CHAPTER- IV
INFLUENCE OF HAIR SENSILLA ON THE SPONTANEOUS AND CIRCADIAN NEURAL ACTIVITY

Circadian rhythms of activity in biological systems abound in nature, and the scorpions are no exception. In fact, the scorpions offer one of the best examples for this ubiquitous and fascinating phenomenon. These animals spend most of the daytime in their burrows or underneath the stones, and come out with the approach of dusk. They remain active during the early part of the dark hours, hunting their prey, before they return to their abodes during the later part of the night. This nocturnal habit of the scorpions is obviously of great significance for their own survival, since they can avoid some of their predators which are active during the day. Several species of birds, for instance, are known to feed on the scorpions (Lourenco and Dekeyser, 1976). The nocturnal habit of scorpions parallels the nocturnal habits of their prey.

Studies on locomotor and physiological rhythms have been reviewed in earlier pages (see introduction). The first analytical attempt made by Rao and Gopalakrishna Reddy (1966) in *H. fulvipes* defined the internal factors influencing the neural activity which in turn would regulate circadian rhythms in overt activity. From their experiments on spontaneous electrical activity of the ventral nerve cord with blood and cephalothoracic nerve mass (CTNM) extracts, they inferred that blood-borne neurohumoral
factors modulate circadian rhythms of activity in the heartbeat in *H. fulvipes*, Devarajulu Naidu and Padmanabha Naidu (1976) suggested that the diurnal rhythmicity in heartbeat could not due to differential effects of neurohormones on the acetylcholine-synthetic mechanism and energy-yielding processes and on the spontaneous activity in the cardiac ganglion. Following this, Vasantha et al.(1977) demonstrated differential effects of day time and night time CTNM extracts on the kinetic parameters of acetylcholinesterase activity in the ventral nerve cord of *H. fulvipes*, attributing the effects to neurohormones. The identity of these so-called neurohumoral factors has never been established, and no work has been done in *Buthus tamulus*.

Biological rhythms are regulated by a physiological mechanism encompassing three essential functional components, viz., receptor system, a clock system and an effector system. Receptor system is the link between the biological clock and the exogenous photoperiod or the Zeitgeber. Effector system is the link between the clock output and the observed biological event. Although a circadian rhythm in the CNS has been shown in *H. fulvipes* (Venkatachari and Muralikrishna Dass, 1968; Venkatachari, 1971), it has not so far been examined whether this rhythm is linked in any way to the sensory receptors, whether there is a rhythm in transmission between the receptors and the CNS, and whether the responses could be altered by blood-borne factors. Further, an antero-
posterior gradient in spontaneous activity in the ventral nerve cord was shown by Venkatachari (1968), and a postero-anterior gradient in the cardiac activity by Devarajulu Naidu (1974) in *H. fulvipes*. It is not known whether a circadian rhythm exists in this gradient as well.

In the light of the above literature on circadian rhythms in general, and on those in the scorpion in particular, an examination of neurophysiological rhythms in a greater detail has been taken up in the scorpion *Buthus tamulus* in the present study. Anatomical studies of the author on the long hair sensilla described in the earlier section in this thesis have prompted to take up this study also on circadian rhythmicity with special reference to the sensory hairs, using normal animals and those under sensory deprivation, and also examining the rhythm in the presence and after transaction of peripheral nerves. Recordings of electrical activity are presented in Plates 4.1 to 4.6, and the data of analysis of electrical activity in Tables 4.1-4.3 and Figures 4.1-4.3

RESULTS

SPONTANEOUS ACTIVITY GRADIENT

i) Normal scorpions

Spontaneous activity recorded from the ventral nerve cord at 20 h, when the overt activity of the scorpion is at the peak, consisted of high frequency firing of both large 'giant' fibres represented by action potentials of large amplitude, and the other fibres represented by action potentials of
Plate 4.1

Oscilloscopic recordings made at 20 h, showing the spontaneous activity from different segments of the intact ventral nerve cord (VNC). Note the presence of an antero-posterior gradient, with the highest activity between the 2\textsuperscript{nd} and 3\textsuperscript{rd} ganglion, and a decrease both anterior and posteriorwards from this segment.

