RESULTS
(a) **Pattern of locomotor activity rhythm in normal day and night conditions**

The scorpion, *Heterometrus fulvipes*, has a clear cut rhythm of locomotor activity under natural conditions of day and night. The figures 1, 2, 3 and 4 (Plate 1) show that the active phase of the locomotor activity rhythm appears between 5 and 6 P.M. and from then onwards the activity is spread over 10 to 12 hours indicating that the scorpion is truly nocturnal. The activity, though almost continuous, is not uniform throughout the active period and the peak of activity in majority of the cases appears one or two hours after the commencement of the active phase. This single active period always alternates with an inactive period and hence *Heterometrus fulvipes* is truly monophasic without many short periods of activity within a cycle of 24 hours. A few movements can be perceived during the inactive or quiescent period but these are not consistent.

The onset of activity in the scorpion coincides with the transition period from light to darkness and intense activity is confined to the first one half of the dark period of the night during which period the peak activity occurs at about 8.00 P.M. The onset of activity does not occur at the same hour each day; the variation may be spontaneous, influenced by the natural variation of the phasing factors, or dependent on the activity of the previous day.

The activity records shown in Figs. 1, 2, 3 and 4 and some
PLATE I

Legend for Figures 1 - 4.

Analysis of actograph records showing the locomotor activity rhythm of the scorpion, H. fulvipes, under natural day and night conditions.

The vertical scale represents the number of flicks per hour. The dates represent the days on which the recordings were made.

Zero hour, at the middle of the horizontal scale, represents the midnight.
of the records obtained from scorpions maintained under laboratory conditions for more than three months speak to the effect that the rhythms of locomotor activity persist for more than three months in the laboratory, of course, when exposed to natural day and night variations in the experimental chamber.

**Rhythm of locomotor activity in constant darkness with all the other natural periodic variables uncontrolled (Plate II, Figs. 5 to 8)**

As is obvious from a comparison of plates I and II there is a marked decrease in the total activity of the organism under conditions of constant darkness, but the pattern of the rhythm remains the same. It has been recorded for more than a month and the rhythm is persistent in constant darkness suggesting that the rhythm may persist indefinitely.

The phasing of the time of onset of activity with reference to the time of the day is not in any way different from that in natural conditions, suggesting that the light or the waning of light is not the only phasing factor. Perhaps the other variables in nature, viz., temperature, pressure, humidity etc., also are effective in setting the phase of the rhythm of locomotor activity.

The decrease in the locomotor activity in constant darkness is clear in two ways. First, there is a decrease in the total activity. Secondly the period of activity is very much
Analysis of actograph records showing the locomotor activity rhythm of the scorpion, *H. fulvipes*, in continuous darkness with other periodic variables following the natural periodicity.

The other details same as in Plate I.
reduced and the activity here lasts for about 6 hours from the
time of onseti; Thus the active period is confined to the first
half of the night (i.e. from 6.00 P.M. to 12 mid-night).

The phase shift, occurring every day in all the circadian
rhythms when subjected to constant conditions, is not evident
here, probably because factors other than light also are effi-
cient in setting the phase of the rhythm. It is possible that
the variations in temperature, humidity etc., associated with
the transition from day to night substitute for the light
variations in setting the phase of the rhythm.

Another common feature between the activity under natural
condition of day and night and constant darkness is the appear-
rance of a few movements during the inactive period. The sig-
nificance of these movements is not clear.

Diurnal rhythm of locomotor activity in constant light with
other variables following the natural periodicity (Plate III,
Figs. 9 to 12)

A study of the pattern of activity rhythm shown in figures
9 to 12 (Plate III) reveals no changes or differences from that
under natural conditions and constant darkness. But a shift
in the time of onset of activity and a marked difference in
the total activity are obvious.

The total activity is in general much greater under con-
ditions of constant light, striking a significant contrast
with that under constant darkness. The delay in the onset of
Analysis of actograph records showing the locomotor activity rhythm of the scorpion, *H. fulvipes* in continuous illumination with the other periodic variables following the natural periodicity.

Other details same as in Plate I.
active phase is about two to three hours. The active phase that normally starts by about 5 or 6.00 P.M. under natural conditions, now starts at about 7 or 8.00 P.M. The active period is not limited as under constant darkness but generally it lasts for about 12 hours or more.

Locomotor activity under controlled conditions of light : darkness 12:12 (Normal) (Plate IV, Figs. 13 to 16)

When the scorpion is subjected to light : dark cycles of 12:12 hours, keeping the temperature nearly constant \((30^\circ \text{C} \pm 1^\circ \text{C})\) the rhythm that appears is again normal and persistent. The activity appears immediately after the onset of darkness showing that a light-off stimulus initiates the activity. As long as the 24-hour cycle of light and darkness (12:12) continues there is a clear cut 24-hour rhythm with onset of active phase synchronized with the onset of darkness. Comparable with this response of the animals to the onset of darkness no conspicuous and significant response, is noticed to the onset of light period. However a close examination of the figures (Plate IV, Figs. 13 to 16) gives an indication of response in the form of negligible activity coinciding with the onset of light.

