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Further Observations on the Scrotal Skin Temperature of the Bull, with some Remarks on the Intra-Testicular Temperature.

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A preliminary note on the scrotal skin-temperature of a bull was published by Quinlan and Riemerschmid in 1941. Since then the instrument used has been improved, the range of open air-temperatures, at which the readings were taken, was extended, and the temperatures over the whole surface of the scrotum were determined by taking readings at several points. Further, an observation was carried out at low air-temperatures, created artificially in one of the cooling chambers of the Meat Research Institute at Onderstepoort. In addition a thermocouple was constructed by which the intratesticular temperature can be recorded, and limited observations on the temperature within the testicles will also be referred to in this article.

I. Technique.

(*a*) *The Improved Instrument for Skin-Temperature Measurements.*

The method used was based on the same principle as that recorded in the previous article, the thermo-electrical method. The new thermocouple was designed so as to minimise the influence of air-temperature and wind as much as possible. Details of the physical factors and practical experience in the development of the new instrument are dealt with in an article by Elder (1941), in this issue of the *Onderstepoort Journal*.

(*b*) *Method.*

It was shown that the difference between readings taken on that side of the scrotum which was exposed to direct sunlight and those taken on the shady side was not significant (Quinlan and Riemerschmid, 1941). Readings under the direct influence of the sun's rays on the scrotum were, therefore, discontinued.

The bull was tied up, facing west, in an open paddock. Direct sunlight was prevented from reaching the scrotum by a piece of hessian hanging losely on the sunny side of the body. All readings were taken on the left side of the scrotum; this side was not exposed to the usually prevailing northerly winds. The skin temperature was taken underneath the hairy coat at the level of the stifle joint in a vertical line with the scrotum. The actual temperature readings were taken similarly to those recorded in the previous article.

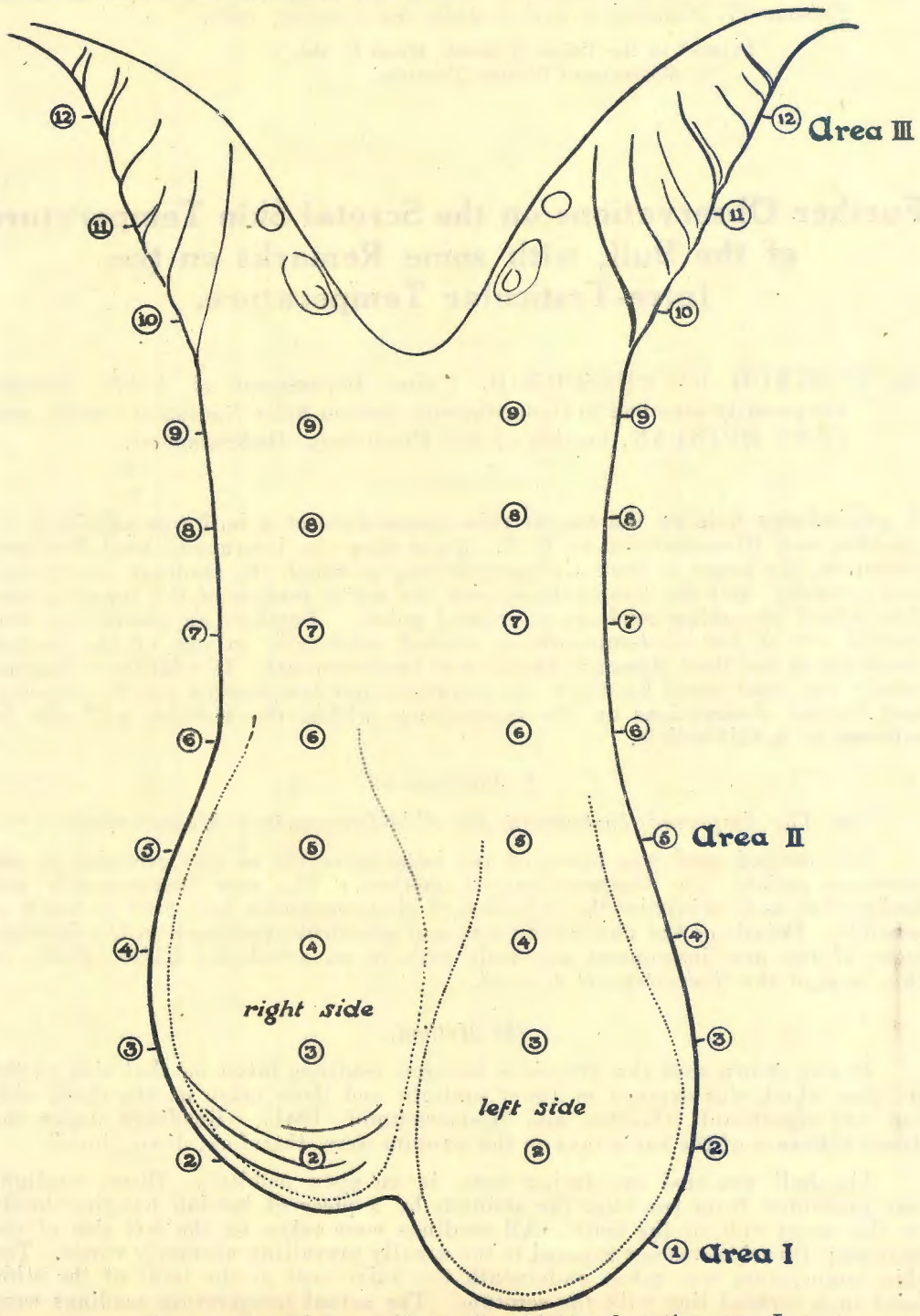

Fig. 1.—Distribution of observation points and routine areas I, II and III, on the scrotum.

II. Results.

1. *Distribution of Skin-Temperatures over the Whole Surface of the Scrotum.*

The temperature was measured on 39 different points on the surface of the scrotum to indicate the representative values of areas I, II and III, where the routine readings, as in the previous observations, were taken. The observation points were distributed at distances of 2·5 cm. apart along perpendicular lines as follows: 12 and 11 points respectively from the ventral to the dorsal aspect on the left and right sides of the scrotum; 8 points on both the left and right cranial surface of the scrotum. Fig. 1 shows diagramatically the points on which the readings were taken and the position of areas I, II and III, of the routine observations. Each series of readings along the perpendicular lines were repeated three times and the mean values computed.