SOG : Suboesophageal ganglion; 1G to 7G: Ganglia of the VNC.

Calibration : 1 cm = 0.1 sec.
Table 4.1

Analysis of spontaneous activity (No. of spikes /2 sec) in different segments of the ventral nerve cord (VNC) recorded at 20 h and 08 h showing the presence of an antero-posterior gradient. Values are mean ± SD of observations from 6 individual animals. Values in parentheses indicate percent change from control. All values are significant at $P<0.001$ except $a=P<0.01$ and $b=NS$ (Not significant).

<table>
<thead>
<tr>
<th>Segment</th>
<th>20 h</th>
<th>08 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOG-1G</td>
<td>180</td>
<td>83</td>
</tr>
<tr>
<td></td>
<td>±17</td>
<td>±12</td>
</tr>
<tr>
<td>1G-2G</td>
<td>226</td>
<td>105(^a)</td>
</tr>
<tr>
<td></td>
<td>±22</td>
<td>±13</td>
</tr>
<tr>
<td></td>
<td>(+25.55%)</td>
<td>(+26.51%)</td>
</tr>
<tr>
<td>2G-3G</td>
<td>294</td>
<td>175</td>
</tr>
<tr>
<td></td>
<td>±30</td>
<td>±20</td>
</tr>
<tr>
<td></td>
<td>(+30.08%)</td>
<td>(+107.62%)</td>
</tr>
<tr>
<td>3G-4G</td>
<td>172</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>±16</td>
<td>±11</td>
</tr>
<tr>
<td></td>
<td>(-41.49%)</td>
<td>(-72.48%)</td>
</tr>
<tr>
<td>4G-5G</td>
<td>165(^b)</td>
<td>51(^b)</td>
</tr>
<tr>
<td></td>
<td>±15</td>
<td>±8</td>
</tr>
<tr>
<td></td>
<td>(-4.07%)</td>
<td>(-15.00%)</td>
</tr>
<tr>
<td>5G-6G</td>
<td>159(^b)</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>±14</td>
<td>±2</td>
</tr>
<tr>
<td></td>
<td>(-3.64%)</td>
<td>(-78.43%)</td>
</tr>
<tr>
<td>6G-7G</td>
<td>96</td>
<td>8(^a)</td>
</tr>
<tr>
<td></td>
<td>±16</td>
<td>±1</td>
</tr>
<tr>
<td></td>
<td>(-39.62%)</td>
<td>(-27.27%)</td>
</tr>
</tbody>
</table>

SOG: Suboesophageal ganglion; 1G to 7G: Ganglia of the VNC.
Fig. 4.1

Histogram showing the anteroposterior gradient in spontaneous activity (No. of spikes/2 sec) the intact ventral nerve cord (VNC), at 20 h and 08 h. Note highest activity at 2G-3G and decreases on either side and higher activity at 20 h compared to that at 08 h. Values are mean ± SD of observation from 6 individual scorpions.

SOG : Suboesophageal ganglion; 1G to 7G: Ganglia of the VNC.

Fig. 4.2

Histogram showing the antero-posterior gradient in spontaneous activity (No. of spikes/2 sec) the intact ventral nerve cord (VNC), after deafferentation of trichobothria (B) as well as the sensory hairs (A), recorded at 20. Note the general decrease in activity compared to that in Fig. 1. Values are mean ± SD of observations from 6 individual scorpions.

