Basic definition of sleep

- Minimal movement
- Typical sleep posture
  - e.g., humans: lying down; bats: hanging upside down
- Reduced responsiveness to external stimulation
- Quick reversibility of reduced responsiveness with relatively intense stimulation
- Distinguishes sleep from other states like death, anesthesia, and coma
- Typical brain activity during sleep stages

Awake

Drowsy

Stage 1

Stage 2

Stage 3/4

REM (20% of sleep)

REM is similar to awake

<table>
<thead>
<tr>
<th>Awake</th>
<th>Drowsy</th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3/4</th>
<th>REM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low voltage, random, fast</td>
<td>Low to 12 cps, alpha waves</td>
<td>3 to 7 cps (theta waves)</td>
<td>12 to 14 cps, sleep spindles and K complexes</td>
<td>Slow waves</td>
<td>Rapid eye movements</td>
</tr>
</tbody>
</table>

NREM

cps: cycles per second (a.k.a. Hz)
Amount of movement

My movement during the night

---

## Daily sleep time in mammals

<table>
<thead>
<tr>
<th>Animal</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Giraffe</td>
<td>1.9</td>
</tr>
<tr>
<td>Roe deer</td>
<td>3.1</td>
</tr>
<tr>
<td>Asiatic Elephant</td>
<td>3.1</td>
</tr>
<tr>
<td>Pilot Whale</td>
<td>5.3</td>
</tr>
<tr>
<td>Human</td>
<td>8.0</td>
</tr>
<tr>
<td>Baboon</td>
<td>9.4</td>
</tr>
<tr>
<td>Domestic cat</td>
<td>12.5</td>
</tr>
<tr>
<td>Laboratory rat</td>
<td>13.0</td>
</tr>
<tr>
<td>Lion</td>
<td>13.5</td>
</tr>
<tr>
<td>Eastern Chipmunk</td>
<td>15.8</td>
</tr>
<tr>
<td>Little Brown Bat</td>
<td>19.9</td>
</tr>
</tbody>
</table>
Sleep in some non-humans

- Birds
  - Like mammals, have NREM (2.5 mins) and REM (9 sec) sleep periods
  - Can sleep while flying and swimming
- Marine mammals (e.g., dolphins, whales)
  - Put one brain hemisphere to sleep at a time

Circadian rhythms

- Biological clock; adjusts to environmental cues (e.g., light)
- Master clock: suprachiasmatic nucleus (SCN)
  - In hypothalamus, located just above the optic chiasm
  - Its internal rhythms (glucose use, electrical activity, etc.) approximate 24-hour cycles
  - SCN entrains peripheral clocks (cornea, liver, pituitary, lungs, kidneys, etc.)
- Melatonin (pineal gland): absent during daytime, onset in dim light

Circadian rhythms in humans

Mean 24.15
Median 24.20
Mode 24.18
STDEV 0.22

Young adults
(9 F, 54 M)
Age 20-41

Czeisler et al. (1999) Science
Wyatt et al. (1999) AJP
Wright et al. (2001) PNAS
Wright et al. (2006) J Cog Neuro
Gronfier et al. (2007) PNAS
Czeisler, Wright, Gronfier, Wyatt, Duffy (unpublished)
Sleep research at CU

- You can study sleep as an undergraduate!
- Integrative Physiology (iPhy) Department:
  - Ken Wright’s Sleep & Chronobiology Lab
    - [colorado.edu/intphys/research/sleep.html](http://colorado.edu/intphys/research/sleep.html)

Why do we sleep?

- 3 theories:
  - Restorative and Repair theory
  - Evolutionary theory
  - Information consolidation theory

Why do we sleep? (1/3)

- **Restorative and Repair theory**
  - Physiologically recovery (muscles, brain, etc.)
  - Promotes immune function
  - Increases in cell division and repair
Why do we sleep? (2/3)

- **Evolutionary theory**
  - Conserve/replenish energy
  - Reduced risk of predation: Earlier man would have been more vulnerable to predators if they slept during the day

Why do we sleep? (3/3)

- **Information consolidation theory**
  - The brain processes experiences and information that we learned during the day.
  - → Memory consolidation.
  - Improve synaptic connections/plasticity
  - “Sleep on it”

Sleep and memory

- Better memory after sleep vs. awake (Jenkins & Dallenback, 1924)
  - Interpretation: Sleep prevents retroactive interference (RI: new info interferes with old)
Sleep and memory

- Ekstrand (1972) (← CU Boulder!)
- Q: Is better memory after sleep due to greater retrograde facilitation by non-REM (no LTP, group A) or enhanced consolidation by REM (LTP, group B)?

