SLEEP

Dr. Steinmetz

OUTLINE

- Physiological and behavioral correlates of sleep
- Dreams
- Neural components of sleep/waking
- Circadian rhythms
- Theories of why we sleep
- The effects of sleep deprivation
- Sleep disturbances
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BEHAVIORAL CORRELATES OF SLEEP

- Quiescence
- Decreased perceptual awareness
- Poor recall of preceding conscious awareness
PHYSIOLOGICAL AND BEHAVIORAL SLEEP RESPONSES

• Rapid Eye Movement (REM) Sleep

• Non-REM Sleep

THE CYCLES OF EVERYDAY CONSCIOUSNESS

- Awake
- Sleep and dreaming
- Circadian rhythms
SLEEP LAB - SLEEP STUDY?

- Electroencephalogram (EEG) - brain activity
- Electromyogram (EMG) - muscle activity
- Electro-oculogram (EOG) - eye movement
**Sleep Cycles**

- Non-REM and REM cycle about every 90 min
- During first part of night, most sleep is slow-wave sleep (Stage 3-4 NREM)
- REM dominates by end of night

![Sleep Cycles Diagram](image)

**Stage 1 Non-REM Sleep**

- Light sleep
  - drift in and out of sleep
  - can be awakened easily
  - Often aren’t aware that were asleep once awakened
- Our eyes move very slowly and muscle activity slows
- Remain in this stage for about 10 minutes typically at the beginning of the night

![Stage 1 Non-REM Sleep Diagram](image)
**Stage 2 Non-REM Sleep**

- 50% of sleep cycle
- Body temp drops
- Breathing & heart rate evens out
- Are sleeping soundly, but may still claim to have never been asleep if awakened

- Eye movements stop and our brain waves become slower, with occasional bursts of rapid waves called sleep spindles

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**Stage 3 Non-REM Sleep**

- Delta waves begin to appear, interspersed with smaller, faster waves

  - If awakened, one does not adjust immediately and often feels groggy or disoriented

  - Together, Stages 3 & 4 are called “deep sleep” and make up “slow wave sleep”
STAGE 4 NON-REM SLEEP

- The brain produces delta waves almost exclusively
- Blood pressure falls, breathing slows, and body temperature drops
- No eye movement or muscle activity
- Essential for restoring energy, strengthening immune system, and prompting the body to release growth hormones
  - May not get to this stage if use sleeping medications!
- Dreams based on episodic memory

STAGE 5 REM (RAPID EYE MOVEMENT)

- Accounts for 20% of the sleep cycle
- Our breathing becomes more rapid, irregular, and shallow, our eyes jerk rapidly in various directions, and our limb muscles become temporarily paralyzed
- Vivid dreaming - less based on episodic memory
- 4-6 REM stages occur each night
# Physiological and Behavioral Sleep Responses

<table>
<thead>
<tr>
<th>Response</th>
<th>SWS</th>
<th>REM Sleep</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEG</td>
<td>High voltage slow</td>
<td>Low voltage fast</td>
</tr>
<tr>
<td>Heart rate</td>
<td>Slow, steady</td>
<td>Irregular</td>
</tr>
<tr>
<td>Respiration</td>
<td>Slow, drifting</td>
<td>Rapid shifts</td>
</tr>
<tr>
<td>Muscle tone</td>
<td>Tonus</td>
<td>Loss of tone</td>
</tr>
<tr>
<td>Dreams</td>
<td>20%</td>
<td>80%</td>
</tr>
<tr>
<td>Blood Pressure</td>
<td>Normal</td>
<td>Increased</td>
</tr>
<tr>
<td>Thermo-regulation</td>
<td>Normal</td>
<td>Suspended</td>
</tr>
</tbody>
</table>

![Diagram showing different states of sleep and their associated physiological responses](image)
THOUGHT QUESTION

- Why would it be harder to deprive someone of just NREM sleep than just REM sleep?

A GOOD NIGHT’S SLEEP
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MENTAL ACTIVITY IN SLEEP

- Mental activity continues during sleep
  - Dreams occur during SWS and REM sleep
  - REM sleep is accompanied by high levels of blood flow in the visual association cortex but low levels in the inferior frontal cortex
  - REM eye movements resemble those made when a person scans a visual image
NIGHT TERRORS

NIGHTMARES CAN OCCUR DURING STAGE 4 OF SWS

WHAT ARE THE MEANINGS OF DREAMS?
ELECTROPHYSIOLOGICAL SUBSTRATE OF DREAMS?

- PGO waves
  - Start in pons (P), move to lateral geniculate (G) and then occipital cortex (O). Each PGO wave is synchronized with an eye movement in REM sleep.

WHY DO WE DREAM?
DREAM THEORIES

- Activation-Synthesis: Hobson & McCarley
  - Brain’s attempt to make sense of random neural activity

- Clinico-Anatomical: Solms
  - Internal or external stimulation activates parietal, occipital and temporal cortex
  - No visual info
  - No prefrontal censorship
  - Develops into hallucinations

CAN DREAMING HELP WITH EPISODIC CONSOLIDATION?