SOG : Suboesophageal ganglion; 1G to 7G: Ganglia of the VNC.
different amplitudes. Recording the activity from interganglionic connectives, starting from the suboesophageal ganglion (SOG) up to the last abdominal (metasomatic) ganglion (7th ganglion), it was apparent that the activity was highest between the 2nd and 3rd ganglia, from where it decreased to a little extent anteriorwards up to the connectives between the SOG and 1st ganglion, and to a significant extent posteriorwards up to the connective between the 6th and 7th ganglia. This decrease was gradual both ways. Thus the spontaneous activity was high at the anterior end and low towards the posterior end. Higher activity was represented by an increased frequency of firing of all the fibres in general, and that of the large fibres in particular, while lower activity was represented by a decreased frequency of firing of all the fibres in general, and that of the large fibres in particular (Plate 4.1; Table 4.1; Fig.4.1). Thus a clear antero-posterior gradient was observed in spontaneous electrical activity in the VNC of Buthus tamulus.

The antero-posterior gradient was also obvious when the recordings were made from an intact VNC at 08 h, when the overt activity of the scorpion is at the lowest. The spontaneous activity at this time was represented by a lowered frequency of firing of all the fibres in general, and by a decrease or total absence of firing of the large fibres. Here again, the activity was highest in the connective between the 2nd and 3rd ganglia, decreasing from there both anterior- and posteriorwards. While the
Plate 4.2

Oscilloscopic recordings, made at 08 h, showing the spontaneous activity from different segments of the intact ventral nerve cord (VNC). Note the general decrease in activity in all the segments compared to that in Plate 3.1, and the persistence of anterior–posterior gradient.

SOG: Suboesophageal ganglion; 1G to 7G: Ganglia of the VNC.

Calibration: 1 cm = 0.1 sec.
Plate 4.3

Oscilloscopic recordings, made at 20 h, showing the spontaneous activity from different segments of the ventral nerve cord (VNC) with deafferentation of trichobothria. Note the general decrease in activity in all the segments compared to that in Plate 4.1, and the persistence of anterior–posterior gradient.

SOG : Suboesophageal ganglion; 1G to 7G: Ganglia of the VNC.

Calibration : 1 cm = 0.1 sec.
decrease was comparatively less anteriorwards, the activity was almost nil between the 5\textsuperscript{th} and 6\textsuperscript{th} ganglia and between the 6\textsuperscript{th} and 7\textsuperscript{th} ganglia (Plate 4.2; Table 4.1; Fig.4.1)

ii) Scorpions under sensory deprivation

In order to ascertain whether sensory receptors have any contribution to the gradient in spontaneous electrical activity in the VNC, the effects of selective blocking of either trichobothria or LHS were examined. These animals had the peripheral nerves intact, to ensure that the effects, if any, were due to blocking of sensory hairs only. The recordings were made at 20h.

In scorpions under deprivation of input from the trichobothria, the activity was still highest between the 2\textsuperscript{nd} and 3\textsuperscript{rd} ganglia, with decreases anteriorwards and posteriorwards. The general activity level in all segments was lower compared to that in the intact animals. Significant decrease was recorded between the SOG and 1\textsuperscript{st} ganglion. It was extremely low or nil in the connective between the 5\textsuperscript{th} and 6\textsuperscript{th} ganglia and between the 6\textsuperscript{th} and 7\textsuperscript{th} ganglia. Thus, despite a decrease in the level of activity in all the segments, the antero-posterior gradient in spontaneous activity still existed in the animals in which the trichobothria were blocked (Plate 4.3: Table 4.2; Fig.4.2).
Plate 4.4

Oscilloscopic recordings, made at 20 h, showing the spontaneous activity from different segments of the ventral nerve cord (VNC). With deafferentation of all the sensory hairs. Note the significant decrease in activity, especially in the posterior region, compared to that in Plate 4.1, and the persistence of anterior–posterior gradient.

SOG: Suboesophageal ganglion; 1G to 7G: Ganglia of the VNC.

Calibration: 1 cm = 0.1 sec.
Table 4.2
Analysis of spontaneous activity (No. of spikes /2 sec) in different segments of the ventral nerve cord (VNC), under deafferentation of trichobothria as well as sensory hairs respectively. The antero-posterior gradient persists. Values are mean ± SD of observations from 6 individual animals. Values in parentheses indicate percent change from control. All values are significant at P<0.001 except a=NS (Not significant).

