Anatomy and Physiology of Sleep/Sleep Deprivation

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What Is The Function of Sleep?

- A Definition of Sleep
  - Behavioral
  - EEG
- Is there more than one function?
- Was there an initial primordial function?
- Sleeping with one eye open (aquatic life)
- Do reptiles and insects do it?
A Brief History of Sleep Medicine

- Sleep and Dreams
  - Is sleep an active or passive process?
- Insomnia
  - Described throughout known history
- Restless Legs Syndrome
  - Ekbom 1945
- Narcolepsy
  - Jean-Baptiste Edouard Gelineau 1880
- Obstructive Sleep Apnea
  - Groups in Germany and France 1965
    (Dickens 1836)
Is The Brain Awake or Asleep?

- Wake
- Sleep
  - NonREM Sleep
  - REM (active) Sleep
Neurotransmitters

Simplistic Wake  high monoaminergic
              high cholinergic
NREM       low monoaminergic
              low cholinergic
REM         low monoaminergic
              high cholinergic

Monoaminergic: dopamine, serotonin, norepinephrine
Staying Awake

- Brainstem Reticular Formation
- Posterior Hypothalamus
- Basal Forebrain
- Subthalamus
- Reticular nuclei of thalamus
Staying Awake (part II)

- Tonic neural activity
- 1 Reticular activating system
  - To thalamus to cortex (forebrain)
  - OR
- 2 Sensory input
  - To subthalamus or posterior thalamus (and basal forebrain) to entire cortex
AROUSAL (with or without coffee)

- Ascending pathways from Pons
  - 1 Ventral: hypothalamus, subthalamus, basal forebrain TO cortex
  - 2 Dorsal: thalamus TO cortex

  - NE locus coeruleus, serotonin raphe nuclei, dopamine ventral tegmentum, histamine post. lateral hypothalamus acetylcholine basal forebrain/brainstem

  - Note: there are compensatory mechanisms if damage to one system
Ascending Reticular Activating System

Aldrich, 1999
Sleep Stages During the Night

Lee-Chiong et al. 2002
Can You be Awake and Not Attend?

• Content of waking consciousness is mediated by the cortex

• Sensory input through thalamus allows selective attention
  - You can enhance or attenuate responses to incoming stimuli
Initiation of Sleep and NREM Sleep

- Neurons of the preoptic area and basal forebrain are critical for initiation
- SLEEP SPINDLES
  - Thalamic transmission to cortex
- DELTA WAVES
  - Hyperpolarization of thalamic reticular neurons results in decreased spindles and increased delta activity
  - **NOTE:** Delta frequency rhythms can be generated in single neurons (like sinoatrial cardiac cells)
REM SLEEP

• Sleep
  - Neurons in midbrain/pons with increased firing (Acetylcholine is essential for REM)
  - Other brainstem neurons are “REM off”
  - Increased cortical activity

• Eye Movements
  - Saccade generators of paramedian pontine reticular formation (possible saccadic eye movements to targets in dreams)
  - Horizontal movements greater than vertical eye movements
REM SLEEP (continued)

• **Muscle Atonia**
  - (Jouvet and Michel 1950s)
  - Pontine cholinergic neurons project via reticulospinal tract to inhibitory glycinergic spinal interneurons which inhibit spinal motoneurons

• **Muscle Twitches**
  - Excitatory glutaminergic input to spinal motoneurons (superimposed on tonic inhibition)
REM and Respiration

- Loss of tonic activity of upper airway dilator muscles

- Loss of tonic activity of diaphragm and accessory inspiratory muscles
  - Diaphragm remains phasically active
Other Sleep Mediators

• **Adenosine**
  - Increased release increases NREM and REM Sleep (caffeine blocks receptor)

• **Melatonin**
  - Secreted by pineal gland
  - Produces drowsiness but more related to Circadian Rhythm
Circadian Rhythm

- **Bimodal Distribution of Sleepiness**
  - (Carskadon and Dement 1987)

- **Highest level of alertness**
  - 8 a.m. to 11 a.m. and 8 p.m. to 10 p.m.

- **Lowest level of alertness (sleepiness)**
  - after lunch and early a.m. hours
    - Internal clock adjusted by light
Sleep Deprivation

• Insufficient Sleep Syndrome
  - The patient simply does not sleep enough, but there is otherwise nothing wrong with his/her sleep.
  
  - Prevalence is unknown, but this is likely the most common cause of excessive daytime sleepiness in the general population.
  
  - However, only about 2% of all patients presenting to a sleep center have this diagnosis (Zorick et al. 1982).
  
  - This should not be confused with insomnia.
Rats Without Sleep

• Increased intake of food
• Weight loss due to greater increase in BMR
• If completely sleep deprived die after 19 days from septicemia
• If REM sleep deprived die after 35 days

(Rechtschaffen et al. 1983)
Humans Without Sleep

• Patrick and Gilbert (1896)
  - 90 hours of sleep deprivation
  Decline in performance of vigilance tasks (improved with encouragement)
  Visual illusions and hallucinations
  Sleepiness worse at night
  Lots of help required to stay awake
  Good recovery after two nights of sleep

• Randy Gardner (1964)
  At 17 years old had a documented record of 264 hours without sleep
  Note: with all cases of voluntary sleep deprivation “microsleep”
  can not be completely eliminated
So How Much Sleep Do We Need?

- Most people likely need 7-8 hours
- Short Sleepers average 5 hours
- Long Sleepers average 9-10 hours
- There appears to be a core 5 hours of sleep that is necessary
  - When a person is sleep deprived recovery sleep results in increased deep or Slow Wave sleep
The Promise of Sleep (1999)

• An overview of sleep disorders and treatments written for the general public.

  - William C. Dement, M.D., Ph. D.