Environmental Physiology

With Special Reference to Domestic Animals

III. Influence of Ambient Temperature, 50° to 100° F., on the Blood Composition of Jersey and Holstein Cows

Publication authorized February 21, 1949

Dairy Department, Missouri Agricultural Experiment Station and the Bureau of Plant Industry, Soils, and Agricultural Engineering United States Department of Agriculture Cooperating; Assisted by the Office of Naval Research.
COOPERATION, ACKNOWLEDGMENTS, AND DIVISION OF LABOR

A cooperative investigation by the University of Missouri Agricultural Experiment Station and the Bureau of Plant Industry, Soils and Agricultural Engineering (generally known as BPISAE) of the United States Department of Agriculture. BPISAE is represented on this project by Harold J. Thompson, resident Agricultural Engineer, and Dorothy M. Worstell, resident office supervisor and statistician. Non-resident participating BPISAE members are J. R. McCalmont, Agricultural Engineer; Wallace Ashby, Head of the Farm Building and Rural Housing Division, and A. W. Turner, Associate Chief of the BPISAE and Chief of its Agricultural Engineering Division.

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—SAMUEL BRODY.

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<td>24</td>
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<tr>
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<td>Samuel Brody</td>
<td>30</td>
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</tbody>
</table>
exploratory nature, beginning with analyses for which standard analytic methods are available. Later, we hope to adapt or develop some newer analytic methods for measuring concentrations and activities of metabolites, hormones, and enzymes, perhaps at cellular levels.

For ambient temperature control we used the two Psychroenergetic, or Climatic, Chambers previously described. Each chamber is 26 x 18 x 9 feet and each houses six cows. The temperature of the chamber used as Control was held between 50° and 60°F; the temperature of the Experimental Chamber was increased systematically from 50° to 100°F at convenient intervals.

Each cow in the Experimental Chamber had a similar, “paired”, cow in the Control Chamber. Each group of cows consisted of three lactating Jerseys, two lactating Holsteins, and one non-lactating, non-pregnant, Holstein. A few facts about the cows and temperature schedules are given in Table 1. The detailed numerical data are given in the second report of the series (Research Bulletin 425).

Blood samples were drawn from the jugular vein* about 7:30 in the morning, shortly after feeding and milking. From the viewpoint of stability or consistency of the blood composition data, it would have been better to draw the blood before feeding, milking, and watering, but this was not practical.

As far as possible, standard methods of blood analyses were employed, such as those outlined by Hawk et al. To save space, original references are omitted when such are given in this textbook and references are made to it.

Sweating and Blood Composition: The influence of high environmental temperature on physiological reactions in general and on blood composition in particular depends on many factors, but mostly on moisture loss by sweating. For instance, man is a profusely sweating species and his exposure to high environmental temperatures is often followed by greater moisture loss by sweating than moisture gain by drinking, with consequent net reduction in the water content of the body, especially of the blood serum. This dehydration of the serum tends, of course, to be associated with an increase in concentration of blood dry residue, including serum protein, non-protein nitrogen, chlorides, sugar, and so on. At the same time the volume of urine output is decreased and the concentration of urine solutes is increased.


**At the beginning, arterial blood was used, but was given up after two or three weeks because of difficulty of obtaining it. The tables (Section 2) include venous blood only. The individual charts (Section 3) include the few arterial blood data as indicated.


Adolph, E. F., "Physiology of Man in the Desert", New York, 1947, gives an excellent review of the literature as well as a report of his own researches on the influence of hot environmental temperature on the water balance in man. It should be noted that R. M. Kark, C. R. Johnson, et al (Medicine, 26, 1, 1947) did not find significant differences (under field conditions) between the hemoglobin (16 gm per 100 ml) and serum protein levels (6.2 in the United States and 6.6 in the Pacific) in troops in the South Pacific Islands and troops in continental United States. D. B. Dill, et al (J. Biol. Chem., 136, 449, 1940), found a clear-cut correlation between arterial blood composition and season or climate; C. W. Paucher, (J. Biol. Chem., 74, XIX-IV, 1927) on the other hand, reported seasonal rhythms in the composition of human blood.
Table 1.--Facts About the Experimental and Control Cows.

<table>
<thead>
<tr>
<th>Experimental Cows</th>
<th>Control Cows</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cow No.</strong></td>
<td><strong>Approx. Age</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Yrs.</strong></td>
</tr>
<tr>
<td></td>
<td>(Apr. 1, 1948)</td>
</tr>
<tr>
<td>Jersey 212</td>
<td>3 1/4</td>
</tr>
<tr>
<td>Jersey 202</td>
<td>3 2/3</td>
</tr>
<tr>
<td>Jersey 994</td>
<td>4 1/2</td>
</tr>
<tr>
<td>Holstein 83</td>
<td>5 1/2</td>
</tr>
<tr>
<td>Holstein 118</td>
<td>4 1/3</td>
</tr>
<tr>
<td>Holstein 106</td>
<td>4 2/3</td>
</tr>
<tr>
<td></td>
<td>(Dry)</td>
</tr>
</tbody>
</table>

Ambient Temperature at Time (7-8 a.m.) Blood Samples Were Obtained

<table>
<thead>
<tr>
<th>Date</th>
<th>Ambient Temp. °F</th>
<th>Cows Sampled</th>
<th>Date</th>
<th>Ambient Temp. °F</th>
<th>Cows Sampled</th>
</tr>
</thead>
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<tr>
<td>April 16</td>
<td>51.5</td>
<td>All 6</td>
<td>April 21</td>
<td>50</td>
<td>All 6</td>
</tr>
<tr>
<td>April 27*</td>
<td>61</td>
<td>212, 83, 106</td>
<td>May 10</td>
<td>50</td>
<td>90, (205, 100)*</td>
</tr>
<tr>
<td>May 3*</td>
<td>60.5</td>
<td>202, 994, 118</td>
<td>May 12</td>
<td>50</td>
<td>504, 132, (204)*</td>
</tr>
<tr>
<td>May 5</td>
<td>70</td>
<td>212, (83, 106)*</td>
<td>May 24</td>
<td>50</td>
<td>205, 504, 90</td>
</tr>
<tr>
<td>May 17</td>
<td>70</td>
<td>994, 118, (202)*</td>
<td>May 26</td>
<td>51.5</td>
<td>204, 100, 132</td>
</tr>
<tr>
<td>May 19</td>
<td>70</td>
<td>212, 83, 106</td>
<td>June 11</td>
<td>52</td>
<td>205, 504, 90</td>
</tr>
<tr>
<td>May 31</td>
<td>69.5</td>
<td>202, 994, 118</td>
<td>June 14</td>
<td>49</td>
<td>204, 100, 132</td>
</tr>
<tr>
<td>June 2</td>
<td>69</td>
<td>212, 83, 106</td>
<td>June 21</td>
<td>53</td>
<td>205, 504, 90</td>
</tr>
<tr>
<td>June 7</td>
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<td>202, 994, 118</td>
<td>June 28</td>
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<tr>
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<td>July 19</td>
<td>52</td>
<td>205, 504, 100, 132, 90</td>
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<tr>
<td>June 22</td>
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<td>July 23</td>
<td>51.5</td>
<td>All 6</td>
</tr>
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<td>June 24</td>
<td>80</td>
<td>83, 118, 106</td>
<td>July 26</td>
<td>58</td>
<td>All 6</td>
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<tr>
<td>June 30</td>
<td>85</td>
<td>83, 118, 106</td>
<td>Aug. 9</td>
<td>55</td>
<td>All 6</td>
</tr>
<tr>
<td>July 2</td>
<td>84.5</td>
<td>212, 202, 994</td>
<td>Aug. 11</td>
<td>57.5</td>
<td>All 6</td>
</tr>
<tr>
<td>July 6</td>
<td>84.5</td>
<td>83, 118, 106</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>July 8</td>
<td>85</td>
<td>212, 202, 994</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>July 14</td>
<td>89.5</td>
<td>212, 202, 994, 83</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>July 16</td>
<td>90</td>
<td>212, 202, 118, 106</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>July 21</td>
<td>90</td>
<td>All 6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>July 28</td>
<td>95</td>
<td>All 6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>July 30</td>
<td>95</td>
<td>All 6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aug. 3</td>
<td>99.5</td>
<td>All 6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aug. 5</td>
<td>100</td>
<td>All 6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

†Relative Humidity was maintained between 60 per cent and 70 per cent in both chambers throughout the experiment.

*Arterial blood.

In slightly sweating species on the other hand, such as our cattle evolved in cool Europe, the moisture loss by sweating is relatively low. Moreover, as will be demonstrated in a future publication in this series, when the drinking water is cooler than the environment, the animals increase their water consumption (for body-cooling purposes) with increasing ambient temperature so that, unlike in man, the urine output is increased and its specific gravity is decreased. In brief, while man tends to be dehydrated and reduces the urine output with increasing temperature because of his inability to consume enough water to compensate for his moisture loss by sweating, European cattle appear, from our results, to become hydrated and to increase the urine output by con-
susing and absorbing more cool water in hot weather than is vaporized. Consequently, while in man the concentration of blood constituents tends to increase with rising ambient temperature, in European cattle the concentration of blood constituents tends to decrease.

Furthermore, the profuse sweating in man tends to keep his body temperature normal while at rest even at 110°F or higher, but in the slightly sweating European cattle, the body temperature increases with increasing environmental temperature, beginning with 80°F, so that at 105°F, the rectal temperature of our Holstein cows reached 108°. This febrile condition may be expected to affect the reaction rates of many processes in the body which could be reflected in changes in the blood composition. This would be especially expected in the ruminant whose nutritional welfare depends so much on the activities of the rumen microorganisms. It is interesting to speculate on the effect of a rectal temperature of 108°F on the rumen temperature, on the activities of rumen organisms, and on the blood Vitamin B levels which depend on the Vitamin B production in the rumen.

