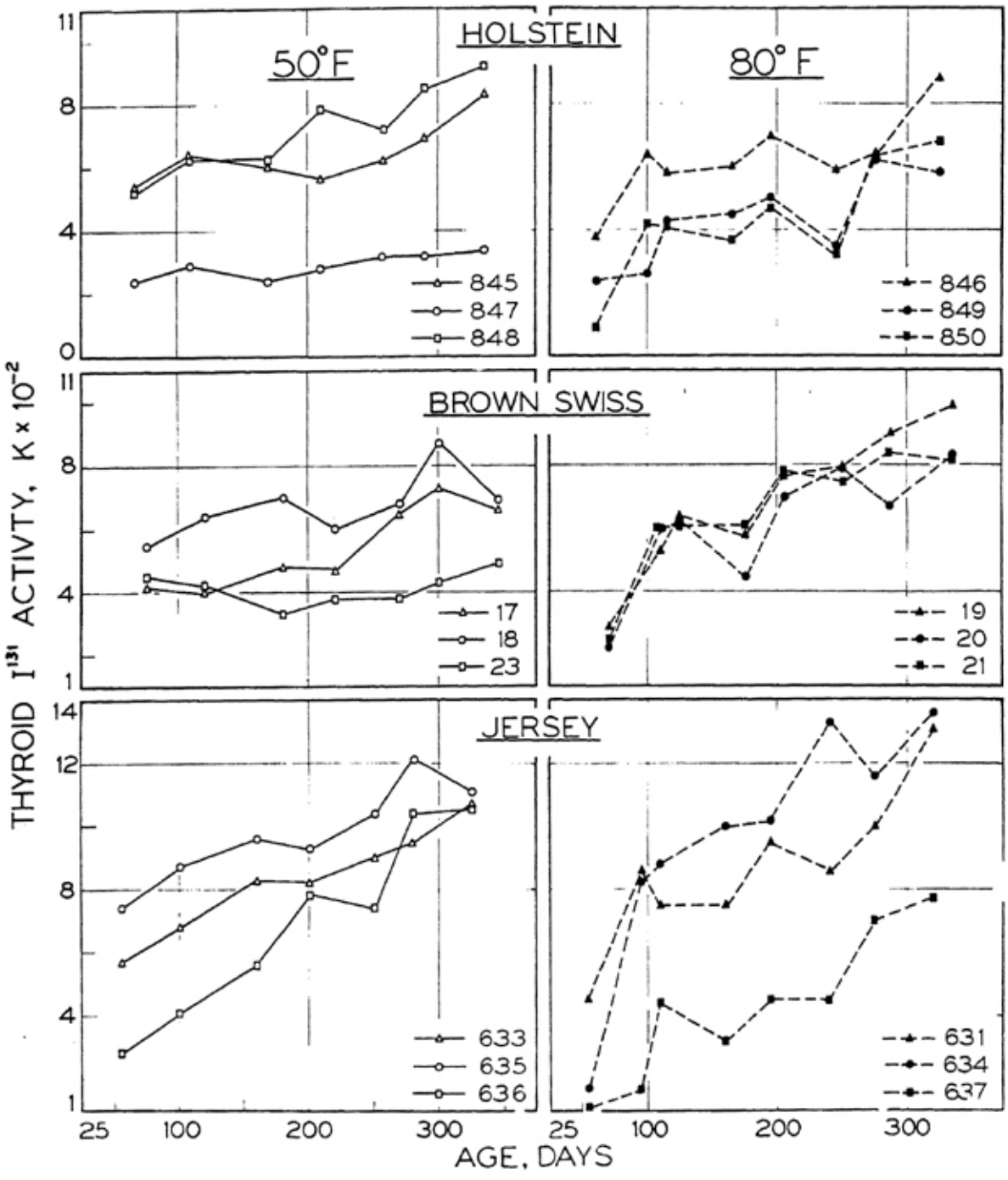

Fig. 3—Thyroid I^{131} activity for individual Holstein, Brown Swiss, and Jersey calves during growth at 50° and 80° F. Graphs indicate considerable individual differences in some breeds which were constant throughout the growth study.

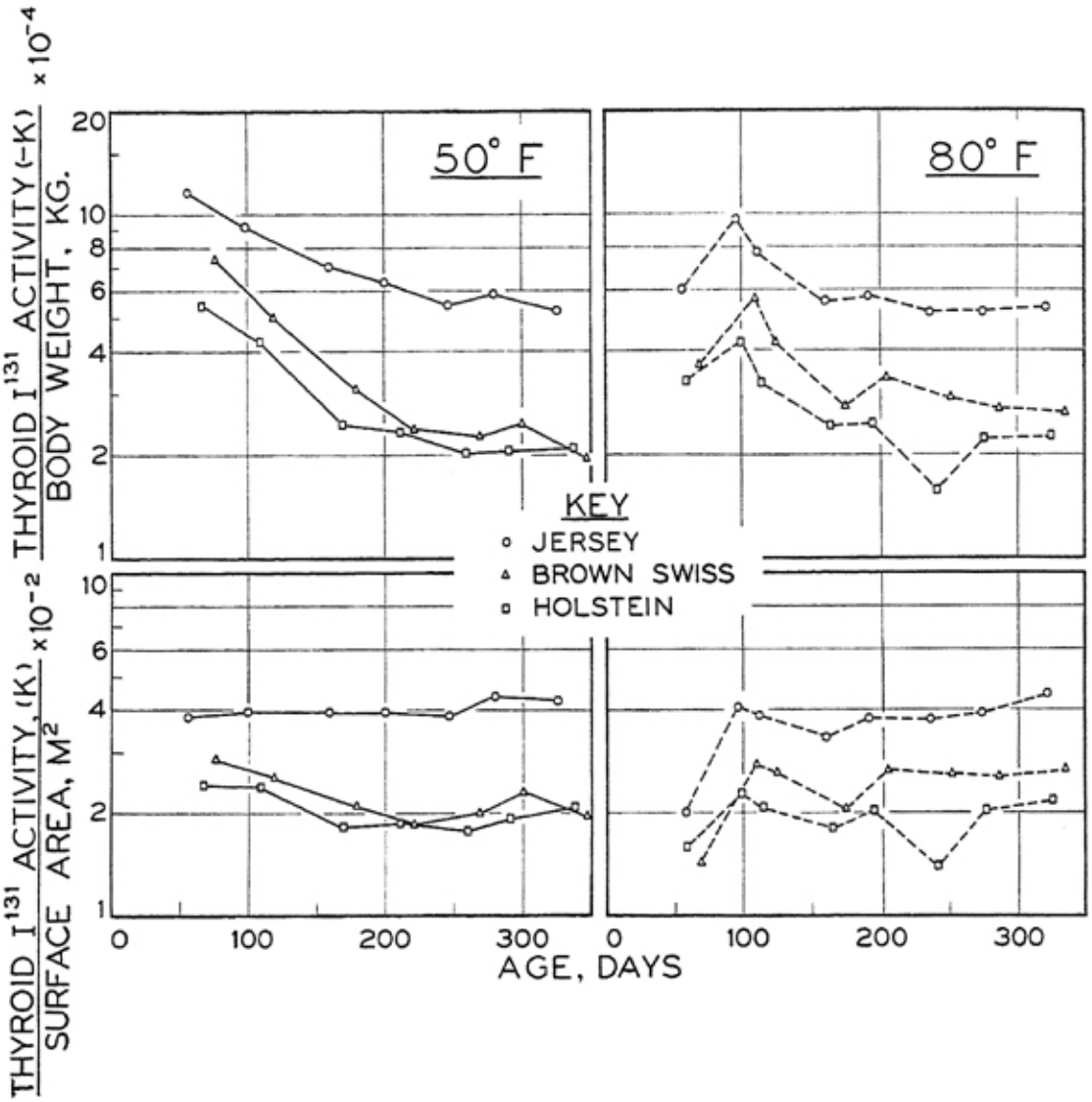

Fig. 4—Thyroid I^{131} activity per unit surface area and per unit body weight for Jersey, Brown Swiss, and Holstein calves raised at 50° and 80° F.

