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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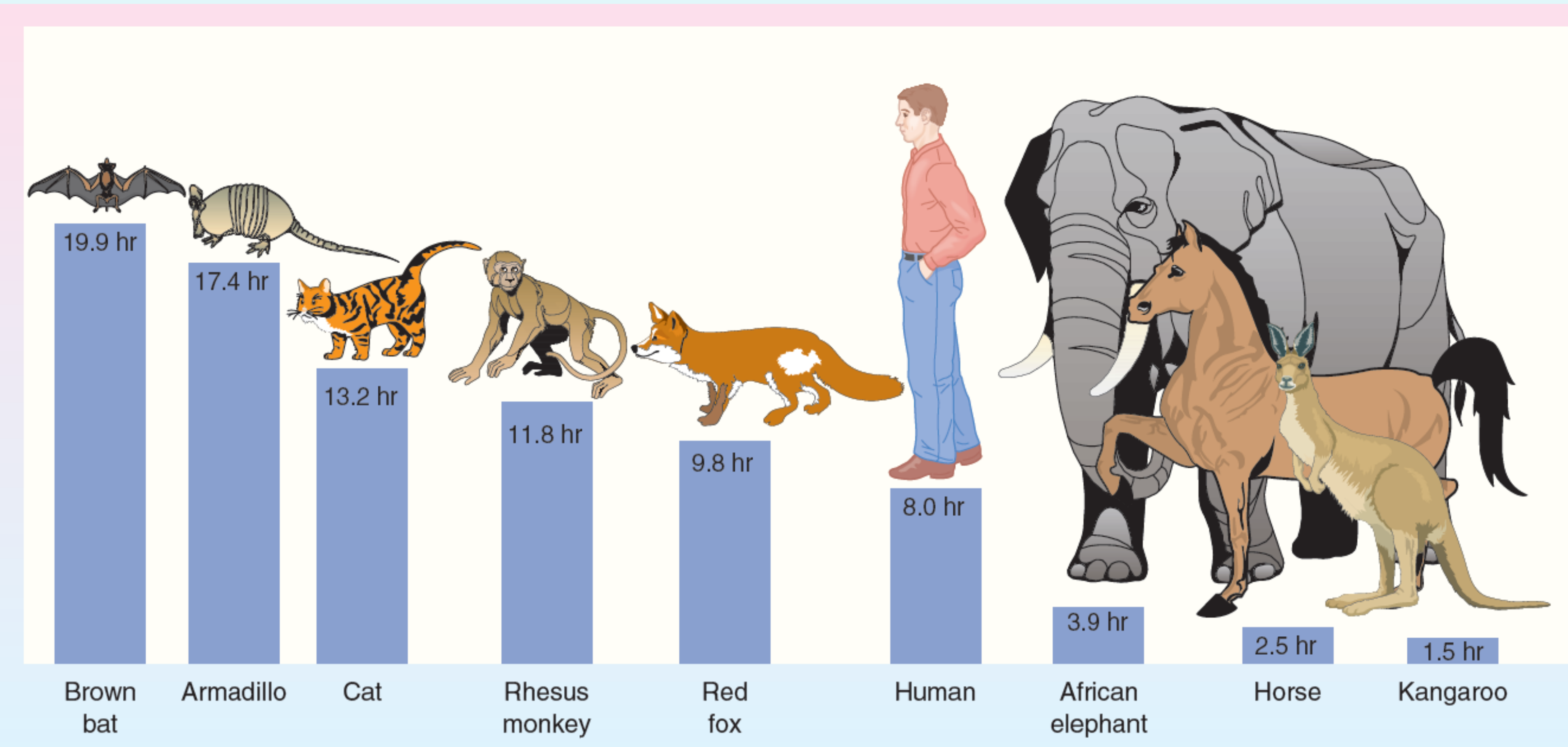
Figure 15.1: Time Spent in Daily Sleep for Different Animals



SOURCE: Based on data from “Animal Sleep: A Review of Sleep Duration Across Phylogeny, by S. S. Campbell and I. Tobler, 1984, *Neuroscience and Biobehavioral Reviews, 8,* 269–300.

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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

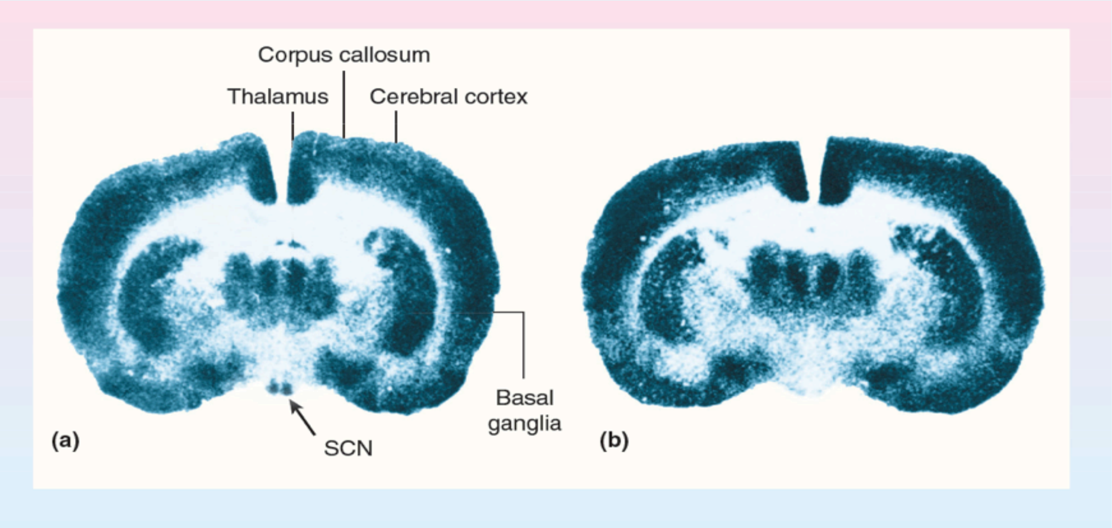

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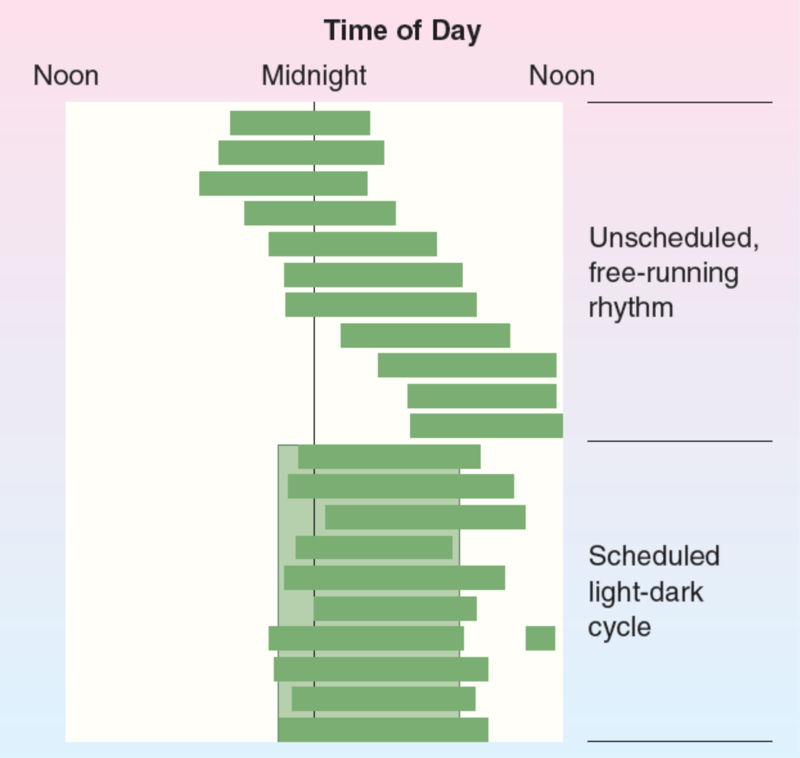
Figure 15.3: Sleep and Wake Periods During Isolation From Time Cues

- 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.



