Sleep and Biological Rhythms

Theories of Sleep Function

- **Restorative Hypothesis**
  - Sleep is a time to restore and repair the nervous system.
  - Sleep time might vary depending on how much restoration was necessary (e.g., after an active day vs a quiet day).

- **Adaptive Hypothesis**
  - Sleep has survival value beyond its restorative functions.
  - Sleep time of a species depends on safety & food acquisition issues.
  - E.g., predators (lions) & species that can hide (bats) sleep a lot.
  - Vulnerable animals (cattle) & those that need to spend hours feeding (elephants) sleep very little.
  - Need for safety & conservation of energy are more constant needs.

Sleep and Dreaming

Figure 15.1: Time Spent in Daily Sleep For Different Animals

- Built-in biological rhythms could encourage conservation of energy & safety at the times when food-seeking is inefficient and/or dangerous.
- **Circadian rhythms** timed to the day/night cycle would do so.

Rhythms of Waking and Sleep

- All animals produce **endogenous circadian rhythms**, internal mechanisms that operate on an approximately 24 hour cycle to regulate:
  - Wakefulness and sleep
  - Body temperature
  - Secretion of hormones
  - Many other biological processes

- Endogenous – generated from within. Rhythms continue even in the absence of all environmental cues about the day/night cycle.
Rhythms

Some animals generate:
- Circannual rhythms - operate on an annual or yearly cycle (e.g. migration, hibernation)
- Circalunar rhythms - e.g. menstrual cycle
- Shorter rhythms - e.g. ~90 minute cycle within sleep

Key Circadian Clock: Suprachiasmatic Nucleus of Hypothalamus (SCN)

- Light resets the SCN via direct connection from the retina: retinohypothalamic path.
- Comes from a special group of ganglion cells that have their own photopigment called melanopsin.
- These cells respond directly to light and do not require any input from the rods or cones.

In the absence of environmental cues, our circadian rhythms are “free-running” on a slightly more than 24 hr cycle (e.g. 24.5 hrs)
- Normally environmental cues “re-set” the clock & keep it to a 24 hr schedule. These cues are called “zeitgebers”
- Light is the primary one.
- Exercise, noise, meals, and temperature are others zeitgebers.
“Free-Running Rhythm”

Sleep hours of someone without environmental indicators of time (very similar to Fig. 9.1 of a squirrel’s rhythms without outside cues)

After 2 weeks w/o lighting cues his bedtime is ~10-11 hrs out of sync with the real world

On a lighter note:


Rhythms Depend on Their Clock

- **SCN lesions** disrupt activity, sleep, eating, & hormone rhythms.
- **SCN transplants** can change an animal’s natural biorhythm to that of donor.
- **SCN** very sensitive, very adaptive – this allows “re-setting” of our biological clock with the seasons, changes in time zones, etc.

Activity cycles (black) of rats before (top) and after (bottom) SCN lesions

- Retinal blindness can disturb resetting if it affects these ganglion cells
- Some blind individuals have “free-running rhythms” for this reason.
- But under normal conditions our internal clock itself is very resistant to disruption.

- The SCN regulates the **pineal gland**, an endocrine gland located posterior to the thalamus.
- The pineal gland secretes **melatonin**, a hormone that increases sleepiness.
Circadian Rhythm Problems

- Jet lag: mismatch between circadian rhythms & outside world due to crossing time zones.
- Sleepiness & impaired functioning during the day and sleeplessness at night until clock resynchronizes with new environment.
- Traveling west = "phase-delay", traveling east = "phase-advance". Phase delays are easier for your clock to adjust to.
- Shift-work sleep disorder, similarly, is related to trying to work when your circadian clock is telling you to sleep and trying to sleep when your SCN is telling you it is time to be awake.

Desynchronization of work cycle and circadian cycle correlated with accidents

Sleep Disorders

- Insomnia may have many causes, but sometimes is linked to abnormal circadian rhythms.
- Circadian phase delay - body temp decrease & sleepiness delayed - have trouble getting to sleep.
- Circadian phase advance - body temp drop & rise occurs early. Get sleepy early, wake up really early.

Owls vs Larks

- Expression of the related genes may change over the lifespan. The owl/lark difference is seen mostly in adolescence/early adulthood.