Another effect of high temperature on nutrition is that feeding is associated with an increase in heat production ("specific dynamic effect"), so that the rate of feed intake appears to behave as if it were a mechanism of temperature regulation with the net result that increasing the ambient temperature reduces the feed consumption. Reduction in feed intake would, then, reduce the milk production, which also involves a heat increment.

Furthermore, increasing ambient temperature profoundly depresses thyroxine production, at least in the rat (a non-sweating species). At an environmental temperature of 1°C, 100-gm rats produced 9.5 µg thyroxine per day, at 25°C they produced 5.2 µg, and at 35°C, 1.7 µg; that is, increasing the environmental temperature from 34°F (1°C) to 95°F (35°C) reduced the thyroid activity by about 80 per cent. Since thyroxine profoundly affects all metabolic and productive processes, these observations on the reduction of thyroid activity in the rat with increasing ambient temperature are of the greatest theoretical and practical significance and need careful study. We hope to report at a later date on this phenomenon as it relates to cattle.

The reduction of the feed consumption and milk production to almost zero at 105°F, and the reduction of the thyroid activity by 80 per cent, may easily halve the metabolic rate. How would such a reduction in metabolic rate affect the nutritional condition and blood composition of the animals? The literature has no answer to this question and we have no very good theoretical

7Dempsey, E. W., and Astwood, E. B., Determination of the rate of thyroid hormone secretion at various environmental temperatures. Endocrinology, 32, 809-18, 1943.
basis for speculation. We must simply get data and look at the facts.

The literature on the effect of environmental temperature on blood composition of cattle is also confused by there being apparently two categories of cattle, the sweating, such as the Zebu or Brahman evolved in hot India, and the non-sweating or slightly-sweating, such as the Holstein and Jersey evolved in cool Europe (the subject of the present report).

While, as explained above, the blood composition of our (European) cattle is likely to react differently to the impact of increasing environmental temperature than that of man, the reaction of sweating Indian cattle may be similar to that of man. This needs to be investigated on the functional (evaporative cooling) and structural (histology of sweat glands) levels. The available data on Indian cattle is even less definite than that on European cattle.

As regards the effect of seasonal changes in outdoor temperature, this did not seem to affect the blood composition of Jersey cattle under the conditions of Louisiana.

The only observations on the blood composition of cattle under controlled laboratory conditions of temperature and humidity have been reported by Riek and Lee on four lactating Jersey cows and on four eight-week-old Jersey calves. They were exposed for seven hours to each of several atmospheres having dry-bulb temperatures of 85° to 110°F and the rather unusual range of absolute humidities from six to sixteen grains moisture per cubic foot. Blood samples were drawn from the jugular vein 15 minutes before entering the chamber and following the seven-hour exposure to the chamber atmosphere. At high temperatures and humidities there was in the cows a marked fall in inorganic phosphates from 5 to 2 mg per 100 ml blood; and a drop in serum calcium from 10.6 to 8.6 mg per 100 ml serum. The decrease in blood sugar from 55 to 45 mg per 100 ml blood was not considered to be correlated with rise in temperature or humidity. The mean red blood cell count showed no significant variation from 5 million per cu. mm. Blood analyses in the calves showed only small changes in serum calcium or inorganic phosphorus from the mean of 10.7 mg per 100 ml serum and 7.2 mg per 100 ml blood. Red blood cell counts remained comparatively constant at 8 million per cu. mm.

It is instructive to note that Conrad reported a 25 to 30 per cent de-


crease in the calcium level in chicken blood on increasing the environmental
temperature from 70° to 90°F, and that at the same time the shell thickness
of the eggs was reduced by the same proportion. Chickens, like European cat-
tle, are slightly sweating or non-sweating with consequent probability of de-
cline in thyroid activity which affects calcium metabolism, including shell
thickness of eggs.

Let us next examine for each blood constituent the numerical data of the
Experimental cows and compare them to the data on the Control cows, then
attempt to integrate the results. As a measure of variability of the data the
standard error of the mean is used except in certain cases where the number
of samples is inadequate, in which case the range is indicated.—S. B.

2. DATA

Calcium: The serum calcium was determined by the method of Roe and
Kahn as outlined by Hawk et al, except that two-fifths quantities of the re-
agents were used. This procedure involves the precipitation of the calcium
as its phosphate, the washing out of other phosphates, and the subsequent de-
termination of the phosphate in the calcium phosphate.

Kennedy et al reported that gestation and lactation have little effect on
the blood calcium level of dairy cattle. Awdejewa et al reported that serum
calcium in cattle increased with increasing ambient temperature in the —10° to
+10°C range.

The application of Fisher's “t” test to our data summarized in Table 2
showed no significant difference between the calcium levels of the Control and
Experimental animals, nor between the Jersey and Holstein cattle.

Table 2.—Comparison of Calcium Levels of Experimental and Control Cows.

<table>
<thead>
<tr>
<th>Ambient Temp., °F, Exp. Cows</th>
<th>Experimental Cows</th>
<th>Control Cows (50-60°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Samples</td>
<td>Mean mg. %</td>
<td>Standard Error</td>
</tr>
<tr>
<td>-------------------</td>
<td>------------</td>
<td>---------------</td>
</tr>
<tr>
<td>70</td>
<td>14</td>
<td>15.8</td>
</tr>
<tr>
<td>80</td>
<td>12</td>
<td>16.3</td>
</tr>
<tr>
<td>85</td>
<td>12</td>
<td>14.8</td>
</tr>
<tr>
<td>90</td>
<td>13</td>
<td>13.0</td>
</tr>
<tr>
<td>95</td>
<td>6</td>
<td>11.7</td>
</tr>
<tr>
<td>100</td>
<td>12</td>
<td>12.3</td>
</tr>
<tr>
<td>Total &amp; Averages</td>
<td>69</td>
<td>14.2</td>
</tr>
</tbody>
</table>

The average serum calcium level of our Control cows was somewhat higher
than that reported in the literature as is shown in Table 3.

Summarizing this section, there was no significant effect of ambient tem-
perature on the blood serum calcium; nor was there any significant difference
between the calcium levels in Jersey and Holstein cows.—G. B. & C. B.

Carbon Dioxide Capacity of Blood Plasma: This was determined by the
Table 3.--Comparison With Calcium Levels Reported by Other Investigators.

<table>
<thead>
<tr>
<th>Investigator</th>
<th>Number of Samples</th>
<th>Mean mg.%</th>
<th>Range mg.%</th>
</tr>
</thead>
<tbody>
<tr>
<td>This Investigation</td>
<td>53</td>
<td>13.97</td>
<td>10.93 - 24.08</td>
</tr>
<tr>
<td>Anderson, et al</td>
<td>55</td>
<td>12.63</td>
<td>9.36 - 16.18</td>
</tr>
<tr>
<td>Berndt &amp; Bethmann</td>
<td></td>
<td>10.33</td>
<td>7.32 - 16.96</td>
</tr>
<tr>
<td>Haag &amp; Jones</td>
<td>160</td>
<td>9.99</td>
<td>8.05 - 11.48</td>
</tr>
<tr>
<td>Newton</td>
<td>150</td>
<td>9.16</td>
<td></td>
</tr>
<tr>
<td>Norris &amp; Chamberlin</td>
<td>773</td>
<td>11.37</td>
<td>9.00 - 15.28</td>
</tr>
<tr>
<td>Rusoff &amp; Piercy</td>
<td></td>
<td>10.89</td>
<td></td>
</tr>
<tr>
<td>Zorn, Kruger &amp; Lachman</td>
<td>52</td>
<td>14.0</td>
<td>0.36 - 22.4</td>
</tr>
</tbody>
</table>

Table 4.--Comparison of Carbon Dioxide Capacity of Experimental and Control Cows.

<table>
<thead>
<tr>
<th>Ambient Temp. °F, of Exper. Cows</th>
<th>Experimental</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Samples</td>
<td>Mean Vol.%</td>
</tr>
<tr>
<td>50</td>
<td>6</td>
<td>51.8</td>
</tr>
<tr>
<td>60</td>
<td>18</td>
<td>53.8</td>
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<td>70</td>
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<td>54.6</td>
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<td>80</td>
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<td>53.7</td>
</tr>
<tr>
<td>85</td>
<td>14</td>
<td>50.6</td>
</tr>
<tr>
<td>90</td>
<td>12</td>
<td>44.4</td>
</tr>
<tr>
<td>Totals &amp; Averages</td>
<td>74</td>
<td>52.1</td>
</tr>
</tbody>
</table>

The manometric method of Van Slyke and Neill as outlined by Hawk\(^3\) \textit{et al} with the results shown in Table 4.

The values for the experimental cows appear to decline beginning with 85° F. Unfortunately, the apparatus broke down and no determinations were made at 100°F.

Sykes \textit{et al} reported 443 carbon dioxide combining capacity determinations in four groups of dairy cows, with averages ranging from 61 to 67 cc per 100 ml blood plasma, and concluded that severe ketosis did not consistently lower it. Dennis \textit{et al} reported that hot weather reduces it. Reduced CO\(_2\) capacity may be due to: 1) \textit{Metabolic acidosis} as that associated with the replacement of bicarbonates by acid-producing foods or by excessive catabolism of body tissue (caused by severe depression of feed intake in a hot environment); or 2) \textit{respiratory alkalosis} (hyperventilation in a hot environment) with reduction in the ratio of \(\text{H}_2\text{CO}_3\) to \(\text{BHCO}_3\) and compensatory increase in bicarbonate excretions and therefore lowered CO\(_2\) combining capacity.

The range for normal cattle is within the lower limits for normal of human beings. Hawk\(^3\) \textit{et al} quote 50-70 volume per cent as normal for man.—G. B.

