Proceedings of the Iowa Academy of Science

Volume 35 | Annual Issue Article 75

1928

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OXYGEN CONSUMPTION AT 20° IN CERTAIN SNAKES[1] *PITUOPHIS SAYI* AND *LAMPROPELTIS GETULUS HOLBROOKI* WITH SOME NOTES ON SIZE AND SEASONAL DIFFERENCE

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Before this section of the Academy last year data were presented on the rate of oxygen consumption in certain turtles,[2] which were interpreted to represent both "basal" and "active" rates in these forms. Data on these points were thought to be of some value in connection with the question as to whether a beginning or a remnant of a heat-regulatory mechanism might not be found in this representative of the reptilian group. While it is the hope of the writer to continue the investigations with the turtles, it so happened that specimens of the snakes in Professor Guthrie's [3] collection were made available for the following observations.

Citation: It seems strange that although considerable work has been done upon many representatives of the animal groups standing phylogenetically above and below the reptiles, only a few workers have recorded their experiments or observations on the metabolic activity of the reptiles, especially the snakes. One of the interesting examples which would indicate that some snakes possess to some degree a sort of regulatory mechanism is the case of the female python [4] which during the period of egg incubation, is able to maintain the body at a high temperature. Since during this time the python is reported not to take food or exercise, the inference is that the excess heat generated is produced by more rapid oxidation of the tissues of this animal. So far as the snakes are concerned no quantitative records on gaseous interchange have as yet been found in the available literature, so that the figures here given become of comparative value.

Materials and Methods: All the experiments here reported upon were carried forward in the Physiological laboratory at Iowa State College, and it is fitting to mention the helpful services ren-

1 The writer here wishes to gratefully acknowledge the hearty co-operation of Prof. J. E. Guthrie, who has allowed free access to his extensive collection of live snakes and who has identified the specimens.
2 Proceedings of the Iowa Academy of Science, Vol. XXXIII, pp. 315-323. 1926.
3 The Snakes of Iowa, Agricultural Experiment Station Bulletin No. 239, 1926.
4 See account given in Schafer, Textbook of Physiology, V: 1; p. 865.

dered by Mr. Russell Daubert, who volunteered to aid in the technique in handling the specimens, as well as to keep the records during the fall period mentioned later. Practically all of the specimens worked upon were from the collection of live snakes maintained in the vivarum by Professor J. E. Guthrie. Although a considerable number of different species were used, and records taken, this report is based largely upon the common Bull-snake (*Pituophis sayi*) and the less common King-snake (*Lampropeltis getulus holbrooki*). Being among the most common snakes of this region, many specimens of the bull-snake were available; sometimes as many as ten or a dozen of various sizes were handy for study.

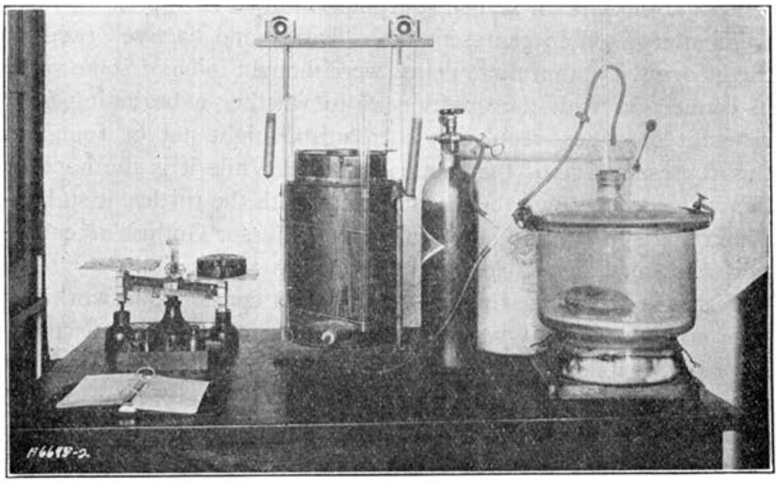

Fig. I. In the right forefront is shown the calorimeter with removable top and a perforated shelf dividing its chamber into an upper and lower compartment. The lower compartment is partially filled with "sansolime," the chemical absorbent for CO_2 and H_2O. Weighted at its base the calorimeter can be completely submerged in the water jar shown in the background and the temperature maintained at the desired level (20°C.). A known volume of oxygen is run into the spirometer (left) from the oxygen tank and when all is in readiness the specimen is weighed and placed in the calorimeter and the cover clamped down. Release of the pinch cock connects the two in series by rubber tubing. The "sansolime" removes the CO_2 as fast as it is formed and the oxygen enters as fast as it is consumed.

