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A Preliminary Note on the Temperature of the Scrotal Skin of the Bull and its Relation to Air, Skin, and Body Temperature.

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The physiological action of the scrotum as a temperature regulating mechanism for the testicles is a subject of considerable interest in tropical and subtropical countries. Recent studies on the optimum temperature for the preservation of the life of spermatozoa *in vitro* have indicated the possible detrimental influence of temperature, closely approximating normal body-temperature or higher, on spermatogenesis and spermatozoa within the genital tract. The skin and body temperatures are, without doubt, influenced by high atmospheric temperatures, as well as other factors, such, for instance, as prolonged fasting (Benedict and Ritzman, 1927; French 1941; Lee, Colovos, and Ritzman, 1941; Bonsma, 1941; Phillips and McKenzie, 1934; and Brody, 1940).

Testicular ectopia, whether due to cryptorchidism or surgical displacement, when the location of the testicle is within the abdominal cavity, produces aspermatogenesis. Crew (1922) suggested that the cause of failure in normal development of such ectopic testicles may be due to an increased temperature. His suggestion was supported by Fukui (1923) who applied a cooling apparatus to the surgically displaced testicles of rabbits and dogs, and found that there was little cytological change, while control testicles, not treated by cooling, showed degeneration. Fukui (1923) and Moore (1924) also showed that the application of local heat to the normally situated testicles of the rabbit and guinea-pig caused cellular degeneration. An interesting observation during these experiments was the short time necessary to produce degenerative changes. The onset of cellular damage was more rapid with the higher temperatures. Moore and Oslund (1924) caused degeneration of the testicles of the ram by insulating the scrotum, thereby maintaining it at a temperature higher than normal. Phillips and McKenzie (1934) raised the scrotal temperature of the ram from 33·3° C. to 36·4° C. by insulation. This treatment produced degeneration of the germinal epithelium and morphological changes in the ejaculated spermatozoa. After two weeks insulation there was cessation of spermatogenesis, and reduction in the size of the testicle followed sixteen weeks insulation.

Therefore there would appear to be no doubt that artificially elevated temperature, maintained over an extended period, causes testicular damage resulting in morphologically changed spermatozoa or aspermatogenesis, and at least temporary infertility. The questions of practical importance in animal breeding are:

(1) How far are the scrotal and testicular temperatures influenced by atmospheric temperature?

(2) What is the reaction of the testicle to temporary rise of temperature?

(3) At what temperature is the physiological action of the testicle interfered with?

(4) How long must elevated temperatures be maintained before they become damaging to testicular function?

(5) When the physiological action of the testicle has been disturbed by elevation of temperature how long does it take to regenerate?

It has been suggested by Bonsma (1941), and French (1941), that "overheating" is a cause of low fertility in European cattle introduced into tropical and subtropical countries.

If atmospheric temperatures experienced in tropical and subtropical countries render male animals temporarily sterile an answer to the above questions is of vital importance to the breeder, and observations are now in progress which will help to elucidate the problem.

Bonsma (1941) states that the bulls of the exotic beef-breeds maintained on the Government Experimental Farm, Messina, often have body temperatures of 106° F. or more, whilst scrotal temperatures of 115° F. or more, have been recorded. He does not state under what circumstances these extraordinarily high scrotal temperatures were recorded. It is unlikely that scrotal temperature will ever exceed body-temperature for extended periods. It is conceivable that the sun shining upon the scrotal skin or contact with the hot, sandy ground, during periods of lying, will cause a temporary rise in temperature, but the scrotum is not exposed to direct sunlight, as a rule, except in the early morning and late afternoon; and even then its position gives it considerable protection. When male animals with pendulous scrota lie in the sun there is a possibility of the scrotum coming in contact with the hot ground, which would have the effect of causing a temporary rise, at least, in scrotal skin temperature.

Under ordinary conditions it may be assumed that the scrotum acts as a temperature regulating mechanism, whereby the temperature of the testicles is maintained relatively constant, some degrees below body temperature. Phillips and McKenzie (1934) state: "The scrotum of the ram functions very much as a thermostat maintaining the testes at a fairly constant temperature considerably below that of the body cavity. The tunica dartos muscle provides the mechanism by which this function is accomplished". These workers found the scrotal temperature of the ram to be approximately 6·5° C. lower than body temperature.