- Dreams only contain fragments from a waking period
- Fosse (2003) study

  **Waking Experience:** "When I left Starbucks, we had so many leftover pastries and muffins to throw away or take home. I couldn’t decide which muffins to take and which to toss..."

  **Sleep mentation:** "My dad and I leave to go shopping. We go from room to room, store to store. One of the stores is filled with muffins, muffins, muffins from floor to ceiling, all different kinds. I can’t decide which one I want..."

- Info from pre-sleep experience combines with remote episodic and semantic memory material
**DREAMING AND EPISODIC MEMORY CONSOLIDATION**

- **NREM**
  - Episodic dreams
  - Cortisol is low
  - Areas involved in episodic memory retrieval active (such as hippocampus)
  - This reactivation may lead to better consolidation

- **REM**
  - Recombined dreams
  - Cortisol is high
  - Hippocampus activity is disrupted
  - REM may be more useful for insight, implicit memory, etc.

Payne and Nadel (2006)
DREAMS AND INSIGHT

- Have you ever been dreaming and woke up and figured something out?

Otto Loewi

"The night before Easter Sunday of that year I awoke, turned on the light, and jotted down a few notes on a tiny slip of paper. Then I fell asleep again. It occurred to me at 6 o'clock in the morning that during the night I had written down something most important, but I was unable to decipher the scrawl. The next night, at 3 o'clock, the idea returned. It was the design of an experiment to determine whether or not the hypothesis of chemical transmission that I had uttered 17 years ago was correct. I got up immediately, went to the laboratory, and performed a single experiment on a frog's heart according to the nocturnal design."
Friedrich August Kekulé von Stradonitz

"...I was sitting writing on my textbook, but the work did not progress; my thoughts were elsewhere. I turned my chair to the fire and dozed. Again the atoms were gamboling before my eyes. . . My mental eye, rendered more acute by the repeated visions of the kind, could now distinguish larger structures of manifold conformation; long rows sometimes more closely fitted together all twining and twisting in snake-like motion. But look! What was that? One of the snakes had seized hold of its own tail, and the form whirled mockingly before my eyes. As if by a flash of lightning I awoke; and this time also I spent the rest of the night in working out the consequences of the hypothesis."
Sleep and “Insight” in the lab

Insight Puzzle:
“Insight” is that don’t need to solve to the end - the correct answer will always be the second digit generated

Wagner et al., 2004
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THOUGHT QUESTION

- Why do we sleep?

WHY DO WE SLEEP?

- **Energy conservation?**
  - But, little difference in brain glucose use of sleeping and waking brains

- **Memory consolidation?**
  - Rideout et al., 1979, REM sleep deprivation reduces maze learning
  - Lucero, 1970, New learning enhances time in REM
MEMORY CONSOLIDATION

Reactivation of Hippocampal Ensemble Memories During Sleep
Matthew A. Wilson* and Bruce L. McNaughton

Simultaneous recordings were made from large ensembles of hippocampal "place cells" in three rats during spatial behavioral tasks and in slow-wave sleep preceding and following these behaviors. Cells that fired together when the animal occupied particular locations in the environment exhibited an increased tendency to fire together during subsequent sleep. . . . Science, 1994, 265(5172): 676-679.

WHY DO WE SLEEP?
- Restoration of function?
  - Protein production and growth hormone high during sleep
WHY DO WE SLEEP?  
MATURATIONAL BENEFITS?

Evolutional vestige?
- Did surviving animals sleep?
- Predators sleep more than prey
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THINGS THAT KEEP YOU AWAKE...

- Reticular formation
- Locus coeruleus (in pons)
- Thalamus (histimine; orexin)
RETICULAR FORMATION: PRODUCES CORTICAL ACTIVATION

- Widespread activating output of reticular formation
- Reticular formation
- Branches from sensory system

THINGS THAT KEEP YOU AWAKE...

- Reticular formation
- **Locus coeruleus** (in pons)
- Thalamus (histimine; orexin)
LOCUS COERULEUS
- Uses Norepinepherine as a neurotransmitter
- Stimulation of this area turns off REM sleep

http://www.youtube.com/watch?v=f4wl21AmBRO

THINGS THAT KEEP YOU AWAKE...
- Reticular formation
- Locus coeruleus (in pons)
- Thalamus (histimine; orexin)
THALAMUS

- Releases histamine – excitatory neurotransmitter
- Releases orexin – neurotransmitter - stimulates wakefulness

Why do anti-histamines make you drowsy?

THINGS THAT KEEP YOU AWAKE...