<table>
<thead>
<tr>
<th></th>
<th>Trichobothria blocked</th>
<th>All hairs blocked</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOG-1G</td>
<td>73 ±10</td>
<td>29 ±5</td>
</tr>
<tr>
<td>1G-2G</td>
<td>119 ±12 (+63.01)</td>
<td>175 ±15 (+75.00)</td>
</tr>
<tr>
<td>2G-3G</td>
<td>148 ±13 (+24.36)</td>
<td>193 ±17 (+10.28)</td>
</tr>
<tr>
<td>3G-4G</td>
<td>141 ±11 (-4.72)</td>
<td>100 ±11 (-48.18)</td>
</tr>
<tr>
<td>4G-5G</td>
<td>137 ±10 (-2.83)</td>
<td>10 ±2 (-90.00)</td>
</tr>
<tr>
<td>5G-6G</td>
<td>12 ±3 (-91.24)</td>
<td></td>
</tr>
<tr>
<td>6G-7G</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SOG: Suboesophageal ganglion; 1G to 7G: Ganglia of the VNC.
A similar trend was noticed in scorpions in which sensory input from all the hairs was blocked. The spontaneous activity decreased further in all the segments, with extremely low activity between the SOG and 1st ganglion and between the 4th and 5th ganglia. The activity was nil between the 5th and 6th ganglia and between the 6th and 7th ganglia. Still, the antero-posterior gradient in terms of highest activity between the 2nd and 3rd ganglia with decrease anterior and posteriorwards was evident (Plate 4.4; Table 4.2; Fig. 4.2).

2. CIRCADIAN RHYTHM IN SPONTANEOUS ELECTRICAL ACTIVITY

i) Intact ventral nerve cord (VNC)

To examine the presence of circadian rhythm in spontaneous electrical activity in the CNS, the connective between the 2nd and 3rd ganglia was chosen, since this segment showed the highest level of spontaneous activity in the ventral nerve cord. Recording the activity at different times of the day-night cycle, it was noticed that the highest activity was present at 20 h. The activity was predominated by a high frequency firing of the giant fibres as well as the other fibres. From this time the activity gradually decreased at 0 h and 04 h, and the lowest activity was recorded at 08 h. As the activity decreased towards this minimum activity period, the large fibre firing declined gradually, and no large fibre firing was present at 08 h. Following this, the spontaneous activity gradually
Plate 4.5

Oscilloscopic recordings, showing the spontaneous activity in the connective between the 2\textsuperscript{nd} and 3\textsuperscript{rd} ganglia of the intact ventral nerve cord (VNC) at different times of the day. Note the maximum activity at 20 h and minimum at 08 h, with corresponding decrease and increase in between respectively.

Calibration: 1 cm = 0.1 sec.
Table 4.3

Analysis of spontaneous activity (No. of spikes /2 sec) in the ventral nerve cord (VNC) at different times of the day, showing the presence of a circadian rhythm, in the presence as well as after transaction of peripheral nerves. Values are mean ± SD of observations from 6 individual animals. Values in parentheses indicate percent change from control. All values are significant at P<0.001 except a=P<0.01 and b= NS (Not significant).

