Sleep and Consciousness

Sleep and Dreaming
The Neural Basis of Consciousness
Sleep and Dreaming

- Consciousness is tough to study... but sleep is
  - *readily observable, consists of different levels of consciousness, and can be studied scientifically
- The purpose of sleep is unclear.
  - *Restorative Hypothesis: busier we are, more sleep we need
    - Species with higher metabolic rates typically spend more time in sleep
    - CSF circulates during sleep to remove toxins
- Adaptive Hypothesis
  - The amount of sleep depends on the availability of food and on safety considerations.
  - Vulnerable animals without shelter (cattle) and those that need to spend hours feeding (elephants) sleep very little.
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Figure 15.1: Time Spent in Daily Sleep for Different Animals

<table>
<thead>
<tr>
<th>Animal</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown bat</td>
<td>19.9 hr</td>
</tr>
<tr>
<td>Armadillo</td>
<td>17.4 hr</td>
</tr>
<tr>
<td>Cat</td>
<td>13.2 hr</td>
</tr>
<tr>
<td>Rhesus monkey</td>
<td>11.8 hr</td>
</tr>
<tr>
<td>Red fox</td>
<td>9.8 hr</td>
</tr>
<tr>
<td>Human</td>
<td>8.0 hr</td>
</tr>
<tr>
<td>African elephant</td>
<td>3.9 hr</td>
</tr>
<tr>
<td>Horse</td>
<td>2.5 hr</td>
</tr>
<tr>
<td>Kangaroo</td>
<td>1.5 hr</td>
</tr>
</tbody>
</table>

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Figure 15.2: The Suprachiasmatic Nucleus.

• Circadian rhythms
  • *Many industrial accidents occur between midnight & 4:00 a.m.
  • *Suprachiasmatic nucleus (SCN) is the main “clock”
  • Zeitgebers: environmental light based stimuli that regulate sleep/wake cycle *via the retinohypothalamic pathway
  • **Melatonin**, a sleep-inducing hormone released by pineal gland is *suppressed by light.
  • *Without light, our circadian rhythm tends to increase to 25 hours
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Figure 15.3: Sleep and Wake Periods During Isolation From Time Cues

• Rhythms During Waking and Sleeping
  • Ultradian rhythms are cycles that are shorter than a day
  • The basic rest and activity cycle is *90-100 minutes long
  • *The ‘after lunch’ siesta or break coincides with a natural ultradian rhythm rest period.

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Figure 15.4: *Retinal Ganglion Cells Containing *Melanopsin.

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Figure 15.5: Electroencephalogram and the Stages of Sleep

- Electroencephalogram (EEG) measurement
  - Awake: *Beta waves (alertness) and Alpha waves (relaxation)
  - Stage 1: *Theta waves
  - Stage 2: *Sleep spindles and K complexes
  - Stages 3 and 4 are slow wave sleep with delta waves

Figure 15.6: Time Spent in Various Sleep Stages During the Night

- The sleeper returns through the stages in reverse order, and then heads into REM sleep for the first time
- Thereafter the percentage of SWS declines with each subsequent cycle
- *Cycling through each series of stages takes about 90 minutes.
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Figure 15.7: Improvement in Learning Following Sleep.

- Functions of REM and Non-REM Sleep
  - REM Sleep
  - Activation-Synthesis Hypothesis
    - During REM sleep, forebrain integrates brainstem neural activity with information stored in memory
  - *REM sleep promotes childhood neural development
  - *REM also promotes maturation of higher brain centers
  - *REM also provides opportunities for memory consolidation
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• Functions of REM and Non-REM Sleep
  • Non-REM Sleep
    • Slow wave sleep responds to temperature
  • *Slow wave sleep may promote cerebral recovery
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Figure 15.8: Correlation of Slow-Wave and REM Sleep With Overnight Task Improvement.

- Sleep and Memory
  - REM sleep promotes memory via theta rhythms in the hippocampus
  - Both REM and slow wave sleep are needed for consolidation
  - The reverse learning hypothesis states that memories are purged during REM sleep.

SOURCE: Adapted with permission from Stickgold et al., “Sleep, Learning, and Dreams: Off-line Memory Reprocessing,” *Science*, 294, 1052–1057. © 2001 American Association for the Advancement of Science. Reprinted with permission from AAAS.
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Figure 15.9: Brain Mechanisms of Sleep.

• Brain Structures of Sleep and Waking
  • Sleep Controls
    • Adenosine accumulates in **basal forebrain area** and preoptic area during wakefulness, ultimately induces drowsiness
    • Preoptic area and pons particularly important for sleep regulation
Figure 15.10: Arousal Structures of Sleep and Waking

• Basal forebrain area
  • Inhibits arousal-producing neurons, inducing drowsiness and reduces EEG.

• Waking and Arousal
  • *Major pathway 1: PPT/LDT
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Figure 15.11: Firing Rates in Brain Stem Arousal Centers During Waking and Sleep

- Waking and Arousal
  - *The Ventromedial POA inhibits activity in Major Pathway 2: which includes the Tuberomammillary nucleus of the Hypothalamus, Locus coeruleus (NE) and raphé nucleus (S)*
  - These areas are active while awake, quiet during non-REM, silent during REM.
• Waking and Arousal
  • Arousing pathway
    • Lateral hypothalamus releases orexin (hypocretin) to prevent the brain from switching into sleep.

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Figure 15.13: PGO Waves, EEG Desynchrony, and Muscle Atonia

- Waking and Arousal
  - Pons: the source of PGO waves
    - Excitation travels from pons through lateral geniculate to occipital area
    - PGO waves trigger EEG desynchrony of REM
  - *The pons sends impulses to the magnocellular nucleus in the medulla to produce REM atonia (paralysis)
  - Disordered atonia is seen in cataplexy, a form of narcolepsy
Sleep Disorders

Figure 15.14: Effects of Disrupted Circadian Rhythm on Sleep.