SOURCE: From *Introduction to Psychology, Gateways to Mind and Behavior* (with InfoTrac) 9th edition, by Coon, 2001. Reprinted with permission of Wadsworth, a division of Thomson Learning.

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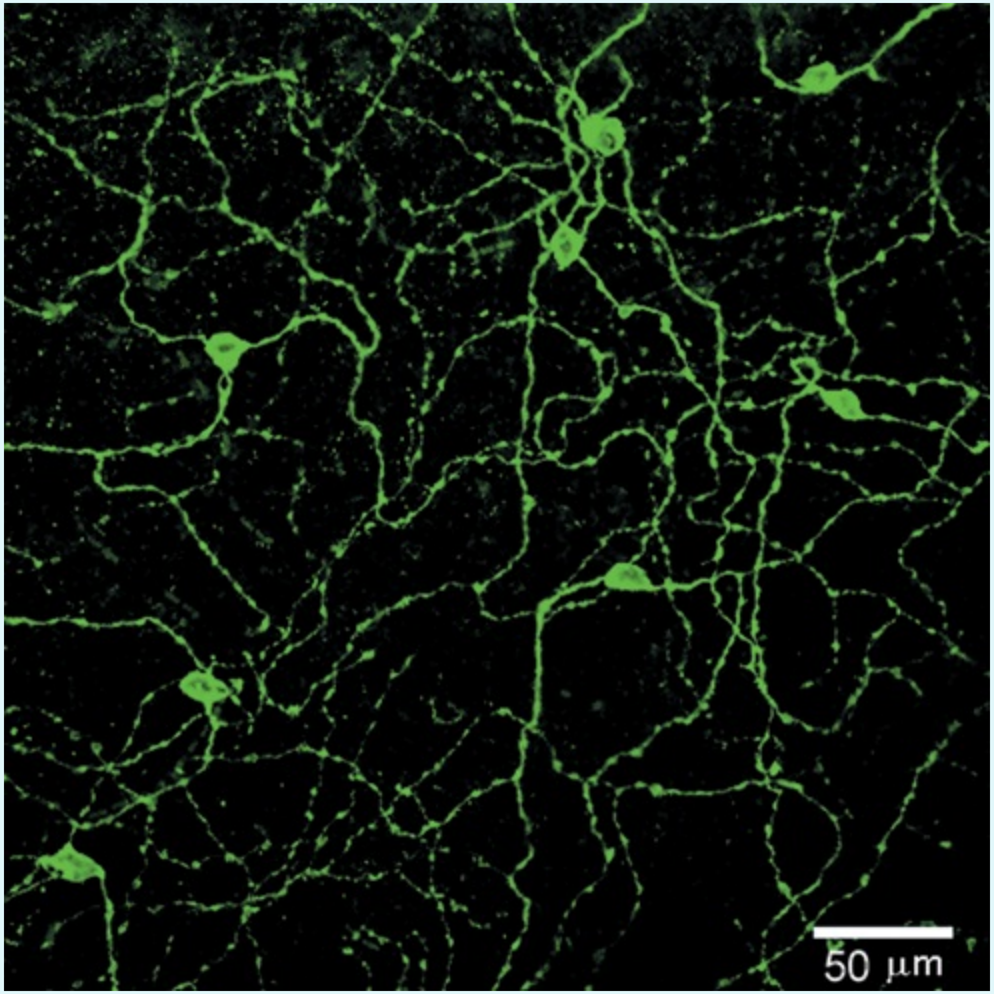
Figure 15.4: *Retinal Ganglion Cells Containing *Melanopsin.



SOURCE: From “Melanopsin-containing Retinal Ganglion Cells: Architecture, Projections, and Intrinsic Photosensitivity,” by Hattar, Liao, Takao, Berson, and Yau, *Science, 295*, 1065–1070. © 2002 American Association for the Advancement of Science (AAAS). Reprinted with permission from AAAS.

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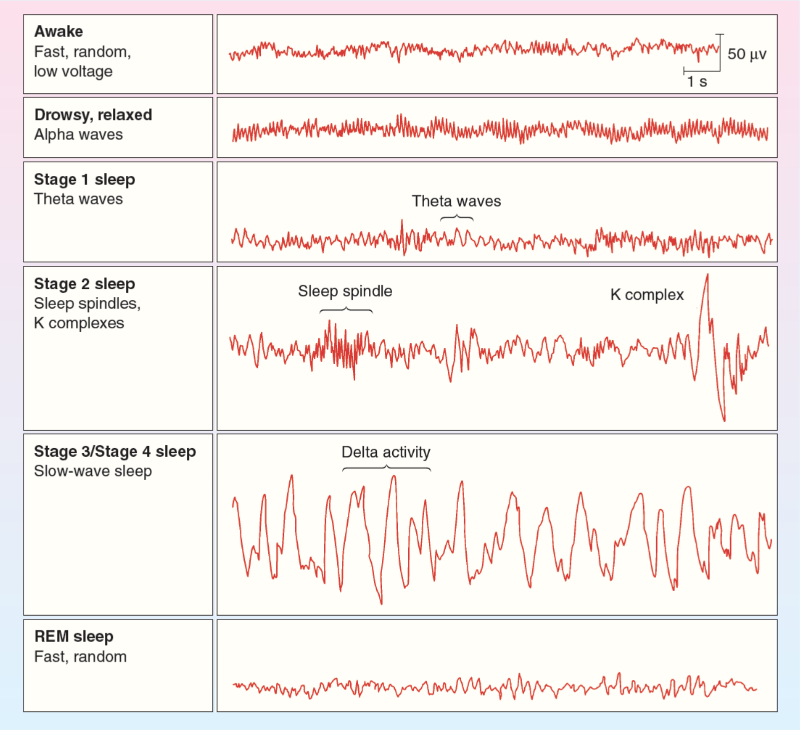
Figure 15.5: Electroencephalogram and the Stages of Sleep

- 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



SOURCE: From *Current Concepts: The Sleep Disorders*, by P. Hauri, 1982, Kalamazoo, MI: Upjohn.

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.