This fact that the onset of activity follows the disappearance of light and onset of darkness would perhaps mean that the light is a master synchronizer or phase setting factor in the absence of other variations.
Legend for the figures 13 - 16

Analysis of actograph records showing the locomotor activity of the scorpion, *H. fulvipes*, under controlled conditions of light : darkness::12:12 with a light period between 6.00 A.M. and 6.00 P.M.

Rest of the details same as in Plate I.
Locomotor activity rhythm under constant temperature (30°C ± 1°C) and (a) constant illumination and (b) continuous darkness

(a) The circadian nature of the rhythm is conspicuous under these constant conditions. As is obvious in the figures 17 to 20 of Plate V the rhythm is not exactly 24-hours but more than 24-hours with the active phase starting an hour or two later each day. Thus a lengthening of the period of the rhythm is demonstrated, which proves the circadian nature of the rhythm.

(b) Figures 21 to 24 representing the locomotor activity in continuous darkness and constant temperature also reveal the circadian nature of the rhythm. But here the period of the rhythm is shorter than 24 hours.

Studies on the reversal of the locomotor rhythm in the scorpion, Heterometrus fulvipes (Plate VI, Figs. 25 to 30)

When the scorpions are subjected to reversed conditions of light and darkness with a dark period extended over 12 hours from 6.00 A.M. to 6.00 P.M. alternating with 12 hours of light from 6.00 P.M. to 6.00 A.M. the reversal of the locomotor rhythm could be demonstrated. This reversal is not quick and sudden in synchrony with the reversed light conditions. Before the rhythm gets completely reversed and reaches the new steady state, in accordance with the new environmental conditions, it passes through a number of transients, taking about 6 to 7 days to reach the reversed steady state.
Legends for the figures 17 - 24

Figs. 17-20: Analysis of actograph records showing the locomotor activity rhythm of the scorpion, *H. fulvipes*, under constant illumination and temperature (30° ± 1°C). The daily shift in the onset of activity is indicated by the broken line.

Figs. 21-24: Analysis of actograph records showing the locomotor rhythm under continuous darkness and constant temperature (30°C ± 1°C). The broken line indicates the daily shift in the onset of active phase.

The other details same as in Plate I.
The transient approach is obvious (Figs. 25 to 30, Plate VI) from the period of the rhythm that is lengthening day by day. The period, until the phase of the rhythm is synchronized with the onset of darkness continues to be an hour or two longer than 24 hours. The reversed rhythm does not persist in constant darkness. The rhythm recorded after leaving the scorpions in continuous darkness for 10 days, exhibits the original pattern.

Locomotory rhythm under light-dark cycles of less than 24 hours

Light dark cycles of 12 hours, L:D: 6:6: As it appears from the figures 31, 32 and 33 of the plate VII, the scorpions do not seem to take up a 12-hour cycle of light and darkness. When the two 12-hour cycles of light and darkness are created within the 24-hours of the day with one dark period from 12 Noon to 6.00 P.M. and the other from 12 midnight to 6.00 A.M. the former does not initiate a phase of activity. The normal active phase of the rhythm that appears by about 6.00 P.M. now shows a tendency to appear later when the dark period is provided between 12 midnight and 6.00 A.M. The active period conforms to this dark period with the result, the rhythm continues to be monophasic though two periods of darkness are provided in 24-hours. Thus the phase setting is determined by the termination of the light period coinciding with the normal active period of the animals and not so much by the other light period during which the animals are normally inactive.
PLATE VII

Legends for the figures 31 - 36

Figs. 31 - 33: Analysis of actograph records showing the locomotor activity rhythm of the scorpion, *H. fulvipes* under light-dark cycles of 12 hours; viz., Light:Darkness::6:6 hours. The black bars alternating with white represent dark and light periods respectively.

Figs. 34 - 36: Locomotor activity under light-dark cycles of 18 hours; viz., 9 hours light:9 hours darkness. The black bars alternating with white represent the dark and light periods respectively.

Other details same as in Plate I.
Again it is demonstrated that the scorpions do not conform to an 18-hour cycle of light and darkness (Figs. 34 to 36; Plate VII). Those dark periods that fall a few hours on either side of the active period of the animals under normal conditions show the reinforcing effect on the old rhythm and initiate the activity. When the scorpions are brought back to continuous darkness the normal original rhythm appears undisturbed.

Effects of temperature on the locomotor activity rhythm

A comparison, of the figures 37, 38, 39 and 40 (Plate VIII) showing the locomotor activity rhythm at $20^\circ C \pm 1^\circ C$ with figures 21, 22, 23 and 24 (Plate V) showing the rhythm at $30^\circ C \pm 1^\circ C$, reveals that lowering the temperature by $10^\circ C$ does not affect the rhythm much. The period of the rhythm almost remains unaltered.
PLATE VIII

Legend for the figures 37 - 40

Analysis of actograph records of locomotor activity in *Heterometrus fulvipes* at 20°C ± 1°C in continuous darkness.

Other details same as in Plate I.
PLATE VIII

Fig 37

Fig 38

Fig 39

Fig 40

TIME OF DAY

ACTIVITY

ACTIVITY

ACTIVITY

ACTIVITY

FEMALE 7.12GMS

MALE 6.28GMS

FEMALE 5.45GMS

MALE 5.28GMS