CHIMPANZEE METABOLISM

BY FRANCIS G. BENEDICT AND JOHN M. BRUHN

NUTRITION LABORATORY OF THE CARNEGIE INSTITUTION OF WASHINGTON,
BOSTON, AND THE YALE LABORATORIES OF PRIMATE BIOLOGY, INC.,
ORANGE PARK, FLORIDA

The respiratory metabolism has been studied with twenty-two chimpanzees selected from the breeding colony of the Yale Laboratories of Primate Biology, Inc., Orange Park, Florida. These animals, which ranged in weight from 2.9 to nearly 50 kg. and in age from 2 months to 15 years, were free from recognizable disease and were adequately fed and cared for. Under the captive conditions provided, the adults showed a record of successful breeding. The adults, with one exception, were captured in Africa, but the infants were born in captivity.

The respiratory exchange was measured with an open-circuit respiration chamber. A rotary blower drew outdoor air into the chamber and forced the outgoing air first through bottles of calcium chloride to remove water vapor, and then through a rotamesser or flow meter and over a sampling jet and finally through two 3-light dry gas meters to record the total volume of air leaving the chamber. During the experiment a proportional part of the outcoming chamber air was collected continuously in a sampling bag.[1] This air sample was subsequently transferred to a storage pump and later analyzed on the Carpenter gas-analysis apparatus.[2] The size of the respiration chamber varied with the size of the chimpanzee. A cage of steel window grills welded together was used inside the chamber for the adult animals. A small chamber without a containing cage was employed for the infants. Provision was made to record graphically the animal's activity throughout the experiment. To obtain periods uncomplicated by muscular activity, all measurements were carried out in the evening when the chimpanzee is usually asleep and quiet. Only the results obtained in periods of muscular repose are considered in the following analysis. The metabolic rate determinations were made usually after a fast of 12 hours, but in certain instances the fast was from 21 to 28 hours. The chimpanzee was placed in the metabolism cage and brought from its living quarters to the laboratory, where a temperature well within the subsequently established zone of thermic neutrality was maintained. It remained in quiet in the cage on the base of the respiration chamber for four hours before the experiment started. Rarely was the animal emotionally excited when placed in tne cage.

Respiratory quotients of 0.78 and 0.74 were obtained after the fasts of 12 and 27 hours, respectively. These quotients indicate that the stimu-

lating action of food was not present during the measurements and, furthermore, that the chimpanzee approaches the post-absorptive state at least as quickly as and possibly more quickly than man.

Previous observation on the gaseous metabolism of the chimpanzee is limited to the measurements of three subjects by Bruhn,[3] who made no attempt, however, to study the factors related to changes in heat production. This present paper deals with the relation of environmental temperature, the menstrual cycle, sex, size and age, respectively, to the heat production of the chimpanzee.

The environmental temperature may have a pronounced effect upon the heat production of an animal. This is especially true in the case of the mouse, the rat and the pigeon, but with other animals such as the goose and the cow this factor does not play so important a rôle. Two chimpanzees living in unheated, but protected quarters during the Florida winter were able to withstand a temperature of 17°C. without an increase in heat production. Although one chimpanzee had a good coat of hair and the other a sparse covering, the poorly covered animal reacted no more to the low temperature than the animal with the good coat of hair. This indicates that at environmental temperatures of 17°C. or above the covering of hair on the chimpanzee plays little or no part in the conservation of heat. Other chimpanzees, which lived in heated quarters during the winter months and hence were not inured to the cold, showed an increase in the metabolic rate between 17° and 20°C., but above 20°C. and up to 29°C. the heat production was at a minimum. The range of temperature within which the heat production of the chimpanzee is at a minimum level is, therefore, fairly wide and corresponds closely to the zone of thermic neutrality for man.

The metabolism of two mature female chimpanzees was studied at thermic neutrality on alternate days during two complete sexual cycles, with the object of determining the relationship of the menstrual cycle to the heat production. Both females had given birth to normal infants and had cared for them for about one year. These two animals were considered to be representative of normal chimpanzees, though they differed in some respects. Josie, who weighed about 39.5 kg., had a fairly good covering of hair, whereas her cage mate Wendy, weighing about 35 kg., was entirely bare of hair in spots. Wendy, in contrast to Josie, has always shown a greater degree of sexual activity and has a shorter sexual cycle (35 days) than Josie (40 days). The 24-hour heat production of Wendy during the first 10 days of the cycle (the first day of bleeding being considered the first day of the cycle) was significantly lower than that during the remaining days of the cycle, averaging 884 and 957 calories, respectively, per 10 times the two-thirds power of the weight. Josie did not have a low metabolic rate during the first 10 days of the cycle, but her

metabolism did undergo a decrease between the 20th and the 30th day. The average heat production during the first 20 days and the last 10 days of her cycle was 943 calories and that for the 20th to the 30th day was 919 calories per 10 $w^{2/3}$.