\textbf{Catalase:} This was determined with some modifications by the method of von Euler and Josephson as outlined by Sumner and Somers (in “Enzymes”, Academic Press, 1947).
**Reagents:** 0.024 M hydrogen peroxide. Prepare fresh substrate daily. The peroxide is made up in 0.0067 M phosphate buffer of pH 6.8.

2 N sulfuric acid.

0.024 M potassium permanganate.

**Procedure:** Chill 5 cc of the hydrogen peroxide solution to 0°C in a chopped ice bath. Add 1 ml of blood diluted 5000 times. After 10 minutes add 2 ml of 2 N sulfuric acid and titrate with permanganate to a faint pink. The control tube is treated exactly the same except that the 2 ml of 2 N sulfuric acid are added before the blood is added. The difference between the test and the control represents the amount of peroxide broken down in 10 minutes. This is expressed in milligrams of peroxide. One activity unit of catalase is that amount of enzyme that will break down one milligram of hydrogen peroxide in 10 minutes under the above conditions.

Table 5 shows the results obtained. They indicate the activity of catalase by the amount of hydrogen peroxide broken down during a certain time interval.

The extreme variability of the data as a whole (all values of the test cows fall within one standard deviation of the control mean) indicates that there is no significant trend of catalase activities with increasing temperature. Inspection of the individual values, however, shows that the catalase activity tends to decrease with increasing environmental temperature. Subsequent to an increase in ambient temperature there is a large increase in catalase activity which falls off again to a lower value. This statement needs to be substantiated by further experimentation.

Summarizing, there is no overall statistical trend in catalase activity with dropping temperature, but inspection of individual values indicates that the catalase activity tends to drop with a rise in ambient temperature; and that there appears to be an adjustment period at high temperatures during which the catalase activity is higher than normal.—J. B.

**Cholesterol:** This was determined by a combination and some modification of the methods of Schoenheimer and Sperry, and of Reinhold and Shields, both of which are quoted in Hawk\(^3\) et al. We employed an alcohol-ether mixture for deproteinization, chloroform for extraction, and the Leiberman-Burchard color reaction for developing color. The color was read on a Coleman Junior Spectrophotometer at a wave length of 660 m\(\mu\).

<table>
<thead>
<tr>
<th>Ambient Temp. °F, of Exper. Group</th>
<th>No. of Samples</th>
<th>Catalase Activity Units</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>70-</td>
<td>5</td>
<td>1732</td>
<td>1630 - 2140</td>
</tr>
<tr>
<td>80</td>
<td>3</td>
<td>1606</td>
<td>1530 - 1734</td>
</tr>
<tr>
<td>95</td>
<td>6</td>
<td>1251</td>
<td>1061 - 1734</td>
</tr>
<tr>
<td>100</td>
<td>6</td>
<td>2584</td>
<td>2244 - 2958</td>
</tr>
<tr>
<td>100</td>
<td>6</td>
<td>1632</td>
<td>816 - 2448</td>
</tr>
</tbody>
</table>

| Temp. of Control Cows 50 - 80°F | 17              | 2028                    | 816 - 4692  |
The cholesterol levels as well as the milk production declined with advancing lactation in both the Experimental (temperature increased) and Control (constant temperature, 50°-60°F) cows, but the decline was steeper in the Experimental cows that had been subjected to progressively higher temperature as illustrated in Table 6.

The cholesterol level in the Experimental cows is seen to have dropped at 100°F to one-third the 50°F level. And in the Control cows during the same time it dropped to three-fourths the original level. As noted in Table 6, dry cows have a lower blood cholesterol level than lactating cows.

The literature indicates that several conditions affect the blood-cholesterol level. For instance, Reinhart reported, for 60 milking cows, that the cholesterol level was 183 mg% 2 hours before milking and 209 mg% 2 hours after milking. In 20 dry cows the cholesterol level was 161 mg% for non-pregnant cows and 156 mg% in heifers.

As noted in the introduction, our cows were bled about an hour after the morning milking and feeding. Their cholesterol value might, therefore, have been lower by 20 or 30 mg% if they were bled before milking.

Allardyce et al reported an increase in the cholesterol level with increasing consumption of corn and sunflower silage and suggested that the normal blood cholesterol range of 120 to 180 mg% in cows is similar to that in man.

Table 6.--Comparison of Cholesterol Levels of Experimental and Control Cows.

A. Jersey Cows - Lactating

<table>
<thead>
<tr>
<th>Ambient Temp. °F, Exp. Cows</th>
<th>Experimental</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Samples</td>
<td>Mean mg. %</td>
<td>Range mg. %</td>
</tr>
<tr>
<td>70</td>
<td>5</td>
<td>145</td>
</tr>
<tr>
<td>80</td>
<td>6</td>
<td>125</td>
</tr>
<tr>
<td>85</td>
<td>6</td>
<td>117</td>
</tr>
<tr>
<td>90</td>
<td>8</td>
<td>80</td>
</tr>
<tr>
<td>95</td>
<td>5</td>
<td>91</td>
</tr>
<tr>
<td>100</td>
<td>6</td>
<td>74</td>
</tr>
<tr>
<td>Totals &amp; Averages</td>
<td>38</td>
<td>113</td>
</tr>
</tbody>
</table>

B. Holstein Cows

<table>
<thead>
<tr>
<th>Ambient Temp. °F, Exp. Cows</th>
<th>Lactating</th>
<th>Control</th>
<th>Non-Lactating</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Samples</td>
<td>Mean mg. %</td>
<td>Range mg. %</td>
<td>No. of Samples</td>
</tr>
<tr>
<td>70</td>
<td>4</td>
<td>121</td>
<td>88-165</td>
</tr>
<tr>
<td>80</td>
<td>4</td>
<td>143</td>
<td>125-158</td>
</tr>
<tr>
<td>85</td>
<td>4</td>
<td>122</td>
<td>75-154</td>
</tr>
<tr>
<td>90</td>
<td>4</td>
<td>99</td>
<td>84-120</td>
</tr>
<tr>
<td>95</td>
<td>4</td>
<td>96</td>
<td>75-117</td>
</tr>
<tr>
<td>100</td>
<td>4</td>
<td>91</td>
<td>71-103</td>
</tr>
<tr>
<td>Totals &amp; Averages</td>
<td>26</td>
<td>124</td>
<td>71-277</td>
</tr>
</tbody>
</table>
The following is a broad comparison of the cholesterol blood serum levels of our Control cows:

<table>
<thead>
<tr>
<th></th>
<th>mg%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lactating Jersey cows</td>
<td>180</td>
</tr>
<tr>
<td>Lactating Holstein cows</td>
<td>153</td>
</tr>
<tr>
<td>Non-lactating Holstein cow</td>
<td>93</td>
</tr>
<tr>
<td>Reinhard's milking cows</td>
<td>183 to 209</td>
</tr>
<tr>
<td>Reinhard's dry cows</td>
<td>161</td>
</tr>
<tr>
<td>Reinhard's heifers</td>
<td>156</td>
</tr>
<tr>
<td>Horse (Brock-Rousseau)</td>
<td>111</td>
</tr>
<tr>
<td>Monkey (Hartman-Fleishman)</td>
<td>118</td>
</tr>
<tr>
<td>Man</td>
<td>150 to 190</td>
</tr>
</tbody>
</table>

Platikanoff reported that the cholesterol values were higher and more variable when cattle were on pasture than in the barn under winter feeding conditions. This result is instructive in connection with the decline with time in the cholesterol level in our cows when placed on an essentially "winter feed" in our chamber.

Bull observed a decline in cholesterol level in man with increasing body temperature. This observation is instructive in connection with the greater decline in our Experimental cows (higher environmental temperature) than in the Control cows.

Summarizing, the blood cholesterol level declined with advancing stage of lactation, i.e., with decline in milk production, but the decline is steeper with increasing environmental temperature perhaps because of the steeper decline in milk production with increasing temperature.—R. T.

NOTE: Since the above was written, the following comparative data on cow blood and milk cholesterol appeared. See Table 7.

Blood Creatinine: This was determined by the Folin-Wu method as outlined by Hawk et al., except that the quantity of blood filtrate and reagents used were reduced by one-fifth. The optical density was read with a Coleman junior spectrophotometer, model 6A, at a wave length of 520 mµ.

While it is generally believed (e.g., Myers, Hunter) that blood creatinine increases with increasing body temperature, there is no definite experimental demonstration thereof. This report on Jersey and Holstein cattle substantiates the belief that increasing body temperature increased the blood-creatinine level.

The numerical data for blood creatinine are presented in Table 8 and Figure 1. The differences in the creatinine levels between the Control and Experimental groups increased progressively with increasing temperature above 80°F; the creatinine increased in the Experimental cows from 1.1 mg% at 80°F to about 1.2 at 85°F, 1.5 at 95°F, and 2.0 at 100°F. The blood creatinine values at the higher temperatures were higher in the Holsteins than in the Jerseys, partly because of the higher rectal temperatures of the Holsteins.

The average blood creatinine values in our Control cows are somewhat below those reported in the literature as shown in Table 9.
Table 7.--Cholesterol (mg/100ml) in Jugular Vein Blood Serum and in Milk of Individual Cows.

(By Natuf, B., Mickelsen, O., Keys, A., and Petersen, W. E., The cholesterol content of cows milk, J. Nut. 36, 504, 1948. Samples obtained in the morning of May 21, on pastured cows.)

