Endocrine and Biological Rhythms

Endocrine rhythms define the biological rhythms in humans (and other animals). These rhythmic fluctuations can occur at random points in time or at regular time intervals. Throughout evolution, the various environmental cycles enforced the organisms to develop “programs” also known as endogenous rhythms. These rhythms can provide anticipatory responses to ongoing environmental changes.

Endogenous Rhythms

1. Circadian (daily) → most important
2. Circatidal (sea tide)
3. Circulunar (moon phase)
4. Circannual (annual)

Variables/factors called “zeitgebers” (=time giver/synchronizer):

1. Light intensity
2. Temperature
3. Food availability
4. Social interaction

Circadian rhythm

The circadian pacemaker in the body is not exactly 24 hours so it is reset daily by the zeitgeber.

Example: when light is shone during subjective day, its effect will be ineffective. However if shone during the onset of the night, the rhythm will be delayed. Conversely, light near the end of the night (premature light), advances the rhythm to keep with the change.

Under conditions of phase shifts in the zeitgeber (eg: air travel across multiple time zones), the interaction of the zeitgeber with the phase response curve will produce a series of transient shifts until a stable relationship between the zeitgeber and the phase response curve occurs.

The biological pacemaker is found in the **suprachiasmatic nuclei**. Its input is received via the retinohypothalamic tract. Additional connections exist to and from: the thalamus, hippocampus, septum and brainstem. Consequently, humoral and neuronal coupling exists (hypothalamo-hypophyseal), between the pacemaker and various physiologic activities.

Pineal gland contribution to circadian cycle

Melatonin produced at pineal gland and the enzymes that produce it, have oscillating levels → melatonin concentrations oscillates throughout the day. Indirect afferent signals are received from the suprachiasmatic nuclei (though Sympathetic Nervous System). Although the pineal gland has an endogenous pacemaker of itself, it is synchronized with the light:

- High light intensity: minimum melatonin production
- Low light intensity: maximum melatonin production

The connections between pineal gland and hypothalamus enable the endocrine rhythm to be synchronized to circadian rhythms. Therefore, melatonin concentration in plasma and its rate of synthesis is synchronized to circadian rhythm, which its synthesis is coupled with secretion (produced on-demand, according to the rhythm). This circadian rhythm can start to free-run in the absence of time cues (=changes in light intensity). The fluctuations between the minimum and maximum (range) concentrations of melatonin, reflect the length of the day (=photoperiod) as it changes throughout the year, thus conveying also information about seasonal changes (→ circannual rhythm).

Hormonal (Endocrine) Circadian Rhythms

1. **Cortisol**: Highest in the morning (wake up), lowest during onset of sleep. Fluctuations can be >100%. Complete reversal requires 1-3 weeks → low dependency on sleep cycles.
2. **Growth Hormone**: Large diurnal differences (100pg/ml → 800pg/ml), with close dependency on sleep cycles. During sleep, GH levels increase and decrease during wakeful state.
3. **Prolactin**: resembles the growth hormone cycle.
4. **Aldosterone**: Secretion is modified by postural changes. For lying-down subjects, it peaks at morning just before awakening, and lowers in the afternoon. It follows ACTH rhythm. Subjects that assume upright position and are active throughout the day, aldosterone secretion rapidly increases upon assuming upright position, peaks during the afternoon and declines in the evening (even if upright position is maintained).
5. **Testosterone**: Follows a low-amplitude circadian rhythm (no large diurnal differences). Lowest during the afternoon, gradually increasing during the night, with episodic bursts of secretion. Maximal values are reached at awakening.

Endocrine Circannual Rhythms

These rhythms mainly serve for synchronizing reproduction within species. In humans, identified regulatory changes with circannual rhythm are urinary electrolyte concentration, body temperature, cortisol plasma concentration and growth hormone concentration. Also changes can be reflected upon food availability → diet composition. The zeitgeber for circannual rhythms are temperature and photoperiod (length of day).

Free-run of endocrine rhythms

In absence of time cues (zeitgebers), free-run occurs, and individual circadian rhythms dissociate and run alone, categorized in 2 groups:

1. Active-like state: rhythms in cortisol conc., body temperature, K^+ excretion in urine, REM sleep.
2. Inactive-like state: GH conc., skin temperature, Ca^{2+} excretion, slow wave sleep episodes.

Clinical Implications on endogenous rhythms

1. Acute phase shift (jet lag)
2. Chronic phase shift (shift work)
3. Drug effectiveness on various parameters that are under endogenous rhythm control (eg: urinary excretion rates, BP, heart rate, etc)
4. Sensitivity to anesthetic agents
5. Disorders of circadian timekeeping (losing sense of time)
6. Delayed sleep phase insomnia
7. Psychiatric illnesses
8. Epilepsy

Links

Related articles

Sources

- Lecture Notes: Prof. MUDr. Jaroslav Pokorný DrSc.

Bibliography

- HALL, John E – GUYTON, Arthur Clifton. *Guyton and Hall Textbook of Medical Physiology.* 11. edition. Saunders/Elsevier, 2005. ISBN 0721602401.
- DESPOPOULOS, Agamnenon – SILBERNAGL, Stefan. *Color Atlas of Physiology.* 5. edition. Thieme, 2003. ISBN 3135450058.

Further reading