[3] J. von Neumann, these PROCEEDINGS, 18, 70–82 (1932).
[4] E. Hopf, these PROCEEDINGS, 18, 93–100 (1932).
[5] G. D. Birkhoff, these PROCEEDINGS, 17, 656–660 (1931).
[6] G. D. Birkhoff and P. Smith, *Journal de Math.*, 7 [9],(1928), p. 365.
[7] H. Poincaré, *Calcul des Probabilitiés*, 2nd Edition, Paris, 1912, 320–333.
[8] This remark is due to B. O. Koopman who privately communicated it to the author two months ago.

THE INCUBATING PYTHON: A TEMPERATURE STUDY

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It is the fixed belief of every farmer's wife that the sitting and the broody hen have high body temperatures. That they are fussy and agitated no one doubts, but in 1911 Simpson[1] showed that sitting and broody birds do not have high temperatures. Singularly enough, this erroneous conception of a feverish state in the sitting or brooding bird has persisted for decades and has led to the conviction that the python coils about her eggs in order to supply heat to incubate them. The authentic history of the incubating python begins with a report from the French naturalist, Lamarre-Picquot[2] who in 1832 stated before the French Academy that the python of India incubates her eggs with sensible heat from the body. Since this statement was accompanied by a story to the effect that there existed likewise a snake that could "withdraw milk from the udder of a cow," his whole communication was given little credence. Indeed, the sharpest critics in the French Academy rejected the statements of Lamarre-Picquot as being hazardous and questionable. There then followed a controversy on the subject, which lasted many years. In 1841 Valenciennes[3] presented some experimental evidence obtained in studying a python that had deposited her eggs in the Jardin des Plantes in Paris and had coiled about them, as usual. Although the method of controlling the temperature in a snake cage was crude at that time in comparison with the more modern methods, Valenciennes tried by every means to rule out all other factors but that of the body heat of the snake, and he was convinced that the python had a high temperature. In this belief he was strongly opposed by the Director of the Jardin des Plantes at that time, Duméril,[4] who contended that in the particular case cited by Valenciennes the eggs were spoiled and the heat produced was in large part due to the fermentation of the eggs themselves. Subsequent observations made in the London Zoölogical Park, first by

Sclater[5] in 1862 and later by Forbes[6] in 1881, seemingly confirmed Valenciennes' observations, but the difficulty of comparing the temperature of the animal and the temperature of the air was always uppermost. Both Sclater and Forbes measured the body temperature not only of a male but of a female python and found that at times the male's temperature was higher than that of the female. In general, however, the female's temperature was above that of the male, and the temperatures of both animals were for the most part above the room temperature.

In a study of the metabolism and the mechanism of heat production of snakes made by the Nutrition Laboratory, chiefly at the New York Zoölogical Park but with some direct calorimetric measurements in Boston, we were led to believe that *under ordinary conditions* the snake has a body temperature slightly below its environmental temperature[7] and that all the heat produced by the snake is lost by vaporization of water. Under two conditions only was the temperature of the snake found to be consistently above that of the environment. At the peak of digestion the snake's temperature was slightly higher than the temperature of the air around it, and after pronounced agitation it was considerably increased. It became important therefore to determine whether a snake, unaided by the process of digestion or by agitation, can operate any mechanism for raising its temperature above the temperature of its environment. Quite by chance it was found that a python was incubating her eggs in the new Reptile House in the National Zoölogical Park at Washington, D. C., and through the kindness of the Director, Dr. W. M. Mann, the Nutrition Laboratory was permitted to make a study of this animal. An electrical equipment consisting of galvanometer, thermo-elements and thermostats was sent to the Park, and since it was realized that it is as difficult to determine accurately the temperature of the environment as that of the animal itself, an experimental procedure was planned that enabled the determination not only of the animal's temperature but of the environmental temperature.

Fortunately the python was most placid and would allow any amount of handling with hardly any indication of disturbance. In the entire series of experiments with this animal she gave but one sign of agitation, which was a heavy, deep breath, approximating a hiss, in the middle of an afternoon session. In any large den in a Zoölogical Park there is always a possible source of heat from water pipes and from sunlight entering through the windows and skylight, and there is possibility of a cooling effect from the contact of the glass window of the den with the cool air of the corridor. One could hardly expect, therefore, that the temperature of the air surrounding the snake in such a den would be equable. Hence, a temperature survey of the air about the python was first made, the animal being considered to be in a hypothetical, rectangular box of air, and the gradients in the temperature of this air at different distances above the floor and away from the snake being carefully noted. Temperature measurements were then made at various points on the exposed surface of the snake, between the folds, between the snake and the gravel on the floor of the den, and occasionally between the folds and the eggs. Since the heating supply of the building was entirely shut off, there was no heat under the gravel.