They were kept in screened, partly glassed boxes specially constructed for the purpose and were fed at irregular intervals. Water was before them for drinking at all times, except the periods under direct experimentation. After being selected from the group for an experiment the specimen was carefully weighed and placed in a separate compartment and notes were kept as to time and amounts of food taken and amount of water drunk. At the time of experiment, the specimen was carefully removed from its accustomed cage and carried in arms to the laboratory, where it was accurately weighed and subsequently placed in a large desiccator which served as the calorimeter. The apparatus used was essentially the same as that described in the preceding report [5] and is shown in figure I. Within the calorimeter was the "Sansolime," the absorbent for the products of combustion, and connected thereto was the oxygen supply tank. By recording the amount of oxygen consumed in a given time and knowing the weight of the animal before and after the experiment, the rate of oxygen consumption can be calculated.

Experimental: The first series of observations involve records from Bull-snakes ranging in average weights from 422 grams up to 822 grams, and extending over intermittent periods from February to May, 1926. Check on temperature throughout was kept, and care was exerted to maintain the calorimeter, as well as the room, at approximately 20°C. During the interval it so happened that several specimens shed their skins within the container, and not infrequently defecation was observed. In recording weights therefore allowance was made in these cases.

Exchange during early spring months: Selective experiments on the Bull-snakes taken during the early spring period are cited in Table I, there being given only representative data throughout the interval of observation.

Table I — Bull-Snake (at 20°C.) (Spring)

Date (1926)	Total Hours Observed	Weight (Ave.) Grams	Total O_2 Consumed cc.	Consumption Gram Hour cc.
Feb. 1-3	49	510	2,400	0.0950
Feb. 23-26	60	792	2,800	0.0580
Mar. 16-18	48	422	1,500	0.0740
Mar. 18-22	48	822	1,650	0.0425
Apr. 22-24	49	764	2,200	0.0610
			Average	0.0661

It is noted that the largest specimen in this group, weighing 822 grams, consumed oxygen at the rate of 0.0425 cc. gram hour, while the smallest specimen, weighing 422 grams, consumed oxygen at the rate of 0.0740 cc. gram hour. While the smaller of the two animals gives indication of more rapid interchange, certain exceptions make it seem apparent that the exchange has no causal relation to size or surface area. In the table the first specimen cited is an example of this. Although falling in weight between the two it has a greater gaseous interchange than either of them. Although the average of the five series of experiments is 0.0661 cc. gram hour, the average of some fifteen experiments in addition becomes

5 See Proceedings of Iowa Academy of Science, Vol. XXXIII, p. 318.

0.0583 cc. gram hour. This figure is significant when compared with the fall interval on the same species to be given next.

Exchange during early fall months: Contributing to the summary to be given on the exchange taking place in the Bull-snakes during the fall months are typical records which appear in Table II.

Table II — Bull-Snake (at 20°C.) (Fall)

Date (1926)	Total Hours Observed	Weight (Ave.) Grams	Total O_2 Consumed cc.	Consumption Gram Hour cc.
Oct. 11-12	24	835	900	0.0450
Oct. 12-13	24	831	500	0.0301
Oct. 16-17	24	272	450	0.0688
Oct. 19-20	24	736	1,938	0.1103
Nov. 24-25	24	748	500	0.0625
Nov. 28-29	24	769	1,475	0.0833
Dec. 1-2	24	765	1,000	0.0540
Dec. 16-17	24	747	750	0.0418
			Average	0.0616