The object of the present observation is to ascertain the scrotal temperature of a bull of an exogenous beef-breed, the Sussex, under the climatic environmental conditions prevailing at Onderstepoort. At the same time the relation of the body and skin temperature to the scrotal temperature was also noted.

TECHNIQUE.

The instrument used to obtain scrotal and skin temperatures was a thermo-couple connected to a micro-ammeter. The physical principle on which this instrument works is, that if two wires of different metals are joined to complete a circuit, and if one junction is raised to a higher temperature than the other, an electric current flows in the circuit. The strength of this current is proportional to the temperature difference. If, therefore, one of the junctions is kept at a constant temperature, in a thermos flask, and the other is placed in

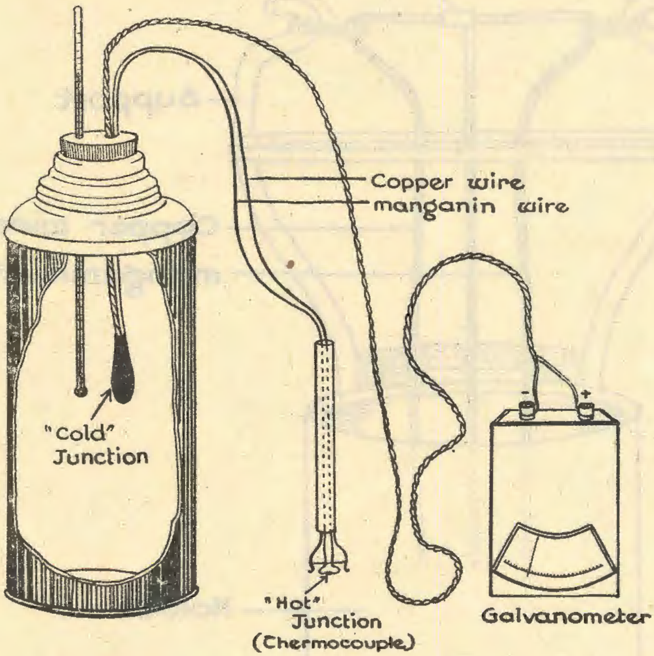

Fig. 1 (*a*).—Diagram of a thermo-couple as connected with the galvanometer, and the insertion of the " cold junction " in the thermos flask.

contact with the skin, the current obtained indicates the temperature of the spot touched by the thermo-couple It was found that a considerable time must elapse before a constant temperature reading is obtained, because the air temperature and the temperature of the holder of the thermo-couple influence the lead wires. After several attempts to find a suitable material for insulating the thermo-couple against these influences, it was found best to use a minimum of solid insulation and to suspend the junction from a wire framework exposed to air. [See Figs 1 (*a*) and (*b*).]

A " point " thermocouple was constructed, i.e., the junction of the two wires formed a small enlargement, about 2 mm. × 1 mm. The loop thus formed by the lead-wires was suspended between two wire hooks. The enlargement and the adjoining quarter of an inch of both the copper and the maganin wire made contact with the skin. The remaining part of the thermo-couple wires extended for 6 inches through a hollow cardboard handle, through which the air circulated freely. From the handle to the " cold " junction the same wires were encased in rubber tubing quarter of an inch in diameter. The " cold " junction wires and the ends of the flex leading to the ammeter were encased in putty and wax.

