Biological Rhythms, Sleep, and Dreaming

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Rhythms of Waking and Sleeping

- Animals generate 24 hour cycles of wakefulness and sleep.
- Some animals generate endogenous circannual rhythms (yearly cycles).
  - Birds’ migration
  - Animals storing food for the winter.
Activity record of a flying squirrel kept in constant darkness

Thick lines: times of activity in a running wheel

Cycle is a bit less than 24 hr.
The biological clock: in the *suprachiasmatic nucleus* (SCN) – above the optic chiasm in the hypothalamus.

Lesions of SCN disrupt circadian rhythms.

SCNs removed from rats’ brains maintain the same cycles of electrical activity as in the intact animal.
There is greater metabolic activity in the SCN during the light phase (a) than the dark phase (b).
The SCN generates its own rhythms. However, special axons from the retina project to the SCN to reset the biological clock.
Mechanisms of the biological clock

• The SCN regulates waking and sleeping by controlling activity in other brain areas, especially the pineal gland.
  ▪ The pineal gland: above the brain stem.
  ▪ It secretes melatonin, which increases sleepiness.
• Melatonin secretion begins 2 to 3 hours before bedtime.

• If taken in the late afternoon, it can promote sleep.

• If you travel across time zones, it may help you adapt to the new day/night cycles.
Setting & resetting the biological clock

• The purpose of the circadian rhythm: to keep our internal workings in phase with the outside world.

• A zeitgeber (German for “time giver”) is any stimulus that resets the circadian rhythms.

• Light is the best zeitgeber, but exercise, noise, meals, and temperature are others.
Two classes of sleep:

**Slow-wave sleep (SWS)** — divided into four stages, characterized by slow-wave EEG activity

**Rapid-eye-movement sleep (REM)** — small amplitude, fast-EEG waves, no postural tension, and rapid eye movements
EEG recordings
• Alpha waves are present when one begins a state of relaxation. (Blue trace is EEG, red trace is eye movements, bottom black line marks seconds.)
Stage 1 sleep is when sleep has just begun.

- The EEG is dominated by irregular, jagged, low voltage waves.
- Brain activity begins to decline.
(c) Stage 2 sleep
Stage 3 and stage 4 make up slow wave sleep (SWS):

- EEG: slow, large amplitude waves.
- Slowing of heart rate, breathing rate, and EEG.
- Highly synchronized neuronal activity.
Rapid eye movement sleep (REM): periods of sleep with rapid eye movements.

Called “paradoxical sleep” because it is deep sleep in some ways, but light sleep in other ways.

- EEG waves are irregular, low-voltage and fast, like in alert wakefulness.
- But postural muscles are more relaxed than in other stages and a person is harder to awaken.
Stages of a night’s sleep
Analogy: Fast beta waves are like a sonogram of a room full of people carrying on multiple conversations. Slow delta waves are like a sonogram of all of those people singing together.
A typical night of young adult sleep:

• Sleep time: 7–8 hours

• 45–50% is stage 2 sleep, 20% is REM sleep

• Cycles: 90–110 minutes.

• Early cycles: stage 3 and 4 SWS; later cycles: more REM
A Typical Night of Sleep in a Young Adult

- Sleep onset
- First REM episode
- Sleep stages
- Final REM episode

**Hours of sleep**

*Biological Psychology 5e, Figure 14.13*
Early dreams are relatively short and are usually about events of the day. Later dreams are longer and less tied to reality.
REM sleep evolved in vertebrates:

• Nearly all land mammals show both REM and SWS.

• Birds also display both REM and SWS sleep
Amounts of Different Sleep States in Various Mammals

- Human
- Baboon
- Cat
- Cow
- Fox
- Squirrel monkey
- Rat
- Rabbit

**Biological Psychology 5e, Figure 14.15**
Mammals sleep more during infancy than in adulthood.

Infant sleep is characterized by:

• Shorter sleep cycles

• More REM sleep – 50%, which may provide essential stimulation to the developing nervous system
Dark periods: sleep

Babies don’t show stable sleep patterns until ~ 16 wks of age.
Human Sleep Patterns Change with Age

![Graph showing the change in sleep patterns with age from neonates to old age. The graph illustrates the decrease in REM sleep and increase in non-REM sleep throughout different age groups.](Image)

_Biological Psychology 5e, Figure 14.18_
As people age, total time asleep declines, and number of awakenings increases.