One set of observations was carried out in the open at a fairly constant air-temperature of 27·7° C. The right side of the scrotum was exposed to a light wind. The procedure during a second set of observations was identical to the above, but the readings were taken inside the stable to eliminate the influence of wind on the scrotum. The readings obtained in these two series of observations are given in Table 1. The general tendency is a comparatively regular increase of temperature from the ventral to the dorsal aspect of the scrotum. On the whole the readings taken in the stable were slightly higher than those taken in the open, although the air-temperature was, in both cases, very similar, namely 27·7° C. and 27·9° C.

Table 1.

Temperature on Various Points of the Surface of the Scrotum.

	Left.				Right.			
	Lateral.		Cranial.		Lateral.		Cranial.	
	Open.	Stable.	Open.	Stable.	Open.	Stable.	Open.	Stable.
1	32·3	33·3	—	32·8	—	—	—	—
2	32·9	32·8	30·9	32·2	30·2	31·7	30·3	32·1
3	33·1	32·4	31·8	32·7	32·2	32·0	31·6	32·7
4	33·2	32·5	31·9	32·2	32·5	32·3	32·2	32·7
5	33·4	33·4	32·0	33·1	32·9	32·6	32·6	33·2
6	33·6	34·1	32·2	34·2	33·1	33·6	32·8	33·8
7	34·3	34·5	32·4	33·8	33·4	34·8	32·8	33·9
8	34·5	35·1	33·1	34·0	33·6	35·4	33·1	34·7
9	34·5	35·1	34·0	34·8	34·2	35·0	33·8	34·8
10	35·2	34·9	—	35·0	35·2	35·3	—	35·6
11	35·5	35·1	—	—	35·4	35·9	—	—
12	36·3	35·6	—	—	36·2	36·0	—	—
Difference between Areas I and III	4·0	2·3	—	—	6·0	4·3	—	—

Mean air-temperature—In the open, 27·7. In the stable, 27·9.

Mean body-temperature—In the open, 38·1. In the stable, 38·2.

The temperatures are given in degrees Centigrade (°C.).

2. *Scrotal and Skin-Temperature at Various Air-Temperatures.*

In the following observations emphasis was laid on the determination of the influence of air-temperature on the temperature of the scrotal skin. The results published in the first article showed that with decreasing air-temperature the scrotal temperature decreased regularly within the range of 18° C. to 33° C. (65° F. to 91° F.). It was, however, unlikely that this would hold for a wider range of air-temperatures. Consequently the range of air-temperatures at which the scrotal temperatures were measured was extended from 10° C. to 40° C. (50° F. to 104° F.). The readings obtained during these observations are given in Table 2, which also provides data on meteorological conditions prevailing during the observations.

The data obtained were statistically analysed by means of the Analysis of Variance technique. For preliminary calculations they were divided into two groups. Group 1 readings were observed in winter, at low air-temperatures (from 10° C. to 25° C.) and Group 2 in summer, at high-air temperatures (from 25° C. to 40° C.).

The mean values of all observations taken at low and high air-temperatures are given in Table 3. The significance of the difference between the two groups of readings is also indicated in this table:—

TABLE 3.

Mean Values of Skin and Scrotal Temperatures at Low and High Air-Temperatures.

	Low Air-temperatures. (10°C. to 25°C.)	High Air-temperatures. (25°C. tot 40°C.)	Difference.	Significance.
Skin	33·6 °C.	36·5 °C.	2·8 °C.	xx
Scrotum I	32·0 °C.	33·9 °C.	1·9 °C.	xx
„ II	31·0 °C.	33·8 °C.	2·9 °C.	xx
„ III	33·0 °C.	36·7 °C.	3·8 °C.	xx

* Significance is represented by: xx = Highly significant. x = Significant. (o) = Insignificant.

The difference between the various scrotal temperatures on the one hand and the skin-temperature on the other hand is given in Table 4. The figures given show how much the skin-temperature exceeded the temperature on scrotal area I, II and III.

TABLE 4.

Difference between Skin and Scrotal Temperatures.

Difference between.	At Low Air-temperatures (10 °C. to 25 °C.). (skin-temperature higher than scrotal temperature.)	At High Air-temperatures (25 °C. to 40 °C.). (skin-temperature higher than scrotal temperature.)
Skin and Scrotal Area I	1·6 °C. xx	2·5 °C. xx*
Skin and Scrotal Area II	2·7 °C. xx	2·7 °C. xx
Skin and Scrotal Area III	·7 °C. (o)	— ·3 °C. (o)

* Significance is represented by: xx = Highly significant. x = Significant. (o) = Insignificant.

Summary of all Observations of Scrotal, Skin

Date, 1941.	Time.	Wind.	Clouds.	Lenght in cm.	Body Temperature.	Skin Temperature.
6.8.....	9 a.m.	Calm	0	—	—	35·3
7.8.....	9 a.m.	Calm	overcast	—	—	—
11.8.....	11.15 a.m.	—	—	31·0	—	35·2
21.8.....	11.30 a.m.	—	—	—	—	36·1
22.8.....	9 a.m.	2–3. E.	Overcast	21·2	—	30·6
22.8.....	10 a.m.	—	5	24·0	—	33·0
22.8.....	11.35 a.m.	—	—	26·5	—	33·3
22.8.....	12.15 p.m.	—	—	25·0	—	35·3
22.8.....	12.45 p.m.	—	—	24·3	—	35·8
22.8.....	2.15 p.m.	2	0	26·5	—	36·1
22.8.....	3.30 p.m.	2	0	25·6	—	35·2
23.8.....	9.10 a.m.	2	0	19·7	—	29·6
23.8.....	10.30 a.m.	2	2, Ci.	21·5	—	35·4
23.8.....	11 a.m.	2–3	0	21·1	—	34·9
25.8.....	9.10 a.m. Sun full	1	8, Nb.	23·8	38·6	32·1

127-128b →

Table 2.

of Scrotal, Skin and Body Temperatures measured at a Range of Air Temperatures betwe

