

polishing the surface. This second screw was passed from below, through an oblong of transite measuring $16 \times 14 \times \frac{1}{4}$ inches. The latter was threaded to hold three brass screws so arranged that the transite base could be leveled rapidly, and secondly threaded for four brass screws so that their filed points would contact with the circular disk noted at the four major compass points (fig. 1a, b). A rim of celluloid, three inches high, was placed

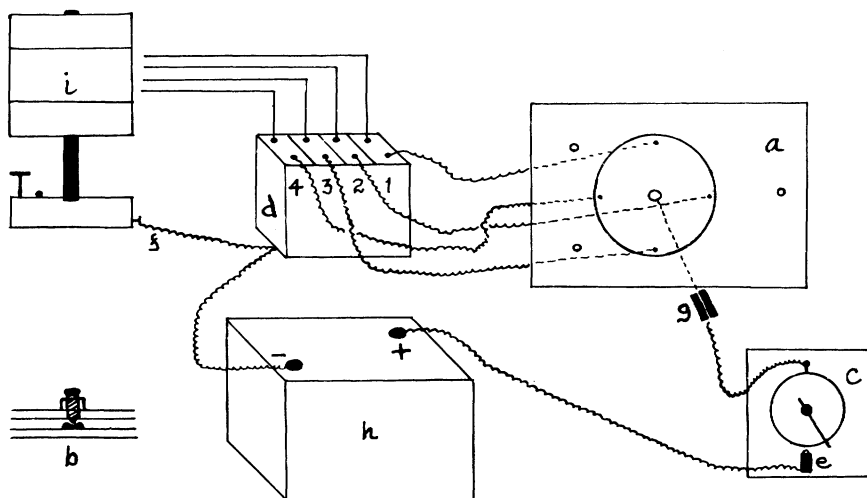


FIG. 1. Recording Apparatus for Measurement of Nocturnal Activity. *a*. Transite plate with three leveling screws, four peripheral contacts, and central contact on which is balanced a circular disk. *b*. Method of balancing circular disk on central contact. *c*. Electric clock. *d*. Model T Ford ignition coil. *e*. Mercury cup contact for sweep-second clock hand. *f*. Shorting wire from Kymograph back to coil. *g*. Fuse wires. *h*. Six volt storage battery (or transformer if using alternating current). *i*. Kymograph drum mounted on 24-hour Taylor clock-works.

against the raised rim of the disk to complete a container for the experimental animals. When in use the transite base was leveled rapidly and the container or disk balanced so that it just cleared the four screw points, or lightly rested on one of them. The plate when balanced could be deflected by a gentle breath and was sensitive to half a gram.

The central contact of the base, upon which the disk is balanced, was wired to an electric clock (fig. 1c), and the four peripheral contacts wired respectively to four vibrators of a Model T Ford coil (fig. 1d), each of which bears a sharpened iron wire. The terminals of this coil are wired to the negative pole of a six volt storage battery, and the positive pole of the latter is wired to a cup of mercury (fig. 1e) so placed that a copper wire or strip attached to the sweep-second hand of the clock passes through the mercury for a fraction of each minute. The use of the storage battery is especially desirable for field recording but in the laboratory a transformer was wired to the coil and alternating current used.

tively large, heavy, hardy forms which are both abundant and characteristic inhabitants of decaying logs, especially of the more mesophytic forest floors.

Results with Passalus cornutus

Individuals or colonies were taken from logs in a climax maple forest and their activity measured in the laboratory at once. They were then kept in fresh, moist log mold in the laboratory until needed for later experiments of the same kind to determine how resistant their activity cycle was to the change in habitat conditions.

The following table (table I) summarizes the results obtained in analysing activity cycles of solitary *Passalus cornutus*. The table is concerned only with the activity of single individuals for twenty-four consecutive hours, so that hunger and fatigue are minimized as much as possible. In part of the trials the cabinet was kept in the laboratory, and partly kept in a basement where the maximum summer fluctuation was only 3.3° C. Within the experimental cabinet the average temperature range was 2 degrees (22.6 to 24.6° C.), with a minimum 24 hour fluctuation of zero to a maximum of 3.5 degrees. The average rate of evaporation in the cabinet was 0.32 cc. per hour, with a minimum hourly rate of zero at saturation, to a maximum hourly rate of 0.44 cc. in other trials. The cabinet interior was in total darkness.