Polysomnogram

- EEG (electroencephalogram)
- EOG (electrooculogram)
- EMG (electromyogram)
- Sometimes additional measures
EEG

Beta waves or LVF desynchronized
- More rhythmical 10-12 cps

The deeper the sleep, the more neurons fire in rhythm with each other

Looks like beta waves of wakefulness

A Typical Night’s Sleep

Longest NREM
- Longest dreams
- ~90 minute cycles within sleep

Figure 15.6: Time Spent in Various Sleep Stages

- The sleeper returns through the stages in reverse order
  - Stage 1 is replaced by rapid eye movement (REM) sleep
  - If you sleep longer you’d have more cycles/more dreams

Non-REM Sleep (Stages 1-4) (80% of night)

- gradual decrease in movements, breathing, heart rate
- change in brain activity from little (low voltage) fast brain waves to big (high voltage) slow, rhythmical brain waves ("delta waves")
- hard to wake up
- sleep-thinking more common than dreaming
- Only rarely (10% of the time) will you report a dream

REM Sleep (20% of night)

- very active LVF irregular to waking
- rapid jerky eye movements
- total loss of tone in most muscles
- breathing, heart rate unpredictable
- 80-90% chance of vivid dream report
- erection; vaginal lubrication

- Most often missing REM → REM rebound

Reticular Activation System

Sends excitatory ACh, NE, and glutamate messages to all of forebrain. Other “stay awake” transmitters in parts of the hypothalamus are orexin and histamine (that’s why some ANTI-histamines make you sleepy)
Sleep and Dreaming

Figure 15.9: Brain Mechanisms of Sleep.

• Brain Structures of Sleep and Waking
• Sleep Controls
  • Adenosine accumulates in basal forebrain area & hyp. preoptic area during wakefulness, ultimately induces drowsiness, suppressing activity in wakefulness areas like RF & locus coeruleus.
  • Preoptic area and pons particularly important for sleep regulation

• During waking, the reticular formation arouses entire cortex. Sleep does not work this way.
• GABA & adenosine promote sleep, but in a more “region by region” fashion. So there are situations where part of the brain is asleep but not the entire brain.
• Drugs that increase effect of GABA (tranquilizers, sleeping pills, alcohol) can facilitate sleep. Drugs that block adenosine (caffeine) can prevent sleep.

NREM Sleep “Disorders”

• Tend to run in families
• Very common in kids. Most outgrow them- only a few adults continue to experience some episodes of NREM disorders.
• Sleep-walking (17% of kids (peaking at 8-12 yrs), 4% of adults)
  • Can be triggered by stress, sleep deprivation, alcohol or Ambien type drugs
  • Individual may engage in quite complex behaviors while sleepwalking
  • Part of brain asleep, part of brain awake
• Night terrors (8% of kids, mostly < 6 yrs)
• Bed-wetting

REM Sleep Disorders

• Much more rare than NREM problems
• Narcolepsy - REM sleep “attacks” with cataplexy (sudden loss of muscle tone), muscle paralysis, & hypnagogic hallucinations. Often triggered by emotion. May have mutation of a gene which in turn reduces orexin (a “stay awake” transmitter)
  • Animal Model of narcolepsy allows research
  Several meds can decrease sleep attacks of narcolepsy:
  • Stimulants like Ritalin or amphetamine or the somewhat safer Provigil (modafinil)
  • or by deepening sleep at night with Xyrem

REM Behavior Disorder

• REM behavior disorder - failure of the usual muscle paralysis mechanism of REM so the person can move during dreaming
• Unlike narcolepsy, REM behavior disorder usually occurs in older individuals
• May be associated brain damage/neurological disease like Parkinson’s disease
• May be triggered by drug use in some
• Treatment – medications that decrease REM

Other Sleep Problems

• Insomnia (over 60 varieties/causes)
  • Treatments:
    • Good sleep “hygiene” or rituals
    • OTC sleeping pills contain antihistamine (diphenhydramine)
    • or the dietary supplement melatonin
    • Prescription
      • Benzodiazepines: (Xanax, Dalmane, Halcion)
      • Non-benzodiazepines (Ambien, Lunesta, Sonata)
• Sleep Apnea
  • CPAP
  • Mouthpiece that adjusts jaw position
  • Tonsillectomy in kids