Scrotum.			Air Temperature.	Date, 1941.	Time.	Wind.	Clouds.
I.	II.	III.					
32·0	31·0	32·0	11·2	25.11	9 a.m.	—	—
32·3	31·3	33·8	11·9				
31·2	—	—	11·5	25.11	10.30 a.m.	—	—
31·0	—	—	11·7				
32·8	31·2	34·7	21·3	25.11	12 p.m.	—	4, Cu.
32·3	31·1	34·8	23·2				
32·8	31·6	35·9	19·0	25.11	12.50 p.m.	—	4, Cu.
30·7	29·7	—	13·5	25.11	2.10 p.m.	—	3, Cu.
31·6	29·8	—	14·1				
32·2	30·6	32·8	15·9	26.11	9.30 a.m.	—	1, Ci
32·5	31·0	32·6	16·2				
32·2	32·1	35·2	18·4	26.11	12.30 p.m.	2, E.	3, Cu.
32·3	32·0	35·1	18·5				
32·3	30·9	34·9	19.3	26.11	2.05 p.m.	—	8, Cu.
32·5	31·2	35·0	19·5				
32·5	31·9	35·8	19·4	26.11	2.25 p.m.	—	—
32·1	31·7	35·0	20·1				
32·0	31·4	35·3	20·5	27.11	9.35 a.m.	1, N.	1, Cu.
31·9	31·1	34·1	20·3				
32·3	31·2	32·9	19.9	27.11	10.24 a.m.	2, N.	2, Cu.
32·5	31·0	33·8	20·0				
31·4	30·8	30·0	12·7	27.11	11.40 a.m.	2, N.W.	1, Cu.
30·9	30·7	30·5	13·6				
31·8	31·0	33·1	15·4	27.11	12.50 p.m.	3, N.W.	1, Cu.
31·7	31·1	33·4	15.8				
31·6	30·6	33·5	15.8	27.11	2.15 p.m.	2, N.W.	2, Cu.
31·3	30·5	33·5	16·0				
32·7	30·8	—	14·6	28.11	9.15 a.m.	2, N.	1, Ci
33·2	31·7	—	16·7				

Note.—All temperatures in °Centigrade.

← 127-128a

127-128c →

Temperatures between 10-40° *C.*

Length in cm.	Body Temperature.	Skin Temperature.	Scrotum.			Air Temperature.
			I.	II.	III.	
30·0	38·6	36·4	34·3	33·5	36·4	20·8
			34·5	33·7	36·4	31·0
31·0	38·8	37·1	35·4	35·2	38·0	34·4
			37·1	35·7	38·3	37·4
30·5	38·8	35·8	35·4	35·1	36·8	33·4
			35·6	35·5	37·0	37·6
30·8	38·9	36·3	35·1	34·8	37·1	34·2
			35·1	35·2	37·5	38·0
31·0	39·2	37·8	35·6	35·6	37·6	38·6
			35·7	35·5	37·3	37·0
28·5	38·3	36·5	33·0	32·8	35·0	26·7
			32·9	32·8	34·8	27·2
28·5	38·5	36·3	34·2	33·3	37·2	28·7
			34·2	33·4	37·2	29·5
29·5	38·6	35·3	34·0	33·4	36·9	31·2
			33·3	32·9	36·6	29·6
29·5	38·6	35·6	33·1	32·9	36·1	30·6
			32·9	32·9	36·1	29·7
27·0	38·4	36·6	32·7	32·8	36·0	25·6
			32·0	32·8	36·3	25·8
27·5	38·3	35·8	31·8	32·7	36·5	28·0
			32·3	32·8	36·6	27·7
29·8	38·6	36·4	33·5	33·4	37·0	31·2
			33·4	33·4	37·1	31·3
28·0	38·4	36·4	33·4	33·7	37·2	32·6
			33·3	33·7	37·1	32·0
30·0	38·7	37·0	34·7	34·5	37·4	34·4
			24·7	34·7	37·5	33·4
27·5	38·3	37·3	31·8	32·4	36·1	27·2
			32·4	32·7	35·6	26·2

← 127-128b

The skin and the various scrotal temperatures were plotted on graphs against simultaneously-measured air-temperatures and are given in Fig. 2 for scrotal areas I and II, and in Fig. 3 for scrotal area III and the skin.

In the previous article this relationship had been found to be linear, with a resulting constant rate of increase over the range 18° C.-33° C. air-temperature. This, however, did not prove to be correct when observations were carried out over a wide range of air-temperatures. From the scattered points on the graph in Fig. 2 it can be seen that a straight line would not represent the best " fit " to the observations; there seems to be a point of discontinuity in the neighbourhood of 25° C. After careful consideration it was decided that the best representation is given by two intersecting straight lines derived by means of the method of least squares. These show the slow increase in scrotal temperatures I and II at low-temperatures, and the more rapid increase at high air-temperatures. Both scrotal areas I and II show the same tendency, that is, a distinct change in the vicinity of 25° C. air-temperature.

From the scatter diagram in Fig. 3, which represents the readings of scrotal area III and skin-temperature plotted against air-temperature, it can be seen that both these temperatures do not show a pronounced tendency to change suddenly. As there was no significant difference between scrotal area III and the skin it is apparent that the same type of smooth curve would fit both series of observations.*

The rate of increase of scrotal and skin-temperatures, with respect to air-temperature, is given in Fig. 4. In the previous article on the scrotal temperature of the bull it was found that 1° C. increase of air-temperature resulted in an average increase of:—

0·17° C. on the skin.
0·19° C. in scrotal area I.
0·20° C. in scrotal area II.
0·13° C. in scrotal area III.

This, however, referred to the information gained from a range of air-temperature between 18° C. and 33° C.

The equations of the curves and straight lines respectively, which fitted the new observations best (Figs. 2 and 3) were used to determine the instantaneous and average rates of increase over a wider range of air-temperatures. The average rate of increase was, for each degree increase in air-temperature:—

for scrotal area I below 26·3° air-temperature 0·058° C.
above 26·3° air-temperature 0·288° C.
for scrotal area II below 23·1° air-temperature 0·087° C.
above 23·1° air-temperature 0·264° C.

The graphs in Fig. 4 show, that the rate of increase of scrotal temperatures I and II was very small at low air-temperatures. It was constant up to about 25° C. when it suddenly changed to a higher level. The rate of increase in the two areas I and II were tested for possible significant difference, but it was found that the difference between their rates of increase was insignificant.

* The curve decided upon was of the form: $Y=a+b \log X$, where Y is scrotal temperature and X is air-temperature, a and b constants determined by method of least squares. In other words, the increase of scrotal temperature is proportional to the relative increase of air-temperature.

The equations are: Scrotal area III:— $Y=21\cdot88+9\cdot94 \log X$.
Skin:— $Y=17\cdot597+12\cdot79 \log X$.