<table>
<thead>
<tr>
<th>Cow</th>
<th>In Serum</th>
<th>Milk Total</th>
<th>Cow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guernsey</td>
<td>20 87 16.0</td>
<td></td>
<td>639</td>
</tr>
<tr>
<td>Holstein</td>
<td>13 92 8.2</td>
<td></td>
<td>474</td>
</tr>
<tr>
<td>Jersey</td>
<td>20 122 15.6</td>
<td></td>
<td>293</td>
</tr>
<tr>
<td>Jersey</td>
<td>20 134 15.3</td>
<td></td>
<td>275</td>
</tr>
<tr>
<td>Guernsey</td>
<td>18 136 11.8</td>
<td></td>
<td>658</td>
</tr>
<tr>
<td>Jersey</td>
<td>24 141 11.5</td>
<td></td>
<td>297</td>
</tr>
<tr>
<td>Guernsey</td>
<td>29 152 12.8</td>
<td></td>
<td>672</td>
</tr>
<tr>
<td>Holstein</td>
<td>19 153 11.1</td>
<td></td>
<td>480</td>
</tr>
<tr>
<td>Holstein</td>
<td>24 183 7.0</td>
<td></td>
<td>838</td>
</tr>
</tbody>
</table>

This table shows no breed difference in blood cholesterol, and no correlation between blood and milk cholesterol. The authors report a significant breed difference in milk (not blood) cholesterol during the winter but not during the summer. They report that the free blood serum cholesterol, 13 to 23 per cent of the total, is roughly the same or slightly lower than reported by Sperry in 1936 for man. The milk cholesterol is in the free, non-esterified form. There is a significant correlation between milk fat and milk cholesterol: Holsteins with a 2.87 per cent milk fat had a 9.6 mg. per cent cholesterol; Guernseys with a 3.98 per cent milk fat, had a 11.5 mg. per cent cholesterol; Jerseys with a 4.70 per cent milk fat had a 12.9 mg. per cent cholesterol.

Table 8.--Comparison of Blood Creatinine Levels of Experimental and Control Cows.

<table>
<thead>
<tr>
<th>Ambient Temp. °F, of Exp. Cows</th>
<th>No. of Samples</th>
<th>Three Jerseys</th>
<th>Three Holsteins</th>
<th>Holsteins &amp; Jerseys Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean, %</td>
<td>Standard Error</td>
<td>Range, mg. %</td>
<td>Mean, %</td>
</tr>
<tr>
<td>70</td>
<td>7</td>
<td>1.02, .067</td>
<td>0.75-1.34</td>
<td>8</td>
</tr>
<tr>
<td>80</td>
<td>6</td>
<td>1.10, .063</td>
<td>0.91-1.29</td>
<td>6</td>
</tr>
<tr>
<td>85</td>
<td>6</td>
<td>1.22, .060</td>
<td>1.02-1.38</td>
<td>6</td>
</tr>
<tr>
<td>90</td>
<td>8</td>
<td>1.25, .021</td>
<td>1.16-1.37</td>
<td>6</td>
</tr>
<tr>
<td>95</td>
<td>6</td>
<td>1.25, .034</td>
<td>1.17-1.35</td>
<td>6</td>
</tr>
<tr>
<td>100</td>
<td>6</td>
<td>1.43, .039</td>
<td>1.36-1.62</td>
<td>6</td>
</tr>
<tr>
<td>Totals &amp; Averages</td>
<td>39</td>
<td>1.21, .028</td>
<td>0.75-1.62</td>
<td>38</td>
</tr>
</tbody>
</table>

No good explanation is available for the mechanism that raised the blood-creatinine level with increasing temperature. The blood-creatinine level was not correlated with water intake, as suggested by Beard, nor with body weight loss (Boy, Goetsch & Brown, Pariset); but it is definitely related to rectal temperature, to a greater extent in the larger Holsteins than in the smaller Jerseys. It is, therefore, apparently also related to body weight (cf. Stearns, Yosudo). If increased rectal temperature had increased the oxygen consumption, the ex-
Fig. 1—Blood creatinine as function of ambient temperature (lower segment) and of rectal temperature (upper segment). Following 85°F ambient temperature and 103°F rectal temperature, the creatinine values rise more rapidly in Holstein than Jersey cows.
Table 9.--Comparison With Blood Creatinine Reported by Other Investigators.

<table>
<thead>
<tr>
<th>Investigator</th>
<th>Number of Samples</th>
<th>Mean mg.%</th>
<th>Range mg.%</th>
</tr>
</thead>
<tbody>
<tr>
<td>This Investigation*</td>
<td>48</td>
<td>1.11 ± 0.19</td>
<td>0.88 - 1.40</td>
</tr>
<tr>
<td>Anderson, et al.</td>
<td>59</td>
<td>1.42</td>
<td>1.19 - 1.94</td>
</tr>
<tr>
<td>Hayden &amp; Tubangui</td>
<td>26</td>
<td>1.84</td>
<td>1.70 - 2.07</td>
</tr>
<tr>
<td>Hayden &amp; Scholl</td>
<td>75</td>
<td>1.37</td>
<td>1.20 - 1.40</td>
</tr>
<tr>
<td>Hayden &amp; Fish</td>
<td>----</td>
<td>1.40 ± 0.09</td>
<td>----</td>
</tr>
<tr>
<td>Allardye, et al.</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>Reihart</td>
<td>60</td>
<td>----</td>
<td>----</td>
</tr>
</tbody>
</table>

*The 49 samples include samples on 26 Holsteins and 28 Jerseys with an average of 1.15 (± 0.125) for the Holsteins and 1.09 (± 0.128) for the Jerseys.

Explanation might be that the increased creatinine level reflects increased endogenous (Hunter), or total (Beard), catabolism. But the oxygen consumption decreased with increasing environmental and rectal temperature.

Summarizing, blood creatinine increased with rising ambient temperature above 80°F, and the rise was steeper for Holsteins than for Jerseys, as was the rise in rectal temperature. There was no correlation between creatinine level and water or feed intake, or body weight gain or loss.—G. B.

Fatty Acid: This was determined by the method of Stoddard & Drury as outlined in Hawk3 et al. It was extracted with an alcohol-ether mixture, saponified with a saturated NaOH solution, separated with 30% HCl, dissolved in hot 95% ethyl alcohol, and the value determined by titration with 0.01N NaOH.

The fatty acid level declined with increasing time and temperature in the Experimental cows but also, to a less extent, in the Control cows, as illustrated in Table 10.

Table 10.--Comparison of Fatty Acids Levels of Experimental and Control Cows.

A. Jersey Cows—Lactating

<table>
<thead>
<tr>
<th>Ambient Temp. °F, Exp. Cows</th>
<th>Experimental</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Samples</td>
<td>Mean mg.%</td>
</tr>
<tr>
<td>85</td>
<td>1</td>
<td>132</td>
</tr>
<tr>
<td>90</td>
<td>7</td>
<td>115</td>
</tr>
<tr>
<td>95</td>
<td>6</td>
<td>88</td>
</tr>
<tr>
<td>100</td>
<td>6</td>
<td>81</td>
</tr>
<tr>
<td>Totals &amp; Averages</td>
<td>20</td>
<td>98</td>
</tr>
</tbody>
</table>

B. Holstein Cows

<table>
<thead>
<tr>
<th>Ambient Temp. °F, Exp. Cows</th>
<th>Lactating</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Samples</td>
<td>Mean mg.%</td>
</tr>
<tr>
<td>85</td>
<td>2</td>
<td>140</td>
</tr>
<tr>
<td>90</td>
<td>3</td>
<td>143</td>
</tr>
<tr>
<td>95</td>
<td>3</td>
<td>120</td>
</tr>
<tr>
<td>100</td>
<td>4</td>
<td>98</td>
</tr>
<tr>
<td>Totals &amp; Averages</td>
<td>12</td>
<td>122</td>
</tr>
</tbody>
</table>
Raising the temperature, therefore, depressed the fatty-acid level as it did
the cholesterol level; the cholesterol and fatty acids levels in the blood appear
to be related in metabolism with the milk production level.

These correlations are substantiated by Williams and Maynard who re­
ported that the blood fatty acids and cholesterol in goats decrease in parallel
on a fat-free diet, that cholesterol in plasma is combined with fatty acids (the
amount varying with the fat intake), and that there was a decline in milk yield
with reduction in dietary lipids.

Hunter and Stringer reported that when chicken erythrocytes were heat
treated from 50 to 60°C there was a 40 per cent decrease in the total lipid
content of the cells. This may be related to the fact that the fatty acids
decreased with rising body temperature.—R. T.

Glucose: This was determined by the Folin-Wu method as outlined by
Hawk.3 The optical density was read on a Coleman junior spectrophotometer,
at a wave length of 420 mμ.

Since there was no breed difference in the glucose levels of the Control
cows, the data for the Control (lactating) Jersey and Holstein cows were aver­
eged together as shown in Table 11.

The somewhat erratic distribution of the data is not surprising since the
glucose level in dairy cattle is influenced by emotional factors, also by age,
stage of lactation and gestation. For instance, Awdejewa reported, and this
seems to be true in this experiment, that the variations from day to day in the
same animal are greater than variations between animals. Several investigators
(Anderson, Hewitt, Hodgson, Reihart) reported a decline in blood sugar of
cattle with increasing age; and that non-lactating cows have a higher glucose
level than lactating. Kennedy does not agree with this statement. Our two

<table>
<thead>
<tr>
<th>Ambient Temp., °F, of Exp. Cows</th>
<th>Lactating Experimental Holsteins</th>
<th>Experimental Jerseys</th>
<th>Control Cows (J. &amp; H.)</th>
<th>Non-lactating Holsteins</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Samples</td>
<td>Mean, mg.</td>
<td>Range, mg.</td>
<td>No. of Samples</td>
</tr>
<tr>
<td>60</td>
<td>5</td>
<td>56.5</td>
<td>51.8-60.9</td>
<td>7</td>
</tr>
<tr>
<td>70</td>
<td>4</td>
<td>57.6</td>
<td>52.1-63.2</td>
<td>6</td>
</tr>
<tr>
<td>80</td>
<td>4</td>
<td>51.7</td>
<td>42.5-59.7</td>
<td>6</td>
</tr>
<tr>
<td>90</td>
<td>4</td>
<td>57.2</td>
<td>55.5-58.8</td>
<td>8</td>
</tr>
<tr>
<td>95</td>
<td>4</td>
<td>55.8</td>
<td>52.1-60.2</td>
<td>6</td>
</tr>
<tr>
<td>100</td>
<td>4</td>
<td>49.2</td>
<td>45.5-51.9</td>
<td>6</td>
</tr>
<tr>
<td>Totals &amp; Averages</td>
<td>25</td>
<td>54.7</td>
<td>42.5-63.2</td>
<td>39</td>
</tr>
</tbody>
</table>
Dry cows had a significantly higher blood glucose level than the milking cows. Weyl investigated the influence of increased outdoor temperature on the blood sugar of rabbits and dogs. His data did not substantiate the belief that the blood sugar level declines with rising temperatures. Scheer reported that the average glucose value in albino rats decreased with increasing temperature. Rick and Lee reported that when milking Jersey cows were exposed to 110°F, there was a decrease in blood sugar from a mean value of 55.2 to 44.5 mg per 100 ml blood. References appear to substantiate our observation that high ambient temperatures depress the blood sugar level.