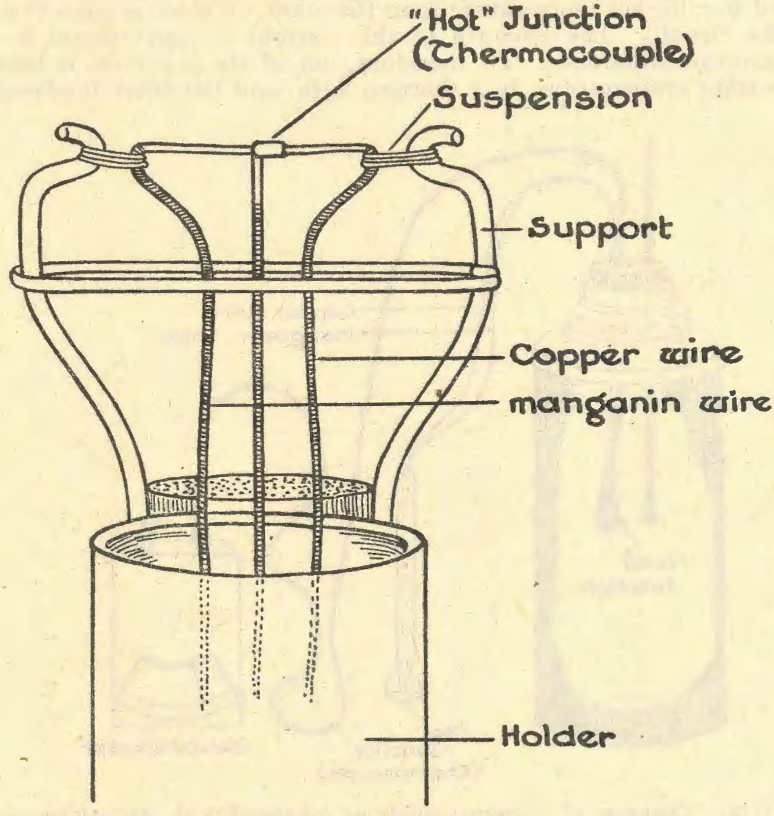

Fig. 1 (*b*).—Diagram showing details of construction of the thermo-couple.

The ammeter used was a Weston micro-ammeter of low (3·8 ohms.) resistance. A change in current showing a deflection of one division on the ammeter corresponded to a change of temperature of 0·6° F.

Procedure.

The observations were carried out in an open yard enclosed by a corrugated iron fence about 7 feet high. The bull was tied up at least half an hour before the first readings were taken. During this period and whilst the observations were carried out, he was kept in a position perpendicular to the incidence of the sun's rays, i.e., so that the radiation had full play on one side of his body. Readings taken on this side of the body will be referred to as *readings in the sun*. Records obtained on the other side of the body will be called *readings in the shade*.

The areas on which the temperature was measured were the following:

I. Lateral aspect of the scrotum, about 1½ inches from its ventral extremity.

II. Lateral aspect of the scrotum, about midway between its ventral and dorsal extremities.

III. Lateral aspect of the scrotum, close to its reflection to the abdominal skin.

IV. Skin on the flank, in a vertical line with the scrotum at the level of the stifle joint.

The various areas on the scrotum were not interfered with. The skin temperature was measured within an area of a square inch on which the hairs were carefully removed with a pair of scissors close to the skin This was done at least one hour before commencing the observations.

The readings were collected during the period 7th of January to 27th March 1941. The exact dates and the times of the day are given in Table 1.

After the bull had been tied up for half to one hour the body temperature was measured; simultaneously the air temperature was determined with a mercury thermometer hanging in the shade and freely exposed to the air.

The following readings were taken:

1. *Scrotal temperature:*

(*a*) Scrotal area I, II, III	Sun	on the side of the body exposed to the sun.
(*b*) Scrotal area I, II, III	Shade	on the side of the body *not* exposed to the sun.

These six readings were taken three times in succession. The mean of the three readings for each area was calculated and taken as the scrotal temperature during that particular period. Air temperature readings were taken after each set of 6 readings and the mean of these referred to as the air temperature during the same period.

2. *Skin temperature*.—The skin temperature was then measured on the prepared areas on either flank, firstly in the sun, and secondly in the shade. This was repeated three times and the mean values calculated. Air temperature at the beginning and at the end of the series of skin temperature measurements provided the air temperature during this period.

3. *Scrotal temperature.*—Nine further scrotal temperature readings, as described under No. 1, completed the set of readings taken at a time. The readings obtained under Nos. 1 and 3 were correlated to the skin temperature as obtained under No. 2.

It is essential to mention, that scrotal area No. I "in the sun" was always actually exposed to the sun's rays; area No. II was sometimes shaded for a few minutes by the hindleg of the bull; area No. III was always in the shade because it was inaccessible to the sun's rays.