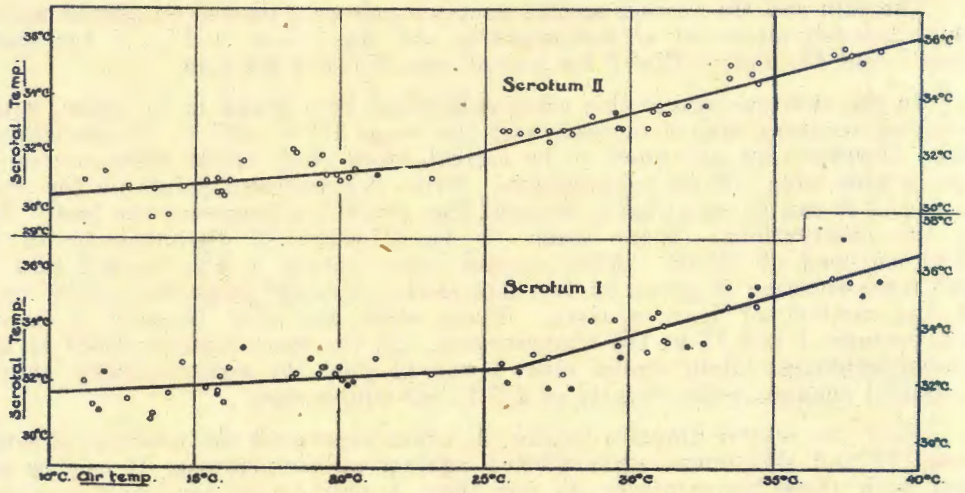

Fig. 2.—Temperatures of scrotal areas I and II in relation to air-temperature.

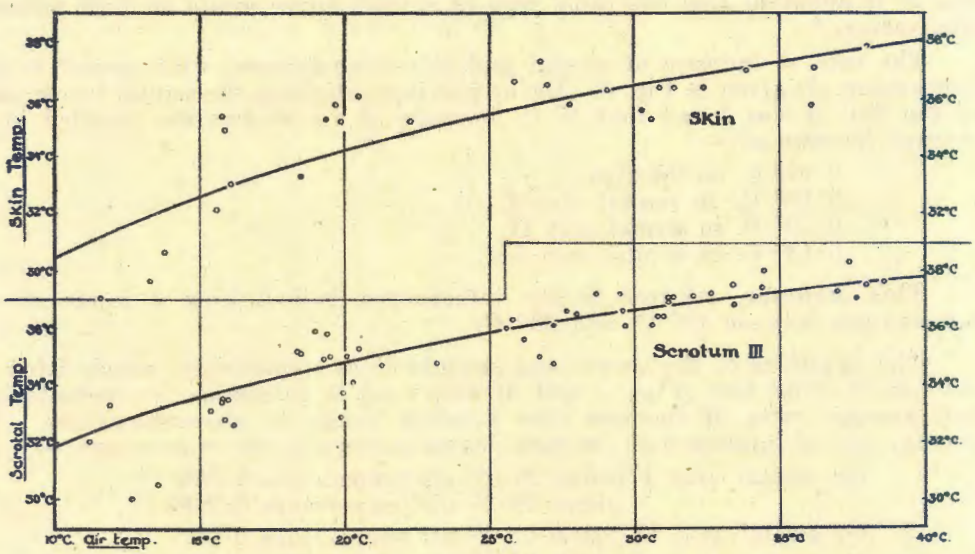

Fig. 3.—Temperatures of scrotal area III and the skin in relation to air-temperature.

While the average rates of increase for scrotal areas I and II are constant, the instantaneous rates of increase for scrotal area III and skin are functions of the reciprocals of air-temperature, viz., $\frac{4 \cdot 32}{X}$ for scrotal area III and $\frac{5 \cdot 55}{X}$ for the skin. The rate of increase varies over the whole range of air-temperatures, and is considerably larger at low than at high air-temperatures. The instantaneous rate of temperature of scrotal area III at 10° C. is 0·43° C., whilst at 40° C. it is only 0·11° C. The skin showed a somewhat higher rate of increase than the scrotal area III. At 10° C. air-temperature its rate of increase is 0·56° C., whilst at 40° C. it is 0·14° C.

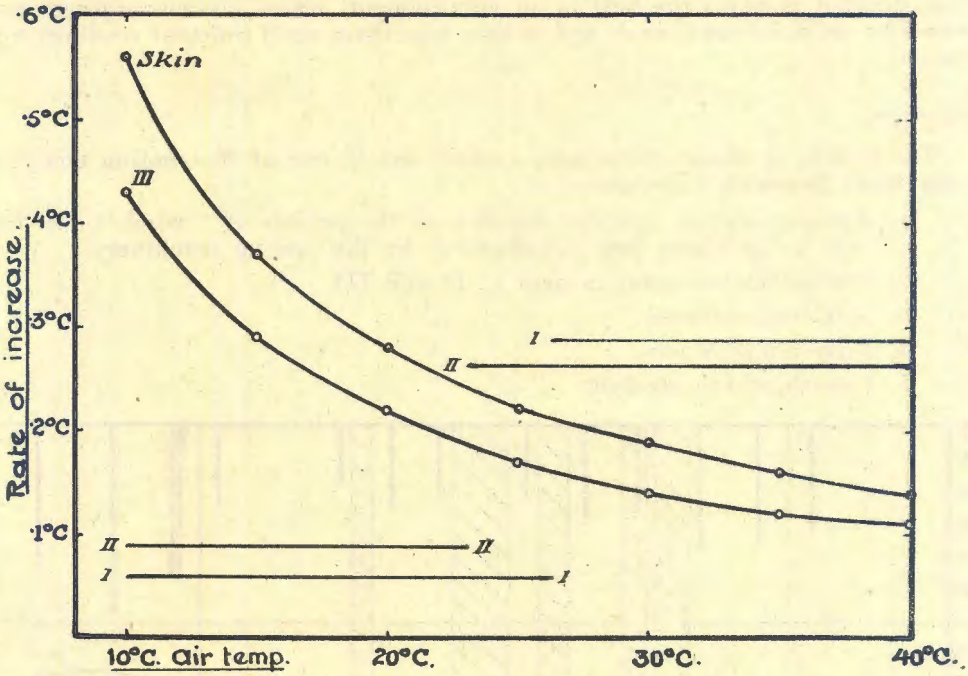

Fig. 4.—Rate of increase of temperature of scrotal area I, II and III, and skin-temperature with relation to air-temperature.