The average glucose level found for our Control lactating cows compares favorably with values reported in the literature, as shown in Table 12. Summarizing, the average blood glucose in our Control lactating cows was about 58 mg%. There were considerable fluctuations in the individual values of both groups with, perhaps, a tendency to decline with increasing temperature.—G. B.

Cells: Total counts were made with standard pipette and hemocytometer. Differential counts of leucocytes were made with Wright's stain. The samples were taken into pipette from thoroughly shaken flasks of oxalated jugular vein blood.

As shown in Table 13, the average counts of the blood cells in the Experimental group have been compared with the corresponding values in the Control group.

Table 12.—Comparison With Glucose Levels Reported by Other Investigators.

<table>
<thead>
<tr>
<th>Investigator</th>
<th>No. of Samples</th>
<th>Mean mg. %</th>
<th>Range mg. %</th>
</tr>
</thead>
<tbody>
<tr>
<td>This Investigation</td>
<td>49</td>
<td>57.1</td>
<td>43.7-71.7</td>
</tr>
<tr>
<td>Hayden and Scholl</td>
<td>75</td>
<td>51.75</td>
<td></td>
</tr>
<tr>
<td>Hayden</td>
<td>253</td>
<td>41.2</td>
<td></td>
</tr>
<tr>
<td>Hodgson</td>
<td>222</td>
<td>53.03</td>
<td></td>
</tr>
<tr>
<td>Hewitt</td>
<td></td>
<td>58.2</td>
<td></td>
</tr>
<tr>
<td>Kennedy</td>
<td></td>
<td>52.2</td>
<td></td>
</tr>
<tr>
<td>Reihart</td>
<td>60</td>
<td>81.3</td>
<td></td>
</tr>
<tr>
<td>Anderson</td>
<td>59</td>
<td>84.1</td>
<td></td>
</tr>
<tr>
<td>Allardyce</td>
<td></td>
<td></td>
<td>50-65</td>
</tr>
</tbody>
</table>

Table 13.—Comparison of the Blood Cell Counts of Experimental and Control Cows.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Experimental</td>
<td>Control</td>
</tr>
<tr>
<td></td>
<td>No. of Samples</td>
<td>Mean</td>
</tr>
<tr>
<td>50</td>
<td>6</td>
<td>6.54</td>
</tr>
<tr>
<td>60</td>
<td>18</td>
<td>6.99</td>
</tr>
<tr>
<td>70</td>
<td>12</td>
<td>6.58</td>
</tr>
<tr>
<td>80</td>
<td>12</td>
<td>6.69</td>
</tr>
<tr>
<td>85</td>
<td>14</td>
<td>6.92</td>
</tr>
<tr>
<td>90</td>
<td>12</td>
<td>6.60</td>
</tr>
<tr>
<td>95</td>
<td>10</td>
<td>6.75</td>
</tr>
<tr>
<td>100</td>
<td>84</td>
<td>6.76</td>
</tr>
</tbody>
</table>

| Totals & Averages | | | | |
|-------------------| | | | |
| 85                | 9,375 | 6850-11750 | 6 | 7,833 | 6800-9600 |
| 9                 | 9,342 | 7600-10700 | 9 | 8,406 | 6800-10350 |
| 10                | 9,412 | 7200-12750 | 9 | 8,983 | 8350-10150 |
| 11                | 9,511 | 7450-12150 | 3 | 9,017 | 8050-10150 |
| 12                | 9,318 | 7200-11800 | 9 | 9,056 | 7250-11150 |
| 13                | 9,346 | 7000-13500 | 12 | 8,268 | 6600-10950 |
| 14                | 8,660 | 6250-10850 | 11 | 8,582 | 6550-10600 |

| Totals & Averages | | | | |
|-------------------| | | | |
| 59                | 9,288 | 6250-13500 | 59 | 8,570 | 6550-11150 |
mental cows at the various temperatures are not significantly different from the average of the Control cows.

Ferguson et al., Russoff, and others suggested that each animal has a unique blood picture peculiar to itself. This seems to hold for our cows, particularly for the leucocyte counts, since the differences between animals were greater than the variations in the same animal. The erythrocyte count seems to be more uniform.

There seems to be no indication of breed difference in these values.

It is interesting to contrast the differential leucocyte count of cattle with that of man. The lymphocyte-neutrophile ratio is reversed, and the percentage of eosinophiles is much greater in cattle than in man.

As shown in Table 14, the averages for the control cows compare favorably with values given by other investigators.—G. B.

Table 14.--Average Blood Cell Counts of Our Control Cows Compared With Data in the Literature.

<table>
<thead>
<tr>
<th>Investigator</th>
<th>Leucocytes</th>
<th>Erythrocytes</th>
<th>Lymphocytes</th>
<th>Neutrophiles</th>
<th>Eosinophiles</th>
<th>Basophiles</th>
<th>Monocytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>This Investigation</td>
<td>8,570</td>
<td>6,760,000</td>
<td>59.12</td>
<td>32.16</td>
<td>6.4</td>
<td>0.5</td>
<td>0.7</td>
</tr>
<tr>
<td>Zemijic, I.</td>
<td>7,008</td>
<td>6,116,900</td>
<td>41.2</td>
<td>34.7</td>
<td>14.87</td>
<td>0.6</td>
<td>7.94</td>
</tr>
<tr>
<td>Ferguson, et al.</td>
<td>9,911</td>
<td>6,322,910</td>
<td>62.0</td>
<td>25.0</td>
<td>5.0</td>
<td>0.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Norris</td>
<td>5,500</td>
<td>10,300,900</td>
<td>54.4-57.0</td>
<td>29.4-32.6</td>
<td>6.4-7.3</td>
<td>0.37-0.58</td>
<td>5.4-6.38</td>
</tr>
<tr>
<td>Rusoff &amp; Piercy</td>
<td>8,411-10,268</td>
<td>4,890,000-10,268,000</td>
<td>51.3</td>
<td>30.18</td>
<td>14.22</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>Manresa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simmons &amp; Gentzkow</td>
<td>5,000-10,000</td>
<td>4,000,000-5,000,000</td>
<td>25-33</td>
<td>54-62</td>
<td>1-4</td>
<td>0-1</td>
<td>3-7</td>
</tr>
</tbody>
</table>

**Hematocrit:** This was first estimated by the copper sulfate specific gravity method as described in Hawk et al. Blood and plasma were dropped in a series of bottles containing CuSO₄ of known specific gravities. The gravities for the blood and plasma were used to calculate the hematocrites from a line chart. This specific gravity method was changed, beginning with the 80°F temperature level, using a graduated Winthrobe tube and reading directly the cell pack percentage.

The mean values were slightly higher for the Control cows than for the Experimental, but the differences were not statistically significant. The range for both Experimental and Control cows was 30% to 38% cell volume, with a few scattered values as low as 29% and some as high as 42%. This is illustrated in Table 15, which does not show any effect of ambient temperature.

The individual readings indicate that each cow has its own hematocrit range. For example, the range for Cow 504 was between 25% and 33%; while of Cow 204, between 36% and 39%.

There was some crenation of the red blood cells, perhaps as a result of overoxalating the sample or from the method of addition of the oxalate, which could introduce a small error in the cell volume reading.
Table 15.--Comparison of Hematocrit Levels of Experimental and Control Cows.

<table>
<thead>
<tr>
<th>Ambient Temp. °F, Exp. Cows</th>
<th>Experimental Cows</th>
<th>Control Cows</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Samples</td>
<td>Mean %</td>
<td>Standard Error</td>
</tr>
<tr>
<td>60</td>
<td>15</td>
<td>34.1</td>
</tr>
<tr>
<td>70</td>
<td>12</td>
<td>34.6</td>
</tr>
<tr>
<td>80</td>
<td>12</td>
<td>35.2</td>
</tr>
<tr>
<td>90</td>
<td>14</td>
<td>35.5</td>
</tr>
<tr>
<td>95</td>
<td>12</td>
<td>32.8</td>
</tr>
<tr>
<td>100</td>
<td>12</td>
<td>34.7</td>
</tr>
<tr>
<td>Totals &amp; Averages</td>
<td>77</td>
<td>34.5</td>
</tr>
</tbody>
</table>

Table 16.--Comparison of Hemoglobin Levels of Experimental and Control Cows.