TABLE 2--ANALYSIS OF VARIANCE OF THYROID I^{131} ACTIVITY PER UNIT WEIGHT

Source of Variation	Df	Mean Square	F	P
Temperatures	1	8.89	3.98	.05
Ages	6	33.40	14.98	.01
Breeds	2	181.45	81.30	.01
Temperatures x Ages	6	10.01	4.48	.01
Temperatures x Breeds	2	2.99	1.34	ns
Ages x Breeds	12	.79	.35	ns
Temperatures x Ages x Breeds	12	.69	.31	ns
Within	84	2.23	.01	ns
Total	125			

Thyroid Activity Per Unit Weight

When expressing the thyroid I^{131} activity per unit weight (upper section of Figure 4 and Table 2), the Jerseys again have the highest values, the Brown Swiss intermediate, and the Holsteins the lowest value per unit weight throughout the study of growth. These differences are statistically significant at the 0.01 level of probability.

It is generally known that all metabolic functions are higher per unit weight in one to three months old calves than in older animals. At this age the thyroid I^{131} activity is approximately two fold greater than in animals approximately one year old. This definite trend for thyroid I^{131} activity per unit weight to decrease with increasing age is evident at both the 50° and 80° F temperatures. The difference in this ratio as a function of temperature was significant at 0.05, while the difference as a function of the interaction of age and temperature was again highly significant, with a probability of 0.01.

It is interesting to note that although the effect of temperature on thyroid I^{131} acivity per unit weight is clearly significant at the 0.05 level of probability, the effect of temperature upon thyroid I^{131} activity *per se* only approaches significance at the 0.10 level. The true effect may be masked by the influence of other variables.

Relationship of Thyroid Activity to Surface Area (M^2)

A constant relationship of thyroid I^{131} activity to growth is shown in the lower section of Figure 4. This graph relates a productive or compensatory productive mechanism such as thyroid I^{131} activity to the major heat conservation or dissipating surface of the animal. Again, as shown in Table 3 the ratios for

TABLE 3--ANALYSIS OF VARIANCE OF THYROID I^{131} ACTIVITY PER UNIT SURFACE AREA (M^2)

Source of Variation	Df	Mean Square	F	P
Temperatures	1	20.96	.20	ns
Ages	6	47.66	.50	ns
Breeds	2	4551.07	48.05	.01
Temperatures x Ages	6	234.60	2.05	.05
Temperatures x Breeds	2	152.10	1.62	ns
Ages x Breeds	12	9.11	.08	ns
Temperatures x Ages x Breeds	12	33.83	.03	ns
Within	84	93.83	.01	ns
Total	125			

the three breeds differ much in the same order, and they are significantly different at the 0.01 level of probability. Figure 5 and surface area data (Kennedy *et al.*, 9) offer an explanation for this relationship. Kennedy demonstrated that the logarithmic relationship of thyroid activity to body weight, which varies with the breed and temperature, is similar to the logarithmic relationship of

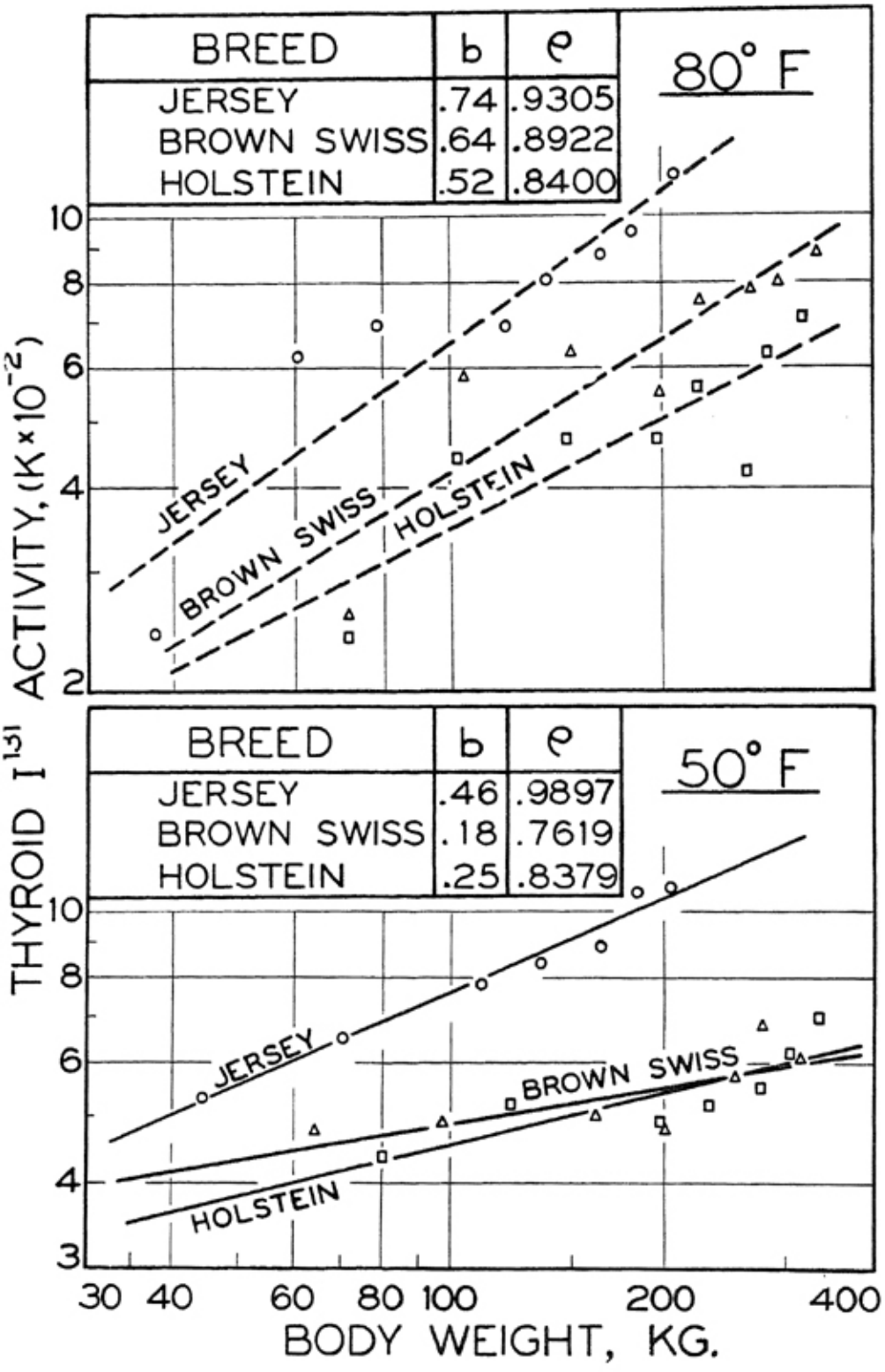

Fig. 5—Thyroid I^{131} activity versus body weight. Levels of significance of the correlation coefficients were as follows: 50° F—Jersey 0.01, Brown Swiss 0.05, and Holstein 0.05; 80° F—Jersey 0.01, Brown Swiss 0.05, and Holstein 0.01.

surface area to body weight. Although the ratio of thyroid I^{131} activity per surface area does not vary appreciably with either age or temperature, it does vary significantly at the 0.05 level as a function of the interaction between age and temperature.

The Logarithmic Relation of Thyroid I^{131} Activity to Body Weight

Data in Figure 5 are expressed by the equation $Y = aX^b$, with the thyroid activity as the dependent variable. Table 4 shows a statistical comparison of the

TABLE 4--STATISTICAL COMPARISON OF "b" VALUES FROM THYROID I^{131} ACTIVITY VS. BODY WEIGHT, KG. (FIG. 6)

Breed and Temperature	"b" Values		t	P
50°F Jersey vs. 80°F Jersey	.46,	.74	2.10	ns
50°F Brown Swiss vs. 80°F Brown Swiss	.18,	.64	3.86	.01
50°F Holstein vs. 80°F Holstein	.25,	.52	2.56	.05
50°F Jersey vs. 50°F Brown Swiss	.46,	.18	3.05	.02
50°F Jersey vs. 50°F Holstein	.46,	.25	2.58	.05
50°F Brown Swiss vs. 50°F Holstein	.18,	.25	.52	ns
80°F Jersey vs. 80°F Brown Swiss	.74,	.64	.66	ns
80°F Jersey vs. 80°F Holstein	.74,	.52	1.48	ns
80°F Brown Swiss vs. 80°F Holstein	.64,	.52	.73	ns

"b" values. An increase in weight (X) by 100 percent is associated with an approximate differential increase in Y (thyroid I^{131} activity) as low as 0.18 (50° F Brown Swiss) to as high as 0.74 (80° F Jerseys). Exponents for the 80° F Jerseys were: 0.74 compared to 0.46 for the 50° F Jerseys; 0.64 compared to 0.18 for the 50° F Brown Swiss; and 0.52 compared to 0.25 for the 50° F Holsteins.