3. *Relationship between Air, Scrotal, Skin, and Body-Temperatures.*

Body-temperature measurements were, unfortunately, only carried out during the high air-temperature period and are not available for measurements at low air-temperatures. This reduced the number and the range of the body-temperature readings considerably. However, it seemed worth while to work out the significance of the relationship between body-temperature on the one side and air, skin, and scrotal temperatures on the other side. The results were:—

Relationship between:—

air and body-temperature	xx
skin and body-temperature	(o)
scrotal area I and body-temperature	xx
scrotal area II and body-temperature	xx
scrotal area III and body-temperature	xx

The length of the scrotum, measured between the dorsal and the ventral aspects, represents the contraction and relaxation of the dartos and cremaster muscles. The length was measured at the beginning and end of each test. The mean values are given in Table 2. The mean values for the two groups of readings were 24·2 cm. at low air-temperatures and 29·0 cm. at high air-temperatures; this difference was found to be highly significant.

4. *Scrotal Temperatures at Artificially Low Air-Temperatures.*

Air-temperatures below 11° C. (52° F.) were not experienced during times when observations on the bull in the open could be carried out. Consequently

it was decided to place the bull in an environment, where air-temperatures were lowered by artificial conditions, and to keep him there until constant readings were obtained.

Procedure.

The following observations were carried out in one of the cooling chambers of the Meat Research Laboratory:—

1. Air-temperature and the duration of the periods of "wind", i.e. cold air being blown into the chamber by the cooling machinery.
2. Scrotal temperatures in area I, II and III.
3. Skin-temperatures.
4. Body-temperature.
5. Length of the scrotum.

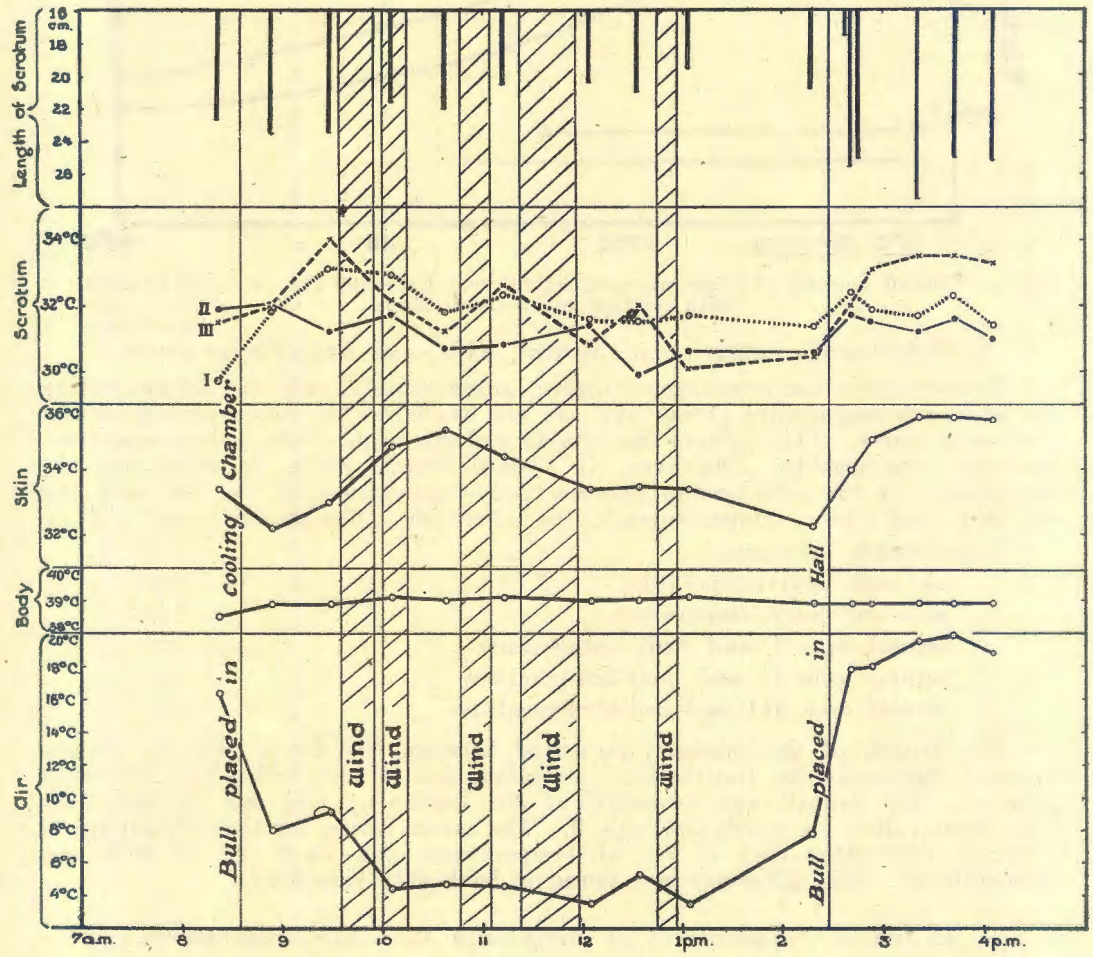

Fig. 5.—Scrotal, skin and body-temperatures and scrotal length at artificially low air-temperatures.

The readings obtained are given in Fig. 5, which shows the time of the day along the bottom line and the scale for the various temperatures at the left side of the graph.

The following notes give details of the procedure during the period of observations:—

8.13 a.m. First readings taken in the hall outside the cooling chamber at an air-temperature of 16·3° C.

8.35 a.m. Placed bull in cooling chamber at 8·7° C. air-temperature, where he remained until 2.25 p.m.

9.35 a.m. Started cooling machinery. The "wind" was stopped when observations were taken, but otherwise it was on and off as required to keep the chamber at a constant air-temperature of 4° C. to 6° C. as far as possible. The wind velocity was measured in the immediate neighbourhood of the scrotum with an anemometer; it showed a velocity of 1 to 1·5 meters per second. The periods of wind are indicated in Fig. 5 by shading across the graphs. The relative humidity in the chamber fluctuated around 65 per cent.

2.25 p.m. The bull was placed in the hall, outside the cooling chamber, at a mean air-temperature of 18·8° C., and remained there until 4 p.m.

Results:

(i) *Air-temperatures:* These were measured with an aspiration psychrometer, next to the bull's scrotum, at the beginning and the end of each observation. Mean values were used for drawing the graphs. They show that the air-temperature slightly increased after the bull was placed in the cooling chamber. Between 10 a.m. and 1 p.m. it was fairly constant at nearly 4° C. and increased during the next one-and-a-half hours to 9° C. In the hall the air-temperature varied between 18° C. and 20° C.