The most dramatic decline is the loss of time in stages 3 and 4.

• At age 60 only half as much time in stages 3 & 4 as at age 20 – by age 90 stages 3 and 4 have disappeared.
  ▪ That is when growth hormone is released, so wound healing decreases in older people.
Effects of **sleep deprivation** (the partial or total prevention of sleep):

- Increased irritability
- Difficulty in concentrating
- Periods of disorientation
- Impairs the immune system
Four functions of sleep:

1. Conserve energy
2. Avoid predators
3. Body restoration
4. Memory consolidation
Energy is conserved during sleep: muscular tension, heart rate, blood pressure, temperature, and rate of respiration are reduced.

Small animals sleep more than large ones, in correlation with their higher metabolic rate.
Fig. 9-17, p. 287

Much sleep per day
- Bat: 19.9 hr
- Armadillo: 18.5 hr
- Cat: 14.5 hr

Moderate amount of sleep per day
- Fox: 9.8 hr
- Rhesus monkey: 9.6 hr
- Rabbit: 8.4 hr
- Human: 8.0 hr

Little sleep, easily aroused
- Cow: 3.9 hr
- Sheep: 3.8 hr
- Goat: 3.8 hr
- Horse: 2.9 hr
Sleep helps animals avoid predators – they sleep during the part of the day when they are most vulnerable.

Sleep restores the body by replenishing metabolic requirements, such as proteins. Growth hormone is released only during SWS.
Biological Functions of Sleep

• Sleep also enhances learning and memory.
  ▪ Performance on a newly learned task is often better the next day after a good night’s sleep.

• There is increased brain activity during sleep, especially REM, in brain areas that were activated during learning.
  ▪ Activity also correlates with improvement in the task on the following day.
Biological Functions of Sleep

Explanations for effects of sleep on memory consolidation:

• Reduce interfering stimuli

• REM may actively consolidate the learned material.
Why Dreams?

• The activation-synthesis hypothesis: dreams begin with spontaneous activity in the pons, which activates many parts of the cortex.
  ▪ The cortex synthesizes a story from the pattern of activation.
  ▪ Normal sensory information cannot compete with the self-generated stimulation and hallucinations result.
• The pons activates the amygdala, giving the dream an emotional content.

• Because much of prefrontal cortex is inactive during PGO waves, memory of dreams is weak.
  ▪ Also explains sudden scene changes that occur in dreams.
Why Dreams?

- Since the brain is getting little information from the sense organs, images are generated without constraints or interference.

- Arousal cannot lead to action, because primary motor cortex and motor neurons in the spinal cord are suppressed.

- Activity in prefrontal cortex is suppressed, which impairs working memory during dreaming.
Why Dreams?

• Activity is high in the inferior parietal cortex, important for visual-spatial perception.
  ▪ Patients with damage there report problems with binding body sensations with vision and have no dreams.
  ▪ Activity is also high in areas outside of V1, explaining the visual imagery of dreams.
Why Dreams?

• Activity is high in the hypothalamus and amygdala, which accounts for the emotional and motivational content of dreams.

• Either internal or external stimulation activates parts of the parietal, occipital, and temporal cortex.

• Lack of sensory input from V1 and no criticism from the prefrontal cortex creates hallucinatory perceptions.
At least 4 neural systems control sleep and waking:

1. A *forebrain* system → SWS

2. A *reticular activating* system – activates the forebrain

3. A system in the pons → REM sleep

4. A *hypothalamic* system – affects the other three
Activation Area adjacent to LC: REM
**Slow Wave Sleep**: generated by the basal forebrain, which sends axons that release GABA to inhibit brain activity.

**Arousal**: The *reticular formation* in the brain stem, and a couple of other areas, activate the cortex.

Transmitters: acetylcholine, glutamate, norepinephrine
An area of the **pons** $\rightarrow$ REM sleep.