The rate of increase of thyroid I^{131} activity with body weight was greater for 80° F Brown Swiss and 80° F Holstein than for the corresponding 50° F animals, the former being significant at 0.01 level of probability and the latter at 0.05. The difference between Jerseys was significant approaching the 0.05 level of probability. It is worthy of note that at 80° F the rate of increase of thyroid I^{131} activity did not differ according to breeds, but at 50° F the Jerseys' rate differed significantly from that of the Brown Swiss (0.02) and of the Holsteins (0.05). Values of thyroid I^{131} release rate and body weight for each of the three breeds at the two temperatures during growth are presented in appendices 1 and 2.

SUMMARY AND CONCLUSIONS

Studies on the effect of age and temperature on thyroid I^{131} release rate of growing calves were conducted under controlled environmental conditions in the climatic laboratory.

Statistically significant results indicated that the three breeds, Jersey, Brown Swiss, and Holstein, differed in thyroid I^{131} activity regardless of temperature. Although overall differences in thyroid I^{131} activity at 50° and 80° F during growth only approached significance, there was a distinct difference in the manner in which they approached 12 month levels. The thyroid I^{131} release rate of Jersey calves was approximately twice as great as the rate for Holsteins and Brown Swiss throughout this growth study. At both temperatures and for all

calves, thyroid I^{131} activity increased with age, whereas thyroid I^{131} activity per unit weight decreased with age. Although all calves showed the same trends, breed differences in the latter relationships were highly significant, Jerseys having the highest ratios, followed by Brown Swiss and Holsteins.

Thyroid I^{131} activity per unit weight was higher at 80° F than at 50° F with breed differences again occurring; the activity varied significantly as a function of age and temperature, and as a result of the interaction between temperature and age. There appears to be a greater decrease in thyroid I^{131} activity per unit weight with age at 50° F than at 80° F. Thyroid I^{131} activity per unit surface area showed no effect of temperature alone, but did increase slightly with increments in both age and temperature.

The rate of increase in thyroid I^{131} activity with increase in weight ("b" value) showed breed differences; the Jerseys' rate was significantly higher than that of either the Brown Swiss or Holsteins. The "b" values were significantly higher at 80° F than at 50° F for the Brown Swiss and Holsteins. Data also revealed an essentially constant relationship between the thyroid I^{131} activity and the surface area of the growing dairy calves between the ages of 1 and 12 months at the environmental temperatures of 50° F and 80° F.

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PART II. THE EFFECT OF RISING ENVIRONMENTAL TEMPERATURES (35°-95°F) ON THYROID I^{131} RELEASE RATE OF HOLSTEIN, BROWN SWISS AND JERSEY HEIFERS

Objectives of this phase of research were: (1) To determine the effect of long-term acclimation** (growth) on responses of dairy heifers to various environmental temperatures, (2) to determine the effect of the rising temperature on thyroid activity of heifers (approximately one year old), and (3) to provide new data by the thyroid I^{131} release rate method on animals that are uncomplicated by lactation or by a high rate of gain.

This study is a continuation of an experiment on the effects of constant 50° and 80°F environmental temperature on changes in thyroid activity of growing Brown Swiss, Jersey, and Holstein calves (13). In the first phase of study, calves were maintained in the laboratory from a few days of age to approximately one year of age. At the conclusion of the growth experiment, these heifers, acclimated to either 50° or 80°F, were exposed to rising environmental temperatures (35° to 95°F). The depressing effect of higher temperature upon physiological responses, including specific functions such as thyroid I^{131} activity, has been studied on mature dairy cows (3) and recently on beef calves (2, 14).

CONDITIONS AND METHODS

Eighteen heifers were used in this experiment. Three calves of each breed were raised at each of the environmental conditions (50° and 80°F). At the completion of the growth experiment all the heifers were exposed to progressively rising environmental temperatures ranging from 35° to 95°F. Management and light conditions remained constant as during the growth experiment. At temperatures lower than 90°F or 95°F the relative humidity was approximately 60 percent; at 90°F and 95°F, it was approximately 50%. The Jerseys were fed 3.3 pounds concentrate per day, while the Holsteins and Brown Swiss were fed 4.6 pounds per day. Alfalfa hay and water were available *ad libitum.*

Differences in body weight, hair color, and density are apparent in the photograph of the heifers taken at the end of the growth experiment and at the beginning of the current study (Figure 1). The Holsteins raised at 50°F were approximately 80 to 90 pounds heavier than those raised at 80°F. The 50°F Jerseys were approximately 20 pounds heavier than the 80°F Jerseys. The 80°F Brown Swiss weighed as much or more than those at 50°F.

**Acclimation is defined as biological changes in animals that have been exposed in the laboratory for more or less prolonged periods to various constant levels of a specific environmental factor, such as temperature, all other factors being the same (J. S. Hart, 1957) (10).

Heifers raised at 50°F, especially the Brown Swiss and the Jerseys, had much heavier and darker coats than those raised at 80°F. Hair density, a manifestation of physical thermoregulation, was measured by a "beta gauge." the average densities for the 50° and 80°F reared animals during growth were approximately 12.3 and 9.2 mg/cm, respectively (12).

Hair color, hair density, and body weight are some of the visible physical adaptations to environmental conditions; however, thyroid activity is an internal physiological adjustment and therefore more difficult to evaluate.

