CHRONOBIOLOGY

The formal study of biological sequential rhythms, such as daily, tidal, weekly, seasonal, and annual rhythms, is called chronobiology. Or, It is the study of “ inbuilt time-keeping sense of organisms” (Biological clocks of animals. Coined from Greek word: Chrono-related to time, Biology-Science of life; F. Hallberg- Beginning of 20th Century).

Animals have evolved to restrict many of their behaviours such as, feeding, drinking, behaviours related to reproduction, locomotion etc., to specific temporal niches in response to a complex web of selective forces. Humans have also evolved to occupy a specific temporal niche; however, with advent of electricity and electrical lights about 130 years ago, humans have overcome their temporal constraint, although they have been through many significant biological consequences (Foster and Roenneberg, 2008; Roenneberg *et al.,* 2013).

**Components of Biological rhythms and biological clocks: Biological rhythms** are the external manifestations of animals which are regulated by the biological clocks. Animal activities and rhythms are directly related to environment frequencies. A **Biological** **rhythm** is a recurrent event that is characterized by its period, frequency, amplitude, and phase (Aschoff, 1981. Figure-).

The **period** is the length of time required to complete one cycle of the rhythm in question, for example, the length of time required to go from peak to peak or trough to trough.

**Frequency** is the number of completed cycles per unit of time (e.g., two cycles per day), and therefore it is reciprocal of the period.

**Amplitude** is the amount of change above and below the average value, i.e., the distance of the peak or trough from the average.

**The phase** is any specified, recognizable part or portion of cycle. E.g., the designated portion of the cycle showing an active feeding phase. It represents a point in the rhythm relative to some objective time point during the cycle. E.g., the phase of onset of the activity portion of a hamster’s activity-rest cycle corresponds closely with the onset of darkness under normal conditions. Therefore, phase relations among various biological rhythms can be described. E.g., the onset of low body temperature phase of a hamster’s daily body temperature cycle tightly corresponds with the onset of the sleep portion of the sleep-wake cycle (Randy J. Nelson and Lance J. Kriegsfeld, 2017).

**Importance of timings in Physiology and behavior:** Although timings have not been considered as important variables in the study of underlying mechanism of physiology and behavior, behavioural patterns such as learning, memory, sensation, perception, attention, and especially motivation vary markedly according to the time of the day or seasonally (Randy J. Nelson and Lance J. Kriegsfeld, 2017). According to the neurobiological perspective, an animal eats because its hunger circuits are activated by specific neurochemicals. However, the response of neural circuits underlying motivated behaviours varies at different times of day or seasons of the year. It’s becoming more and more apparent that disruptions of biological rhythms have pronounced negative impact on our mental and physical health, contributing to the etiology of a number of disease states including cancer, cardio-vascular disease, neural cell death, peptic ulcers, obesity, rheumatoid arthritis, bipolar disorder, depression, and schizophrenia (Golombek *et al.*, 2013). For most of people, there are relatively chronic disruptions to timings which include limited exposure to sunlight during day, use of artificial light at night and sleeping late, especially during weekends (Roenneberg *et al., 2013;* Dominoni *et al.,* 2016). Therefore, considering the negative impacts of modernization on mental and physical health, it is crucial to maintain the biological timings as much as possible in different fields of work for better outcome.

**Nature of biological rhythms:** Biological rhythm may be characterized by several specific properties:

1. It is temperature compensated: Whereas temperature changes alter the rate of most chemical reactions and cellular processes, biological rhythms are temperature-compensated.

2. Biological rhythms are generally unaffected by metabolic poisons or inhibitors that block biochemical pathways within cells.

3. The periods of biological rhythms occur with approximately the same frequency of one or more environmental features.

4. Biological rhythms are self-sustaining, maintaining approximately their normal cyclicity even in the absence of environmental cue.

5. It can be entrained to environmental cues: The self-sustaining pacemaker mechanisms may be set and adjusted according to input from the external environment.

**Exogenous versus endogenous control of Biological clocks:**

Since ancient times, some behavioral rhythms have been attributed to exogenous (outside the organism) factors. However, it is established that the endogenous (inside the organism) timing mechanisms mediate many of the observed rhythms in physiology and behavior.

How is it established whether a rhythm is the result of exogenous factors or an endogenous clock? Following convincing evidences exist:

1. Isolation experiments: The persistence of a biological rhythm in the absence of environmental cues provides compelling evidence that the rhythm in question is generated within the animal, and not driven by the environment. Whereas, if a biological rhythm disappears under constant conditions, then it is reasonable to suggest that some cyclic cue in the environment drives the biological rhythm (This logic was first applied in 1729 after an experiment done by French astronomer Jean Jacques d’Ortous de Mairan who did the following experiment).

**Tension-relaxation pattern of a Heliotropic plant:** When the plant was maintained in the total darkness of a cellar for several days, the plants continued to open and close in synchrony with the day-night cycle, suggesting that this rhythm has an endogenous, rather than an exogenous source. His report was the first recorded observation that biological rhythms can persist in the absence of environmental cues. (This observation was ignored over 100 years)

1. Augustin de Candolle (1832), a French botanist, expanded the observation of de Mairan’s experiment. He observed that, Mimosa (*Mimosa pudica*) leaf movements also continued in constant dark conditions, but like most other internally generated biological rhythms, these rhythms displayed slight to moderate deviations from 24 hours in period length in the absence of environmental cues.

Several other experiments followed after these, and now it is established that “the clocks driving physiology and behavior are inside the organism and, though often synchronized by the environment, are not driven by the environment.” Several evidences support this conclusion:

1. Animals maintained in constant conditions aboard a spacecraft orbiting far above the earth, far away from subtle geophysical cues, display biological rhythms with periods similar to those observed on earth.
2. Animals maintained in adjacent, but separate cages in the absence of environmental cues display biological rhythms with stable but slightly different periods, suggesting that they are not being driven by the same geophysical cues.
3. The period (and phase) of the biological rhythms of one individual can be transferred to another individual by means of tissue transplants.
4. The period (and phase) of the biological rhythms is heritable and depends on identified genes.

(Reference source: Randy J Nelson & Lance J Kriegsfeld, 2017)