

In Series II there was no difference in the lactogen content of pituitaries from animals in early pregnancy and late pregnancy. As in Series I, the pituitary glands from animals in lactation contained more lactogen than did those from animals in early and late pregnancy. These results are summarized in Table I.

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**Plasma pH, CO<sub>2</sub> Content of the Blood and "Tissue Gas" Tensions During Hibernation.**

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An increased CO<sub>2</sub> content of the blood as well as a reduction in body temperature occurs in the European marmot during "winter-sleep" according to Dubois,<sup>1</sup> who used these data as support for his carbonic auto-narcosis theory of hibernation. Rasmussen<sup>2, 3</sup> has shown that the CO<sub>2</sub> content of the arterial and venous bloods of woodchucks is increased, but that the CO<sub>2</sub> absorbing power of the blood is decreased during hibernation. The pH of the blood during hibernation, however, has not been determined.

Foster<sup>4</sup> has observed that hibernation can be induced in a large percentage of well fattened and sexually inactive ground squirrels (*Citellus tridecemlineatus*, Mitchill) if, after water is withheld for 48 hours, they are placed in a cold room at 32°-40°F. This procedure was used in these experiments on the same species of ground squirrels. The animals which did not hibernate despite the above procedures are termed "non-hibernators" in this study, although it is possible that they would have hibernated had they been given sufficient time.

Two separate studies have been undertaken. The first has been concerned with the determination of the hematocrit, plasma pH, and CO<sub>2</sub> content of arterial blood by the micro-method of Shock and Hastings.<sup>5</sup> In this study 4 normal, 9 hibernating, and 7 "non-

<sup>1</sup> Dubois, R., *Compt. rend. soc. biol.*, 1894, ser. x, i, 821.

<sup>2</sup> Rasmussen, A. T., *Am. J. Physiol.*, 1915, **39**, 20.

<sup>3</sup> *Ibid.*, *Am. J. Physiol.*, 1916, **41**, 162.

<sup>4</sup> Foster, M. A., Foster, R. C., and Meyer, R. K., *Endocrinology*, 1929, **24**, 603.

<sup>5</sup> Shock, N. W., and Hastings, A. B., *J. B. C.*, 1934, **104**, 565.

hibernating" animals were used. Blood samples were obtained by heart puncture or decapitation, collected in closed funnels under oil, and immediately drawn into the diluting pipettes. The analyses were then carried out according to the procedure of Shock and Hastings.

The results of this study are presented in Table I. The r.b.c. averaged 53.2% in the normals, 57.6% in the hibernating animals, and 58.5% in the "non-hibernating" animals. This increase in the hematocrit is most probably due to dehydration of the animal.

The CO<sub>2</sub> content of the blood averaged 45.5 vol. % in the normal control animals, 71.9 vol. % in the "non-hibernating" animals, and 85.7 vol. % in the hibernating animals.

The plasma pH averaged 7.43 in the normal controls, 7.29 in the "non-hibernators," and 7.10 in the hibernators. The high level of blood CO<sub>2</sub> or a decrease in base bicarbonate might be responsible for the lowering in pH. Rasmussen ascribes the decrease in the absorbing power of the blood for CO<sub>2</sub> during hibernation to a probable decrease in the alkalinity of the blood.

TABLE I.

Animal No.	Hematocrit % cells	Arterial blood		
		pH (plasma) corr. to temp. of animal	CO <sub>2</sub> content Vol. %	
*F 1	53	7.52	40.0	Normal-stock animal
F 2	52	7.38		" " "
M 3	55	7.45	45.3	" " "
M 4	54	7.38	51.2	" " "
Avg	53.5	7.43	45.5	
F 30	65	7.30	67.7	Non-hibernator (in cold for 5 days without H <sub>2</sub> O)
F 28	55	7.35	71.3	" "
F 32	59	7.25	76.9	" "
M 19	60	7.27		" "
M 13	59	7.25		" "
M 15	58	7.40		" "
M 14	54	7.20		" "
Avg	58.5	7.29	71.9	
M 10	57	7.20	89.7	Hibernator
M 11	64	7.11	79.5	"
M 12	60	7.07	77.7	"
F 26	57	7.01	89.2	"
M 27	53	7.02	73.8	"
F 25	55	7.19	93.4	"
F 32	55	7.04	92.8	"
M 21	56	7.04	88.0	"
M 20	62	7.19	87.7	"
Avg	57.6	7.10	85.7	
M 37	67	7.27	57.0	24 hr out of hibernation

\*F—female. M—male.

In the second study "tissue gas depots" were established in the peritoneal cavities of 5 normal ground squirrels according to the procedure developed by Campbell.<sup>6</sup> Gas samples were drawn from these pockets without air contamination and analyzed for CO<sub>2</sub> and O<sub>2</sub>, using the micro-gas analysis apparatus described by SeEVERS and Stormont.<sup>7</sup> From these data the CO<sub>2</sub> and O<sub>2</sub> gas tensions in mm of Hg were calculated\* (corrected to 740 mm bar. press.). Samples were taken approximately every second day before, during, and after hibernation.