TABLE I. *Activity of single Passalus cornutus for 24 consecutive hours in total darkness*

Date of trial	Animal	Trial	Experiment started	Total Activity in hrs. for 24 hrs.	Night Activity (6 P.M.-6 A.M.) in hrs.	Day Activity (6 A.M.-6 P.M.) in hrs.
10-17-31	No. 1	1st	10:00 P.M.	8.83	6.33	2.50
10-27-31	No. 2	1st	4:00 P.M.	9.75	3.75	6.00
10-31-31	No. 3	1st	2:00 P.M.	6.50	4.50	2.00
5-31-32	No. 4	1st	3:00 P.M.	7.50	3.00	4.50
6- 4-32	No. 4	2d	8:45 A.M.	3.25	0.50	2.75
10-19-32	No. 5	1st	11:30 A.M.	11.25	4.50	6.75
11-10-32	No. 6	1st	10:10 A.M.	8.33	3.00	5.33
1- 9-33	No. 50	1st	9:00 A.M.	9.50	0.50	9.00
1-24-33	No. 50	2d	1:10 P.M.	15.00	7.00	8.00
1-26-33	No. 52	1st	10:00 A.M.	10.00	3.25	6.75
2- 2-33	No. 51	1st	9:05 A.M.	7.50	2.75	4.75
2- 8-33	No. 51	2d	10:30 A.M.	14.75	10.25	4.50
2-14-33	No. 50	3d	11:00 A.M.	22.00	12.00	10.00
9 individuals in 13 trials for a total of 312 animal experimental hours.						
Total hours active:		134.16	Twenty-four hour average: 10.32 hours			
Night hours active:		61.33	Nightly active average: 4.71 hours			
Day hours active:		72.83	Daily active average: 5.60 hours			

From this table we see that apparently time of year, time of start of trial, familiarity with apparatus as indicated by trial sequence, and interval spent in laboratory have little appreciable affect upon the character of the activity. As expected, some animals tended to give individualized behavior, as was indicated earlier for another beetle, *Patrobus longicornis* (Park and Keller '32).

The experimental conditions of darkness, constant moisture, temperature, etc., at least parallel the physical conditions obtaining in the natural log habitat. This is interesting in view of the chief conclusion reached, *e.g.* that *Passalus cornutus* has no definite rhythm or periodicity of activity. The daily activity is roughly 54 per cent, and the nightly activity is 46 per cent, of the total, and these averages are not applicable to all individuals. Therefore, in

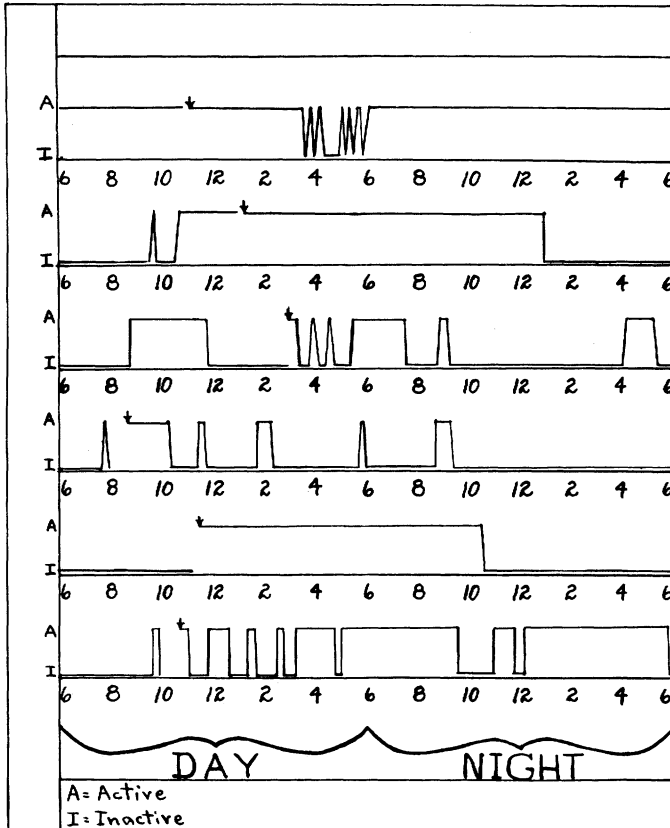


FIG. 2. Arrhythmic Activity of Individual *Passalus cornutus* in Total Darkness. Temperature, humidity and evaporation rate practically constant. Arrows indicate start of each trial.

addition to the Inherent and Environmental types of activity rhythms, defined previously, we are led to postulate a third, or Arrhythmic type. The following graphs (fig. 2) illustrate this third condition.

I find this arrhythmic condition in *Passalus cornutus* especially interesting, since the passalids in general are equipped with a body of social "instincts," live in colonies and care for their young (*cf.* account of Ohaus in Wheeler ('23); Miller ('32)). Further investigation may show that the social species of insects, *e.g.* the ants, etc. have less inherently fixed rhythms of ac-

tivity than the solitary species. This has been indicated previously for ants (Park, Lockett and Myers, '31; Flint, '14), where individuals were apparently never all active at the same time, and there was a general absence of species activity rhythm. If this is true, the social habit may be advanced either as a possible outcome of the arrhythmic condition, or as an underlying causal factor for the appearance of this aperiodicity.

On the other hand, the activity rhythm of a species may be wholly unrelated to the social matrix. If such is the case, this arrhythmic habit may be viewed as a loss or impairment of an original inherent activity rhythm through time, since all stages of the life cycle of *Passalus cornutus* are passed within the dark, stable log mold save when adults move from one log to another.