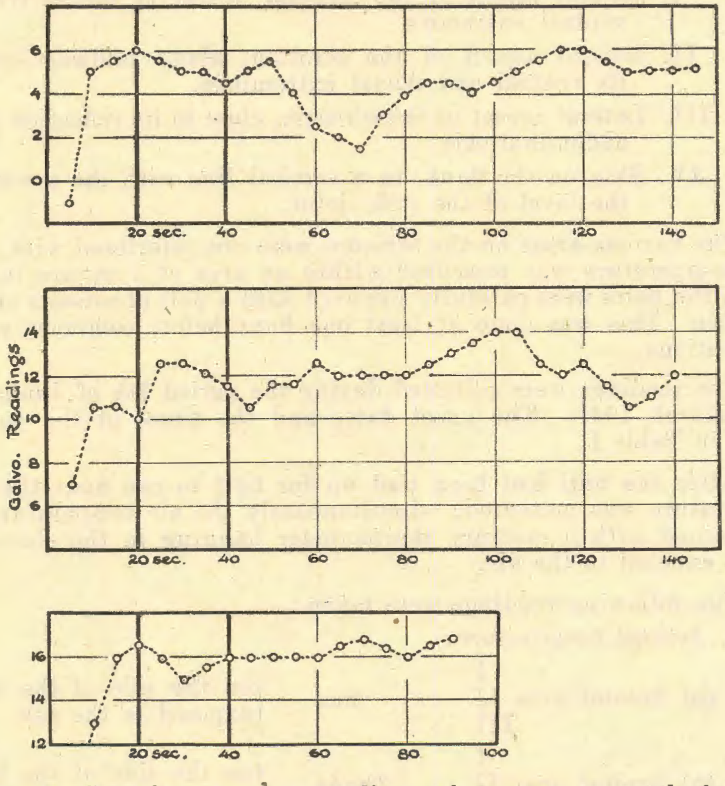

Fig. 2.—Scrotal temperature readings taken every 5 seconds from the moment contact was made. Actual records were made from readings taken between 20 and 40 seconds, indicated by heavy lines.

The actual readings were taken 20-40 seconds after the thermocouple had been placed in contact with the area to be measured. To check whether this was the right moment for taking the actual measurement, readings were taken every 5 seconds from the moment when contact was made. A few examples given in Fig. 2, show that within the limit of error of about $\pm 1 \cdot 0^{\circ}$ F. the time factor did not alter the results.*

* Owing to the cooling effect of the air on the thermo-couple it is possible that the readings obtained were somewhat low. Subsequent measurements with an instrument which was designed so as to obviate this defect indicated that there was a possible error of about $\pm 1^{\circ}$ F. due to this cooling effect.

Results.

The total number of readings taken in this experiment is given in Table 1.

Columns 1 and 2 give the date and time of the beginning of each set of readings. Column 3 indicates whether the sun was shining during the period of observation; it also indicates the wind conditions prevailing in the yard. Column 4 contains the mean body temperature at the time when either a set of scrotal or of skin temperatures was taken. Column 5 gives corresponding mean air temperatures for the period. The remaining columns contain skin and scrotal temperatures in the order they were taken during each period of investigation.

The readings in Table 1 were used to work out the following results:

1. Temperatures of the various scrotal areas.
2. Difference between scrotal temperatures measured in the sun and in the shade.
3. Behaviour of scrotal temperature at various air temperatures.
4. Relationship between skin and scrotal, and skin and air temperatures.
5. Variation of body temperature as compared with air temperature.
6. Relationship between body and scrotal temperature, and body and skin temperatures.

Before discussing the various results obtained it is essential to emphasize the following:

Assuming that the air temperature would be the main environmental factor influencing the animal, the range of air temperature at which the scrotal temperatures were measured is most important. The observations referred to in this article were carried out at temperate air temperatures, i.e., it was neither very cold nor very hot, and the range of air temperatures was comparatively small (64·8° F. to 91·2° F.). (Readings taken at an air temperature range from 30-60° F. might give different results). Nevertheless this range was large enough to expect variations of the various temperatures measured. It is, however, imperative to realize that in the following chapters reference is always made to this range of air temperature only, and that any statement made may not be applicable to any other range of air temperature.

