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CIRCANNUAL ACTIVITY RHYTHM OF THE MONGOLIAN GERBIL, MERIONES UNGUICULATUS

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ABSTRACT - Activity rhythms of six male gerbils, Meriones unguiculatus, were monitored under continuous, dim illumination for 18 months. A circannual activity rhythm was obtained for all animals; the first minimum occurred in December-January, the second minimum in February, and the maximum in April. Individually, the animals had unique circannual periods with highs and lows being statistically significant. The results can be explained by both the external and internal hypotheses relating to biological clocks.

INTRODUCTION

"Clocks" timing biological rhythms may be defined ambiguously as that mysterious mechanism(s) used by organisms for timekeeping purposes. Although "clocks" have many periods each with various lengths, this paper emphasizes circannual in that its length is approximately one year. Only recently have circannual rhythms and clocks been included in cyclic studies. Its cognomen has changed over the years, from "circennial" (Farner, 1970) to "circannian" (Pengelley, 1967) to the present and most widely accepted expression "circannual."

The classical publications give little reference to the topic, (Bunning, 1973; Cold Spring Harbor, 1960; Harker, 1964; Aschoff, 1965; and Sollberger, 1965). A more recent symposium has one chapter on circannual rhythms (Menaker, 1971). Presently one can find entire symposia devoted to the topic, Circannual Clocks (Pengelley, 1974). It is obvious that interest in circannual rhythms is increasing as evidenced by the quantity of research papers being published.

A milestone in this area of study began with the historical works of Garner and Allard (1920) with plants and Rowan (1925) with birds. As with all rhythmic studies, the topics ran the gamut of research subjects. Seasonal activity rhythms have been reported in Kangaroo rats (Kenagy, 1976), fish (Andreasson and Muller, 1969), Wood mice (Gurness, 1974), and birds (McMillan et al., 1970). Berthold (1969) and Gwinner (1975) researched annual reproductive rhythms in birds. Hamilton (1962) reported circannual rhythms in bird migration, and Gronau and Schmidt-Koenig (1970) studied yearly fluctuations in pigeon homing.

Laboratory studies of circannual rhythms reflect properties similar to those of circadian rhythms. The potentially constant condition of the laboratory aids in elucidating the nature of the underlying timing mechanism. Such conditions were employed to study the circannual locomotor rhythms of squirrels (Mrosovsky et al., 1976) and birds (Pohl, 1971). Circannual frequencies of body weight and hibernation in squirrels were reported by David (1976) and Mrosovsky and Lang (1971). Long-term cycles of the reproductive system were found in crayfish (Jegla and Poulson, 1970), mice (Haus and Halberg, 1970), and monkeys (Michael and Bonsall, 1977). Brown and Park (1975) described an annual sensitivity to light in planarians, and Brock (1975) detailed growth and development cycles in cnidarians.

Circannual rhythms provide the organism with the adaptive advantage of anticipating future environmental situations and help synchronize the various, complex physiological processes occurring within the organism. It is hoped that this study furthers the knowledge of the properties of this phenomenon, and will alert other scientists, as circannual rhythms might affect the outcome of their research.

MATERIALS AND METHODS

Six, 6 week-old male Mongolian gerbils, *Meriones unguiculatus*, were housed singly in activity chambers which were pivoted on a knife blade. Partitions within th activity chamber forced the animal to walk around the outer edge (Boyer and Truchan, 1969). As movement occurred, the cage tipped causing a deflection of one of two micro-switches positioned under opposite corners of the cage. The micro-switches were wired to a 20 channel Esterline Angus recorder which continuously monitored the deflections and/or movements of the gerbils. Purina rat chow and water were replenished *ad libitum*, and any necessary maintenance was provided at random hours, every 5 to 10 days.

Data collection began 7 October 1975 and ceased 31

March, 1977. Three animals died within the last month of the experiment. The six activity chambers were placed in a circular fashion around a central, continuous dim light source of four, six-watt incandescent light bulbs. The intensity of the light at the center of the cage was 2.2 lux as measured by a Weston light meter (Model No. 703-60). Frequent replacement of the lamp bulbs prevented dimuation of the light intensity and bulb failures. The room was thermostatically controlled at 20 + 2°C; during experimentation, the temperature was registered continuously by a Taylor Thermograph Recorder (Model No. 2350). Any deviation in temperature was not seasonally correlated.