(ii) *Scrotal Temperatures:* (*a*) *Area I* (*ventral*): The first set of readings taken in the hall, at a mean air-temperature of 16° C., showed a very low scrotal temperature, namely 30° C. This was probably due to the fact that the bull had been lying on the cold floor of the stable during the previous very cold night. After being placed in the cooling chamber, at an air-temperature of approximately 8° C., the scrotal temperature immediately increased and reached a maximum of 33° C. after one hour. This was maintained for half an hour. It then decreased by 2° C. and fluctuated slightly between 31° C. and 32° C. during the following four hours. In the afternoon only a slight increase resulted from placing the bull in the hall at a mean air-temperature of 18·8° C.

(*b*) *Area II* (*middle*): The temperature on area II was higher than on area I before the bull was placed in the cooling chamber. During the exposure to low air-temperatures in the cooling chamber area II always showed *lower* temperatures than area I, the difference amounting to 3° C.

(*c*) *Area III* (*dorsal*): The temperature on area III showed greater fluctuations than the lower parts of the scrotum. An explanation may be found in the fact that area III which is not in such close contact with the underlying testicle becomes more corrugated than areas I and II. The summits of the folds and the hollows between them certainly must have different temperatures.

Area III reacted soon after the bull was placed in the cooling chamber with a marked increase of temperature. During the period in the cooling chamber it showed (similarly to area I and II) a slightly decreasing tendency. From 10 a.m. onwards it remained 2° C. to 4° C. lower than the skin-temperature.

(iii) *The Skin-temperature* dropped slightly immediately after the bull was placed in the cooling chamber, but showed a steady increase between 9 a.m. and 11 a.m., with a maximum of 35° C. (at an air-temperature of 4° C. only!). It then decreased continually and did not seem to have reached a constant level when the bull was taken out of the cooling chamber. After placing him in the hall at a higher air-temperature, the skin-temperature increased by 3° C. to 35·6° C. within an hour.

(iv) *Shivering:* During the period while the bull was in the cooling chamber he showed marked shivering, which took place over the whole body. The first indication of shivering commenced after one-and-a-half hours. It lasted throughout the entire period the bull was in the cooling chamber and continued one-and-a-half hours afterwards.

(v) *Pulse Rate and Respiration:* The pulse was 66 per minute at 10.45 a.m., and 62 at 2.10 p.m. After removal of the bull from the cooling chamber to the hall it was 64 at 2.35 p.m., 64 at 3 p.m., and 58 at 3.25 p.m.

(vi) *The respirations* were 16 per minute at 2.10 p.m. and 13 at 3.25 p.m.

Both pulse and respirations were taken with great difficulty owing to the marked shivering.

(vii) *The length of the scrotum* during the period of observations is shown at the top of the graph in Fig. 5. The measurements are given in centimeters.

After placing the bull in the cooling chamber the scrotal length increased slightly. With the continuous decrease of all the temperatures, both scrotal and skin, the length of the scrotum decreased, thereby preventing too great a loss of heat by reducing the total surface area considerably. Removing the bull into warm air (15° C.) resulted in an immediate very strong contraction, which was maintained for less than 10 minutes. After this period there was marked relaxation, which lasted until the termination of the observations.

(viii) *Body-temperature:* After an increase of body-temperature, which may be due to the normal diurnal variation or to an increase in metabolic rate, following the walking from the stable to the cold storage building (a distance of 175 yards), the body-temperature remained remarkably constant at approximately 39·0° C.

5. *Intra-testicular Temperatures.*

A limited number of intra-testicular temperature measurements were carried out with the newly designed thermo-needle (Elder, 1941). The temperatures were measured in the centre of the testicles. The results are given in Table 5, which also contains the observations on body and skin-temperatures and a mean value of the temperatures of scrotal areas I and II. All these readings were taken shortly before the intra-testicular temperature was measured.

In order to ascertain the influence of close contact between the testicle and the body on the testicular temperature, and at the same time to observe the temperature reaction of the scrotum when it was removed from close contact

with the testicle a further observation was made. Both testicles were forced upwards in the scrotum so that the dorsal extremity was in contact with the abdominal wall, but the long axis was not disturbed. They were maintained in this position by means of an elastoplast bandage placed around the scrotum. Care was taken that the bandage was not put on too tightly lest the capillary circulation in the scrotum may be interfered with. The bandage used was 5 cm. wide and would have covered scrotal area II. That portion of the scrotum below the bandage was about 6 cm. long when measured in contraction.

TABLE 5.

Intra-Testicular Temperatures.

Date.	Place.	Temperatures, °C.				
		Air.	Body.	Scrotum I and II.	Testicle Left Side.	Testicle Right Side.
25.11.41.....	Paddock, bull in sun, scrotum shaded	37·8	39·1	35·6	37·0	36·6
13. 1.42.....	Hospital.....	31·0	38·6	34·2	35·4	—
5. 1.42.....	Stable.....	29·1	38·2	33·1	34·7	34·5
15. 5.42.....	Stable.....	24·6	38·6	32·2	34·3	34·4
13. 8.42.....	Stable.....	19·1	38·7	31·7	34·6	34·6
28. 9.42.....	Stable.....	15·2	38·6	31·8	34·8	34·7

NOTE.—The first reading (25.11.41) was taken at 4.50 p.m. after the bull had been standing in the sun since 9 a.m.

The following are the readings taken before and after the testicles had been kept for an hour in this position.

TABLE 6.

Intra-Testicular Temperature, and Scrotal Surface-Temperature before and after Testicular Displacement.

Temperature of.	Before Testicular Displacement.	1 Hour after Testicular Displacement.		15 Minutes after Testicular Replacement.	
Body.....	38·6		38·9		—
Air.....	30·6		32·0		31·8
Skin.....	37·2		37·6		—
Scrotal area I	34·5	Points over displaced testicle 1.	36·7	Scrotal area I	34·7
,, II	33·9	2.	37·4	,, II	34·3
,, III	36·3	3.	37·5	,, III	37·5
		Scrotum lowest extremity.....	28·2		
		5 cm. higher up.....	31·0		
Intra-testicular..	35·4		37·9		36·6

Discussion.