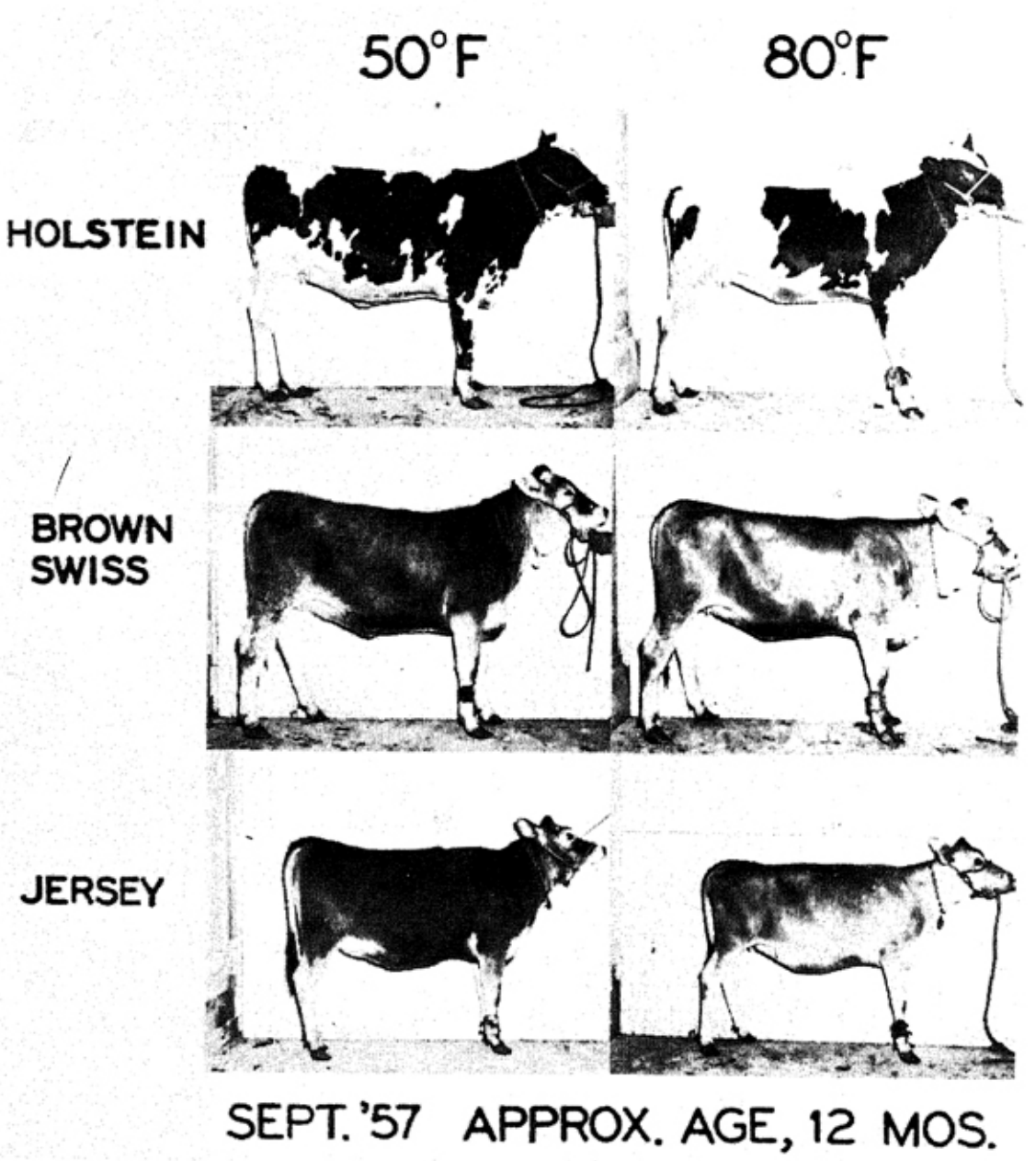

Fig. 1—Appearances of Holstein, Brown Swiss, and Jersey heifers at the conclusion of the growth experiment and at the initiation of this experiment where the animals were exposed to various environmental temperatures (35°-95°F).

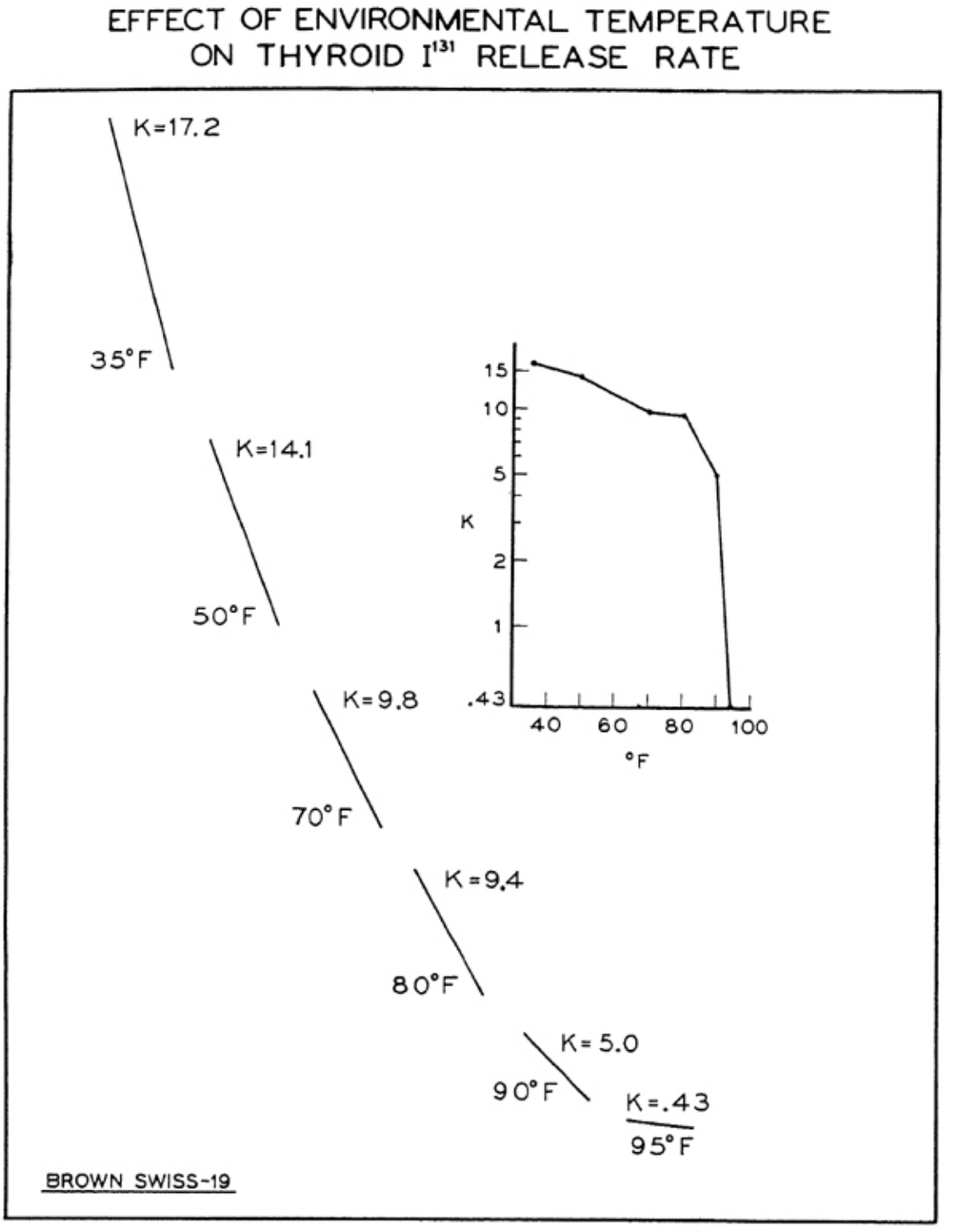

Fig. 2—Effect of environmental temperature on thyroid I^{131} release rate (K). Values for Brown Swiss No. 19 were used as an example.

The *in vivo* restraining method of measuring thyroid I^{131} release rate, a direct index of thyroid activity of animals, was used. It is described in part I of this bulletin. At the beginning of the experiment the heifers were injected in the jugular vein with 200 uc of sodium I^{131} and, thereafter, the uptake and release were measured throughout the experiment with the counting appartus described in Part I. The scintillation detector was spaced about 30 cm. from the

thyroid region of the animal. Readings for maximum count were made with a Nuclear Chicago rate meter.

The heifers were counted daily for several days or weeks, depending on the environmental temperature level. Corrections for isotope decay were determined by expression of the data as percentage of dose. These values were plotted on semi-logarithmic paper. The slopes were determined by fitting a regression equation ($Y = Ae^{kt}$) to the data by the method of least squares. Figure 2 shows graphically a typical slope as it compares to the K value—an empirical value used in the following graphs. The K values and the slopes decrease as the environmental temperature increases. The slopes or rates of release of thyroid I^{131} activity from the thyroid region represent a direct index of the function of the thyroid gland.

DATA AND DISCUSSION

In Figure 3, each of the datum points represents the average rate (K) of thyroid I^{131} release at each temperature level for the various breeds. The environmental scale indicates the number of days at each temperature. There is a striking decline in thyroid activity on exposure to the higher environmental temperatures. A negative correlation between thyroid activity and temperature proved to be significant below the 0.05 level of probability for each breed. Correlation coefficients are presented in Table I. Regression coefficents did not vary significantly with breed or with temperature in any instance.

