Effect of Rapid Transposition Around the Earth on Diurnal Variation in Body Temperature.* (29133)

TAKASHI SASAKI† (Introduced by L. C. Carlson)
Department of Physiology and Biophysics, Medical Center, University of Kentucky, Lexington

Observations on the diurnal variation in body temperature during a voyage were made early in the current century by Gibson(1) and Osborne(2). The shift of the daily routine as the result of time changes during the trip was accompanied by an adjustment of body temperature to local time. Sasaki(3) reported temperature measurements during a transpacific voyage suggesting a disparity between the external periodicity and the endogenous rhythm. Ogata and Sasaki(4) referred for the first time to the relationship of the daily shift of temperature rhythm to the speed of transposition across longitudes. The present paper reports measurements of body temperature during more rapid transport across longitudes, as well as observations of the diurnal temperature pattern in summer and winter.

Methods. The subjects in this experiment were 3 members of a family including a 6-year-old child. They left Tokyo (longitude 140°E) around noon on Sept. 3, after making a 23-hour stopover at Honolulu (158°W) on the same date, spent 4 days in Seattle (122°W) (Sept. 4 through 7) and arrived at Lexington, Ky. (84°W) on Sept. 8, 1962. The trip resulted in an advance of local time as much as 10 hours in one travel time. Oral temperatures were taken at frequent intervals, 5 times a day on an average, from Sept. 2 to 15, covering a period of 7 days after the flight. Ambient temperature was never above 29°C. (Tokyo and Honolulu, 28-28.5°C day and night; Seattle, 23-25°C; and Lexington, 24-27°C.) Observations on the diurnal pattern of body temperature were also made in June and July, and December and January in Lexington, Ky.

Results. The distinctive characteristics of the temperature pattern of each subject are summarized in Fig. 1. These characteristics are (1) time of morning rise, (2) time of evening fall, and (3) phase lag and regularity of the cycle.

1) *The time of morning rise* in temperature is the time of maximum rise for any 4-hour period in the morning. During and for a few days after the flight the morning rise occurred later than usual when compared with respective local time of the subject. The lag decreased progressively with considerable fluctuation, and after 8-11 days it was negligible. The time lag in the child was smaller and had less fluctuation.

2) *The time of evening fall* analyzed in the same way gave similar results in all respects except that the adjustments to a new local time took place later than in the case of morning rise. The time of evening fall was not so characteristic as the time of morning rise and it was readily affected by casual influences.

3) *The phase lag and regularity of the diurnal pattern* were determined from three 8-hour-interval temperature readings (interpolated if necessary) in a day. In other words a gross diurnal curve composed of the temperature readings at 8, 16 and 24 hours was graded, or scored as typical, less typical or irregular. The procedure was repeated in regard to each local standard time, irrespective of the actual time zone the subject belonged to, and the local time zone in which the highest score was achieved was illustrated with respective grade marks of ⊙, ○ and ×. Therefore the curve connecting these marks may disclose all-round information including the above mentioned morning rise and evening fall.

During different seasons of the year diurnal rhythm of body temperature was determined on subject T to relate the rhythm to time of sunrise and sunset. Averages of 6 days in June-July period and of 5 days in December-January period are given in Fig. 2. The first determination of temperature before sun-

* Aided in part by NIH Grant.

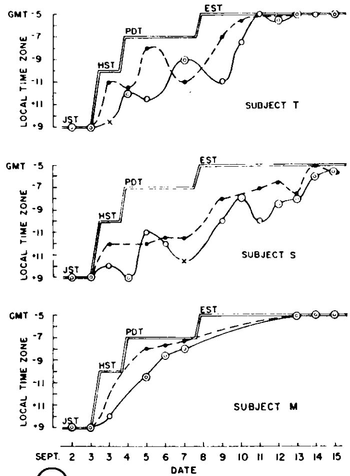
† Dept. of Physiology, Inst. of Constitutional Medicine, Kumamoto Univ., Kumamoto, Japan.

rise was made at least 30 minutes after getting up. The time course of body temperature in both seasons during the day and evening was identical. The difference in the time of sunset, amounting up to 2½ hours, had no effect. Body temperature in winter rose suddenly following sunrise, while in summer the level of temperature during the night hours was considerably higher and it rose gradually after sunrise.

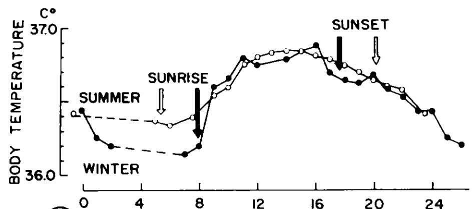
Discussion. In the previous paper(4) the author pointed out that the morning rise is an essential feature of the rhythm and subsequent changes in the temperature curves are often subject to casual influences. The data in Fig. 1 give additional proof that of the many features of diurnal pattern the time of morning rise shows least time lag and the best adjustment to a new local time, while the time of evening fall is easily affected by environmental, bodily and mental conditions.

In experiments of non-24-hour routines the rise following getting up is small and often absent, while the rise during the actual morning hours is dominant(3). This fact supports the presence of circadian rhythm(5) in man. The routine of life is not the one and only component of the "Zeitgeber"(6), which modifies and synchronizes the circadian rhythm to exact 24-hour rhythm, or in this case to a certain non-24-hour rhythm. Evidently environmental conditions such as light and darkness or alternation of day and night have more influence than bodily conditions such as activity and food intake.