<table>
<thead>
<tr>
<th>Time of the day (hrs)</th>
<th>With PN</th>
<th>PN cut</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>303 ± 25</td>
<td>191 ± 18</td>
</tr>
<tr>
<td></td>
<td>(-24.42)</td>
<td>(-16.75)</td>
</tr>
<tr>
<td>4</td>
<td>229 ± 20</td>
<td>159 ± 16</td>
</tr>
<tr>
<td></td>
<td>(-5.67)</td>
<td>(-15.72)</td>
</tr>
<tr>
<td>8</td>
<td>216 ± 18</td>
<td>137 ± 14</td>
</tr>
<tr>
<td></td>
<td>(-46.75)</td>
<td>(-59.12)</td>
</tr>
<tr>
<td>12</td>
<td>95 ± 13</td>
<td>56 ± 6</td>
</tr>
<tr>
<td></td>
<td>(-35.32)</td>
<td>(-59.12)</td>
</tr>
<tr>
<td>16</td>
<td>143 ± 16</td>
<td>76 ± 8</td>
</tr>
<tr>
<td></td>
<td>(-2.83)</td>
<td>(+35.71)</td>
</tr>
<tr>
<td></td>
<td>179 ± 17</td>
<td>132 ± 14</td>
</tr>
<tr>
<td></td>
<td>(+25.17)</td>
<td>(+73.68)</td>
</tr>
</tbody>
</table>
Fig. 4.3

Graph showing the circadian rhythm in spontaneous activity (No. of spikes/2 sec) in the ventral nerve cord, recorded from the connective between 2nd and 3rd ganglia at different times of the day, in the presence as well as after transection of all the peripheral nerves. Note the general decrease in activity following transection of peripheral nerves, with the rhythm being persistent. Values are mean ± SD of observations from 6 individual scorpions.
Fig. 4.3

TIME OF THE DAY (Hrs)

NO. OF SPIKES/25 sec
Plate 4.6

Oscilloscopic recordings, showing the spontaneous activity in the connective between the 2nd and 3rd ganglia of the intact ventral nerve cord with all the peripheral nerves transected. Note the decrease in activity compared to that in Plate 4.5, with the circadian rhythm being persistent with the maximum activity at 20 h and minimum at 08 h.

Calibration : 1 cm = 0.1 sec.
increased at 12 h and 16 h, reaching the peak again at 20 h. Thus a typical circadian rhythm in spontaneous activity was recorded from the ventral nerve cord of *Buthus tamulus* (Plate 4.5; Table 4.3; Fig.4.3).

ii) VNC with peripheral nerves transected

In order to assess the contribution of peripheral input to the circadian rhythm in spontaneous electrical activity, the activity was recorded at different times of the day-night cycle, as done in the intact animal, after transection of all the peripheral nerves arising from the ventral nerve cord. The recordings showed that transection of the peripheral nerves causes a decrease in the spontaneous activity throughout the VNC. However, a circadian rhythm was still found to persist, with the peak at 20 h and nadir at 08 h with decreases and increases inbetween as in the intact VNC (Plate 4.6; Table 4.3; Fig.4.3).

**DISCUSSION**

In the previous chapter it was reported that external recordings made from the afferent fibres arising from the LHS do not show spontaneously active action potentials. The results in this chapter, however, clearly indicate that –

a) spontaneous electrical activity exists in the ventral nerve cord (VNC) and exhibits an antero-posterior gradient;

b) deprivation of sensory input leads to a general decrease in activity throughout the cord and does not affect the gradient;
c) a circadian rhythm in spontaneous electrical activity exists in the VNC;

d) transection of peripheral nerves does not change the nature of circadian rhythmicity although it causes a general decrease in spontaneous activity throughout the cord;

ANTERO-POSTERIOR GRADIENT IN SPONTANEOUS ACTIVITY OF THE VNC

From the characteristics such as a simple waveform, smooth contour, steep ascending and descending phases and short duration of the spontaneous impulses recorded from the VNC, it may be inferred that the discharges belonged to single neurons, and therefore they are presumably unit potentials. It is also possible that the endogenous activity of the cord is that of the interneurons rather than of the motor neurons, since the latter are normally segmental in distribution.