1. *Temperatures of the various Scrotal Areas.*

It was found that significant differences existed between the temperatures of the various areas of the scrotum. The mean values are as follows:—

	Sun.	*Shade.*	*Air temperature range.*
Scrotal area I	92·1° F.	90·2° F.	
Scrotal area II	93·5° F.	92·3° F.	65-91° F.
Scrotal area III	95·8° F.	95·6° F.	

TABLE 1.

Date.	Time.	Sun and Wind.	Body.	Air.	SUN.				SHADE.			
					Skin.	Scrotum °F.			Skin.	Scrotum °F.		
			°F.	°F.	°F.	I.	II.	III.	°F.	I.	II.	III.
7th January.........	3 p.m.	Sun free: Calm................	103·0	90·8	102·3	—	—	—	99·0	—	—	—
			103·5	90·5	—	96·9	98·1	99·1	—	94·7	97·6	99·4
8th January.........	9 a.m.	Sun free: Calm................	102·8	80·6	97·8	—	—	—	97·8	—	—	—
			102·8	83·4	—	92·0	93·4	96·8	—	91·5	94·0	96·8
			102·9	83·6	98·7	—	—	—	98·2	—	—	—
	3 p.m.	Sun partly free: Calm.........	102·8	90·5	100·6	—	—	—	99·7	—	—	—
			103·0	91·2	101·7	—	—	—	98·9	—	—	—
			—	89·6	—	97·2	97·9	100·0	—	94·0	97·2	99·1
10th January.........	9 a.m.	Sun free: Breeze..............	102·6	81·2	—	93·6	95·3	97·7	98·1	91·4	94·7	97·9
			103·3	83·4	99·4	—	—	—	98·1	—	—	—
11th January.........	10 a.m.	Sun partly free: Breeze........	102·0	77·8	—	91·1	93·3	95·8	—	91·2	92·7	95·3
14th January.........	9 a.m.	Sun free: Calm................	102·3	79·0	—	92·2	93·2	96·6	—	91·2	92·1	95·9
			102·7	80·6	—	92·0	94·4	97·2	—	92·2	92·3	96·7
15th January.........	9 a.m.	Sun partly free: Wind.........	101·7	79·4	—	92·8	92·7	95·8	—	90·9	91·0	94·8
			101·9	81·5	99·3	—	—	—	96·0	—	—	—
27th January.........	9.30	Sun free: Calm................	101·8	76·8	—	90·4	91·1	96·3	—	91·0	92·5	95·5
	a.m.		102·3	79·7	96·6	—	—	—	95·0	—	—	—
			102·8	80·6	—	93·6	94·6	97·6	—	93·0	93·6	96·6
12th February........	9.30 a.m.	Sun free: Breeze..............	102·8	85·4	—	93·8	94·9	96·6	—	93·1	94·4	95·8
14th February........	3 p.m.	Sun mostly free: Breeze.......	103·1	88·3	—	98·0	99·2	99·3	—	92·9	97·4	98·4
			103·2	89·6	101·2	—	—	—	99·8	—	—	—
			103·3	88·7	—	100·0	100·7	98·7	—	92·9	97·5	99·0
18th March...........	9,30 a.m	Sun partly free: Slight breeze..	101·3	68·3	—	90·0	89·2	93·0	—	87·4	88·7	91·8
19th March...........	9.30	Sun free: Calm................	101·0	69·2	—	—	—	91·0	—	87·2	89·7	92·2
	a.m.		101·0	71·0	—	90·7	91·0	93·6	—	87·7	89·8	93·0
20th March...........	9 a.m.	Sun free: Calm................	101·4	72·3	—	88·9	90·8	92·1	—	87·6	89·7	93·7
			101·5	73·8	94·8	—	—	—	94·1	—	—	—
			101·5	74·5	—	87·8	89·0	93·4	—	88·4	91·1	93·7
21st March...........	9 a.m.	Sun free: Calm................	101·1	72·8	—	90·4	92·2	94·5	—	89·6	91·5	95·2
			101·3	77·2	97·2	—	—	—	96·2	—	—	—
26th March...........	9.30	Sun free: Calm................	100·6	64·8	—	88·3	92·0	92·4	—	85·6	88·7	93·9
	a.m.		100·7	66·6	—	89·2	91·5	94·0	—	86·6	90·1	95·1
			100·8	68·2	96·1	—	—	—	92·4	—	—	—
			101·0	69·2	—	89·1	92·0	94·5	—	86·5	90·7	94·8
27th March...........	9.30	Sun free: Calm................	101·1	70·4	—	89·1	91·1	94·6	—	86·6	88·2	94·3
	a.m.		101·3	72·4	97·7	—	—	—	94·1	—	—	—
			101·5	72·8	—	89·3	92·3	94·6	—	87·3	89·9	95·0
28th March...........	9.30	Sun free: Slight wind.........	101·0	76·0	—	93·7	93·3	95·0	—	90·5	90·7	93·1
	a.m.		101·3	77·0	96·5	—	—	—	93·8	—	—	—

