8229 C

Influence of Temperature on Respiration of Cows.

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The increase in the respiratory frequency as described by earlier workers for various animals, particularly for the dog,[1] has been observed in cows by Regan during his investigation on the influence of environmental temperature on milk production.

The data obtained with 2 cows indicate that the frequency of respiration is about doubled as the environmental temperature increases 10°C. By the method of least squares the results have been fitted to the Arrhenius equation:

$$\frac{f_2}{f_1} = e^{\frac{\mu}{R}\left(\frac{1}{T_1}-\frac{1}{T_2}\right)}$$

where

f = frequency of respiration, breaths per minute
R = Gas constant, 1.985 cals per degree centigrade
T = environmental temperature in degrees Kelvin
μ = temperature characteristic[2]

The temperature characteristic thus calculated for the respiratory frequency was 11,980 cals for one cow and 13,070 cals for the other. The data with the respective regression lines are shown in Fig. 1. At environmental temperatures below 10°C. the influence of changes in temperature seems to be smaller than above 10°, which is probably not far from the critical temperature of milk cows during lactation.

The increase in the respiratory frequency with increasing temperature (above the critical temperature) is part of the animal's physical heat regulation. Particularly animals that do not have well developed sweat glands, as dogs and cattle, make use of polypnoea as a means of increasing evaporation of water for cooling. The question arose to which extent this mechanism for temperature regulation is operated ultimately by the environmental temperature at the body surface or by the temperature of the inspired air or both.

In order to answer this question a cow was kept in a large cham-

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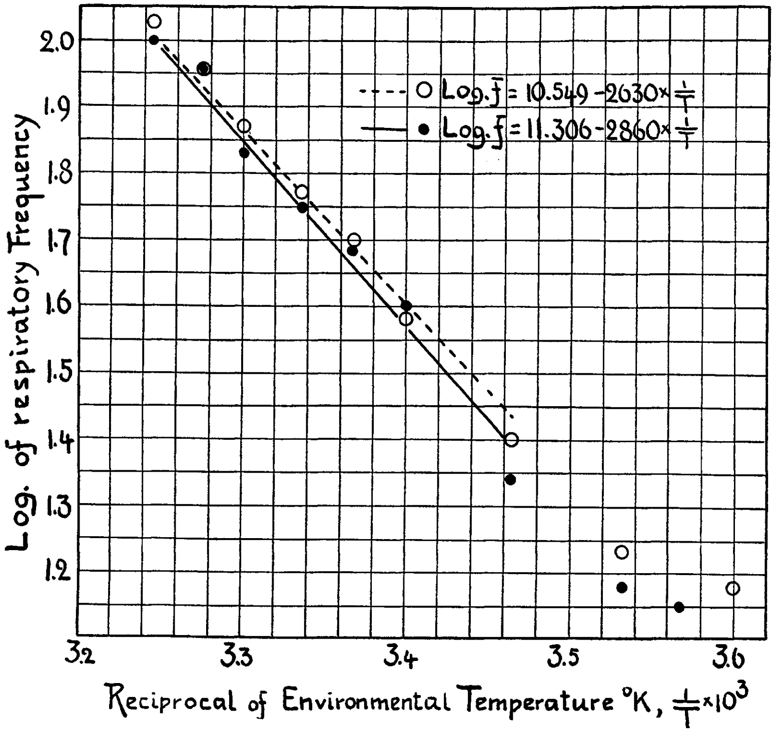
[1] Review given by Bayer, *Handb. d. norm. u. path. Physiol.*, 1925, **2**, 272.

[2] Crozier, W. L., *J. Gen. Physiol.*, 1924, **7**, 123.



ber where the environmental temperature and humidity were controlled, the latter at about 50% saturation. The cow was breathing through a muzzle similar to that used by Brody[3] for respiration trials. The respiratory movements were recorded on a kymograph by an air buffer similar in principle to the "concertina" apparatus used by Haldane.[4] The amount of air expired was measured in a dry gas meter. Two air pumps (one at each end of the air duct), together with 2 valves operated electrically by a rubber bag manometer connected to the muzzle, helped to reduce the pressure against which the cow had to breathe.

Each experimental period lasted 10 minutes. During a first period the cow was allowed to inspire air from the chamber. For the second period the muzzle was connected to a smaller psychrometric cabinet regulated independently outside the main chamber. The cow inspired thus air which differed in temperature from that surrounding her body. The low heat capacity of the air and the heat exchange to the environment made it necessary to recondition the air in the muzzle itself. This was done in the first few trials by

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3 Brody, S., *Univ. Missouri Research Bul.*, 1930, **143**.

4 Haldane, J. S., *Respiration*, 1927, 133.

immersing the muzzle in a cooling mixture or a hot bath. The procedure was later improved by providing the muzzle with a rubber jacket, through which hot water or cold brine was pumped.

Four trials have so far been completed with a low environmental temperature ranging from 6 to 9°C. and with a change of the temperature of the inspired air from 11 to 15°C. during the first period to a high level during the second period, ranging from 31 to 35°C. In 5 trials the cow was kept at an environmental temperature ranging from 32 to 37°C. The temperature of the inspired air was similar to that of the environment during the first period, subsequently the inspired air was cooled to a temperature ranging from 4 to 7°C.

TABLE I.
Frequency of Respiration.