Fig. 1 shows the changes obtaining in the "peritoneal tissue gas tensions" before and during hibernation. The final readings were made when the animals had been removed from the cold-room and given food and water. Lowered metabolism probably accounts for

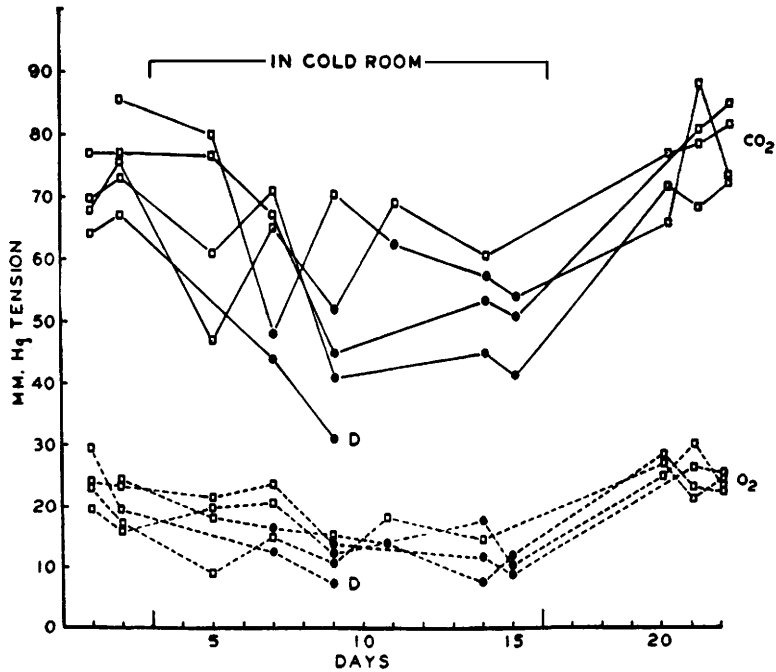


FIG. 1.

CO<sub>2</sub> tensions and O<sub>2</sub> tensions in the peritoneal cavities of five animals. White squares—awake; black circles—hibernating; D—animal found dead next day.

<sup>6</sup> Campbell, J. A., *J. Physiol.*, 1923, **57**, 273.

<sup>7</sup> SeEVERS, M. H., and Stormont, R. T., *Ind. and Eng. Chem. (Anal. Ed.)*, 1937, **9**, 39.

$$* \text{mm tension} = \text{Vol. \% dry gas} \times \frac{\text{Obs. Bar. Press.} - Q}{100} \times \frac{740}{\text{Obs. Bar. Press.}}$$

Q = tension of H<sub>2</sub>O vapor at temp. of animal.

the decrease in both the  $\text{CO}_2$  and  $\text{O}_2$  tensions. There is a definite small mortality among ground squirrels hibernating for the first time. It is, hence, of interest to note the low tensions of  $\text{O}_2$  and  $\text{CO}_2$  in one animal (D, Fig. 1) 24 hours before death from hibernation.

The equation developed by Hastings and Shock<sup>8</sup> for the calculation of the arterial blood  $\text{CO}_2$  tension ( $\text{pCO}_2$ ) from the hematocrit, plasma pH, and  $\text{CO}_2$  content values was modified to apply theoretically for blood at  $4^\circ\text{C}$ , and an attempt was made to calculate the  $\text{CO}_2$  tensions of the bloods of the hibernating animals. The resulting values averaged 50% higher than the  $\text{CO}_2$  tensions obtained by direct tonometry in the peritoneal cavity. The validity of the use of the Hastings-Shock equation extrapolated to  $4^\circ\text{C}$  may be questioned on the bases that the arterial  $\text{O}_2$  saturation was not determined, the state of the  $\text{CO}_2$  in the blood under these conditions is not definitely known, and the ionic or protein concentrations in the blood of these dormant animals may be significantly different from that in man or the ox. Roughton<sup>9</sup> suggests that the carbamino mechanism might play a more important rôle in  $\text{CO}_2$  transport in the case of cold blooded animals since carbamino compounds are more readily formed at lower temperatures.

It should be noted that the rise in arterial  $\text{CO}_2$  content and the fall in the pH of the blood are similar to those noted in asphyxia.<sup>10</sup> The hibernating animal is suggested as a possible test object for physiological and pharmacological studies of animals in a fixed acidotic state.

*Summary.* During hibernation arterial blood  $\text{CO}_2$  content increases to an average of 85.7 vol. % compared to an average normal of 45.5 vol. %. The plasma pH changes from an average of 7.43 to 7.10. The tensions of  $\text{CO}_2$  and  $\text{O}_2$  in the peritoneal gas pocket decrease significantly.

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<sup>8</sup> Hastings, A. B., and Shock, N. W., *J. B. C.*, 1934, **104**, 575.

<sup>9</sup> Roughton, F. J. W., *Physiol. Rev.*, 1935, **15**, 241.

<sup>10</sup> Koehler, A. E., Behneman, H. M. F., Berrell, O. E., and Loevenhart, A. S., *Am. J. Physiol.*, 1925, **74**, 590.