<table>
<thead>
<tr>
<th>Study</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>non-REM</td>
<td>REM</td>
</tr>
</tbody>
</table>

Due to greater retrograde facilitation (Group A)

REM & Long-Term Memory

- REM induces Long-Term Potentiation (LTP)
- Non-REM blocks LTP
- The sequence of NREM and REM sleep is critical for memory consolidation
  - NREM is most particularly involved in procedural memory
  - REM is involved in declarative memory
  
  Rauchs et al. (2005)

Motor skill learning after sleep

Walker et al. (2005b)
**Synaptic homeostasis**

Connect and adjust weights!

Start!

Sleep deprivation

- Characterized by:
  - poor attention
  - decreased performance in tasks requiring executive functioning
  - increased memory errors
  - irritability
  - exhaustion
  - impaired immunity
  - increased stress
  - psychotic behaviors (e.g., hallucinations)


UC Berkeley Psych133 sleep outreach project by Evan Ehrenberg and Jesse VanFleet (taught by Matthew Walker)
**All-nighter = 4 beers**

![Graph showing attention lapses following one night sleep loss vs. alcohol intoxication](image)

**Fall-asleep car crashes on the highway**

- **Peak occurrence:** 7-8 AM

![Histogram of time of day of crashes](image)

**Sleep inertia vs. sleep deprivation**

- **Graph showing cognitive performance score over time of day and sleep deprivation.**

![Graph showing cognitive performance score over time of day and sleep deprivation](image)
Sleep disorders

• Insomnia
  • Many causes: drugs (including alcohol and abuse of sleep aids), stress, hormone shifts, recent exercise, poor sleep hygiene, and other medical conditions

• Narcolepsy
  • Genetic. Correlated with reduced presence of the protein Orexin.

Pharmacological sleep aids

• Diphenhydramine: OTC (e.g., Unisom)
  • Antihistamine (sedative)

• Zolpidem: (a.k.a. Ambien)
  • GABA<sub>A</sub> receptor agonist (where benzodiazepines bind): neural inhibition
  • Only helps initiate sleep (half-life=2–3 hours); many side-effects

What are dreams?

• Not well studied. We really don’t know much!

• Primarily occur during REM sleep (but also NREM)

• Consciousness without external input

• Activation-synthesis hypothesis (and AIM): brain activity during REM produces dreams

• Epiphenomenon? Have no adaptive function?
Many proposed functions of dreams

- Allow the repressed parts of the mind to be satisfied through fantasy.
- Freud: bad dreams help learn to gain control over emotions.
- Jung: may compensate for one-sided attitudes held in waking consciousness.
- Ferenczi: may communicate something that is not being said outright.
- Regulate mood.
- Hartmann: function like psychotherapy (integrate thoughts that may be dissociated during waking life)
- Griffin: act out unfulfilled emotional expectations in order to lower stress levels in mammals.
- Epiphenomenon: by-product of brain activity.
- ...
Incubation/Insight

- Problem solving in your dreams: sleep on it!
- Dijksterhuis's unconscious thought research
- Benzene ring structure (Friedrich August Kekulé)
- Periodic table layout (Dmitri Mendeleev)

Lucid dreaming

- Aware that you're dreaming. Active participation in dream events.
- PFC normally shuts down during REM, but activating it might allow recognition that you're dreaming
- Potential treatment for nightmares

Dreaming eases painful memories

- With REM sleep (Group A):
  - less amygdala activity, more PFC activity (vs. Group B)
- Dreaming helps us recover emotionally.

[bbc.co.uk/news/health-15862384]
How will you remember all of this?

- Get good sleep; turn down the lights as the evening progresses.
- Prevent retroactive interference in some other way, but don’t forget it’ll mess up your REM!

Learn more!

- Radiolab episode: radiolab.org/2007/may/24/
- Be a subject or research assistant in Ken Wright’s iPhy lab: colorado.edu/intphys/research/sleep.html