When readings taken over the whole surface of the scrotum are considered (Table 1) it will be observed that, as a rule, the temperature increases from the ventral to the dorsal aspect. Scrotal area I may be more influenced by the cooling wind and would lose more heat by conduction, convection, and radiation, due to its greater curvature. Area II appears to be representative of a greater area than I. During scrotal contraction it overlies the testicle, but during total scrotal relaxation it lies just on or above its dorsal extremity (Fig. 1). Area III shows higher readings than the others recorded over the lateral aspect of the scrotum. It appears to represent an area of transition between the scrotal and inguinal skin over which there is no significant difference between the scrotal and skin temperature. That there was no significant difference between the temperature recorded over scrotal area III and the skin was also shown in the previous report.

It has been observed that, at low air-temperatures (10° C. to 25° C.), the temperature over scrotal area I was frequently higher than over II (Tables 2 and 3). The reason for this is not apparant, but it appears probable that at certain stages of scrotal contraction and relaxation area I is in closer contact with the underlying testicle than area II. In fact during complete relaxation scrotal area II was just on the extreme dorsal extremity of the testicle. At higher air-temperatures scrotal area I was also found to have a somewhat higher temperature than scrotal area II, but the differences, when they were observed, were only very slight.

In spite of the fact that the readings in the open and in the stable were taken at approximately the same air-temperatures (27·7° C. and 27·9° C.) and the same body-temperatures (38·1° C. and 38·2° C.), the scrotal surface-temperatures were, as a rule, slightly higher when measured in the stable. It is probable that this tendency is due to the absence of air movement within the stable.

The mean values of the skin and scrotal temperatures recorded at low air-temperatures (10° C. to 25° C.) and at high air-temperatures (25° C. to 40° C) (Table 3) showed that there was a highly significant difference. The readings show that at low air-temperatures the skin and scrotal temperatures are on an average lower than at high air-temperatures. The differences, 2·8° C. for the skin, and 1·9° C., 2·9° C., and 3·8° C., for scrotal areas I, II and III, although small, are highly significant. It would appear, therefore, that the heat regulating mechanism of the skin and scrotum is not entirely capable of overcoming the influence of environmental temperature. However, the physiological mechanism provided to counteract environmental temperature appears to be extraordinarily efficient, because the air-temperature range over which the observations were made was 30° C., and the difference between the mean values of the readings at low and high air-temperatures, within the range 10° C. to 25° C. and 25° C. to 40° C., did not exceed 3·8° C. for the scrotum and 2·8° C. for the skin. The readings taken over scrotal area III were always higher than those taken over scrotal areas I and II. Further, the skin-temperatures was always higher than that recorded over scrotal areas I and II, but there was no significant difference between the skin temperature and that recorded over scrotal area III. The latter result is not surprising, because scrotal area III, being so close to the reflection of the scrotal skin to the inguinal skin, cannot be so much under the influence of the physiological factors created by the contraction and relaxation of the scrotum acting under the influence of the dartos and cremaster muscles.

It is important to observe that the readings at low air-temperature were taken at a mean air-temperature of 17·1° C., while the scrotal and skin temperature varied between 31° C. and 33·6° C.; at high air-temperatures (mean 31·4° C.), the scrotal and skin-temperatures varied between 33·5° C. and 35·3° C. These readings would appear to emphasise the extra-ordinary efficiency of the heat regulating mechanism of the scrotal skin and the body-skin in counteracting the influence of environmental temperature, and thereby keeping the skin-surface temperature within a very narrow range. However, it must be remembered that these records were taken under very constant conditions, where the wind was never strong, and the bull was always exposed to the sun. The reaction under different conditions, such as wind, rain, and clouds have not yet been studied.

Measurements of the influence of low and high air-temperatures on contraction and relaxation of the scrotum, as indicated by its length, have shown that the regulating mechanism is sensitive to both cold and warmth. The degree of scrotal reaction, as indicated by contraction and relaxation, appears to be related to the air-temperature. The difference in length recorded at low and high air-temperatures was 5·8 cm., and this proved to be highly significant.

Generally greatest contraction occurs at the lowest temperature while the greatest relaxation occurs at the highest temperature. There is no doubt that relaxation and contraction are highly important factors in maintaining the scrotal and intra-testicular temperatures below body and skin-temperatures. During contraction the scrotum keeps the testicle in closer contact with the body, from which the heat is derived, and the cooling influences on the scrotal skin are reduced. During relaxation the testicle is further from the body, and the cooling influences have more freedom of action on the smooth and greatly increased scrotal surface. It is doubtful if this relaxation and contraction, as purely physical phenomena, are the only factors governing the heat regulating mechanism of the scrotum. It appears highly probable that during scrotal contraction there may be vascular contraction, and during relaxation there may be vascular dilatation, thereby exposing the capillaries to the cooling influences of the surrounding air.

If Figs. 2 and 3 are consulted it will be observed that at low air-temperatures there is only a slow increase in the temperature of scrotal areas I and II. The increase becomes more rapid as the air-temperature increases. There appears to be a " critical point ", 26·0° C. for scrotal area I, and 23·0° C. for scrotal area II, at which the rapidity of this increase is greater; up to this " critical point " the mean increase, as shown by scattered points, can be represented by a straight line, while after reaching the critical point the increase is more rapid but also linear. However, it must be pointed out that, with our present knowledge, too much importance cannot be attached to this " critical point ". It would, perhaps, be better to consider it as a critical temperature region, about 25° C., which represents an air-temperature at which certain physiological factors of the heat-regulating mechanism become modified.

There is no significant difference in the rate of increase of temperature over scrotal areas I and II.

The increase in temperature over scrotal area III and the skin-temperature for different air-temperatures show a similar tendency. These observations would appear to indicate that there is an extra physiological factor governing scrotal skin areas I and II and testicular temperature, besides those regulating the body skin-temperatures.

It is quite evident that the factors controlling the scrotal skin and intra-testicular temperatures are capable of maintaining them at a lower level than the body, skin *and* the air-temperature, if the latter is very high. Some observations made on a very hot day, when the air-temperature (38·6° C.) approached body temperature, showed a scrotal temperature over area I between 35° C. and 36° C., with the exception of one reading of 37.·1° C., while scrotal area II never exceeded 36° C. These temperatures are no doubt due to the cooling effect of evaporation and increased *perspiratio insensibilis*.

The relationship between body-temperature and air, scrotal, and skin-temperatures was observed only during periods of high air temperature. There was a significant relationship between the air and the body-temperature, and between the scrotal and body-temperature; but there was no significant relationship between the skin and the body-temperature. However, it must be emphasised that the number of body-temperature readings were too limited to draw any definite conclusions.