The approximate 66,000 gerbil-hours of data recorded by the Esterline Angus were quantified by measuring the percent of each hour that an animal was active. A value of 0 was assigned to indicate rest, and 10 was assigned to indicate 100 percent activity during any hour that activity was monitored. Via this method, mean hourly, daily, and monthly activity could be obtained for each gerbil and averaged for six gerbils. The strips from the event recorder were sectioned, so that consecutive days of data for one gerbil could be placed below one another to identify any overt activity pattern. The free-running period of each gerbil was calculated by noting the daily periods for an experimental animal which were averaged; and, a standard deviation was determined for the entire 18-month experiment. The daily period was measured from a clear, regular recurring point, either activity onset to activity onset or end-of-activity to end-of-activity. It is well known that animals which share a common room might mutually entrain each other by auditory and/or olfactory events. Such mutual entrainment was not noted by the author.

RESULTS

Figure 1 illustrates the circannual rhythms for the mean monthly activity for all gerbils, and the circannual cycle of two representative animals. (Nos. 1 and 5). The cyclic pattern is strong and consistent; there are distinct minima (L_1 and L_2) around December-January and January-February, and a maximum April-May on the summated curve.

Because each animal has its genetic history, no two cyclic patterns are identical. The first low point of activity (L_1) for Animal 1 (Fig.1) is in January and a second at (L_2) in December; its peak of activity occurs in May. Animal 5 shows the first minimum activity point during December-January and a second in February, over a year later; the maximum occurs in March.

The activity maximum of the summated curve was not

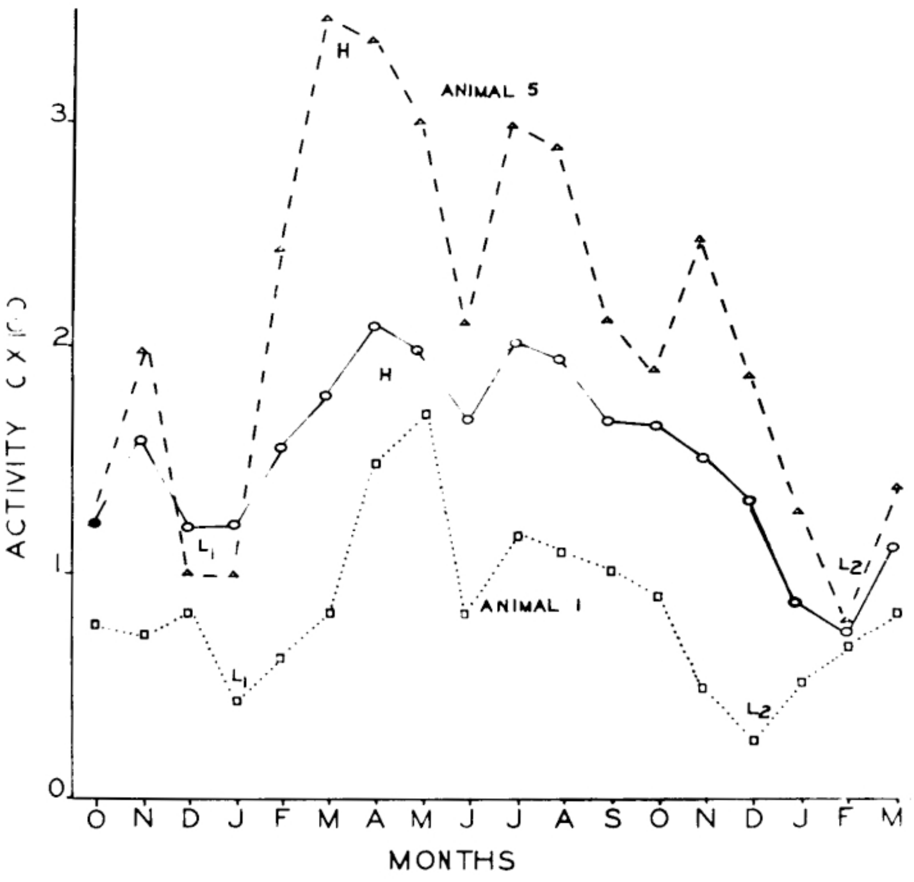

Figure 1. Circannual Rhythm of Activity of the Gerbil. The solid curve represents the composite of the monthly mean for six gerbils. The dot-curve and dashed-curve are the circannual rhythm of Animals 1 and 5 respectively. L_1- First minimum of activity; L_2- Second minimum of activity; H-Maximum of activity.