It is interesting to note that the lowest area on the scrotum showed a temperature which was 3-5° lower than that obtained at the top of the scrotum, near the body.

NOTE.—Phillips and McKenzie, 1934, found in rams, at a room temperature range from 55 to 75° F., an average scrotal temperature of 92° F.

2. *Difference between Scrotal Temperatures " in the sun " and " in the shade ".*

A comparison of the results of readings taken in the sun and those taken in the shade showed a difference which did not prove to be significant. This is not surprising since only scrotal area No. I was actually exposed to the sun's rays. Further, the actual duration of such exposure was very irregular as the bull constantly shaded the scrotum by movement of his legs.

3. *Behaviour of Scrotal Temperature at various Air Temperatures.*

The relationship between the scrotal temperature and the air temperature proved to be significant, the correlation coefficient being for:—

	Sun.	*Shade.*
Scrotal area I	·89	·95
Scrotal area II	·63	·94
Scrotal area III	·92	·85

This correlation coefficient does not prove whether the relationship would be the same if any other influencing factor, e.g., wind, would vary. It can, however, be stated, that with the wind and radiation conditions as they were, and with a range of air temperature of 26° F., the changes in scrotal temperature were proportional to the changes in air temperature. One degree increase of air temperature resulted in an average increase of:—

Sun.	*Shade.*
·39° F.	·34° F. in scrotal area I.
·25° F.	·36° F. in scrotal area II.
·27° F.	·23° F. in scrotal area III.

The relationship between air and scrotal temperature is demonstrated in Figs. 3 and 4, which present the figures given in Table 1 in the form of a graph.

The line drawn through the single readings was fitted to the data by the method of least squares. It was found that a straight line best represents the above relationship within the air temperature range of 65°-91° F. The deviations of the single readings from this line can also be seen on Figs. 3 and 4. This scattering is probably mostly due to the influence of the wind on the thermo-couple. Even a slight breeze made it sometimes very difficult to obtain a constant reading on the ammeter.

4. *Relationship between Skin and Scrotal and Skin and Air Temperatures.*

The skin temperature measurements were taken, as mentioned above, on a prepared area on the flank of the bull. It is fully realized that the cutting of the hairy coat involves a severe interference with the natural conditions in so far as the protecting layer of air in between the hairs is also removed. Nevertheless this procedure was chosen because the difficulties in obtaining correct and reliable measurements of the temperature inside the hairy coat have, as yet, not been technically overcome. On the other hand by cutting the hairy coat the surface conditions were very similar to those on the scrotum.