TABLE 1
COEFFICIENTS OF CORRELATION BETWEEN THYROID I^{131} ACTIVITY AND ENVIRONMENTAL TEMPERATURE

Breed		50°F Animals
	r	P
Brown Swiss	-.8122	<0.05
Holstein	-.8715	<0.02
Jersey	-.8050	<0.05
		80°F Animals
Brown Swiss	-.9722	<0.01
Holstein	-.8893	<0.01
Jersey	-.9317	<0.01

Analysis of variance showed that the 50° F Jerseys' thyroid I^{131} values were significantly higher than those of the 50° F Holsteins at 50° F (<0.05) and at 90° F (<0.01). Significant differences appeared between the 50° F Jerseys and the 50° F Brown Swiss at 35° F (<0.05), 80° F (<0.05), and 90° F (<0.05). The Jerseys raised at 80° F, moreover, showed higher thyroid I^{131} activity than the

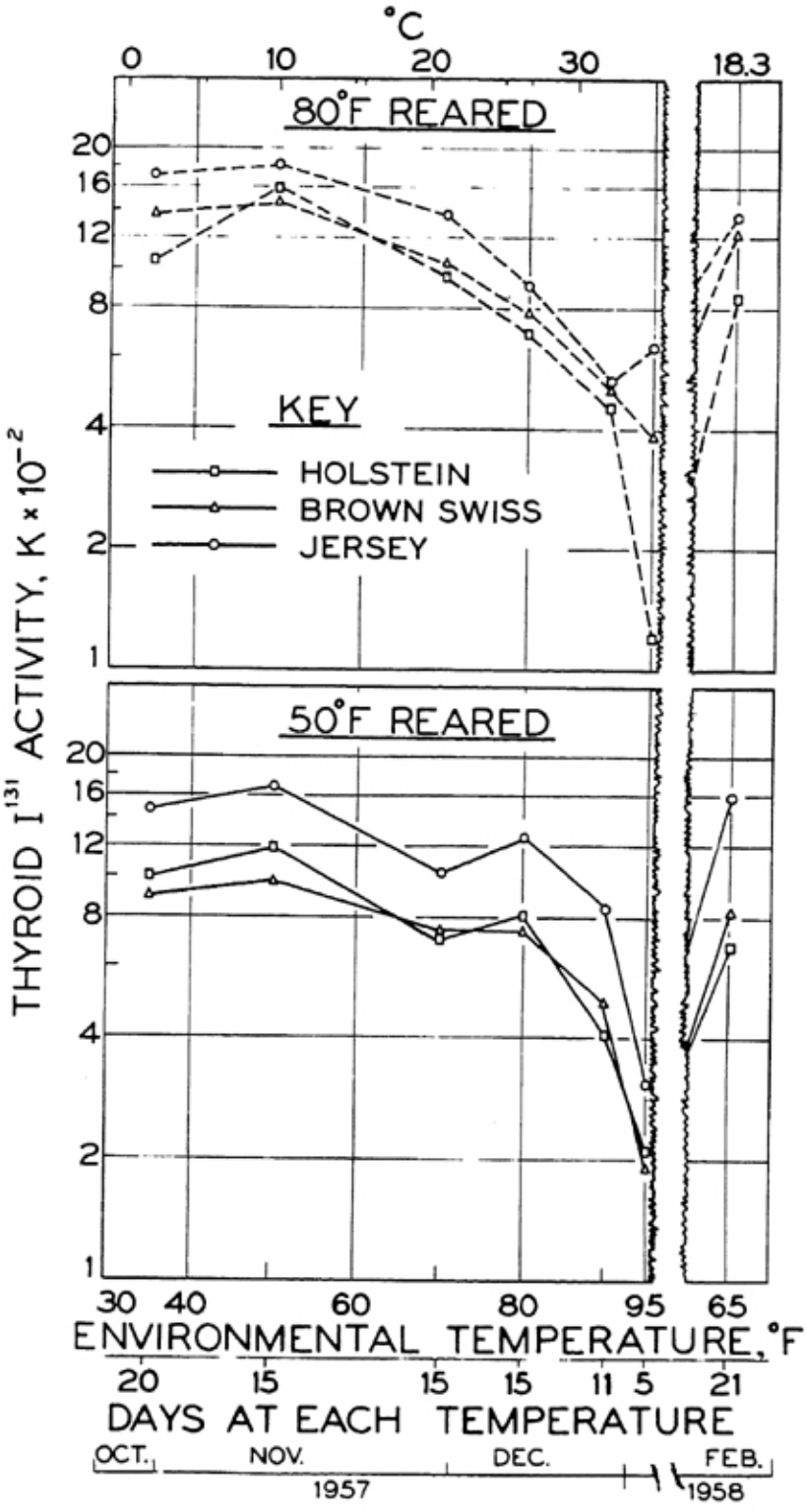

Fig. 3—Thyroid I^{131} activity vs. environmental temperature for 50° and 80° F reared Holstein, Brown Swiss, and Jersey heifers.

80° F Holsteins, at 35° F (<0.10) at 70° F (<0.05), and at 95° F (<0.02). They differed from the 80° F Brown Swiss at 70° F (<0.10). Both the 50° F and the 80° F Brown Swiss and Holsteins had about the same levels of thyroid I^{131} activity at the various temperatures. Statistical tests did not indicate a difference between the latter two breeds. Individual datum points of the calves at each temperature are shown in Appendix III and tables of statisical analyses of breed differences are in Appendix IV.

After the animals were exposed to the high temperature of 95° F they were exposed to 65° F. As indicated in Figure 4, both groups of animals, regardless of breed, responded fully within three weeks with a value comparable to an earlier 60°-70° F value. These data further emphasize the ability of the thyroid gland to respond readily to the environment.

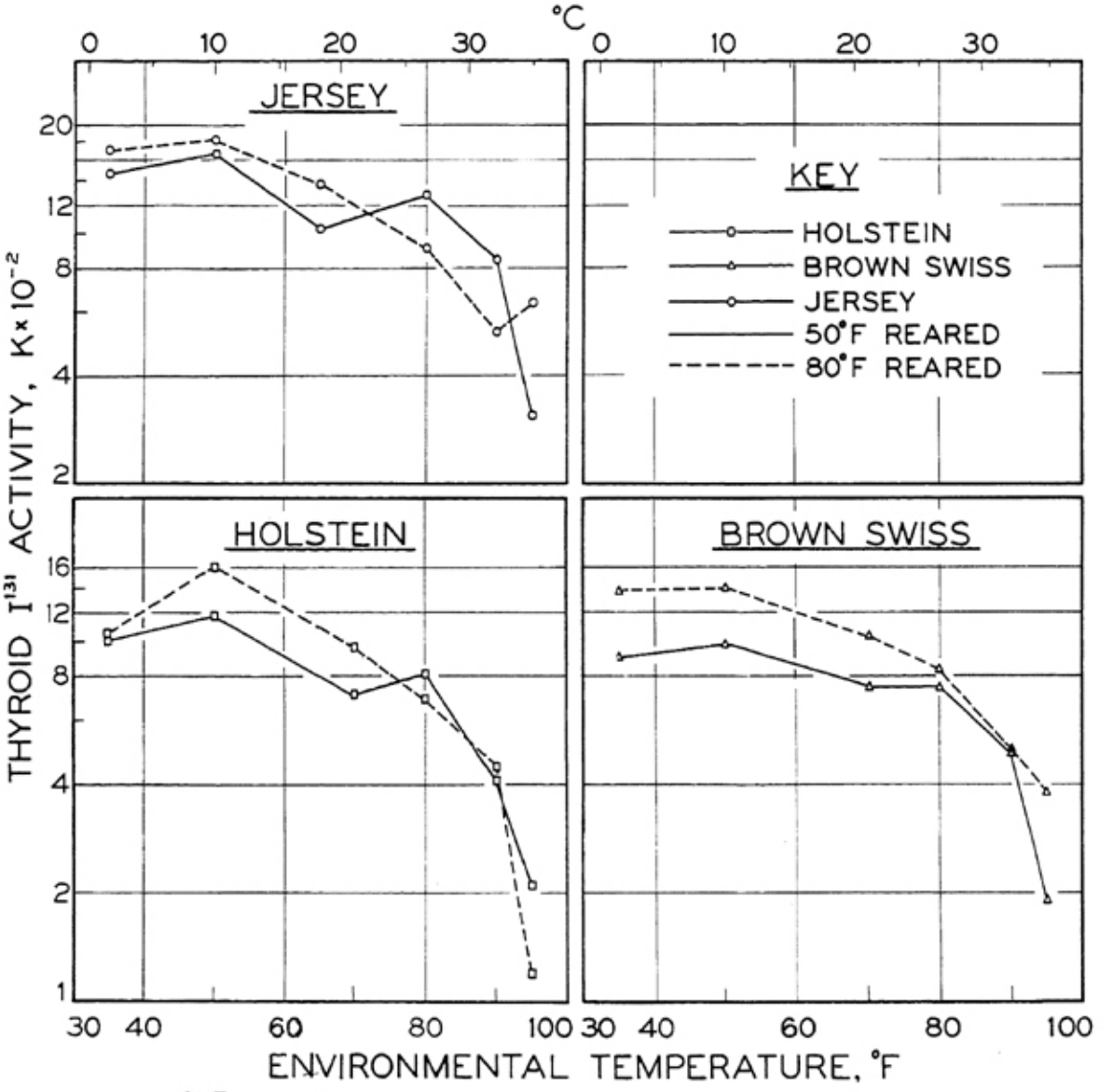

Fig. 4—Effect of acclimation at 50° and 80° F on thyroid I^{131} activity of Holstein, Brown Swiss, and Jersey heifers when exposed to varying environmental temperatures.