- Insomnia
  - Inability to sleep or obtain quality sleep
  - Can shorten the lifespan and may contribute to obesity
  - *Triggers include stress, depression and using sleeping pills. It is more common in people with mental health issues.
- Drugs used in treatment can be addictive
- Circadian phase delay or advance
  - Desynchrony between body temperature and sleep period
Sleep Disorders

- **Sleepwalking**
  - Occurs during slow wave sleep
  - Can be triggered by stress, alcohol and sleep deprivation
  - Individual may engage in complex behavior while sleepwalking

- **REM Sleep Behavior Disorder**
  - Characterized by physical activity during REM sleep and can lead to injury
  - Often associated with a neurological disorder or a tumor
Sleep Disorders

Figure 15.15: Cataplexy in a Dog

• **Narcolepsy**
  - *Fall into REM sleep suddenly during waking hours*
  - *Cataplexy (a symptom) is when person has sudden experience of atonia - full body paralysis while fully awake.*
  - 85% have mutation of HLA-DQ6 gen, which reduces orexin
  - *Not unique to humans: some breeds of dogs are prone to it.*

SOURCE: Courtesy of Stanford University Center for Narcolepsy.
Sleep Disorders

• Sleep as a Form of Consciousness
  • Lucid dreamers are aware of when they are dreaming and in some cases can control the nature of the dream
  • The gradations of sleep lead us to confront the question of what defines consciousness
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Figure 15.17: Synchronized Activity Among Areas Involved in Learning.

• Awareness
  • Awareness of something specific is easier to study than pure awareness
  • Binding problem: how the brain combines information about an object
  • Synchronized 40-Hz activity between V1 and V5 in cats.

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Figure 15.18: Setup for Demonstrating the Cheshire Cat Effect

- **Attention**
  - How the brain allocates limited resources to focus on some inputs while excluding others.
  - **Cheshire cat effect**: Binocular rivalry example

- **Physiological process**
  - Changes in attention matched with changes in neural activity
  - Thalamus is a critical region
  - *Dorsal Attention network allows us to direct our attention (toward a goal or object)*
  - Also requires working memory and other brain areas
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- Sense of Self
  - Self recognition, sense of agency
  - *Body Image (my tongue, my hand, etc)
  - *Mirror neurons for social ‘understanding’
  - *Memory
    - A sense of self would likely be severely impaired by the loss of long term, but not necessarily short-term, memory.
    - Confabulation suggests the importance of memory to self identity
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Figure 15.20: (a) The Anterior Cingulate and (b) the Insula

- Sense of Self
  - Self recognition, sense of agency
- Body image
  - Anterior cingulate and Insula involved in sense of body image

SOURCE: (a) Courtesy of Heal Collection, University of Utah. (b) Reproduced with the permission of the Museum of neuroanatomy Tomas A Mascitti; Institute of Cognitive Neurology (INECO)
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Figure 15.21: Brain Areas Involved in the Sense of Agency

- **Sense of Self**
  - Self recognition, sense of agency
  - Anterior cingulate and Insula involved in sense of body image

SOURCE: From “Experiencing Oneself Vs. Another Person as Being the Cause of an Action: The Neural Correlates of the Experience of Agency,” by C. Farrer et al., *Neurolmage*, 15, 596–603, fig. 2 and fig. 3, p. 598. © 2002 with permission from Elsevier, Ltd.
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Figure 15.23: Different Intentions Distinguished by Mirror Neurons

- **Sense of Self**
  - Self, Theory of Mind, and Mirror Neurons
    - Mirror neurons (Ch14) responsible or social understanding
    - Understanding intentions of others (figure below)

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Figure 15.24: Split-Brain Patient Engaged in the Task Described in the Text.

• Disorders of Self
  • Split Brains
    • Surgical separation of the hemispheres
      Observe different aspects of consciousness
  • Brain interpreter
    • Likely located in the left hemisphere
    • Integrates all cognitive processes

SOURCE: Gazzaniga (2002). Based on an illustration by John W. Karpelou, BioMedical Illustrations.
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Figure 15.25: Chris Sizemore

• Dissociative Identity Disorder (DID)
  • (multiple personality disorder)
  • Shifts in consciousness and behavior suggesting distinct personalities
  • ‘Alters’ (distinct personalities) differ from one another in
    *skin conductance, cardiovascular measure, and EEG.
  • *90-95% report childhood abuse
  • May be a mechanism to cope with extreme stress
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Figure 15.26: Hippocampal Activity During the Switch Between Multiple Personalities

- **Dissociative Identity Disorder (DID)**
  - Increasing incidence raised questions of how many cases are “real”
  - Amnesia associated with DID may be state-dependent learning
  - MRI data suggest learning mechanisms may be involved

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Figure 15.27: Map of Event Related Potentials to Masked and Unmasked Visually Presented Words.

- Network Explanations
  - Theories require a widely distributed neuronal network
  - Theorized to be coordination of this network
  - Crick suggested claustrum is executive center or director of consciousness

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IN THE NEWS: Consciousness and the Dying Brain

• Near Death Experiences
  • 3% have experienced this state
  • Out of body experience

• Brain mechanisms
  • Widespread, synchronized brain activity
  • Similar to aroused brain

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Figure 15.28: Awareness and Arousal in Normal and Impaired Consciousness.

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APPLICATION: Determining Consciousness When It Counts

Conscious controls \((n = 110)\)

Vegetative state \((n = 33)\)

Locked-in syndrome \((n = 5)\)

Minimally conscious state \((n = 7)\)