<table>
<thead>
<tr>
<th>Ambient Temp. °F, Exp. Cows</th>
<th>Experimental Cows</th>
<th>Control Cows</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Samples</td>
<td>Mean gm. %</td>
<td>Standard Error</td>
</tr>
<tr>
<td>60</td>
<td>12</td>
<td>11.4</td>
</tr>
<tr>
<td>70</td>
<td>12</td>
<td>12.2</td>
</tr>
<tr>
<td>80</td>
<td>12</td>
<td>12.7</td>
</tr>
<tr>
<td>90</td>
<td>14</td>
<td>12.9</td>
</tr>
<tr>
<td>95</td>
<td>12</td>
<td>12.4</td>
</tr>
<tr>
<td>100</td>
<td>12</td>
<td>12.9</td>
</tr>
<tr>
<td>Totals &amp; Averages</td>
<td>74</td>
<td>12.4</td>
</tr>
</tbody>
</table>

Summarizing, the blood cell volume was not significantly affected by changes in ambient temperature.—R. T.

**Hemoglobin (Hb):** This was determined by the Alkaline hematin method of Todd Sanford as outlined by Hawk\(^3\) et al.

Kark et al found no significant difference between the hemoglobin levels of U. S. Army Troops in the South Pacific and in the Continental United States during the recent war. Bazett et al found that the hemoglobin level in man increased with an increase in ambient temperature but soon returned to its initial level on continued exposure. Manresa observed a reduction in the hemoglobin level of Philippine cattle with rising atmospheric temperature. Table 16 summarizes our data: 

^The data for the two breeds were averaged together since Fisher's "t" test showed no significant difference between the two breeds nor between the Control and Experimental cows.

The average hemoglobin level of our Control cows is somewhat higher than that reported in the literature as shown in Table 17.

Summarizing, the hemoglobin level was not influenced significantly by
Table 17.—Comparison with Hemoglobin Levels Reported by Other Investigators.

<table>
<thead>
<tr>
<th>Investigator</th>
<th>No. of Samples</th>
<th>Mean gm. %</th>
<th>Standard Error</th>
<th>Range gm. %</th>
</tr>
</thead>
<tbody>
<tr>
<td>This Investigation</td>
<td>60</td>
<td>12.7</td>
<td>0.18</td>
<td>8.6 - 14.9</td>
</tr>
<tr>
<td>Allcroft</td>
<td></td>
<td>11.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brooks &amp; Hughes</td>
<td>295</td>
<td>10.96</td>
<td>0.64</td>
<td></td>
</tr>
<tr>
<td>Lammarre</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>McCay</td>
<td>900</td>
<td>10.9</td>
<td>0.86</td>
<td></td>
</tr>
<tr>
<td>Manresa &amp; Reyes*</td>
<td>36</td>
<td>8.28</td>
<td>0.17</td>
<td></td>
</tr>
</tbody>
</table>

*Holstein cows in the Philippine Islands.

ambient temperature in the range 50° to 100°F. There was no significant difference between Jersey and Holstein cows.—C. B.

Magnesium: This was determined in the serum with titan yellow following the procedure of Kunkel et al as modified by Platner, and in red cells by calculation from wholeblood magnesium and hematocrit with results shown in Table 18.

Fisher's "t" test showed no significant difference between the breeds nor between the Control and Experimental cows within the breed.

The literature reports increasing serum magnesium with decreasing body temperature (Suomalainen; Lustig; Platner) as well as decreasing magnesium (Heagy) with increasing body temperature.

Allcroft & Green reported for cattle a seasonal variation in serum magnesium from 1.4 mg% in December to 2.2 mg% in August; Eveleth et al reported for dairy cattle a seasonal variation in serum magnesium from 2.8 mg% in January to 4.0 mg% in July; Duncan et al reported just the opposite—low plasma magnesium in June and July and higher in December. The average serum magnesium in our cows for Experimental 3.60 to Control 3.84 mg% were obtained in June, July, and August, but under the artificial conditions of the Climatic Laboratory.

Eveleth et al suggested that serum hypermagnesemia may have a dietary origin, from lack of fresh greens.

The average magnesium value in our cows was somewhat above those

Table 18.—Comparison of Blood Magnesium Levels of Experimental and Control Cows.

<table>
<thead>
<tr>
<th>Ambient Temp. °F, Exp. Cows</th>
<th>Experimental Cows</th>
<th>Control Cows (50°-60°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Samples</td>
<td>Mean mg. %</td>
</tr>
<tr>
<td>70</td>
<td>3</td>
<td>2.99</td>
</tr>
<tr>
<td>80</td>
<td>12</td>
<td>3.30</td>
</tr>
<tr>
<td>85</td>
<td>12</td>
<td>3.89</td>
</tr>
<tr>
<td>90</td>
<td>13</td>
<td>3.64</td>
</tr>
<tr>
<td>95</td>
<td>12</td>
<td>3.81</td>
</tr>
<tr>
<td>100</td>
<td>12</td>
<td>3.53</td>
</tr>
<tr>
<td>Totals &amp; Averages</td>
<td>64</td>
<td>3.80</td>
</tr>
</tbody>
</table>
Table 19.--Comparison With Blood Magnesium Values of Different Species.

<table>
<thead>
<tr>
<th>Species</th>
<th>No. of Samples</th>
<th>Magnesium mg. %</th>
<th>Investigator</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>serum</td>
<td>red cells</td>
</tr>
<tr>
<td>Cattle</td>
<td>10</td>
<td>2.80</td>
<td>1.80</td>
</tr>
<tr>
<td>Dairy</td>
<td>109</td>
<td>3.70</td>
<td>3.07</td>
</tr>
<tr>
<td>Beef</td>
<td>7</td>
<td>3.38</td>
<td></td>
</tr>
<tr>
<td>Chicken</td>
<td>5</td>
<td>2.80</td>
<td>9.20</td>
</tr>
<tr>
<td>Dog</td>
<td>21</td>
<td>2.90</td>
<td>8.10</td>
</tr>
<tr>
<td>Goat</td>
<td>3</td>
<td>3.20</td>
<td>4.50</td>
</tr>
<tr>
<td>Guinea pig</td>
<td>25</td>
<td>2.90</td>
<td>8.80</td>
</tr>
<tr>
<td>Hedgehog</td>
<td></td>
<td>3.20##</td>
<td></td>
</tr>
<tr>
<td>Horse</td>
<td>10</td>
<td>2.40</td>
<td>6.80</td>
</tr>
<tr>
<td>Human</td>
<td>58</td>
<td>2.70</td>
<td>6.61</td>
</tr>
<tr>
<td>Pigeon</td>
<td>16</td>
<td>2.44</td>
<td>42.55</td>
</tr>
<tr>
<td>Rabbit</td>
<td>7</td>
<td>3.10</td>
<td>8.40</td>
</tr>
<tr>
<td>Sheep</td>
<td>10</td>
<td>2.90</td>
<td>3.80</td>
</tr>
<tr>
<td>Swine</td>
<td>10</td>
<td>3.10</td>
<td>10.50</td>
</tr>
</tbody>
</table>

# For seasonal variation in cattle see text.
## Serum Mg increases to 6.0 mg. % during hibernation.

reported in the literature as shown in Table 19, which, for a broad comparison, includes data for other species.

Note the relative species constancy of serum, but wide range of red-cell, magnesium. Particularly intriguing are the high red-cell magnesium values in birds, especially the pigeon, and low values in ruminants, especially cattle and, in general, very low cell-to-serum magnesium ratios in cattle.

Summarizing, the blood magnesium in our cows was not significantly affected by environmental or body temperature; their cell-to-serum magnesium ratio was low; hypermagnesemia may be associated with insufficient intake of fresh green feed.

It was instructive, in connection with the above analysis of blood magnesium, to examine the milk and urine magnesium of these cows as shown in Tables 20 and 21.

The magnesium concentration in milk appeared to be only slightly affected by ambient temperature. The milk of the Experimental cows had a slightly lower magnesium value (18.4 mg% for Jersey and 16.0 mg% for Holsteins) than the Control cows (20.2 for Jersey milk and 17.2 for Holstein milk). Sanders reported 16.5 mg% magnesium for Jersey milk and 12.9 for Holstein milk.

The urinary magnesium appears to be dependent somewhat on the hay (alfalfa) intake; it was least in the dry cows (106 and 90) that consumed least hay, next lowest in the lactating Holsteins (who suffered most from heat and so consumed less hay), and most in the Jerseys (the cows suffering least from the heat).

The magnesium concentrates in the urine, of course, varied with the urine volume output, ranging from 6 to 27 mg%.—W. P.

Non-Protein Nitrogen (NPN): This was determined by the method of
Table 20.--Comparison of Milk Magnesium Levels of Experimental and Control Cows.

<table>
<thead>
<tr>
<th>Ambient Temp. °F, Exp. Cows</th>
<th>Experimental</th>
<th>Control (50 - 60°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Jersey</td>
<td>Holstein</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>Standard</td>
</tr>
<tr>
<td>No. of Samples</td>
<td>Samples mg.%</td>
<td>Error</td>
</tr>
<tr>
<td>80</td>
<td>17</td>
<td>16.5</td>
</tr>
<tr>
<td>85</td>
<td>17</td>
<td>19.7</td>
</tr>
<tr>
<td>90</td>
<td>21</td>
<td>20.0</td>
</tr>
<tr>
<td>95</td>
<td>15</td>
<td>17.5</td>
</tr>
<tr>
<td>100</td>
<td>5</td>
<td>17.1</td>
</tr>
<tr>
<td>Totals &amp; Averages</td>
<td>75</td>
<td>18.4</td>
</tr>
</tbody>
</table>

Table 21.--Comparison of Urine Magnesium Levels of Experimental and Control Cows.