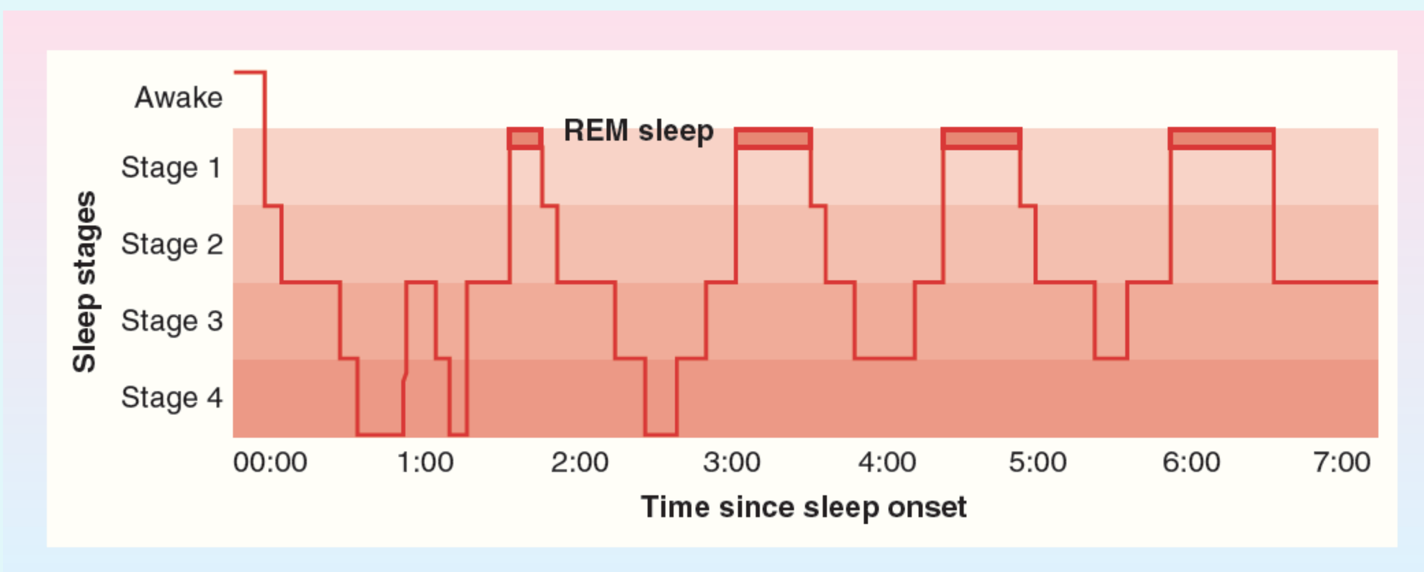


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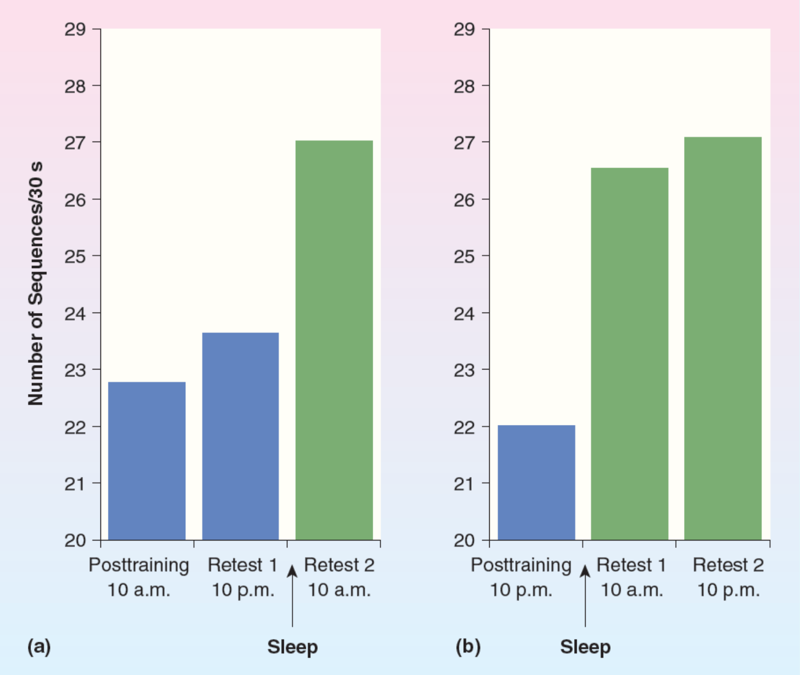
Figure 15.7: Improvement in Learning Following Sleep.

- 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

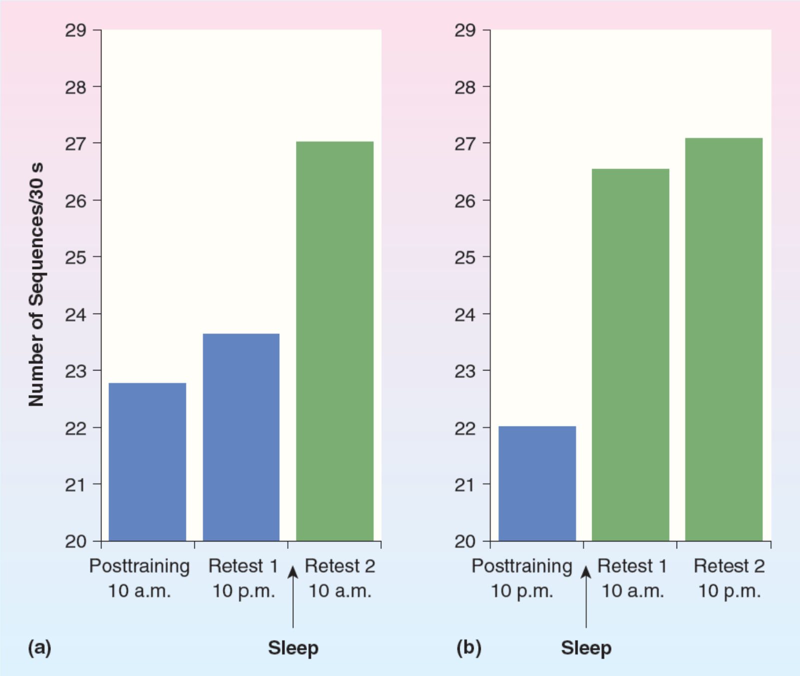

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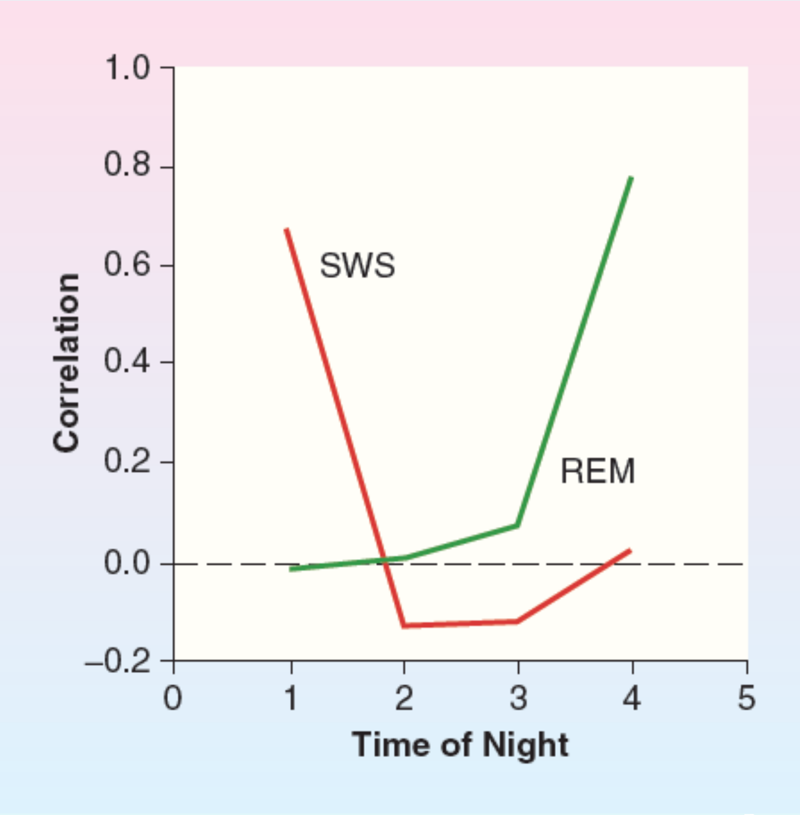
Figure 15.8: Correlation of Slow-Wave and REM Sleep With Overnight Task Improvement.

- 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.