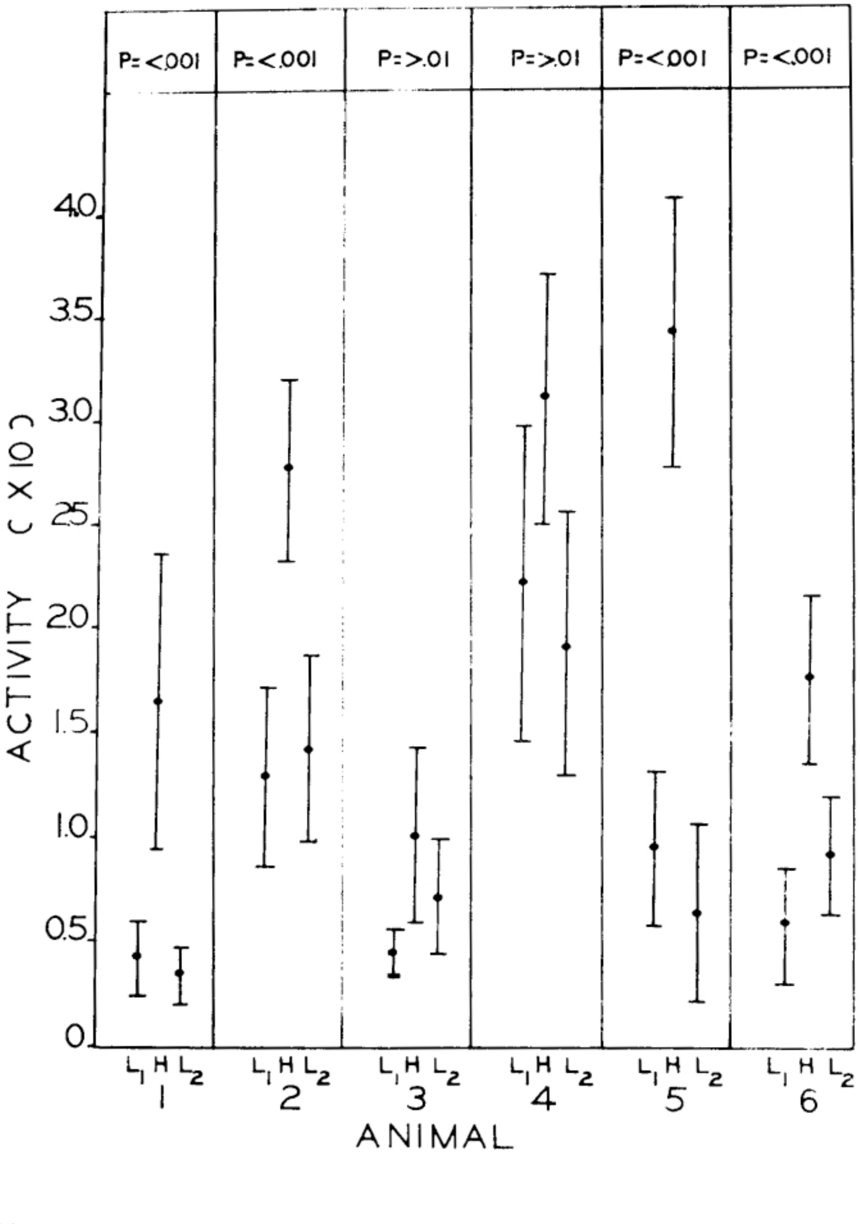

Figure 2. ± One standard deviation around the high and low activity months for six gerbils, each animal acting as its own control. Probability was determined by student's t test indicating statistical significance between high and low months.

statistically significant from the activity minimum. The amount of activity for any animal was quite different (Fig. 1); range occurred from 2% to 35% mean activity. Animals 1 and 5 are illustrated as examples; animals 2, 3, 4, and 6 fall on either side of these two representatives (Fig. 1).

Another common analytical method in periodic studies is for each experimental animal to act as its own control. This is demonstrated in Figure 2 which compares the lows of each circannual rhythm of a gerbil with its high. For all but two animals (Animals 3 and 4) are the valleys and peaks statistically different from each other.

The null hypothesis would assert that there is no difference between the high and low point of activity. The probability (P) of four of the animals was .001 (student's t test) which indicated that the difference between the high and low did not occur by chance; that is, there is a statistically significant circannual rhythm. The statistical description reinforces the strong visual impression.