With both these chimpanzees low values of about 850 calories were obtained on several days, and high values of slightly over 1000 calories on several other days. The average value for all the days when Wendy was studied is 939 calories, the average in Josie's case is 936 calories. Inspection of the results indicates that, although the metabolism of the female chimpanzee is subject to considerable variation from day to day, a series of determinations made over a period of two weeks will give an average value close to that obtained in observations extending over one or two months. However, in experiments designed to study the effect of some factor superimposed upon the basal metabolism, especially when the effect is small and subtle, the average value of a series of metabolism measurements made over an extended length of time cannot be used as the base-line, because of the possible magnitude of the variation in the metabolism from day to day. Rather the basal heat production should be determined immediately before such an experiment.

On the basis of experience with man, one would not expect a sex difference in the metabolism of young animals. In our study of the heat production of four infant male and four infant female chimpanzees we have found no evidence of a higher metabolism in the males than in the females. Among humans, the metabolism of women is about 7 per cent lower than that of men. The metabolic rate of the 7 adult female chimpanzees that were studied averaged 993 calories per 10 $w^{2/3}$ and that of the two adult males 999 calories, a value nearly equal to the rate of the females. However, the data for the males are not sufficient to establish, with any degree of reliability, the average metabolism of this sex.

With the chimpanzee, as with other animals and man, the larger animal has the greater heat production. Among the males, for example, the range in the average *total heat production per 24 hours* was from 226 calories by a chimpanzee weighing 2.9 kg. to 1227 calories by a chimpanzee weighing 48 kg. However, the smaller animal has a greater heat production per kilogram of body weight than the heavier animal, the range for the males being from 76.8 calories for the 2.9-kg. chimpanzee to 25.6 calories for the 48-kg. chimpanzee. In contrast, the 24-hour heat production referred to the two-thirds power of the body weight times the factor 10 is singularly uniform for chimpanzees of vastly differing weights and of both sexes, averaging 980 calories (measured at thermic neutrality).

Since this last method of expressing the heat production is commonly employed to minimize any rôle played by differences in the sizes of animals, we may examine the data thus expressed to note whether the factor of age

has any effect upon the metabolism. Only one chimpanzee at the age of 2 to 3 months was available for study. The average heat production of this infant was 1104 calories. Six chimpanzees one year of age, weighing from 4 to 7 kg., had a fairly constant heat production averaging 975 calories. With adolescent chimpanzees weighing 25 kg. and adults weighing over 30 kg., values closely approximating 1000 calories were found. It is concluded that the chimpanzee, unlike man, does not have an extremely high intensity of metabolism per $10 \ w^{2/3}$ in infant and pre-adolescent years.

[1] Described in detail by Benedict, F. G., *Carnegie Inst. Wash. Pub.* No. 474 (1936), in press; see, also, brief description by Carpenter, T. M., and Fox, E. L., *Arbeitsphysiologie*, 4, 527 (1931).

[2] Carpenter, T. M., *Abderhalden's Handb. biolog. Arbeitsmethoden*, Abt. IV, Teil 13, 593–618 (1933).

[3] Bruhn, J. M., *Amer. Jour. Physiol.*, 110, 477–484 (1934).

A DETERMINATION OF THE MAGNITUDE OF THE CELL "SENSITIVE VOLUME" ASSOCIATED WITH THE WHITE-EYE MUTATION IN X-RAYED DROSOPHILA—II

By C. P. Haskins and E. V. Enzmann

Biological Laboratories, Harvard University, and the Haskins Laboratory, Schenectady, New York

In a previous communication[1] we described the methods used and the results obtained in a probability determination of the magnitude of the volume and radius of the cell "sensitive volume" associated with the mutation to white eye in *Drosophila melanogaster*, and pointed out that such a figure might be tentatively interpreted as the minimum limiting value for the size of a gene. More recently additional work has been completed giving a more reliable determination of this figure. The order of magnitude of the volume is not essentially changed.

Two of the points on the curve of percentage mutation against x-ray dosage have been independently re-determined by one of us, using a new stock of eosin, furnished by Turtox Service. One new point, at an exposure of one-quarter minute, has been added. The x-ray conditions have been maintained identical with those earlier described, a similar tube being used. The earlier and later values of the re-determined points differ by less than their respective probable errors as given in the earlier paper. Thus the earlier determination of the percentage of affected eyes at an exposure of one minute was 0.52 per cent, the later, 0.48 per cent; the respective corresponding values at the four-minute point were 2.14 per cent and 1.63 per cent.