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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

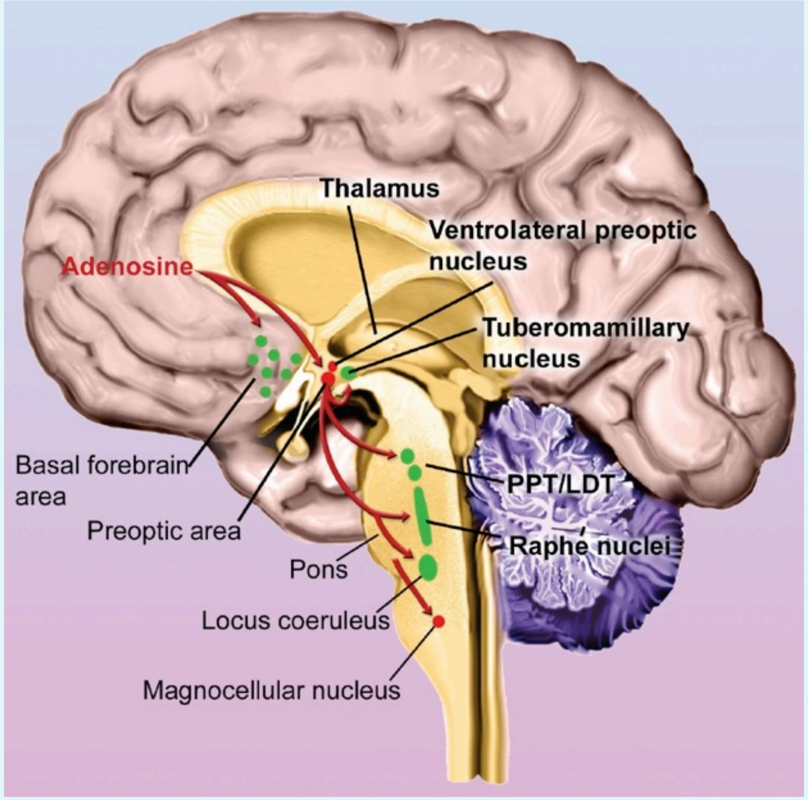

Figure 15.10: Arousal Structures of Sleep and Waking

- **Basal forebrain area**
  - Inhibits arousal-producing neurons, inducing drowsiness and reduces EEG.
- Waking and Arousal
  - *Major pathway 1: PPT/LDT

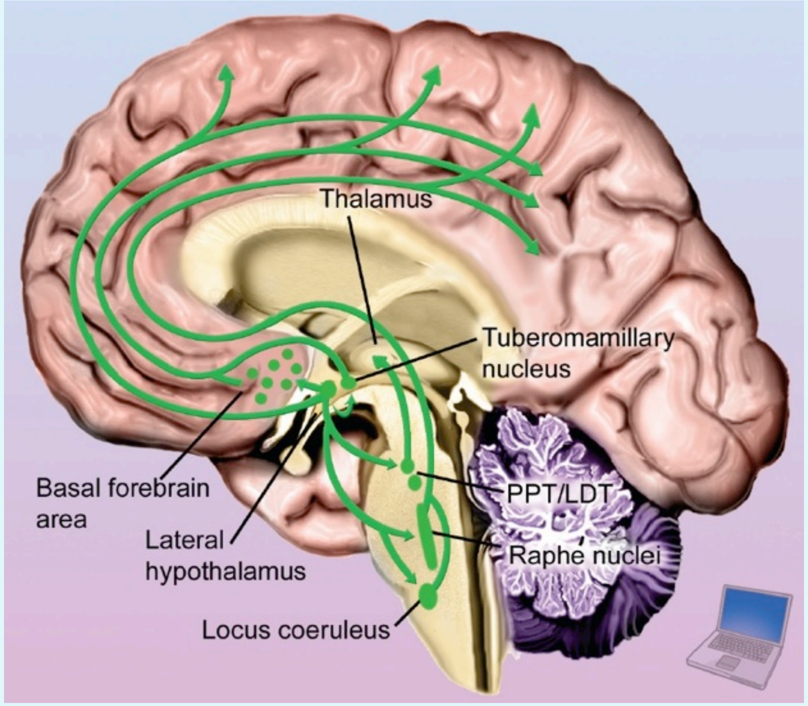

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Figure 15.11: Firing Rates in Brain Stem Arousal Centers During Waking and Sleep

- 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.

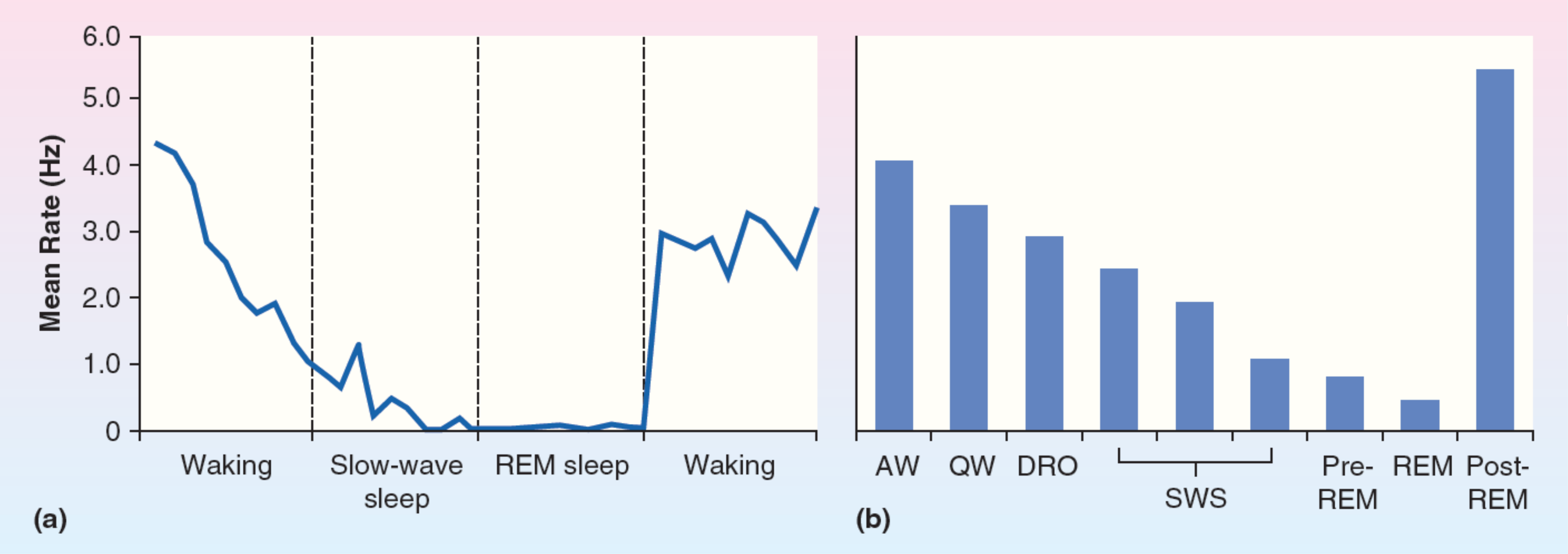

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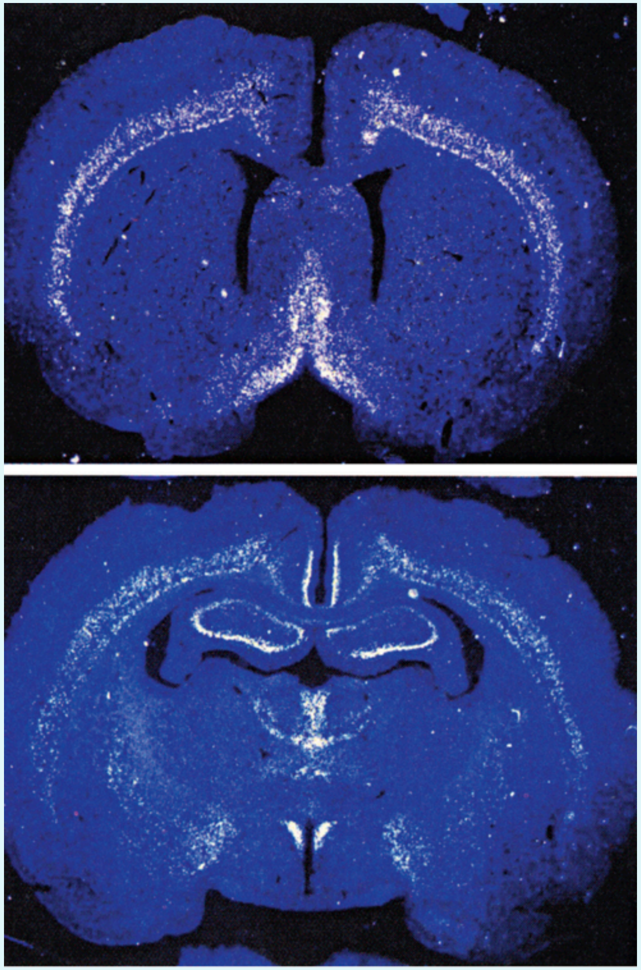
Figure 15.12: Locations of Orexin Receptors in the Rat Brain

- Waking and Arousal
  - Arousing pathway
    - Lateral hypothalamus releases **orexin (hypocretin)** to prevent the brain from switching into sleep.