Figure 4 is designed to show differences in thyroid activity between 50° and 80° F reared animals. It presents differences related to acclimation at 50° F and 80° F when the animals so acclimated were exposed to various environmental temperatures (35°-90° F). The dotted lines signify the 80° F-reared animals' values and the solid line, the values of the 50° F-reared animals.

According to results of an analysis of variance, all the 80° F animals had higher thyroid I^{131} activity from 35° to 70° F, the difference at 70° F between the 80° F and the 50° F animals being significant at <0.10 for Jerseys and at <0.10 for Brown Swiss. Both graphic presentation and statistical analysis indicate that above 70° F the thyroid activity of the 50° F Holsteins and Brown Swiss is similar to that of the corresponding 80° F group. At 80° F the 50° F-raised Jerseys showed greater thyroid activity than the 80° F-raised group, and at 90° F they differed to a highly significant degree (<0.02). The values of this variance analysis are presented in Appendix V.

An inference from the *graphical* presentation of these data is that upon exposure to cold, the 80° F Jerseys were more cold stressed, as indicated by their generally higher thyroid I^{131} activity and, upon exposure to heat, the 50° F-raised Jerseys were more heat stressed, as suggested by their initially higher thyroid I^{131} activity. The animals which were raised in a cool or "near" optimum environment for cattle, 50° F, showed a response different from that of the 80° F animals. Cool acclimated heifers displayed lower thyroid I^{131} activity than did heat acclimated heifers until the environmental temperature reached or exceeded 80° F. At 80° F they began to show relatively higher rates, indicating an adjustment different from that of the 80° F group in the case of the Jerseys, but remaining similar for the Brown Swiss and Holsteins. Statistical analyses tended to support this inference. Even though the trend is one of general depression, the rise at 80° F may indicate that the *initial* reaction to the stressor, which for the 50° F Jerseys is a temperature of 80° F, is one of marked increase in thyroid I^{131} release rate.

The percentage decrease in thyroid I^{131} activity from 35° F to 95° F was the least for the Jerseys and Brown Swiss, approximately a 75% relative loss occurring for these two breeds, and the greatest for the Holsteins which exhibited an 87% relative loss in thyroid I^{131} activity.

The results of this study are in general agreement with others concerning the effects of cold temperature upon turkeys (13), red foxes, and porcupines (11), pigeons (18), and rabbits (14). The similarity to this study on calves is due primarily to the resemblances in experimental procedures. Metabolic data on various other species of small animals are not directly comparable because of differences in experimental techniques 2, 6, 8, 9, 10.

Assuming that the tendency toward lower thyroid I^{131} activity in 50° F-raised calves on exposure to 35° F is an indication of cold acclimation, then data on calves are theoretically in general agreement with the experimental results of Ogle and Mills (15) and Blair (1).

In addition to the thyroid or "metabolic" adjustment there was a difference in hair coat density (12), a difference in peripheral insulation. The lower hair density of the 80° F raised animals may well be a causative factor of the higher thyroid I^{131} activity at the colder temperatures.

The very remarkable individual differences in thyroid activity within the various breeds are apparent in Figure 5. All the animals displayed general de-

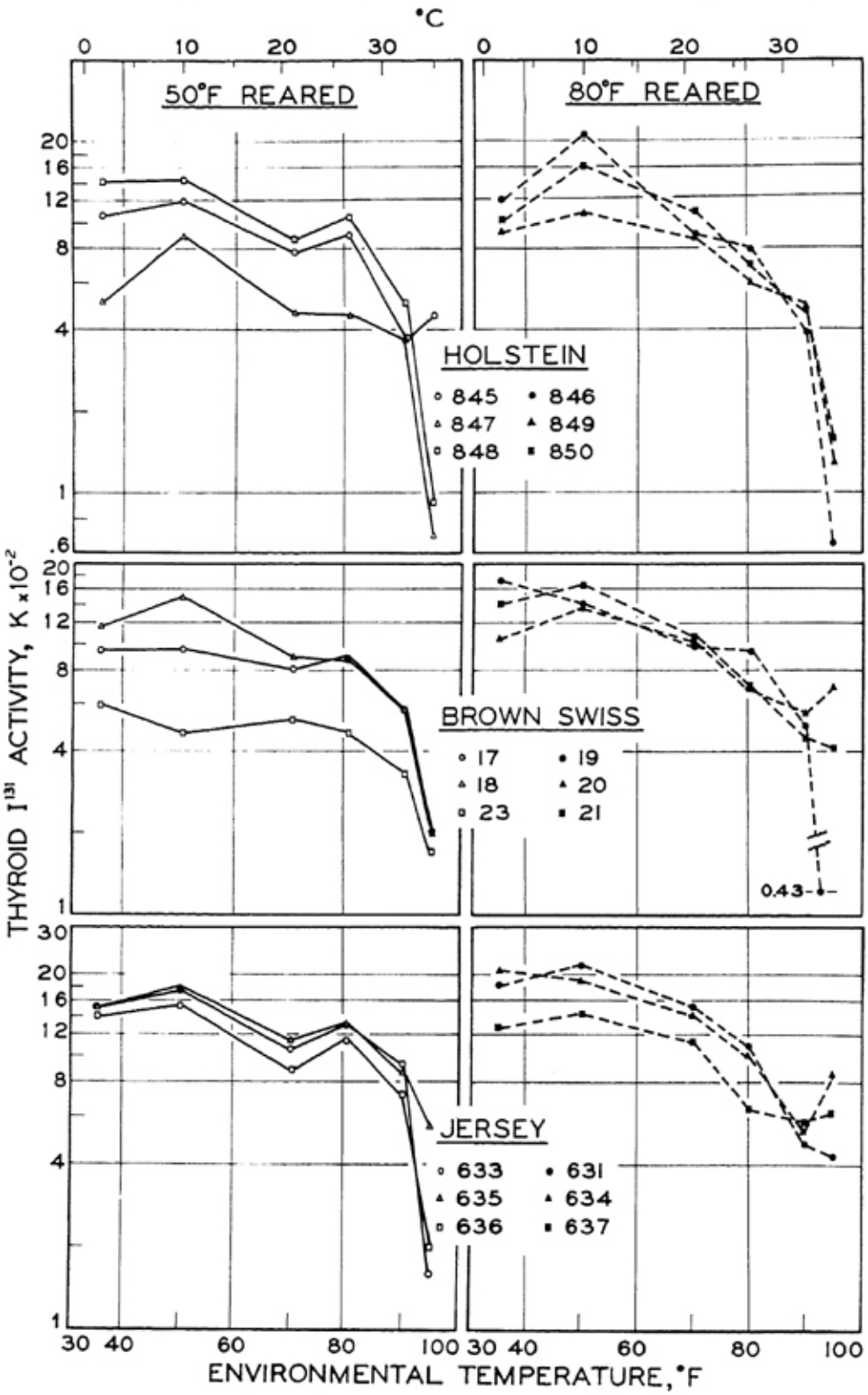

Fig. 5—Thyroid I^{131} activity vs. environmental temperature for individual Holstein, Brown Swiss, and Jersey heifers.

pression in thyroid I^{131} activity as environmental temperatures increased. However, as in the previous growth studies, (13) there were individual differences in the absolute level of thyroid I^{131} activity regardless of the temperature. There were distinct, consistent differences in certain animals, such as Brown Swiss No. 23, Holstein 847, and Jersey 637. At a later date when all data on the other phases of the experiment are complete, correlation will be made on the relation of the individual's thyroid function to the degree of heat tolerance and/or ability to gain.