<table>
<thead>
<tr>
<th>Date Sampled</th>
<th>Ambient Temp. °F</th>
<th>mg. output per 24 hours</th>
<th>mg. %</th>
<th>Experimental Cows</th>
<th>Control Cows</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>J-212</td>
<td>J-205</td>
</tr>
<tr>
<td>6/22-23</td>
<td>80</td>
<td>367</td>
<td>298</td>
<td>534</td>
<td>509</td>
</tr>
<tr>
<td>7/7-8</td>
<td>85</td>
<td>485</td>
<td>312</td>
<td>529</td>
<td>508</td>
</tr>
<tr>
<td>7/15-16</td>
<td>90</td>
<td>624</td>
<td>258</td>
<td>473</td>
<td>283</td>
</tr>
<tr>
<td>7/27-28</td>
<td>95</td>
<td>880</td>
<td>533</td>
<td>535</td>
<td>301</td>
</tr>
<tr>
<td>8/4-5</td>
<td>100</td>
<td>900</td>
<td>477</td>
<td>404</td>
<td>301</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>J-212</td>
<td>J-205</td>
</tr>
<tr>
<td>6/29-30</td>
<td>50-60</td>
<td>529</td>
<td>279</td>
<td>510</td>
<td>279</td>
</tr>
<tr>
<td>8/9-10</td>
<td>50-60</td>
<td>259</td>
<td>371</td>
<td>196</td>
<td>301</td>
</tr>
</tbody>
</table>

Table 22.--Comparison of Non-Protein Nitrogen Levels of Experimental and Control Cows.

<table>
<thead>
<tr>
<th>Ambient Temp., °F, Exp. Cows</th>
<th>Experimental Cows</th>
<th>Control Cows (50-60°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of Samples</td>
<td>Mean mg. %</td>
</tr>
<tr>
<td>50</td>
<td>6</td>
<td>40.0</td>
</tr>
<tr>
<td>70</td>
<td>18</td>
<td>42.5</td>
</tr>
<tr>
<td>80</td>
<td>12</td>
<td>45.2</td>
</tr>
<tr>
<td>85</td>
<td>12</td>
<td>44.1</td>
</tr>
<tr>
<td>90</td>
<td>14</td>
<td>40.4</td>
</tr>
<tr>
<td>95</td>
<td>12</td>
<td>39.8</td>
</tr>
<tr>
<td>100</td>
<td>12</td>
<td>39.0</td>
</tr>
<tr>
<td>Totals &amp; Averages</td>
<td>86</td>
<td>41.73</td>
</tr>
</tbody>
</table>

Koch and McMeekin as outlined by Hawk et al., except that 2.5 ml, rather than 5 ml, of Folin-Wu filtrate was used. The optical density of the Nesslerized solution was read at a wave length of 4800 Å on a Coleman junior spectrophotometer.

The distribution of the NPN values was somewhat erratic, but the means show a declining trend above 85°F as shown in Table 22.

Fisher's "t" test showed no significant difference between the breeds nor between the Control and Experimental cows below 90°F. Consequently, the
data for the two breeds were averaged together. There is, however, a statistically significant difference between the Control and Experimental animals at 90°F and above. This decrease in NPN with increasing temperature is, perhaps, the result of decreased consumption of NPN-rich alfalfa hay with increasing environmental temperature.

The average blood NPN in our Control cows was above those reported in the literature as shown in Table 23.

Table 23.--Comparison With Non-Protein Nitrogen Levels Reported by Other Investigators.

<table>
<thead>
<tr>
<th>Investigator</th>
<th>Number of Samples</th>
<th>Mean mg. %</th>
<th>Standard Error</th>
<th>Range mg. %</th>
</tr>
</thead>
<tbody>
<tr>
<td>This Investigation</td>
<td>51</td>
<td>44.40</td>
<td>0.68</td>
<td>33.65 - 56.64</td>
</tr>
<tr>
<td>Anderson</td>
<td>59</td>
<td>30.07</td>
<td></td>
<td>20.67 - 42.12</td>
</tr>
<tr>
<td>Kennedy</td>
<td></td>
<td>38.82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Norris</td>
<td>24.26</td>
<td>6.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reihart</td>
<td>60</td>
<td>24.40</td>
<td>2.7</td>
<td></td>
</tr>
</tbody>
</table>

Summarizing, the blood NPN decreased significantly with rising ambient temperature above 85°F and amounted to approximately 10 per cent at 100°F. No significant breed differences were observed in the temperature range studied. The drop in blood NPN at the higher temperatures presumably is the result of reduced alfalfa hay intake as alfalfa is rich in NPN.—C. B.

Inorganic Phosphorus: This was determined in blood serum by the method of Fiske and SubbaRow as outlined by Hawk et al except that two-fifths quantities of all the reagents were used.

Our experimental data are summarized in Table 24. Fisher's "t" test indicates a significant breed difference between Jersey and Holstein cows in the Control group. The mean for the three Control Jerseys was 5.00 (29 sam-
samples) and for the three Control Holsteins, 6.05 (30 samples). The difference between the Control and Experimental animals was significant at 90°F and above for the Jersey cows and at 95°F and above for the Holstein cows.

The blood inorganic phosphorus levels of our Control animals compare well with those reported in the literature as shown in Table 25.

<table>
<thead>
<tr>
<th>Investigator</th>
<th>Number of Samples</th>
<th>Mean mg. %</th>
<th>Range mg. %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jersey cows</td>
<td>29</td>
<td>5.00</td>
<td>2.82 - 8.24</td>
</tr>
<tr>
<td>Holstein cows</td>
<td>30</td>
<td>6.05</td>
<td>2.91 - 9.71</td>
</tr>
<tr>
<td>Anderson, et al.</td>
<td>20</td>
<td>4.46</td>
<td>3.09 - 6.17</td>
</tr>
<tr>
<td>Haag &amp; Jones</td>
<td>105</td>
<td>5.2</td>
<td></td>
</tr>
<tr>
<td>Norris &amp; Chamberlin</td>
<td></td>
<td>4.44</td>
<td></td>
</tr>
<tr>
<td>Palmer, et al.</td>
<td>26</td>
<td>5.87</td>
<td></td>
</tr>
</tbody>
</table>

It appears from the literature that age, season, stage of lactation and food supply affect the inorganic phosphorus level in the blood. Van Landingham, Henderson and Bowling reported that in their first lactation, dairy cows tend to have a lower blood phosphorus level during the winter and early spring than in the summer and early fall. Berndt and Baumgarten observed that dietary phosphates influence the blood inorganic phosphorus level and, consequently, the results of Van Landingham may reflect the seasonal nutritional condition of the animals. Van Landingham, Henderson and Bowling also reported that there was a decrease in the blood inorganic phosphorus of lactating cows with the advancing number of lactations up to the third or fourth lactation. Johnson observed that the inorganic phosphorus decreased steadily with increasing age of the cow. Wilson reported that inorganic phosphorus tends to fall during the first three days after calving. Eveleth, Eveleth and Walch reported that the inorganic phosphorus level was slightly higher in Holstein than in Jersey cows and that there was a slight rise in inorganic phosphorus during the first and second months of pregnancy which was maintained throughout gestation. Kennedy, Anderson, Bechdel and Shingly, however, could find no significant effect of gestation and lactation on the blood calcium and phosphorus levels of dairy cattle. Borchardt found that the blood phosphate level of sweating animals, under field conditions in the tropics was well within the normal range of values.

Summarizing, increasing ambient temperature above 85°F increased in our cows the blood inorganic phosphorus level. The blood phosphorus level of the Experimental animals at 100°F was of the order of 30 per cent above that of the Control animals. The Holstein cows had a significantly higher blood inorganic phosphorus level than the Jersey cows.—G. B. & C. B.

Blood Plasma Protein: This was determined by the microkjeldahl method of Wang as described by Hawk³ et al, except that hydrogen peroxide was used as the oxidant rather than potassium persulfate. The optical density of the
Nesslerized solution was determined at 4800 Å, using a Coleman junior spectrophotometer. The factor 6.25 was used to convert protein nitrogen into protein.

Bazett et al demonstrated that the plasma protein level in man increased with increasing ambient temperature but soon returned to its initial value after continued exposure. Kark et al could find no significant difference between the plasma protein levels of U.S. Army Troops in the South Pacific and in the Continental United States. Awdejewa et al found no significant effect of ambient temperature of the plasma protein level of cows in the range —10 to +10°C.

Fisher's "t" test indicates a significant breed difference between our data for the Control Jersey and Holstein cows. The mean for the three Control Jersey cows was 8.44, and for the three Control Holstein cows, 9.04. There was, however, no significant difference between the Control and Experimental cows. Increasing environmental temperature did not affect the plasma protein level as shown in Table 26.

<table>
<thead>
<tr>
<th>Ambient Temp., °F, of Exp. Cows</th>
<th>Experimental Cows</th>
<th>Control Cows (50-60°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Three Jersey</td>
<td>Three Holstein</td>
</tr>
<tr>
<td>No. of Samples</td>
<td>Mean mg.%</td>
<td>Range mg.%</td>
</tr>
<tr>
<td>60</td>
<td>8.37</td>
<td>7.45-9.38</td>
</tr>
<tr>
<td>70</td>
<td>5</td>
<td>8.67</td>
</tr>
<tr>
<td>80</td>
<td>6</td>
<td>8.70</td>
</tr>
<tr>
<td>90</td>
<td>8</td>
<td>8.61</td>
</tr>
<tr>
<td>95</td>
<td>6</td>
<td>8.61</td>
</tr>
<tr>
<td>100</td>
<td>6</td>
<td>8.52</td>
</tr>
</tbody>
</table>

Since the plasma protein is the principal regulator of the blood colloid osmotic pressure, the consistency of the data in Table 26 indicates that ambient temperature had no significant effect on the water balance between blood and other tissues.

Summarizing this section, blood plasma protein level was not influenced significantly by ambient temperature in the range 50° to 100°F. This indicates that the water balance between blood and tissue remained constant. There was a significant breed difference between Jersey and Holstein cattle.—C. B.
Missouri Agricultural Experiment Station

BIBLIOGRAPHY

Calcium Section


Zorn, W., Krüger, I. & Lachman, F., Reaction of the animal body to environmental changes as evidenced by blood chemistry in cattle. Z. Tierzücht. Züchtungsbil. 29, 119, 1941.