SOURCE: From "Mice Lacking the M3 Muscarinic Acetylcholine Receptor Are Hypophagic and Lean," by Yamada et al., *Nature, 410,* 207–212, © 2001. Used with permission.

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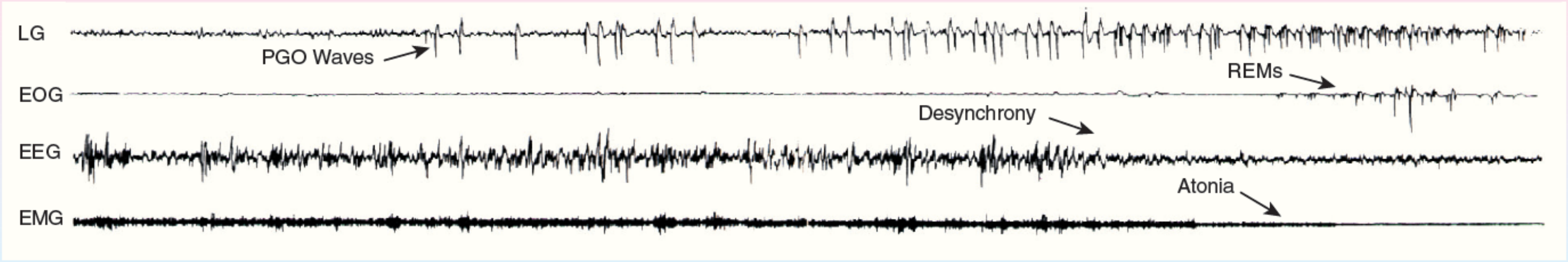
Figure 15.13: PGO Waves, EEG Desynchrony, and Muscle Atonia

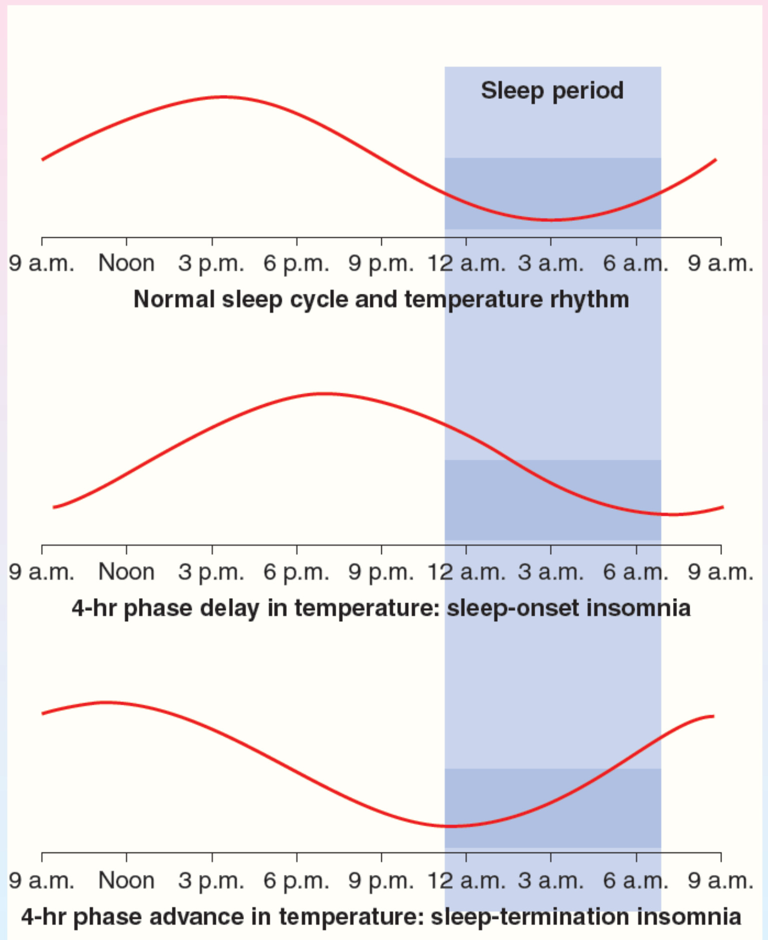
- Waking and Arousal
  - Pons: the source of PGO waves
    - Excitation travels from pons through lateral geniculate to occipital area
    - PGO waves trigger EEG desynchrony of REM
  - *The pons sends impulses to the magnocellular nucleus in the medulla to produce REM atonia (paralysis)
  - Disordered 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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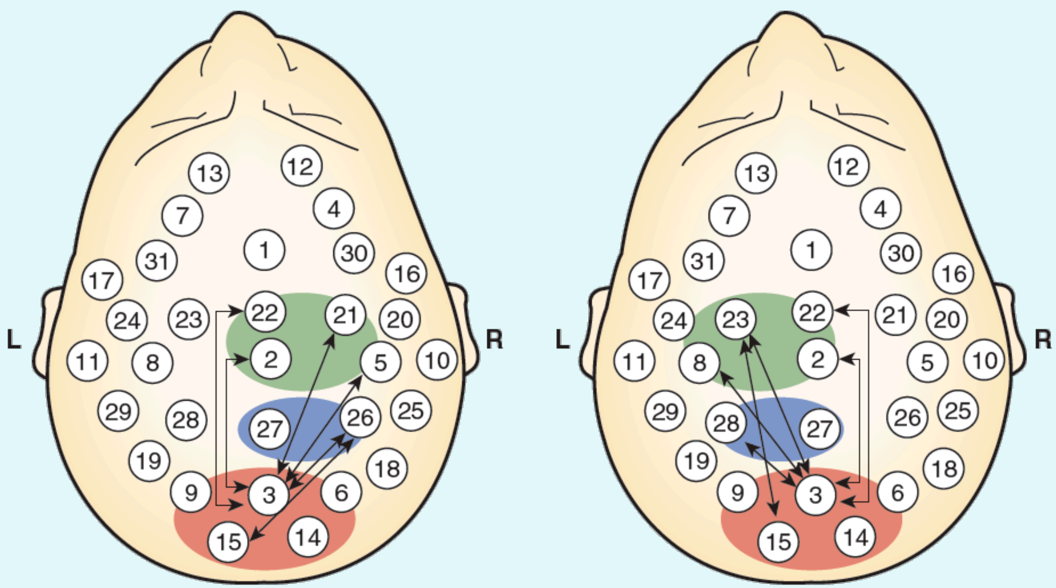
Figure 15.17: Synchronized Activity Among Areas Involved in Learning.

- 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.



(a) Shock left midfinger (b) Shock right midfinger

SOURCE: Adapted from "Coherence of Gamma-Band EEG Activity as a Basis for Associative Learning," by Miltner et al., *Nature 397,* 434–436. © 1999 Nature Publishing. Reprinted by permission.