Relation of Thyroid Activity to Other Physiological Functions.†

Figure 6 presents other physiological responses such as rectal temperature, water, and feed consumption in relation to thyroid activity. On exposure to the higher environmental temperatures, 80° F and above, temperatures at which the animal's compensatory mechanisms such as respiratory and vaporization rates could not continue to control the animal's body temperature, the animal's body temperature rose. This is indicated by data of both the 50° and 80° F reared animals. However, it is graphically apparent that the 50° F reared animals showed a sharper rise in body temperature with a simultaneously rapid rise in water consumption. Around 80° F the TDN consumption declined very sharply in both 50° and 80° F-reared animals as the body temperatures increased. Also, thyroid activity decreased as shown in the lower section of Figure 6. Among the questions suggested by these data are (1) Would controlled or forced feeding enable the animal's thyroid to maintain a higher level of activity at higher temperatures? (2) Would higher thyroid I^{131} activity, achieved by substitution therapy with thyroprotein, for example, allow the animals to maintain a higher TDN consumption? These questions may be answered readily by critical experiments conducted in climatic laboratories.

†Feed, water, respiration, and ventilation data will be described at a later date by Ragsdale, *et al,* and by Kibler, *et al,* in separate publications.

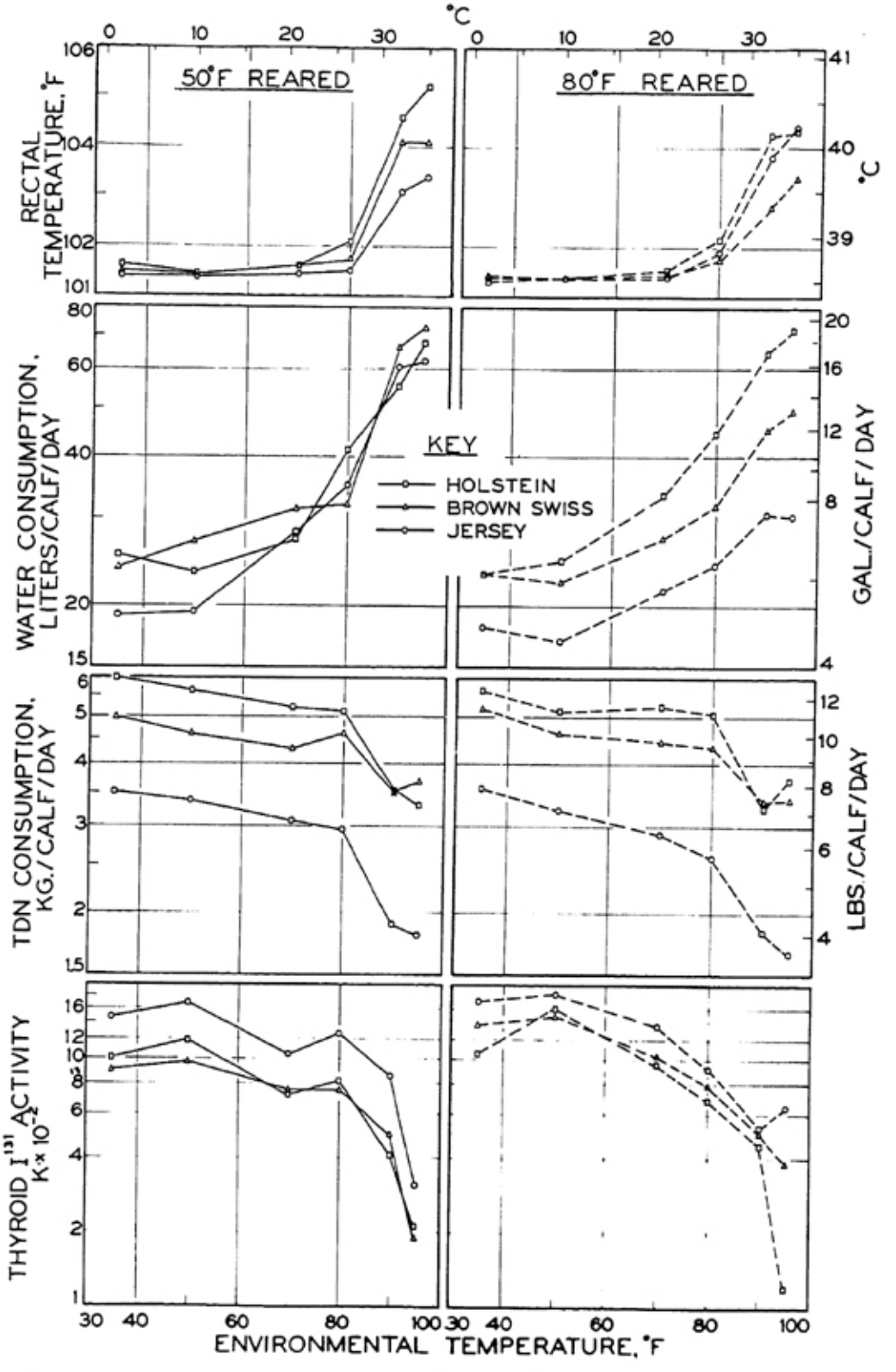

Fig. 6—Effects of varying environmental temperature on rectal temperature, TDN consumption, water consumption, and thyroid I^{131} activity of 50° and 80° F acclimated heifers.

SUMMARY AND CONCLUSIONS

1. There were many distinct, consistent, individual differences in the thyroid activity of several of the animals used in this study. Graphic indications of breed differences were present at several high temperatures. Statistical analyses supported differences between the Jerseys raised at each temperature and the other two corresponding breeds. The Jerseys displayed higher rates. In no instances were there thyroid I^{131} release rate differences between Holsteins and Brown Swiss.

2. There was a negative correlation between thyroid I^{131} release rate and temperature for each breed raised at each temperature. Correlations for the 50° F animals were statistically significant below the 0.05 level of probability and for the 80° F animals they were significant below the 0.01 level. As the environmental temperature increased from 35° F to 80° F there was a gradual decrease in thyroid I^{131} release rate. Above 80° F there was a sharp decline in thyroid I^{131} activity.

3. Within the range of environmental temperatures from 35° F to 70° F the animals raised at 80° F displayed thyroid release rates higher than those of the animals raised at 50° F. At 80° F and 90° F the 50° F Jerseys exhibited higher activity. The Jersey differences approached statistical significance. At the lower temperatures graphic differences between the Brown Swiss and the Holsteins raised at the two temperatures appeared to be present, but they were not generally suppored by statistical analysis.

4. At temperatures of 80° F and above, when regulatory mechanisms could not control body temperature, both groups showed considerable rises in body temperature concomitant with decreases in thyroid I^{131} activity and TDN consumption. The rise of the 80° F group was not as sharp as that of the 50° F group.

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APPENDIX I. THYROID I^{131} RELEASE RATES ($-Kx10^2$) DURING EXPERIMENTAL GROWTH PERIOD

Holsteins (50°)

Calf. No.	Age, Days (Average Birthday, September 6, 1956)						
	67	109	169	211	258	290	336
	Thyroid Values						
845	5.4	6.4	6.0	5.6	6.2	6.9	8.3
847	2.4	2.9	2.4	2.8	3.2	3.2	3.4
848	5.2	6.3	6.3	7.8	7.2	8.5	9.2
Av.	4.33	5.2	4.9	5.2	5.5	6.2	7.0

Holsteins (80°)

	Age, Days (Average Birthday, September 10, 1956)							
	59	99	114	163	195	242	277	325
	Thyroid Values							
846	3.8	6.4	5.8	6.0	7.0	5.9	6.4	8.8
849	2.4	2.6	4.3	4.5	5.0	3.5	6.2	5.8
850	0.9	4.2	4.1	3.7	4.7	3.2	6.3	6.8
Av.	2.4	4.4	4.7	4.7	5.6	4.2	6.3	7.1

Jersey (50°)

Calf No.	Age, Days (Average Birthday, September 17, 1956						
	56	98	168	200	257	288	335
	Thyroid Values						
633	5.7	6.8	8.3	8.2	9.0	9.5	10.7
635	7.4	8.7	9.6	9.3	10.4	12.1	11.1
636	2.8	4.1	5.6	7.8	7.4	10.4	10.6
Av.	5.3	6.5	7.8	8.4	8.9	10.7	10.8

Jersey (80°)