	Breaths per Minute	
Temperature of Inspired Air		
Hot (31-36° C.)	15.4 ± 1.2	46.0 ± 3.8
Cold (4-15° C.)	15.5 ± 0.3	28.0 ± 2.0
	Cold (6-9° C.)	Hot (32-37° C.)
	Temperature of Environment	

Table I shows that the frequency of respiration was not increased when the inspired air was heated in a cold environment. The cooling of the inspired air in a hot environment, however, caused a marked decrease of the respiratory frequency. The random probability of this decrease is below 1%, the difference is thus statistically highly significant. The respiratory frequency was lower with the muzzle than without it. The data in Table I are, therefore, not directly comparable with those in Fig. 1, which were obtained without muzzle. Haldane[5] has shown in man that resistance in the air duct decreases the frequency of respiration. The resistance in our line during the experiment described here did not cause differences of pressure more than 2 cm. water level, yet at an environmental temperature of 35° we observed a drop in the respiratory frequency from 75 breaths per minute without the muzzle to 56 breaths per minute with the muzzle. When in a later trial the resistance was reduced so as to cause a pressure of approximately 5 mm. water level only, there was no marked difference in the counts of the frequency of respiration with or without the muzzle. In this trial the cow was breathing first cold air (11°C.) in a hot environment (38°C.) and then hot air (40°C.) in the same environment, the sequence of procedure was thus reversed from that followed in the earlier trials.

[5] Haldane, J. S., *Respiration*, 1927, 49.

The respiratory frequency increased from 47.1 ± 1.3 breaths per minute when cold air was inspired to 72.6 ± 0.7 breaths per minute when the inspired air was as hot as the environment. This result thus checks the earlier findings and leads to the conclusion that in the trials with a difference of pressure up to 2 cm. water level, the effect of temperature on the respiratory frequency was superimposed on the effect of the resistance in the air duct.

TABLE II.
Rate of Pulmonary Ventilation.

	Liters$_{(S)}$ per Minute	
Temperature of Inspired Air		
Hot (31-36° C.)	55 ± 1.5	105 ± 5.4
Cold (4-15° C.)	52 ± 3.2	82 ± 7.2
	Cold (6-9° C.)	Hot (32-37° C.)
	Temperature of Environment	

The rate of pulmonary ventilation (Table II) was practically unaffected by raising the temperature of the inspired air in a cold environment. A considerable decrease of the rate of ventilation was observed, when the inspired air was cooled while the environment was hot (random probability 3.5%).

TABLE III.
Depth of Respiration.

	Liters per Breath	
Inspired Air		
Hot (31-36° C.)	3.6 ± 0.25	2.2 ± 0.04
Cold (4-15° C.)	3.4 ± 0.23	2.7 ± 0.14
	Cold (6-9° C.)	Hot (32-37° C.)
	Environment	

Table III shows the influence of temperature on the depth of respiration obtained by dividing the rate of ventilation into the frequency. The depth of respiration was not materially affected by the increase in temperature of the inspired air in a cold environment. The cooling of the air in a hot environment on the other hand increased the depth of breathing considerably.

The decrease in the depth of respiration may be important when polypnoea is a normal means of physical temperature regulation since it enables the animal to increase the rate of ventilation and yet not overventilate the alveoli, which would tend to lead to a depletion of CO_2 in the blood and thence possibly to apnoea. The effective ventilation for the exchange of CO_2 and O_2 is the tidal air minus the dead space. For the evaporation of water in the respiratory system, however, the whole tidal air is effective since the entire respiratory duct is lined with a moist membrane. By increasing the dead space per breath the animal can, therefore, increase the rate of pulmonary ventilation and hence evaporation without increasing the rate of alveolar ventilation. Shallow breathing as observed in polypnoea in our cow presumably increases the dead space per breath.

Summary. Increase in environmental temperature above 10°C. increased the respiratory frequency of 2 cows according to the Arrhenius equation with a temperature characteristic of 12 and 13 thousand calories respectively. Cooling the inspired air in a hot environment decreased the respiratory frequency as well as the rate of ventilation and increased the depth of breathing. Heating the inspired air in a cold environment did not significantly affect respiration. Shallow breathing at high frequency with increased dead space per breath enables an animal to combine a large total ventilation and evaporation of water with a relatively small alveolar ventilation.

8230 C

High-Titer Blood-Grouping Serum.

M. C. TERRY. (Introduced by W. H. Manwaring.)

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The importance of using only serum of high titer in determining human blood groups has been emphasized by Coca.[1] The risk involved in accepting a serum merely on correctness of type without attention to titer is shown by Coca's findings on examination of 16 sera in actual use in New York City, none of them coming up to his Grade I and only 4 to his Grade II.

Coca's standard for Grade I requires that a 1-4 suspension of cells be agglutinated macroscopically in one minute by a 1-4 dilution of the serum; by a 1-2 dilution for Grade II. Group "B" serum of acceptable titer (Grade II or better) is fairly common among persons of that relatively rare group. This cannot be said of Group "A", however. In either group a high-titer serum is the exception. It would seem, therefore, that a method for raising a low-titer serum to acceptable grade would be useful, particularly in the case of the usually low titer Group "A" serum.

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1 Coca, Arthur F., *J. Lab. and Clin. Med.*, 1931, **16**, 405.