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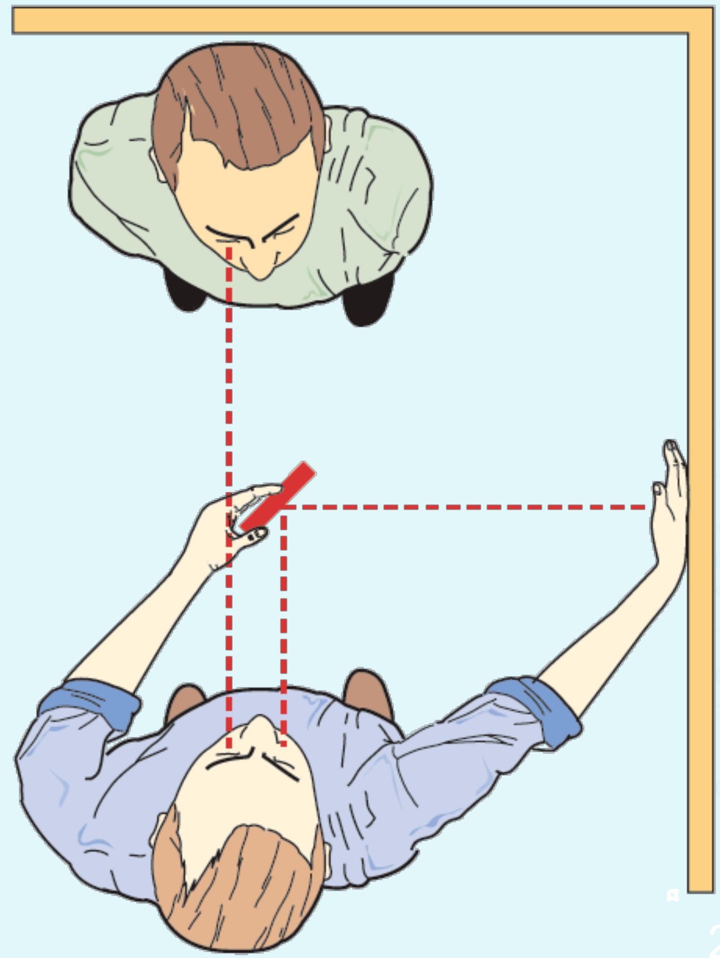
Figure 15.18: Setup for Demonstrating the Cheshire Cat Effect

- **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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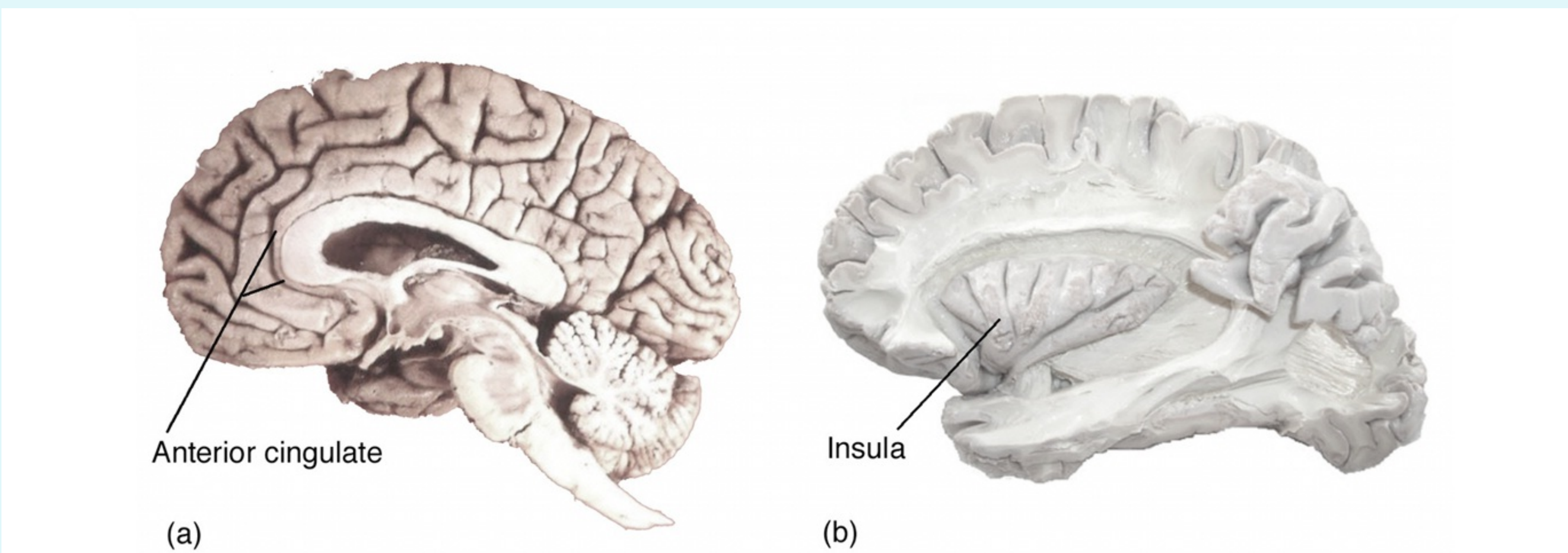
Figure 15.20: (a) The Anterior Cingulate and (b) the Insula

- 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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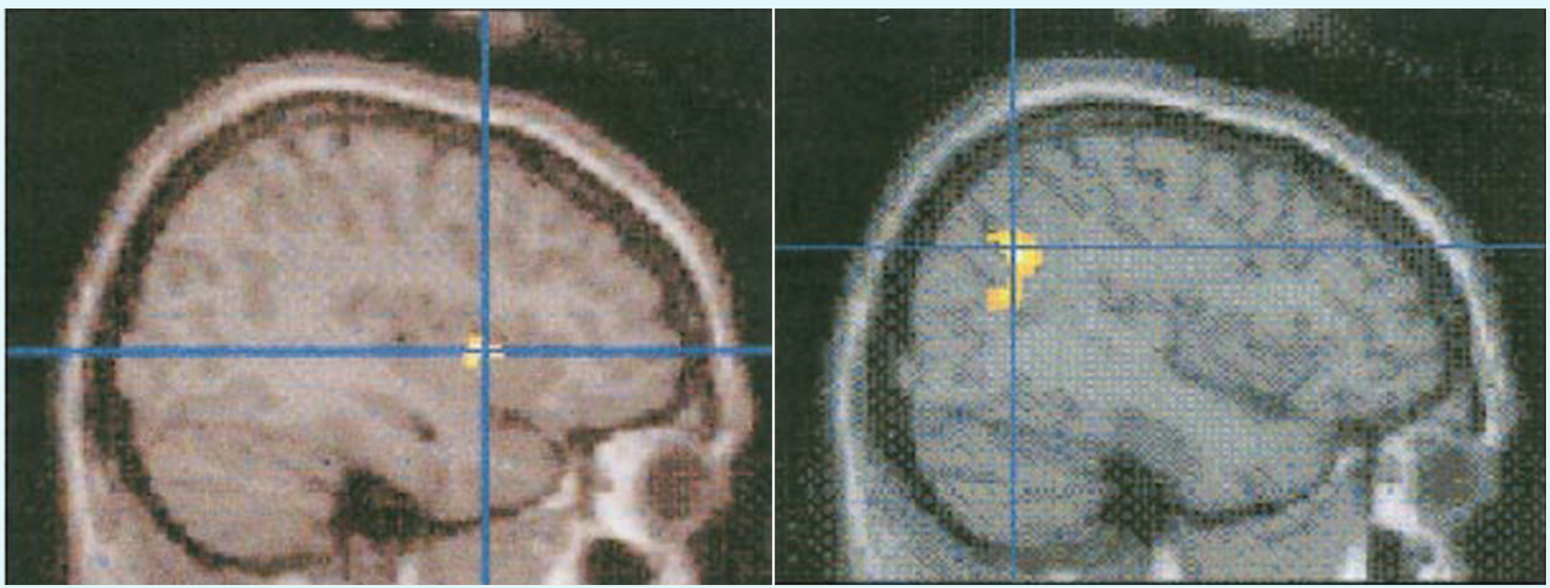
Figure 15.21: Brain Areas Involved in the Sense of Agency

- 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., *NeuroImage, 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)

SOURCE: From “Grasping the Intentions of Others With One’s Own Mirror Neuron System,” by M. Iacoboni, 2005, *PLoS Biology, 3,* pp. 529–535, fig. 1 upper right and lower right, p. 530.