The present study revealed that the spontaneous activity of the VNC recorded at 20 h is highest between the 2nd and 3rd ganglia, from where it decreases anterionwards and posteriorwards (Plate 4.1; Table 4.1; Fig.4.1). This pattern differs in many respects from that obtained by Devarajulu Naidu (1974) on the gradient in spontaneous electrical activity recorded from the cardiac ganglion in the same scorpion, where he demonstrated a postero-anterior gradient in the burst amplitude, while finding an inconsistent trend in the burst frequency and burst
duration, with an antero-posterior gradient in the interburst interval. However, in keeping with the results of the present study, Venkatachari (1971) showed an antero-posterior gradient in the spontaneous activity of the VNS *Buthus tamulus*. It is interesting that within the same animal contrasting gradients should exist in parallel running systems, such as heart with its cardiac ganglion, and the ventral nerve cord. No plausible explanation for postero-anterior gradient in cardiac activity and in spontaneous activity of the cardiac ganglion was offered, excepting the indication that the point of origin of heartbeat was presumably located at the posterior end (Devarajulu Naidu, 1974). However, Venkatachari (1971) came up with a convincing explanation for the antero-posterior gradient in the VNC. He stated that although anatomical studies on the fibres in the posterior region, most of them are smaller in size and could be sensory. The percentage of smaller fibres was found to be less in the anterior half, which has a greater number of larger fibres that could be interneurons. The profusion of fibres is presumably the highest between the 2nd and 3rd ganglia, thereby contributing to the maximum level of spontaneous activity in this segment as observed in the present study. Electrophysiological studies on the VNC by Sanjeeva Reddy (1969) further confirmed that a major contribution to the posterior part of the cord is from the axons of the long hair sensilla, which are not spontaneously active. Thus the low level of spontaneity in the posterior
part of the cord inspite of the greater number of fibres may be due to a
greater percentage of sensory fibres. An antero-posterior gradient in
the spontaneous activity was also reported in the crayfish nerve cord
(Prosser, 1934).

The gradient in spontaneous activity in the VNC was also present
when the recordings were made at 08 h, although the general level of
activity was very low throughout the cord at this time (Plate 4.1; Table
4.1; Fig.4.1). This indicates that the antero-posterior gradient is an
inherent property of the ventral nerve cord, and is exhibited at all times
of the day, with necessary adjustments in the intersegmental levels of
activity which are appropriate to the time of the day.

Results of the present study on the gradient in spontaneous activity
of the VNC following deprivation of sensory input fall in line with the
above discussion. Deafferentation of either trichobothria, or long hair
sensilla, which are sensitive to air currents and mechanical stimulation
led to a decrease in spontaneous activity throughout the cord (Plate
4.1; Table 4.1; Fig.4.1).

The contribution of sensory input to the level of spontaneous activity
in the VNC was all the more conspicuous when sensory input from all
the hairs was blocked. This resulted in a significant reduction in the
level of spontaneous activity throughout the cord, reaching zero level in
the posteriormost segments. The probable regulatory role of these
hairs sensilla in maintaining the level of the spontaneous activity in the VNC is discussed in the earlier chapter (Page No.63). What is important, however, is the observation that the presence or absence of sensory input contributes to the overall level of spontaneous activity in the VNC, and the presence of an antero-posterior gradient seems to be an inherent character of the ventral nerve cord. The nature of the gradient does not get altered depending on the nature or the total presence/absence of sensory input.

CIRCADIAN RHYTHM IN SPONTANEOUS ELECTRICAL ACTIVITY

The present study also revealed the presence of a circadian rhythm in spontaneous electrical activity of the VNC of *Buthus tamulus* (Plate 4.5; Table 4.3; Fig.4.3). The rhythm was perceptible in terms of the overall activity, percentage of large fibre firing as well as the frequency of firing of other fibres. The rhythm was consistent, with the maximum at 20 h and minimum at 08 h, with corresponding decreases in between. The types of fibres showing spontaneity varied depending upon the time of the day, with the large fibre firing being greater during the higher activity period. Therefore, enhanced activity during the peak period of rhythm could be attributed to the recruitment of larger neurons and also of the other neurons which were probably silent at other times of the day. This increased activity of the nervous system due to the recruitment of larger neurons also reflect the increased excitatory state.
of the animal (Bullock and Horridge, 1965). The smaller units which were continuously firing during all times of the day may be to maintain the tonus of the body musculature (Prosser and Brown, 1961).