The observation which was conducted on the temperature of the testicle and scrotum, when the testicle was retained in close contact with the body for an hour, showed that the intra-testicular temperature (37·9° C.) was raised considerably, so that it approximated body-temperature (38·9° C.). It was 2·5° C. higher than the temperature taken with the testicle in its normal position at approximately the same body-temperature, an hour previously. This indicates that contraction of the scrotum and consequent closer contact of the testicle with the body, causes a rise in intra-testicular temperature approximating body temperature, when the latter is 38·6° C. to 38·9° C. That portion of the scrotum which was not in close contact with the testicle showed a marked decrease in temperature, 28·2° C. at its lowest extremity, and 31·0 C., about 5 cm. higher up, as compared with 34·2° C. an hour previously at approximately the same skin (37·2° C.) and body temperature (38·6° C.). The scrotal skin over the testicle showed a marked increase in temperature, 37·0° C. (mean value for two measurements over the testicle) when compared with that recorded, 34·2° C., with the testicle in the normal position, an hour previously. This indicates that the scrotal temperature is influenced by the testicular temperature when close contact is maintained, while the scrotal temperature is markedly influenced by environmental factors when that contact is artificially prevented. The scrotal temperature actually dropped 4° C. below the level of the air-temperature at its lowest extremity.

In view of the marked decrease in the surface temperature of the scrotum when removed from contact with the testicle it is suggested that some physiological factor acted besides the influence of air-temperature. The scrotum was moist from *perspiratio insensibilis* and it is suggested that there was an attempt by the temperature-regulating mechanism of the scrotum to maintain the intra-testicular temperature, which had increased considerably from close contact with the body, at its normal temperature with respect to the prevailing air-temperature.

Summary.

1. The temperature of the scrotal surface has been recorded at various air-temperatures within the range 10° C. to 40° C. (50° F. to 104° F.).

2. At low air-temperatures (10° C. to 25° C.) the temperature on areas I, II, and III gave a mean value of 32·0° C., 31·0° C., and 33·0° C.; at high air-temperatures (25° C. to 40° C.) the same areas were 33·9° C., 33·8° C., and 36·7° C.

3. Readings (28) of the skin-temperature underneath the hairy coat, taken simultaneously, gave mean values of 33·6° C. at low air-temperatures and 36·5° C. at high air-temperatures.

4. The mean body-temperature at which the high temperature group readings (15) were taken was 38·6° C.

5. Scrotal temperatures at areas I and II increased almost similarly with increasing air-temperature, i.e. slow increase at low air-temperatures (0·06° C. and 0·09° C. per 1° air-temperature increase) and more rapid increase at high air-temperatures (0·29° C. and 0·26° C. per 1° air-temperature increase).

Scrotal temperatures of area III and skin-temperatures increased similarly with increasing air-temperature over the whole range of 10° C. to 40° C. air-temperature. The rate of increase for scrotal area III was 0·43° C. at 10° C. air-temperature, and 0·11° C. at 40° C. air-temperature. The rate of increase on the skin was 0·56° C. at 10° C. air-temperature, and 0·14° C. at 40° C. air-temperature.

6. The degree of contraction and relaxation of the scrotum, as indicated by its length from the dorsal to the ventral extremity, gave a mean value of 24·2 cm. at low air-temperatures and 29·0 cm. at high air-temperatures, a difference of 4·8 cm.

7. From limited observations on the body-temperature, at high air-temperatures only, there appears to be a highly significant relationship between the body-temperature and that of the air and scrotal areas I, II, and III. There was no significant relationship between body and skin-temperature.

8. An observation was carried out at artificially created low air-temperatures. The bull was exposed to a temperature of 4° C. to 6° C. for six hours.

9. Under these conditions scrotal area I increased immediately from 30° C. to 33°C. It then decreased and fluctuated between 31° C. and 32° C. During the following 4 hours, scrotal area II always showed lower temperatures than area I (up to 3° C.). Scrotal area III increased markedly at the beginning and then showed a slight tendency to decrease, but after one-and-a-half hours remained 2° C. to 4° C. lower than skin-temperature.

10. There was marked shivering, which began one-and-a-half hours after exposure, and continued until one-and-a-half hours after the bull was removed from the cooling chamber.

11. The pulse rate per minute varied from 66 to 62 in the cooling chamber and dropped from 64 to 58 within an hour after removal.

12. The respiration count was 16 per minute after six hours exposure and 13 per minute one hour after removal.

13. The skin-temperature showed steady increase, up to 35° C. (air-temperature 4° C.). It then decreased continually to 32·6° C. at the end of the experiment, but a constant level had apparently not been reached. After removal from the cooling chamber, there was an increase of 3° C. within an hour.

14. The length of the scrotum decreased with a fall of scrotal and skin-temperature during exposure. There was marked relaxation upon removal to higher air-temperature.

15. The body-temperature increased by 1° C. at the commencement of exposure, and remained remarkably constant at about 39° C. throughout the exposure and after removal from the cooling chamber.

16. The intra-testicular temperature, measured with a thermo-needle, at an air temperature range of 15·2° C. to 37·8° C. remained within a narrow range, between 34·8° C. to 37·° C. for the left testicle and 34·7° C. to 36·6° C. for the right testicle.

17. Artificial displacement of the testicle to close contact with the body resulted in an increased intra-testicular temperature of 2·5° C. and a decrease in the temperature of the scrotal area not overlying the testicle, of 6·0° C. and 3·2° C. The scrotal surface over the displaced testicle also increased considerably to 37·0° C..

18. The heat regulating mechanism of the scrotum is extraordinarily efficient in maintaining the testicular and scrotal surface-temperatures within a very narrow range at air-temperatures between 10° C. and 40° C. It is suggested that this efficiency is not purely physical, due to the action of air-temperature on the contracted or relaxed scrotum. This suggestion is strengthened by the fact that scrotal areas I and II, in close contact with the testicle, behaved similarly but differently to scrotal area III and the skin. It appears probable that vascular reaction accompanies scrotal contraction and relaxation.

19. The scrotal temperature reaction over that portion of the scrotum removed from close testicular contact, is extraordinary in that there was a very marked decrease in temperature to 28·2° C., i.e. 3·8° C. lower than air-temperature, and 8·8° C. lower than intra-testicular temperature (average for points 1 and 2). It is suggested that this reaction was an attempt by the temperature regulating mechanism of the scrotum to maintain the testicular temperature, which was raised by contact with the body, at the normal temperature for prevailing air-temperature.

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