It also inhibits spinal motor neurons, thereby disabling the motor system during REM sleep.
This kitten is in SWS.

This kitten is in REM (muscles relaxed).

*Biological Psychology 5e, Figure 14.26*
The study of *narcolepsy* revealed a hypothalamic sleep center.

Narcolepsy sufferers:

- Have frequent sleep attacks and excessive daytime sleepiness.
- Do not go through SWS before REM.
- May show cataplexy – a sudden loss of muscle tone, leading to collapse.
Narcolepsy in Dogs

A narcoleptic dog becomes excited when offered a treat. He becomes wobbly, & finally falls down.

*Biological Psychology 5e, Figure 14.27*
Narcoleptic dogs have a mutant gene for a **hypocretin** receptor.

Hypocretin (also named orexin) normally prevents the transition from wakefulness directly into REM sleep.

Interfering with hypocretin signaling leads to narcolepsy.
Hypocretin neurons send axons to areas that control SWS, REM, and waking.
The hypothalamic hypocretin center may act as a switch, controlling wakefulness, SWS sleep, & REM sleep.
Degeneration of hypocretin neurons in humans with narcolepsy

(a) Normal

(b) Narcoleptic
Sleep paralysis: the brief inability to move just before falling asleep, or just after waking up.

It may be caused by the pons continuing to signal for muscle relaxation, even when awake.
Sleeping pills are not perfect – most increase GABA activity throughout the brain.

Continued use of sleeping pills:

- Makes them ineffective
- Changes sleep patterns that persist even when not taking the drug
- Can lead to drowsiness and memory gaps
• **Sleep apnea**: inability to breathe while sleeping.

• Consequences include sleepiness during the day, impaired attention, depression, and sometimes heart problems.

• Cognitive impairment can result from loss of neurons due to insufficient oxygen levels.

• Causes include, genetics, hormones, old age, obesity, and deterioration of the brain mechanisms that control breathing.
“Night terrors” are experiences of intense anxiety from which a person awakens screaming in terror.
  ▪ Usually occurs in NREM sleep: not a bad dream.

“Sleep talking” occurs during both REM and NREM sleep.

“Sleepwalking” runs in families, mostly occurs in young children, and occurs mostly in stage 3 or 4 sleep.
Summary

- Animals have internally generated rhythms of activity lasting ~ 24 hours.

- The suprachiasmatic nucleus (SCN) in the hypothalamus generates circadian rhythms for sleep & temperature.

- The SCN controls the body’s rhythms partly by controlling melatonin release from the pineal gland. Melatonin increases sleepiness.

- The biological clock can operate in constant light or constant dark. However, light can reset the clock by a branch of the optic nerve that goes to the SCN.
Summary

• During a cycle of 90 minutes, a sleeper goes through stages 1, 2, 3, and 4 and then returns through stages 3 and 2 to REM (rapid eye movement) sleep.

• Stages 3 and 4 and are characterized by slow, high amplitude EEG waves and release of growth hormone.

• REM has faster brain activity than other sleep stages and complete relaxation of postural muscles, irregular breathing and heart rate, and an increased probability of vivid dreams.
• Wakefulness is induced by the reticular formation and other areas, which send axons widely throughout the brain.

• Sleep is induced by the basal forebrain, which sends axons that release the inhibitory neurotransmitter GABA throughout the brain.

• REM is elicited by an area in the pons.
Summary

• Hypocretin neurons in the hypothalamus control transitions between SWS, REM, and waking.
  ▪ Loss of hypocretin neurons, or of hypocretin receptors, leads to narcolepsy, in which people or animals go directly from waking to REM sleep.

• Sleep is a mechanism that evolved to force us to save energy. It also helps to restore the brain and consolidate memories.
Implications for humanism

• What IS consciousness? Can a computer be conscious? Does it depend on certain chemical reactions?

• There was a report recently that a group appears to have created a living cell. (I don’t know any details.) This previously seemed impossible. Perhaps, if we understood consciousness better, we could restore it in those who are in a coma. Would that be a good thing?