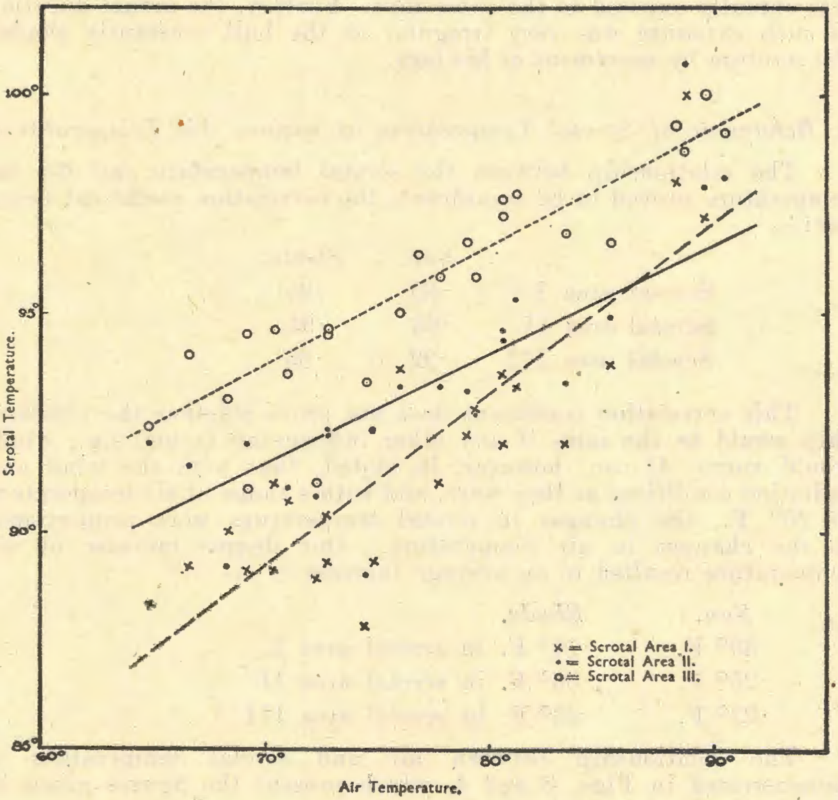

Fig. 3.—Relationship between air and scrotal temperatures in the sun.

The skin temperature readings obtained are given in Table 1 with a mean value of 98·6° F. on the sunny and 96·7° F. on the shaded side of the body. If these figures are compared with the temperatures measured on area No. III of the scrotum (95·8° F. in the sun and 95·6° F. in the shade) it will be seen that the difference between skin (in the shade) and scrotal area No. III (in the shade) is relatively small, in fact this difference did not prove to be significant. We can, therefore, state that when measuring in the shade, the top of the scrotum, close to the body, showed nearly the same temperatures as the prepared area on the flank.

The variation of the skin temperature as compared with the air temperature showed a correlation coefficient of ·90 in the sun and ·94 in the shade, i.e., the skin temperature varied more or less proportionally to the change in air temperature. An increase of 1° F. air temperature resulted in an average increase of ·28° F. skin temperature in the sun and ·31° F. in the shade.

There was a significant difference between the skin temperatures taken in the sun and those taken on the shaded side of the body.

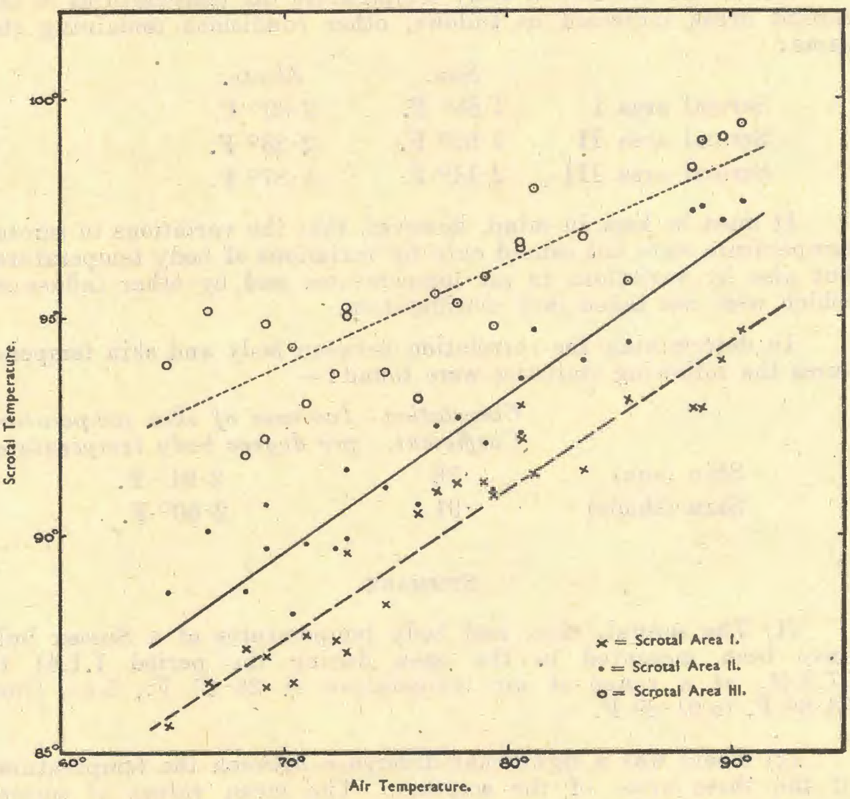

Fig. 4.—Relationship between air and scrotal temperatures in the shade.