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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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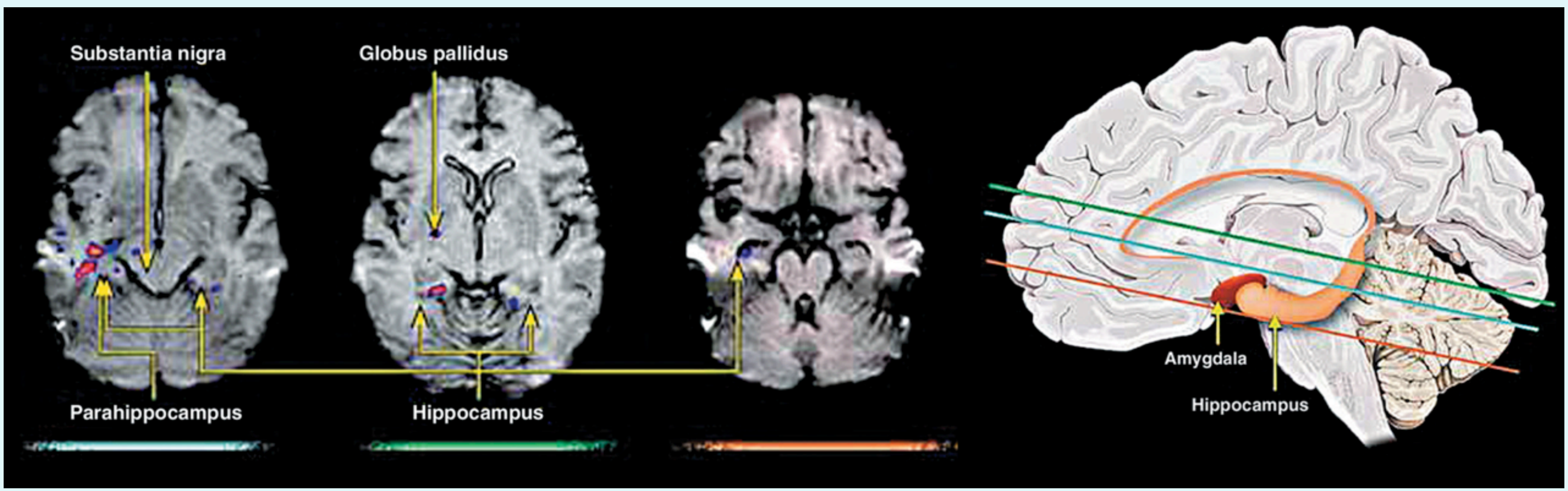
Figure 15.26: Hippocampal Activity During the Switch Between Multiple Personalities

- 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



SOURCE: From “Functional Magnetic Resonance Imaging of Personality Switches in a Woman With Dissociative Identity Disorder,” by Tsai et al., *Harvard Review of Psychiatry, 7*(15), pp. 119–122. © 1999. Reprinted by permission of Taylor & Francis.

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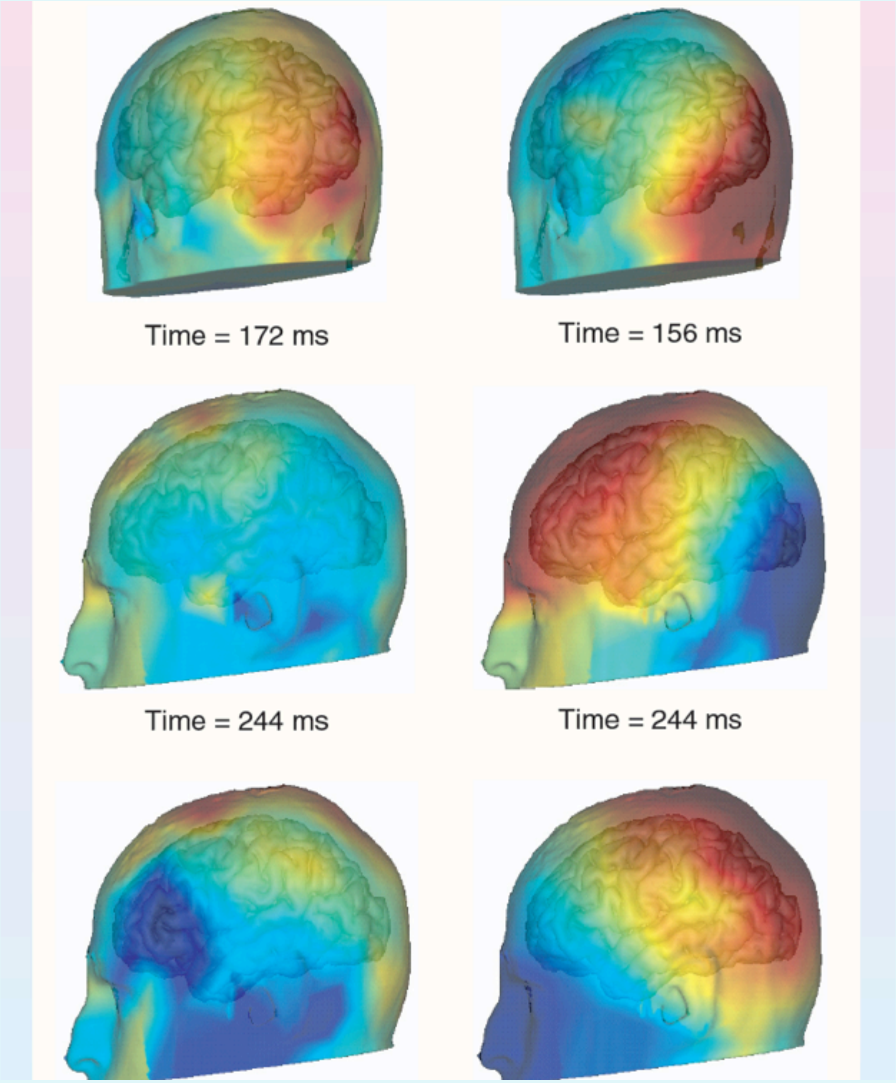
Figure 15.27: Map of Event Related Potentials to Masked and Unmasked Visually Presented Words.

- 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



SOURCE: From "Cerebral Mechanisms of Word Masking and Unconscious Repetition Priming," by S. Dehaene et al., *Nature Neuroscience, 4*, 752–758, fig. 3, p. 755. © 2001 Macmillan Publishing. Used with permission.