Table 1 lists the free-running periods for all six gerbils and the recurring point from which it was calculated, either activity onset or end-of-activity. Each animal has a free-running period, which results from a lack of entrainment to a physical parameter, greater than 24-hours.

TABLE 1. The free-running period for the six experimental animals and the point of measurement.

Animal	Period (hr.)	Point of Measurement
1	24.42 ± 0.62	End of Activity
2	24.67 ± 0.92	Onset of Activity
3	24.50 ± 0.52	End of Activity
4	24.58 ± 1.17	End of Activity
5	24.67 ± 0.73	Onset of Activity
6	24.58 ± 0.63	End of Activity

DISCUSSION

According to Figures 1 and 2 an external expression of circannual rhythm of activity in the Mongolian gerbil. Evidenced is a peak around April-May and a low around December-January-February.

Criteria in determining circannual periods (Pengelley and Asmundson, 1974) include (1) the absence of synchroniation with any geophysical rhythm; (2) rhythm either longer or shorter than a year and at least a cycle and a half to demonstrate this criterion; and (3) a rhythm relatively independent of the ambient temperature.

Circannual activity rhythms found in mammals are not common. Mrosovsky et al. (1976) and Pengelley and Asmundson (1970) reported a circannual rhythm of circadian activity cycles in a golden mantled ground squirrel. Stutz (1973), studying seasonal differences in activity in the Mongolian gerbil, showed synodic monthly rhythms as indicative of a circannual rhythm. The data reported here, resulting from constant conditions, are supportive of the conclusion of cirrannual activity rhythms in the Mongolian gerbil.

There are two fundamental, theoretical views which attempt to explain biological rhythms, the endogenous and exogenous timing hypotheses. For an excellent and simplified survey the reader is directed to see Palmer (1976). Seasonal rhythms can be accounted for by the natural entrainment of a physiological process to the annual rhythms of photoperiod, temperature, barometric pressure, weather, etc. In addition, these environmental parameters may entrain some unknown, endogenous, circannual clock which would then control the physiological rhythm. Under the constant conditions of the laboratory the annual clock without entrainment seeks its natural frequency or assumes its circannual frequency. Goss (1969) clearly demonstrated the effect of photoperiod in entraining the antler replacement cycles in deer. Pengelley and Asmundson (1970) reported that blinded squirrels produce more accurately defined circannual rhythms than sighted animals, thus indicating the photoperiod influenced the circannual clock. The annual rhythms of moult, migratory restlessness, and reprodective capabilities in birds are modified by the photoperiod (Gwinner, 1973; Lewis, 1975). Conflicting data were obtained by Hammer (1971). In his experiments with birds, the photoperiod did not entrain a circannual rhythm since he could not demonstrate the presence of a circannual rhythm under his experimental conditions. Elliott (1976) has drawn opposite conclusions with mammals and has included a possible site for the circannual clock as the suprachiasmatic muclei and pineal gland.

The exogenous point of view, as proposed by Brown (1972), states that there is no such entity as a biological clock. The clock is found in the environment; therefore, its substance cannot be biological. Nevertheless, there are particular unknown, internal mechanisms which cue to the physical rhythms, and these physical rhythms permeate almost all experimental conditions. Thus, circannual rhythms are free-running rhythms because of an annual periodicity in sensitivity to the light or temperature and sensitivity rhythm (Brown and Park, 1975; Pohl, 1977). Most of the properties of rhythms can be incorporated into both schools of thought. Hopefully, the future will see a synchronization of the two clock theories.

The significance of annual rhythms cannot be underestimated. Many animals invest a great deal of energy in preparation for yearly reproductive, migratory, moulting, fat deposition, etc. behaviors. The seasonal clock enables the organism to anticipate changes in the environment. The endogenous clock would need to be synchronized to the ambient environment cycles. The presence of a timing mechanism would allow an organism to keep the proper time even though there may be a long, stormy, interim which would invert the photoperiod or a long, warm interval which would confuse the temperature cycle. Like any good chronometer, "noise" would not affect its time keeping properties (see Klein, 1974). In addition, an accurate timing mechanism may be used to determine the compass direction in the space-time continimuum. Time has arrived now to unwind the secrets of the timing mechanism. There are still too many mysteries within this ubiquitous phenomenon.

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