In general, the same discrepancy exists here with reference to size of the animal and the relative rate of the exchange taking place. Datum 3 is from the smallest animal in this series, but the rate of exchange is roughly only about one-half that of an animal twice its size as indicated in datum 4. Other characteristic differences are observed in a study of the table. Many of the specimens worked with during this interval were secured in the late summer and early fall, and presumably they had had opportunity to secure abundance of food and to put on the necessary reserve weight to prepare them for the oncoming winter months. This is not true of the specimens experimented upon in the spring interval, for they had been carried over the hibernating term in a wakeful state and had been fed intermittently, as they would take food. In spite of the fact that the spring group were apparently sluggish and somewhat reduced in physical appearance for want of the usual hibernating rest period, as compared to the freshly captured animals in the fall, the average rate of interchange in the two groups checks remarkably closely. These two rates from data cited in the two tables respectively are: 0.0661 cc. gram hour as against 0.0616 cc. gram hour. When all data from both intervals are included the agreement is almost exact, being 0.0583 cc. gram hour for the spring groups as against 0.0580 cc. gram hour for the fall series. If these data are valid it would certainly seem that no material seasonal difference exists in the lives of these animals. On the side of activity alone, since the temperature during both series of experiments was under control, one would be inclined to reason that tissue metabolism and therefore oxygen consumption would be at a rather low ebb in the springtime. Doubtless other factors, the analyses of which are difficult to make, contribute to the results. It would seem that the figures represent basal metabolism in both series of observations and that superimposed energy ("active") increments are of short duration in a sluggishly moving form such as the snake naturally is. That this is true would seem to be substantiated by the frequent and general observation that after the specimen is placed in the calorimeter, activity gradually merges into a restful state which if the animal is unmolested continues to the end of the experiment. Some experiments have been carried on to determine the effect of a full meal (rat or several mice or birds) on the rate of metabolism in these forms, both immediate and during the absorptive stage, but as yet no definite conclusions are at hand on these points.

The King-snake: A less extended series of observations were carried out on the King-snake, but since in general it is a much smaller snake in the adult, it was thought it might yield interesting comparisons with the larger Bull-snake. These experiments were made during the spring period, and thus the specimens had been more or less active during the winter months. Selecting the records of February 24, March 1, and April 3 as typical, the data are summarized in Table III.

Table III — King-Snake (at 20°C.) (Spring)

Date (1926)	Total Hours Observed	Weight (Ave.) Grams	Total O_2 Consumed cc.	Consumption Gram Hour cc.
Feb. 24	54	221	800	0.0618
Mar. 1	48	281	2,100	0.1510
Apr. 3	54	319	500	0.0291
			Average	0.0806

While in the main the King-snake shows a somewhat more rapid rate of oxygen consumption as compared to the Bull-snake individual differences are frequent and striking. In datum 3 the rate is lower while in datum 2 it is higher than any cited for the Bull-snakes during the same season.

Summary: Using the method of indirect calorimetry under temperature control, several series of observations were obtained on the oxygen consumption in two of the common snakes of Iowa. In the first series on the Bull-snakes (*Pituophis sayi*), extending over a period from February to May, 1926, the smallest snake, averaging 422 grams in weight, consumed oxygen at the rate of 0.0740 cc. gram hour, while the largest one in this group, averaging 822 grams in weight, consumed oxygen at the rate of 0.0425 cc. gram hour.

The average rate of consumption for all specimens in this group was 0.0661 cc. gram hour. Although at first sight these figures might seem to indicate that the *law of surface area* might apply, individual differences were so varied that no causal relation between surface and energy exchange can be drawn. Data on eight Bull-snakes, beginning in October and extending through December, 1926, furnish the basis for comparison with figures cited for the early spring months. Figured on the same basis the highest consumption in this group was at the rate of 0.1103 cc. gram hour and the lowest rate was 0.0301 cc. gram hour. The average for all during this interval was 0.0616 cc. gram hour, which although not identical was approximately the same as in the first series. In another series involving the King-snake during the spring period the highest rate of oxygen consumption, 0.1510 cc. gram hour, was from a specimen weighing 221 grams and the lowest rate of 0.0291 cc. gram hour was from a specimen weighing 319 grams. Seasonal differences in consumption are apparently of no consequence when temperature is controlled. Work involving the hibernation period as well as sex differences in these forms is being carried forward.

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