- Reticular formation
- Locus coeruleus (in pons)
- Thalamus (histimine; orexin)

How do we turn them off?
Table 9.1 Brain Structures for Arousal and Sleep

<table>
<thead>
<tr>
<th>Structure</th>
<th>Neurotransmitter(s) It Releases</th>
<th>Effects on Behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pontomesencephalon</td>
<td>Acetylcholine, glutamate</td>
<td>Increases cortical arousal</td>
</tr>
<tr>
<td>Locus coeruleus</td>
<td>Noradrenaline</td>
<td>Increases information storage during wakefulness; suppresses REM sleep</td>
</tr>
<tr>
<td>Basal forebrain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excitatory cells</td>
<td>Acetylcholine</td>
<td>Excites thalamus and cortex; increases learning, attention; shifts sleep from NREM to REM</td>
</tr>
<tr>
<td>Inhibitory cells</td>
<td>GABA</td>
<td>Inhibits thalamus and cortex</td>
</tr>
<tr>
<td>Hypothalamus (parts)</td>
<td>Histamine</td>
<td>Increases arousal</td>
</tr>
<tr>
<td>Dorsal raphe and pons</td>
<td>Serotonin</td>
<td>Maintains wakefulness</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Interrupts REM sleep</td>
</tr>
</tbody>
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CIRCADIAN RHYTHMS

- Circadian cycles (cycles over 24 hr period)
  - Circadian rhythm - endogenous or intrinsic rhythm

SUPRACHIASMATIC NUCLEUS (SCN)

- Area responsible for circadian cycle
- Neurons - electrical, metabolic, & biochemical cycles
  - Greater activity during the day
  - Monitors but doesn't directly control wakefulness
  - Releases hormones into blood stream
**Light and the SCN**
- Special ganglion cells from retina go directly to the SCN
- Branch of the optic nerve
- Respond to light even if rods and cones aren’t activated

**Thought Questions**
- Is it possible for the onset of light to reset the circadian rhythms of a blind person?
- Why would evolution have enabled blind mole rats to synchronize their SCN activity to light, even though they cannot see well enough to make any use of the light?
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SLEEP DISTURBANCES

- Narcolepsy
  - Irresistible sleep attacks
  - Last <15 min
  - Loss of muscle tone – Cataplexy
  - Hypnagogic hallucinations
    - Vivid images during drowsiness: Vision, hearing, smell may be involved
  - Genetic basis
NARCOLEPSY
EARLY REM ONSET

Narcoleptic Sleep Onset

10mm=1 second

<table>
<thead>
<tr>
<th>EEG</th>
<th>patient fully awake here.</th>
</tr>
</thead>
</table>

EEG:
Narcoleptics go directly from wake to REM sleep:
EEG typical of REM sleep (absence of spindles and high voltage slow activity).

EOG:
Rapid eye movement potentials in EOG tracings indicate REM sleep episodes fully established.

SLEEP DISTURBANCES

- Insomnia
  - Types:
    - onset insomnia-trouble falling asleep
    - maintenance insomnia-awaken frequently during the night
    - termination insomnia-wake up too early and cannot get back to sleep
  - Complaint - not a disorder
    - Symptom of many disorders (depression)
  - Self-perpetuating problem
  - Often a misperception
Sleep Disturbances

- Sleep Paralysis
  - Inability to move as going into/out of sleep
- Somnambulism: Moving sleeper
  - Unaware of behavior – but eyes open
  - Children and adolescents (40%)
  - Most likely to occur in 1st stage-four episode
- Sleep apnea – cessation of breathing
  - SIDS - alarms
  - Treatment: Maintain airway or surgery to remove tissue

Continuous Positive Air Pressure (CPAP)

- [http://www.putanendtosno ring.com/cpap.htm](http://www.putanendtosno ring.com/cpap.htm)
REM Behavior Disorder

- Not paralyzed and act out dreams
- Problem with pons inhibiting spinal cord neurons
- [http://www.youtube.com/watch?v=MU2KRBh1MOA&feature=related](http://www.youtube.com/watch?v=MU2KRBh1MOA&feature=related)

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SLEEP DEPRIVATION

Peter Tripp (awake 8.4 days):
- [http://www.youtube.com/watch?v=nSNRdvusmQs](http://www.youtube.com/watch?v=nSNRdvusmQs)

EFFECTS OF SLEEP DEPRIVATION

- **Short term (<60 Hrs)**
  - Enhanced anxiety
  - Irritability
  - Learning deficits
- **Task-dependent behavioral consequences**
  - Poor performance on vigilance tasks
- **Long term**
  - Modern record is 453 hour and 40 min – Robert McDonald
  - Personality dependent psychotic-like symptoms, e.g., hallucinations
- **Peter Tripp: 201 Hr**
  - Recovery in 13 hours
SLEEP DEPRIVATION STUDIES

- Human sleep deprivation studies indicate that sleep deprivation can impair cognitive function
  - Perceptual distortions and hallucinations
  - Impaired ability to concentrate
  - Death by sleep deprivation? Medieval records. Diseases - FFI.

- Animal studies indicate drastic health consequences of sleep deprivation
  - Rats that are forced to walk on rotating platform lose sleep
  - Sleep deprived rats exhibited increased eating and activity and eventually became ill and died

THE FAMILY THAT COULD NOT SLEEP BY D.T. MAX

- Fatal Familial Insomnia (FFI)
  - http://www.youtube.com/watch?v=nleTVVAEFn8
  - http://abcnews.go.com/Health/story?id=3675223&page=1
COMING UP…

- Study for Exam 3!