	Age, Days (Average Birthday, September 9, 1956)							
	56	96	111	160	192	237	274	322
	Thyroid Values							
631	4.5	8.6	7.5	7.5	9.5	8.6	10.0	13.1
634	1.7	8.3	8.8	10.0	10.2	13.3	11.6	13.6
637	1.1	1.6	4.4	3.2	4.5	4.5	7.0	7.7
Av.	2.43	6.2	6.9	6.9	8.1	8.8	9.5	11.5

Brown Swiss (50°)

Calf No.	Age, Days (Average Birthday, August 27, 1956)						
	77	119	179	221	268	300	346
	Thyroid Values						
17	4.20	4.0	4.8	4.7	6.5	7.3	6.6
18	5.5	6.4	7.0	6.0	6.8	8.7	6.9
23	4.5	4.2	3.3	3.8	3.8	4.3	4.9
Av.	4.7	4.9	5.0	4.8	5.7	6.8	6.1

Brown Swiss (80°)

	Age, Days (Average Birthday, August 31, 1956)					
	69	109	124	173	205	251
	Thyroid Values					
19	2.9	5.3	6.4	5.8	7.7	7.9
20	2.3	6.0	6.3	4.5	7.0	7.9
21	2.5	6.0	6.1	6.1	7.8	7.5
Av.	2.6	5.8	6.3	5.5	7.5	7.8

APPENDIX II. BODY WEIGHTS DURING EXPERIMENTAL GROWTH PERIOD

Holsteins (50°)

Calf No.	Age, Days (Average Birthday, September 6, 1956)						
	67	109	169	211	258	290	336
	Weight, Kg.						
845	90	137	215	250	288	310	330
847	76.5	119	191	225	277	303	335
848	73	111	190	223	263	291	333
Av.	79.83	122.33	198.67	232.67	276	301.33	332.67

Holsteins (80°)

	Age, Days (Average Birthday, September 10, 1956)							
	59	99	114	163	195	242	277	325
	Weight, Kg.							
846	78	111	159	215	244	272	286	319
849	66	94	136	180	209	253	269	309
850	69	101.5	142	192	221	266	291	325
Av.	71	102.16	145.67	195.67	224.67	263.67	282	317.67

Brown Swiss (50°)

Calf No.	Age, Days (Average Birthday, August 27, 1956)						
	77	119	179	221	268	300	346
	Weight, Kg.						
17	70	98.5	159	195	244	269	301
18	61.5	100.5	166	211	260	280	320
23	61.5	90.5	159	199	248	278.5	318
Av.	64.33	96.5	161.33	201.67	250.67	275.83	313

Brown Swiss (80°)

	Age, Days (Average Birthday, August 31, 1956)							
	69	109	124	173	205	251	287	335
	Weight, Kg.							
19	75	105	150	201	234	272	299	335
20	62	92	130	172	194	237	261	303
21	77	112	168	221	250	294	319	364
Av.	71.33	103	149.33	198	226	267.66	293	334

Jerseys (50°)

Calf No.	Age, Days (Average Birthday, September 17, 1956)						
	56	98	158	200	247	278	325
	Weight, Kg.						
633	46	75	116	141	172	193	218
635	52	75	114	138	163	181	203
636	35	59	100	122	155	175	194
Av.	44.33	69.66	110	133.66	163.33	183.	205

Jerseys (80°)

	Age, Days (Average Birthday, September 9, 1956)							
	56	96	111	160	192	237	274	322
	Weight, Kg.							
631	47.5	74	107.5	139	155	180	196	224
634	36	61.5	93	128	148	180	196	224
637	29	44	65	90	106	130	152	181
Av.	37.5	59.8	88.5	119	136.33	163.33	181.33	209.67

APPENDIX III. EFFECTS OF RISING ENVIRONMENTAL TEMPERATURES (35°F TO 95°F) ON THYROID I^{131} RELEASE RATES ($-k \times 10^2$)

Calves Raised At 50°F

		Holstein			Brown Swiss			Jersey		
Temperature	Calf No.	845	847	848	17	18	23	633	635	636
35°F		10.7	5.1	14.1	5.9	11.6	9.5	15.1	15.1	13.9
50°F		12.0	8.9	14.5	4.7	15.0	9.6	17.7	17.7	15.4
70°F		7.8	4.7	8.7	5.2	8.9	8.1	10.6	11.4	8.8
80°F		9.0	4.6	10.4	4.7	8.7	8.8	13.1	13.1	11.5
90°F		3.7	3.7	5.0	3.3	5.7	5.7	9.3	8.8	7.2
95°F		4.6	0.7	0.9	1.7	2.0	2.0	1.6	5.6	2.0
65°F		8.5	4.7	7.7	4.9	10.9	9.4	15.7	18.1	14.2

Calves Raised At 80°F

		Holstein			Brown Swiss			Jersey		
Temperature	Calf No.	846	849	850	19	20	21	631	634	637
35°F		12.1	9.3	10.0	17.2	10.4	14.0	18.4	20.3	12.7
50°F		21.0	10.8	16.1	14.1	13.9	16.4	21.3	19.0	14.2
70°F		8.9	9.0	11.0	9.8	10.6	10.4	15.2	14.3	11.3
80°F		7.9	6.0	6.9	9.4	7.0	7.0	10.9	10.0	6.4
90°F		3.9	4.9	4.8	5.0	5.5	4.5	4.8	5.4	5.7
95°F		0.6	1.3	1.6	0.4	6.9	4.1	4.3	8.6	6.3
65°F		9.4	8.1	8.2	13.1	11.3	12.5	14.7	15.1	10.5

APPENDIX IV. STATISTICAL ANALYSIS OF BREED THYROID I^{131} DIFFERENCES AT TEMPERATURES FROM 35°F TO 95°F

Temp. °F	Mean Thyroid I^{131} Release Rate of 50°F Animals			t	P	t	P	t	P
	Holstein	Brown Swiss	Jersey	H vs. BS		H vs. J		BS vs. J	
35	10.0	9.0	14.7	.98	ns	1.78	ns	3.33	<.05
50	11.8	9.8	16.9	.62	ns	3.61	<.05	2.33	ns
70	7.1	7.4	10.3	.63	ns	2.22	ns	1.76	ns
80	8.0	7.4	12.6	.27	ns	2.50	ns	3.39	<.05
90	4.1	4.9	8.4	.84	ns	5.27	<.01	3.46	<.05
95	2.1	1.9	3.1	.13	ns	.56	ns	.92	ns

Temp. °F	Mean Thyroid I^{131} Release Rate of 50°F Animals			t	P	t	P	t	P
	Holstein	Brown Swiss	Jersey	H vs. BS		H vs. J		BS vs. J	
35	10.5	13.9	17.1	1.59	ns	2.74	<.10	.95	ns
50	16.0	14.8	18.2	.38	ns	.86	ns	.15	ns
70	9.6	10.3	13.6	.88	ns	2.90	<.05	2.77	<.10
80	6.9	7.8	9.1	.90	ns	1.47	ns	.82	ns
90	4.5	5.0	5.3	1.09	ns	1.85	ns	.77	ns
95	1.2	3.8	6.4	1.38	ns	4.09	<.02	1.11	ns

APPENDIX V. STATISTICAL DIFFERENCES IN THYROID I^{131} ACTIVITY BETWEEN 50°F AND 80°F ANIMALS AT TEMPERATURES FROM 35°F TO 95°F

Temp. °F	R°F*	Mean Thyroid Activity			t	P	t	P	t	P
		Jersey	Brown Swiss	Holstein	J vs. J		BS vs. BS		H vs. H	
35	50	14.7	9.0	9.97	1.05	ns	1.89	ns	.29	ns
	80	17.1	13.87	10.47						
50	50	16.93	9.77	11.80	.55	ns	1.62	ns	1.28	ns
	80	18.17	14.80	15.97						
70	50	10.27	7.40	7.07	2.37	<.10	2.49	<.10	1.84	ns
	80	13.60	10.27	9.63						
80	50	12.57	7.40	8.00	2.35	<.10	.24	ns	.59	ns
	80	9.10	7.80	6.93						
90	50	8.43	4.90	4.13	4.55	<.02	.12	ns	.66	ns
	80	5.30	5.0	4.53						
95	50	3.07	1.90	2.07	1.87	ns	1.00	ns	.70	ns
	80	6.40	3.80	1.17						