It is known that in the scorpion many of the activities like respiratory and locomotory activities are highest during the dusk, and are at the lowest level during the dawn (Gopalakrishna Reddy, 1966; Babu et al. 1988). These phases correspond to the existence of highest and lowest spontaneous electrical activity in the VNC as shown in the present study. The fact that many rhythmic phenomena in scorpions have a similar time course as that of the spontaneous electrical activity suggests that the rhythmicity in these activities flows from the rhythmicity in the central nervous system. In fact, it is evident from literature that short and long term rhythmic phenomena in many invertebrates are centrally determined through the rhythmicity in the central nervous system (Bullock and Horridge, 1965; Prosser and Brown, 1961).

The low level of spontaneous activity in the central nervous system could be correlated to sluggish activity of the animal during daytime. Maximum activity in the evening could be responsible for the increased locomotor activity and high sensitivity of the animals to the external stimuli. The innate drive of the animal coupled with appropriate environmental factors such as the light and temperature, becomes the
driving force for the animal to come out and hunt for its prey. This rhythmicity in various activities would flow from the central nervous system through the peripheral nervous system. The present study makes this point clear. In scorpions in which all the peripheral nerves were transected, there was a significant reduction in the spontaneous activity throughout the VNC. However, the rhythmicity was still persistent, with the highest activity at 20 h and the lowers as 08 h (Plate 4.6; Table 4.3; Fig.4.3). In a preliminary study, the results showed that recordings made from peripheral nerves cut distal to the segmental ganglion show a circadian rhythm of spontaneous activity with peak period of activity at 20.00 h. This means a parallel rhythmic activity also exists in the motor neurons as in the VNC. Thus the rhythmicity in spontaneous activity of the central neurons appears to an inherent property and the overall level of this activity at any given time of the day would also partly depend on the sensory input. Thus the level of locomotor and other activities of the animal are predominantly controlled by the level of central nervous activity, and this regulation is of survival value.

The results of the present study on different aspects of spontaneity make it quite clear that the hair sensilla have no role in the regulation of basic rhythmicity in the central nervous system, which obviously is endogenous in nature. This was evident a) from the persistence of
Append lveys

The I can also be employed to measure thin layer embedded in the radar volume defined interferometry technique (FDI) typhoon system associated precipitation and 3-dimensional wind field.
- front structure and related weather phenomena,
- meteor tail events and mesospheric wind and tides and diffusive coefficient,
- aspect sensitivity of backscatter and associated turbulence structure,
- ionospheric irregularities and soon.

Aspect sensitivity of backscatter studies of troposphere using VHF radars by Chu et al., [1990]; from stratosphere by Hocking et al., [1990]; from mesosphere by Adams et al., [1989]; in troposphere and stratosphere by Hooper and Thomas, [1995]; of Polar Mesosphere Summer Echoes from Poker Flat by Human and Balsley, [1998]; over Andenes and Norway by Czechowisky et al., [1998]; Palmer et al., [1998]; Woodman and Chu, [1989] with Chung Li VHF radar, MU radar by Tsuda et al., [1986]; tilted aspect sensitive scatterers in the lower atmosphere by Worthington et al., [1988]; using Indian MST radar by Jain et al., [1997]; multi layer structure of tropical tropopause using Indian MST radar by Jaya Rao et al., [1994]; VHF radar interferometric observations of lightning echoes by Rottger et al., [1995]; gravity waves generated by Thunderstorms by Rottger et al., [1981]; Thunderstorm out flows by Craig Coff, [1976]; wind shear observations in thunderstorm density currents by Hall et al., [1976]; Thunderstorm generated solitary waves by Doviak and Christie, [1989]; E-region irregularities by Chen et al., [1996]; Yamamoto et al., [1997]; equatorial