Our preliminary measurements showed that the skin temperature of the snake was definitely above the environmental temperature. The importance of this observation decided us to make three entirely independent temperature surveys, after each of which the instruments were dismantled, the thermostats reset, and the galvanometer and the thermo-junctions recalibrated. An abstract of the results is given in table 1. The actual number of readings represented by each average temperature is recorded. The first half of the table contains the average air temperatures as measured on the graveled floor near the python, and 10, 30 and 60 cm. in a vertical line above the floor, these vertical gradients being determined at four different points about the snake. The second section of the table contains the skin temperature.

TABLE 1

COMPARISON OF ENVIRONMENTAL AND SKIN TEMPERATURES OF AN INCUBATING PYTHON

	SURVEY 1		SURVEY 2		SURVEY 3		
MEASUREMENT	NO. OF READINGS	°C.	NO. OF READINGS	°C.	NO. OF READINGS	°C.	AVERAGE TEMPERATURE[1]
Air temperatures:							
Gravel near python	27	31.38	3	32.49	8	31.08	31.65
10–15 cm. above floor	20	31.01	8	30.23	9	30.67	30.64
30 cm. above floor	19	31.07	8	30.39	5	29.41	30.29
60 cm. above floor	9	31.24	3	30.44	4	29.28	30.32
Grand average							*30.73*
Skin temperatures:							
Under python	10	33.15	15	33.32	10	33.23	33.23
Near gravel	6	33.00	..	...	4	33.19	33.10
On exposed surface	33	33.73	16	34.31	17	33.90	33.98
Between folds	15	33.85	10	34.61	13	34.81	34.42
Grand average							*33.68*

[1] Not weighted according to number of readings taken.

There was a singular uniformity in the temperature of the air at the various parts of the hypothetical air box. In spite of the cool air of the corridor outside the glass window of the den, the high temperature of the air inside the den, and the presence of the observer (although his activity was kept at a minimum), the temperature of the air about the snake was reasonably constant, averaging for the three surveys 30.73°C. The skin temperature of the python was highest between the folds. These temperatures should perhaps more properly be designated as the "body temperature," since there was no chance for vaporization between the folds and a higher temperature here is to be expected. The average of all the skin temperature measurements is 33.68°C. There was, therefore, a difference of almost exactly 3°C. between the average temperature of the air about the python and the temperature of the animal itself. If one considers that the rectal temperature (had it been taken) would be more nearly approximated by the temperature between the folds, which was found to average 34.42°C., the difference between the air and the body temperatures would be almost 4°C.

Under the head of "air temperatures" in table 1 we have included the temperatures of the gravel near the python. It is more than likely that these temperatures were influenced by the higher temperature of the animal itself and there were convection currents, although rather feeble. If the temperatures of the gravel are not taken into consideration, the average environmental temperature becomes somewhat lower, averaging 30.4°C. This temperature is a full 4° below the temperature between the snake's folds, that is, the probable body temperature. Although subsequently the python's eggs were found to be infertile and partially decomposed, it is extremely improbable that such bacterial action can account for more than a very small percentage of the sensible heat noted in this study.

This observation, that the incubating python has a body temperature higher than the air surrounding it, bids fair to be of considerable importance in comparative physiology. Since in the various stages of animal development from the cold-blooded or poikilotherm to the warm-blooded or homoiotherm the birds represent the next advancement after the reptiles, and since birds invariably incubate their eggs, it is possible that the incubating python forms an intermediary stage between the non-incubating reptile and the bird.

The details of this study are soon to appear in a monograph on "The Physiology of Large Reptiles" (Carnegie Institution of Washington Publication No. 425), which is now in press.

[1] Simpson, S., *Proc. Roy. Soc. Edinburgh*, **32** (Pt. 1), No. 5, p. 25, and No. 11, p. 131, 1911–1912.

[2] Lamarre-Picquot, *L'Institut*, **3**, p. 70, 1835.

[3] Valenciennes, A., *Compt. Rend.*, **13**, p. 126, 1841.

[4] Duméril, *Ibid.*, **14**, p. 193, 1842.

[5] Sclater, P. L., *Proc. Zoöl. Soc., London*, p. 365, 1862.

[6] Forbes, W. A., *Ibid.*, p. 960, 1881.,

[7] Benedict, F. G., and E. L. Fox, *Proc. Nat. Acad. Sci.*, **17**, p. 584, 1931.