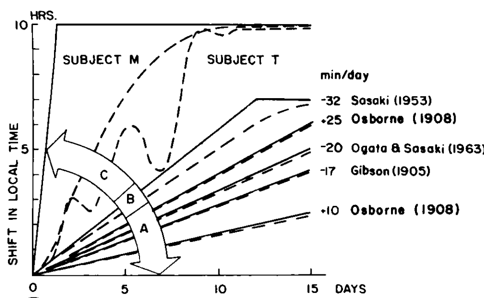
The results in Fig. 2 show that time of morning rise is not primarily related to time of sunrise and time of evening fall is not related to time of sunset. According to Miyazaki(7) both morning rise and evening fall in an old age group took place earlier than in the adult control. Observations by the Australian National Antarctic Research Expedition Team(8) showed that there was no relation to the hours of daylight. Therefore the information the body makes use of is not the time of day when some particular environmental events take place but the 24-



1



2



3

FIG. 1. Day-to-day shift of diurnal temperature pattern. ═ Local time zone of subject. --- Shift of time of morning rise. —— Shift of diurnal body temperature rhythm. ⊙ Typical diurnal pattern. ○ Less typical diurnal pattern. × Irregular diurnal pattern. GMT = Greenwich Mean Time.

FIG. 2. Diurnal body temperature rhythm in summer and winter with reference to time of sunrise and sunset.

FIG. 3. Schematic presentation of adjustment of diurnal body temperature rhythm to a new local time at different speeds of transposition. Group A: At low speed the diurnal pattern follows the local time change without delay. Group B: At medium speed the time course of diurnal pattern shows a slight tendency to lag behind the local time change. Group C: At high speed a considerable time lag is developed. —— Shift in local time. --- Shift in temperature pattern. + Westbound transposition. — Eastbound transposition.

hour periodicity determined by them. The combination of a circadian rhythm and "Zeitgebers" is established so firmly that it buffers changes and introduces a marked time lag in modification made by a shift of daily routine as a result of a change in local time.

Observations by previous investigators on the temperature rhythm during a voyage showed a satisfactory adjustment to day-to-day change of longitude, while the present observations revealed a time lag. The difference is accounted for a wide difference in the speed of transposition across the longitudes. Fig. 3 is a schematic representation of the relation of a change in local time to a shift of body temperature pattern. So long as the speed of transposition is slow enough(1,2,4) and the resulting change of actual length of a day is less than 25 minutes, the 2 curves coincide well (Group A in Fig. 3). An east-bound transpacific voyage at a faster speed which resulted in a reduction of a day by 32 minutes revealed that the diurnal rhythm could not follow the day-to-day change of local time (Group B in Fig. 3). A rapid trip leaves a great amount of time lag (Group C, Fig. 3). During the first few days the adjustment to the new local time took place slowly, then proceeded more rapidly. The rate of adjustment shown here is considered to be the upper limit man can attain. In the adult the average was 50 minutes per day in subject T and 39 minutes in subject S, while in the child the rate was much higher.

Summary. The diurnal pattern of body temperature was observed on 3 members of a family including a 6-year-old child for 2 weeks covering the period during and after an east-bound flight which resulted in an advance of daily routine as much as 10 hours. Adjustment of diurnal rhythm to a new local time was discussed with reference to the speed of transposition. With a rapid shift of local time zones the characteristics of the normal pattern were disturbed, but gradually approximated the new time pattern (approximately 40-50 minutes shift per day).

The author wishes to thank Dr. Loren D. Carlson for advice and support in this study.

1. Gibson, R. B., *Am. J. Med. Sci.*, 1905, v129, 1048.

2. Osborne, W. A., *J. Physiol.*, 1908, v36, 39 P.

3. Sasaki, T., *Bull. Res. Inst. Diath. Med.* (Kumamoto, Japan), 1953, v3, 262.

4. Ogata, K., Sasaki, T., *Jap. J. Physiol.*, 1963, v13, 84.

5. Halberg, F., *et al.*, Publ. No. 55, *Am. Assn. Adv. Sci.*, 1959, 803.

6. Aschoff, J., *Naturwiss.*, 1954, v41, 49.

7. Miyazaki, M., cited in (4).

8. Palmai, G., *Med. J. Austral.*, 1962, v2, 989.

Received December 4, 1963. P.S.E.B.M., 1964, v115.

A Simple Method of Obtaining Venous Blood from Small Laboratory Animals. (29134)

DAVID A. SORG AND BEVERLY BUCKNER (Introduced by Walter D. Block)
Caylor-Nickel Research Foundation, Bluffton, Ind.

Stone(1) reported a technique by which venous blood could be obtained from the orbital sinus in a mouse or rat. As described, the method required the puncture of the venous sinous behind the eyeball with a glass tube which had been drawn out to a capillary tip. It was originally suggested that the capillary end be introduced into the anterior angle of the eye and it was claimed that over 1 ml of blood could be obtained.

Although puncture made into the anterior angle will produce blood flow, nose bleeds and eye trauma frequently result. The authors find it far more satisfactory to use the posterior or outer canthus. Also, the use of standard microhematocrit capillary tubes further simplifies the technique.

With the method described below, repeated punctures can be made with a high degree of safety on rats, mice, guinea pigs, rabbits