Results with Spirobolus marginatus

Turning to the millipedes, it was found earlier that under natural conditions, *e.g.* in the forest at night, they were nocturnal (Park, Lockett and

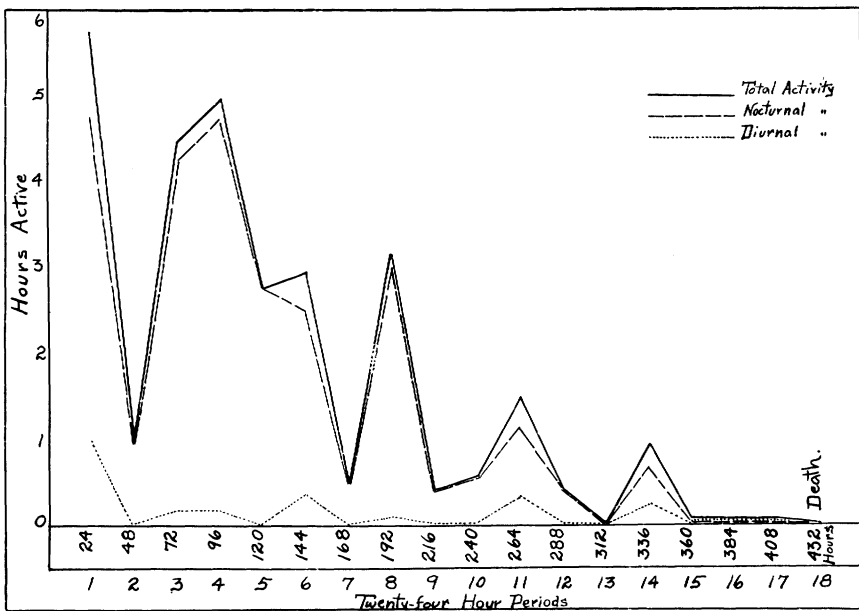


FIG. 3. Inherent Nocturnal Activity of *Spirobolus marginatus*. Showing relation of total, nocturnal, and diurnal activity in constant darkness, temperature and humidity to rhythm persistence, *vs.* starvation. Weight at start of experiment 1.50 grams; weight at death 0.86 grams. Note that for the first fifteen twenty-four hour periods the starving animal manifested 88 per cent of nocturnal activity as against 8.5 per cent of diurnal activity, and that the relative inactivity increased with increase of hunger and fatigue.

Myers, '31). The data taken on *Spirobolus marginatus* bear out these observations. Under the identical experimental conditions used in studying

Passalus cornutus, this species of millipede was rarely active by day and predominantly active at night. Therefore, *Spirobolus marginatus* has an inherent nocturnal rhythm.

After the innate nature of the rhythm had been established, individuals were allowed to remain in the experimental cage, without anything to eat or drink. As would be expected under such conditions, they lived from ten to eighteen days, with a gradual decrease in weight and activity. However, as shown by table II and figure 3, which summarizes a typical case, the general character of the rhythm did not change, the animals being preponderantly active at night.

TABLE III. *The effect of starvation upon the Inherent Nocturnal Activity of a Spirobolus marginatus until death (432 hours), under constant darkness, humidity, temperature and evaporation rate. Weight at start (3:00 P.M., June 28), 1.50 grams; Weight at death (3:00 P.M. to 10:15 P.M., July 16), 0.86 grams. (Hours="'; Minute="")*

Elapsed time in hours	Total activity per 24 hrs.	Night activity (6 P.M.-6 A.M.)	Day activity (6 A.M.-6 P.M.)
24	5' 45"	4' 45"	1' 00"
48	1' 00"	1' 00"	0 00"
72	4' 25"	4' 15"	0 10"
96	4' 55"	4' 45"	0 10"
120	2' 45"	2' 45"	0 00"
144	2' 50"	2' 30"	0 20"
168	0 30"	0 30"	0 00"
192	3' 10"	3' 05"	0 05"
216	0 25"	0 25"	0 00"
240	0 35"	0 35"	0 00"
264	1' 30"	1' 10"	0 20"
288	0 25"	0 25"	0 00"
312	0 00"	0 00"	0 00"
336	0 55"	0 40"	0 15"
360	0 05"	0 00"	0 05"
384	0 05"	0 00"	0 05"
408	0 05"	0 00"	0 05"
432	0 00"	0 00"	0 00"
Total Experimental Hours: 432			
Total Inactive Period: 402' 45"			
Total Active Period: 29' 15"			
Total Night Activity: 26' 10"			
Total Day Activity: 2' 35"			
(Including adjustment period of 30 min. activity at start of experiment).			

Thus in the experiment graphed, of a total of 432 hours spent in the dark experimental chamber, roughly 88% of the activity of the starving animal was at night, and 8.5% during the day. Hence we are led to believe that their innate activity is a deep-seated mechanism.

From this graph we also find that the general activity rises and falls, on the average reaching a maximum every second night, until the very end of the experiment when exhaustion made any but the smallest movements