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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

SOURCE: *ScienceDaily,* http://www.sciencedaily.com/releases/2013/08/130812153553.htm

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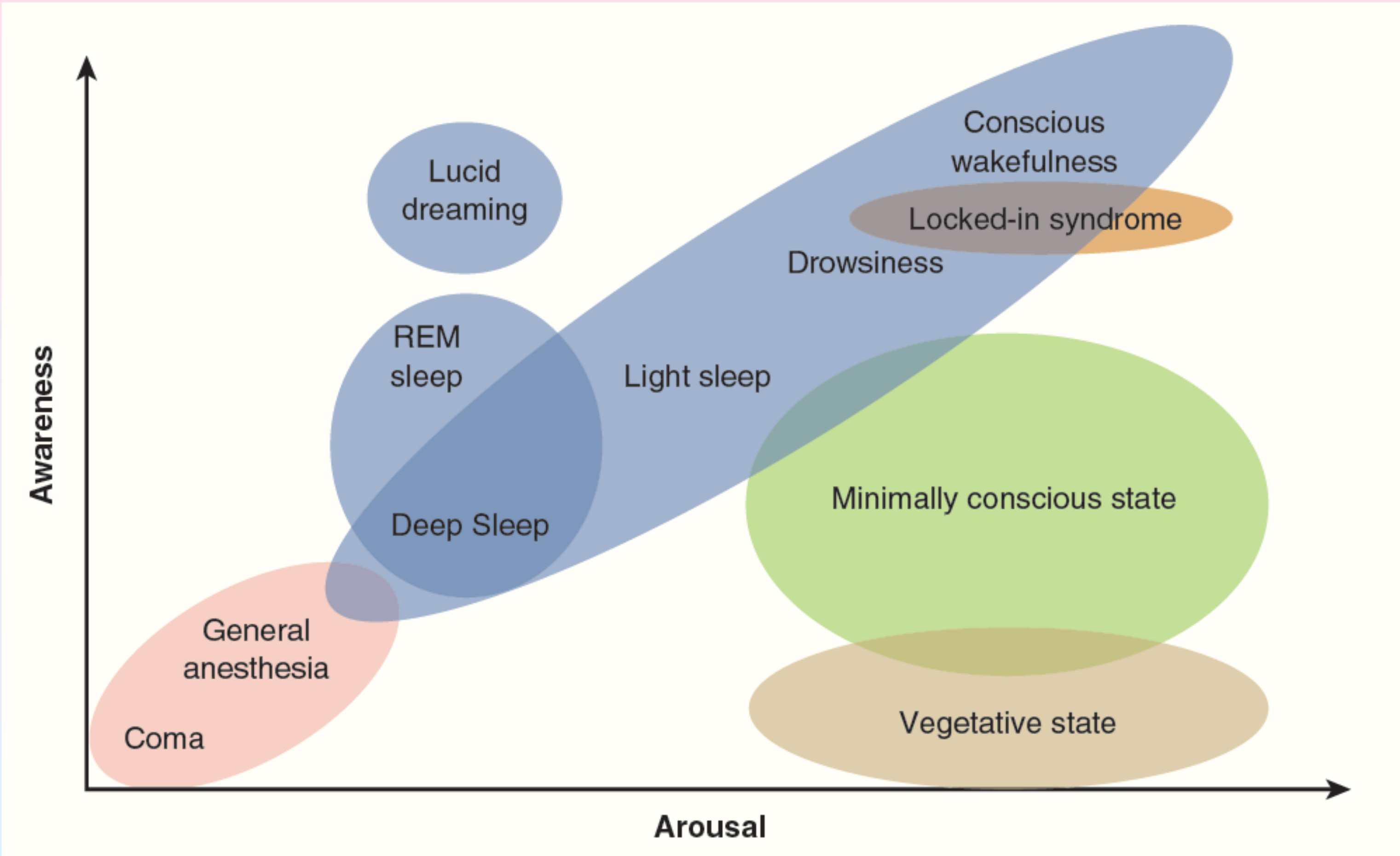
Figure 15.28: Awareness and Arousal in Normal and Impaired Consciousness.



SOURCE: Adapted from "The Neural Correlate of (Un)awareness: Lessons From the Vegetative State," by S. Laureys, 2005, *Trends in Cognitive Sciences*, *9,* 556–559.

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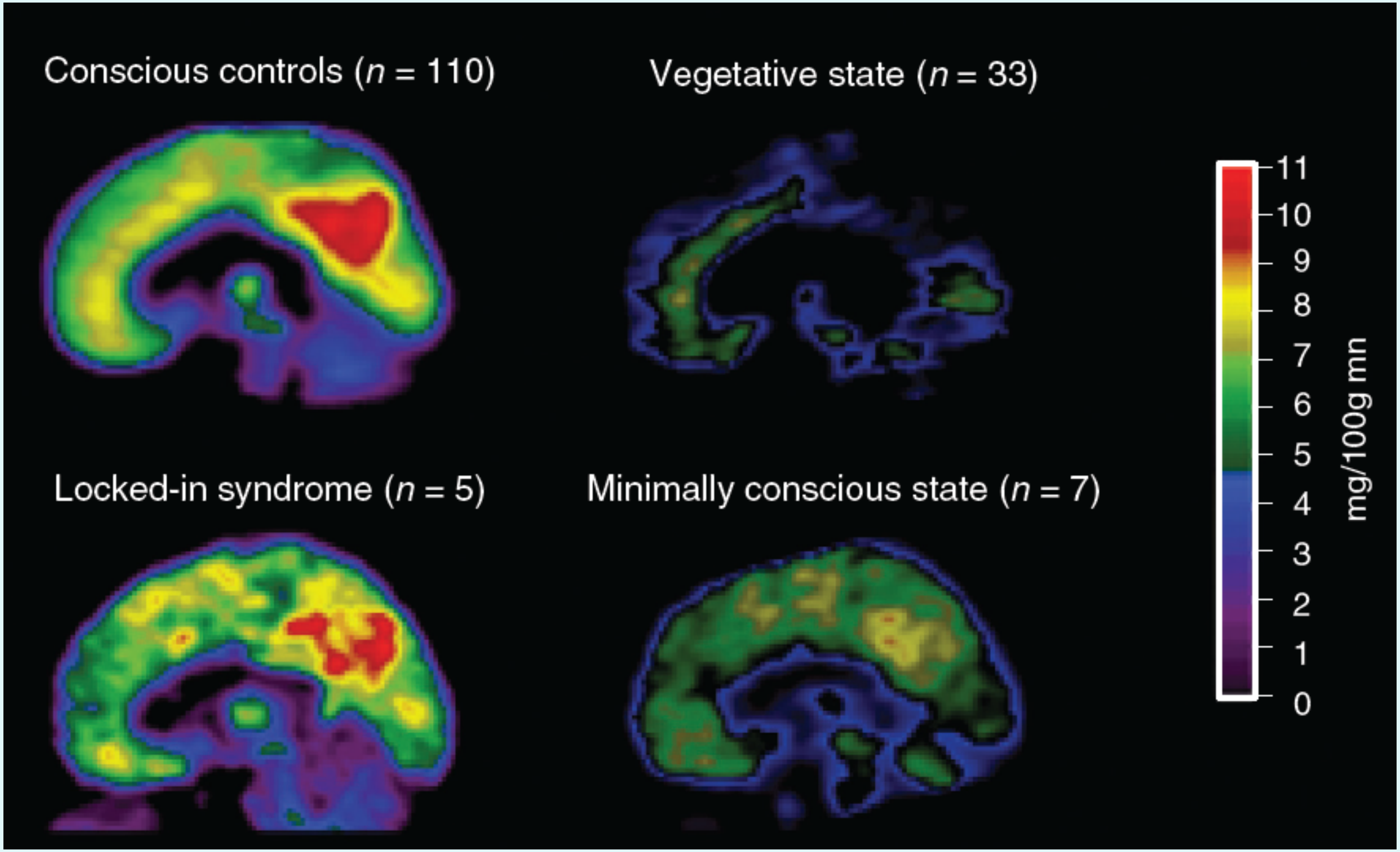
APPLICATION: Determining Consciousness When It Counts



SOURCE: From “Brain Function in Coma, Vegetative State, and Related Disorders,” by S. Laureys, A. M. Owen, and N. D. Schiff, 2004, *Lancet Neurology, 3,* 537–546.