5. *Variation of Body Temperature as compared with Air Temperature.*

The body temperature of the bull varied only from 101·0° to 103·5° F. during the periods when measurements were carried out. This range of body temperature was too small to find any definite correlation between body and air temperatures. Further observations must be made when circumstances allow for measurements at higher and lower atmospheric temperatures.

6. *Relationship between Body and Scrotal Temperature, and Body and Skin Temperature.*

The body temperatures were correlated with the scrotal temperatures measured simultaneously and it appears that a direct relationship exists. The following correlation co-efficients were calculated.

	Sun.	*Shade.*
Scrotal area I	·80	·81
Scrotal area II	·80	·91
Scrotal area III	·90	·86

For 1° F. increase of body temperature the temperatures of the scrotal areas increased as follows, other conditions remaining the same:

	Sun.	*Shade.*
Scrotal area I	2·85° F.	2·69° F.
Scrotal area II	2·62° F.	2·83° F.
Scrotal area III	2·11° F.	1·87° F.

It must be kept in mind, however, that the variations in scrotal temperature were not caused only by variations of body temperature, but also by variations in air temperatures and by other influences which were not taken into consideration.

In determining the correlation between body and skin temperatures the following statistics were found:—

	Correlation Coefficient.	*Increase of skin temperature per degree body temperature.*
Skin (sun)	·76	2·01° F.
Skin (shade)	·91	2·60° F.

Summary.

(1) The scrotal, skin, and body temperatures of a Sussex bull have been measured in the open during the period 7.1.41 to 27.3.41, at a range of air temperature of 26·4° F., i.e., from 64·8° F. to 91·2° F.

(2) There was a significant difference between the temperatures of the three areas of the scrotum. The mean values of scrotal measurements were:

Area.	*In Sun.*	*In Shade.*
I	92·1° F.	90·2° F.
II	93·5° F.	92·3° F.
III	95·8° F.	95·6° F.

(3) There was no significant difference between scrotal temperature measurements taken on that side of the body exposed to direct sun's rays and those taken of the opposite side.

(4) There was a significant relation between scrotal temperature and air temperature. For an increase of 1° F. of air temperature the increase of scrotal temperature of the areas measured was:

Area.	*In Sun.*	*In Shade.*
I	·39° F.	·34° F.
II	·25° F.	·36° F.
III	·27° F.	·23° F.

(5) The mean skin temperature readings, taken on an area on the flank from which the hair had been removed, were 98·6° F. in the sun and 96·7° F. in the shade. These approximated the readings on scrotal area III, i.e., 95·8° F. and 95·6° F. In fact there was no significant difference between the temperatures recorded on the skin and scrotal area III.

(6) There was a relation between the skin temperature and the air temperature; an increase of 1° F. of air temperature resulted in an increase of skin temperature of ·28° F. in the sun and ·31° F. in the shade.

(7) There was a significant difference between the skin temperatures taken in the sun and in the shade.

(8) The range of body temperature was too small, i.e., 101° F. to 103·5° F., to find a definite correlation between body and air temperature. The observations must be repeated at higher and lower atmospheric temperatures to establish such correlation.

(9) There was a direct correlation between body and scrotal temperatures. For 1° F. increase of body temperature the increase of scrotal temperature of the areas measured was:

Area.	*In Sun.*	*In Shade.*
I	2·85° F.	2·69° F.
II	2·62° F.	2·83° F.
III	2·11° F.	1·87° F.

(10) The correlation between body and skin temperature showed that for 1° F. increase in body temperature the skin temperature increased 2·01° F. in the sun and 2·6° F. in the shade.

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