Carbon Dioxide Capacity


Catalase Section


Cholesterol Section


Hartman, C. G. & Fleischmann, W., Serum cholesterol in the rhesus monkey. Endocrinology, 29, 793, 1941, (Cf. C. A. 36, 537)


Creatinine


Hayden, C. E. & Tubangui, M., Studies on the normal blood of the domesticated animals. ibid., p. 181,191, 1919-20.


Pariset, G., The synthetic formation of creatine at the expense of tissue proteins. Compt. Rend., 197, 704, 1933. (Cf. C. A. 28, 514)


ease. J. Pediatrics, 18, 12, 1941.

**Fatty Acid**


**Glucose**


**Blood Cells**
Manresa, M. & Faison, P. R., Fluctuations in the Hb of Indian Nellore Oxen as affected by season. Philippine Agr. 28, 187, 1939.

**Hemoglobin**

**Magnesium**
Duncan, C. W., Lightfoot, C. C. & Huffman, C. F., Seasonal variations in the level of magnesium in the blood plasma of growing dairy calves. J. Dairy Sci. 23, 125, 1940.
Greenberg, D. M., Lucia, S., Mackey, M. A., & Tufts, E. V. The magnesium content of the plasma and red blood corpuscles in human blood. J. Biol. Chem. 100, 139, 1933.


**Non-Protein Nitrogen**


**Inorganic Phosphorus**


**Plasma Protein**

3. INTEGRATION

By way of introduction, let us look at the following charts, Figs. 2 and 3, reflecting the rising thermal stress and, presumably, the febrile discomfort of the cows with rising ambient temperature.

Fig. 2—Rise in rectal temperature (upper segment) and respiration rate (lower segment) in Holstein (broken curves) and Jersey (continuous curves) cows. Note the steeper rise and higher rectal temperature for the Holstein, but the steeper rise and higher respiration rate for the Jersey; and the critical ambient temperature 75° to 80°F for rectal temperature and 70° to 75°F for respiration rate.
Fig. 3—Jersey Cow 994—as she looked in an environment of 100°F (August 1948) respiration rate about 130 per minute as contrasted to about 22 at ambient temperature 50° to 60°F, rectal temperature near 106° as contrasted to 101° at 50° to 60°F.

The upper curves in Fig. 2 show that the rectal temperature began to rise between 70° and 80°F (21 to 27°C) ambient temperature. This contrasts with normal man whose rectal temperature does not rise even at 110°F ambient temperature because of the cooling effect of his vaporizing sweat—if the humidity is not excessive. It is this deficient sweating of European cattle that renders them a problem in certain regions of Asia, Africa, Australia and in the Americas.

Note from Fig. 2 that the rectal temperature rises more steeply and to higher levels in the large Holstein cows (broken curves) than in the small Jersey cows (continuous curves). This is understandable, because the larger the animal, the smaller per unit weight is the surface area through which the heat is dissipated. An instructive experimental illustration thereof is the greater rate of rise in rectal temperature in a 218-lb. than in a 134-lb. athlete, both walking up grade at the same rate, expending energy at about ten times the basal level.\(^\text{14}\)

The cow's deficient cooling by sweating is compensated in part by increased

cooling by panting, that is, by increased rate of air flow over the moist lung and oral surfaces. The panting appearance of Jersey 994 at 100°F (Fig. 3) may be of interest in this connection. The respiration rate of 20 to 30 per minute at the control temperature (50° to 60°F, or 10° to 15°C) is seen in Fig. 2 to increase to about 100 per minute in the Holsteins (broken lines) and to 130 in Jerseys (continuous lines). Note that the Holsteins have a lower respiration rate although their rectal temperature is higher than that of the Jerseys; or is the rectal temperature of the Holstein higher because of their lower respiration rate? Note also that the visible rise in respiration rate begins at about 70°F (21°C) ambient temperature, perhaps 10°F below that for the corresponding rise in rectal temperature at about 80°F. It appears that temperature regulation by panting begins anticipatingly prior to the consistent rise in body temperature.

How does the rise in body temperature, in respiration rate, and in general febrile discomfort, affect the composition of the blood? But first, how shall we present the numerical data so that the reader may get a total picture of the situation?

The eye is usually more sensitive to the degree of consistency of trends and of deviations, and more easily takes in the situation as a whole, when looking at a page of curves as in the following charts (Figs. 4a, b, c) than when looking at some 50 columns of numerical data as shown in the preceding Section 2. Let us, then, look at Figs. 4a, b, c, try to verbalize briefly our total impressions, and attempt to integrate them with the literature.

Looking at these curves, one is impressed by the fact that the change in blood composition with rising ambient temperature is least in the apparently most important constituents: sugar, protein, non-protein nitrogen, and cells. On the other hand, the most consistent and dramatic rise occurred in the apparently least important constituent, creatinine (the upper chart in Fig. 4a). The creatinine level was doubled in the Holstein cows—dry as well as lactating—when the ambient temperature was raised from about 80° to 100°F. The causative factor is, apparently, not rectal temperature alone because when plotted against rectal temperature (see Figure 1) in the creatinine section), the rise in the creatinine level was consistently steeper and attained a higher level in the Holstein than in the Jersey cows. Body size has something to do with it, perhaps, because a given rectal temperature at a given depth in a large cow reflects a higher internal (e.g. liver) temperature than in a small cow.

Why, of all things, should the creatinine level rise most steeply with rising temperature? Assuming that creatinine is derived from creatine, a rise in creatinine may reflect a rise in creatine (we have no data at this time on blood creatine). Why should creatine rise with increasing temperature? One possibility is that the feed intake, the milk yield and, in general, the metabolic level and, therefore, the creatine-phosphate turnover in the carbohydrate phos-
Fig. 4a—The time course of several (venous) blood constituents of individual cows. Experimental (changing temperature) on the left; Controls (constant temperature) on the right side. Note the dramatic rise in creatinine in the Experimental cows, especially Holsteins (broken curve), but not in the Controls. Note the breed and individual differences in the curve levels and patterns.

phorylation cycle, is less at high than at low temperatures. If this assumption is correct, there would be, so to speak, a damming up of creatine, which would increase proportionately the creatinine level. We are now collecting data on creatine to see how its level is affected by temperature.

Unlike creatinine, which is a part of the non-protein nitrogen, the NPN seems to follow a declining course with rising temperature beginning with 85°F, presumably because of the decline in NPN-rich alfalfa consumption. But
the controls (at 50° to 60°F) likewise seem to show some decline. If reduced kidney function were involved, such decline would not occur in the controls, and the NPN would perhaps also rise along with the creatinine. We shall have to collect data on the urinary levels of these constituents to throw further light on these subjects. There appears to be no breed difference in NPN levels.
The plasma protein shows no decisive trend, although its value at 100°F tends to be below that at 90°. The plasma protein level in the Jerseys tends to be below that in the Holsteins.

The glucose level shows disorderly fluctuations, presumably because of its sensitiveness to emotional factors, which may mask the temperature trend, if any. Yet one gets the impression that there is a decline in the sugar level beginning with 90°F, and that the sugar level in the Jerseys is below that of the Holsteins.

In Fig. 4b the fatty acid values appear to follow a declining course with
Fig. 5—The lower chart illustrates in detail cholesterol as function of milk yield, and how temperature and breed affect the levels and course of the cholesterol curves in relation to milk yield. The upper chart similarly illustrates cholesterol as function of rectal temperature, which, of course, affects milk yield and composition, and which is affected by breed (body size) as illustrated in Figs. 1 and 2.

rising temperature, but also with the advance in the lactation period in the control chamber. The cholesterol likewise declines steadily and rather conspicuously with increasing ambient temperature and, judging by the curves in the control chart in Fig. 4b and also in Fig. 5, the cholesterol decline is associated in part with the advance of the stage of lactation, or decline in milk
yield independent of temperature. Fig. 5 brings out especially well the relative effects of rising temperature and advancing stage of lactation on the Jersey and Holstein cows.

In Fig. 4c the calcium seems to decline, but rather irregularly, with increasing temperature and, apparently, also as a result, in part, of advancing period of lactation. The nature of the phosphorus trend, if any, is blurred as is the magnesium trend.

The trends of leucocytes, and erythrocytes is uncertain. The trends of hemoglobin and hematocrit seem to rise somewhat.

The CO₂ capacity seems definitely to decline beginning 85°F.

The variability of the data is due, in part, to the effect of acclimatization. The reaction of animals to a given temperature, changes with time spent in the given temperature. The animal either acclimatizes or deteriorates depending on its homeostatic powers and on the severity of the environmental conditions. The fluctuations in blood composition presumably reflect these adjustments, the fluctuations in acclimatization or deterioration.

Another observation is that while individual differences in blood composition are slight by comparison with individual differences in body weight, form, color, and milk yield, yet Figs. 4a, b, and c, show unmistakable individual differences in blood composition.—S. B.

For extensive data on whole-blood inorganic-phosphorus data trends with advancing age, lactation, and gestation, see Van Landaingham, A. H., Henderson, H. O., and Bowling, G. A., J. Dairy Sc. 25, 537, 1942.
ABSTRACT

Data and backgrounds are presented on the influence of ambient temperatures 50° to 100°F on the composition of blood (constituents listed in Section II of the Table of Contents) of six heavily lactating Jersey cows, four heavily lactating Holstein cows, and two non-lactating, non-gestating, Holstein cows. The most dramatic changes in blood composition occurred in creatinine (rise with increasing temperature) and cholesterol (decline with increasing temperature). Other blood constituents showed minor trends. There is considerable individuality in the blood pictures of the cows.
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