Bear: Neuroscience: Exploring the Brain 3e

- Chapter 19: Brain Rhythms and Sleep

Introduction

- Rhythmic Controls of Brain
  - Sleeping and waking, hibernation, breathing, walking, electrical rhythms of cerebral cortex
  - Cerebral cortex: Range of rapid electrical rhythms
  - Circadian rhythms: Change in physiological functions according to daily clocks in brain

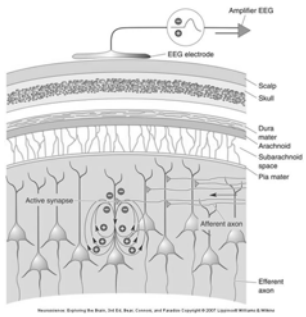
The Electroencephalogram

- EEG: Classical method of recording brain rhythms

- The Electroencephalogram (EEG)
  - Measurement providing glimpse of generalized activity of cerebral cortex
  - Function
    - Diagnose neurological conditions such as epilepsy, research purpose

The Electroencephalogram

- EEG Fluctuations and Oscillations



The Electroencephalogram

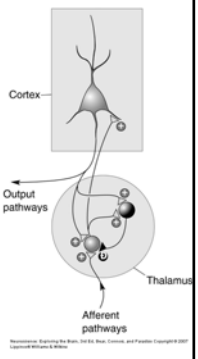
- Magnetoencephalography (MEG)
  - Recording miniscule magnetic signals generated by neural activity
- Comparison with EEG, fMRI, PET
  - MEG localizes sources of neural activity better than EEG
  - MEG cannot provide detailed images of fMRI
  - EEG, MEG→ measure neuron activity,
  - fMRI, PET→ changes in blood flow, metabolism

The Electroencephalogram

- EEG Rhythms
  - Categorization of rhythms based on frequency
    - Beta: Greater than 14 Hz, activated cortex
    - Alpha: 8-13 Hz, quiet, waking state
    - Theta: 4-7 Hz, some sleep states
    - Delta: Less than 4 Hz, deep sleep
  - Deep Sleep
    - High synchrony, high EEG amplitude

The Electroencephalogram

- Mechanisms and Meanings of Brain Rhythms
  - Synchronized oscillation mechanisms
    - Central clock/Pacemaker
    - Collective methods ("jam session")
  - Thalamus→ massive cortical input→ influence cortex
    - Neuronal oscillations
    - Voltage-gated ion channels



The Electroencephalogram

- Functions of Brain Rhythms
  - Scarcity of data→ No satisfactory answers
  - Hypotheses
    - Brain's way of disconnecting cortex from sensory input
    - No direct function, by-products of strongly interconnected circuits
  - Neural rhythms coordinate activity, synchronize oscillations, bind together

Sleep

- Sleep
  - Universal among higher vertebrates
  - Sleep deprivation, devastating
  - One-third of lives in sleep state???
  - Defined: "Sleep is a readily reversible state of reduced responsiveness to, and interaction with, the environment."

Sleep

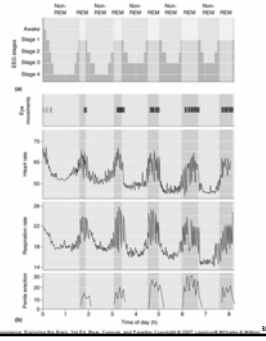
- The Functional States of the Brain

Table 19.1 Characteristics of the Three Functional States of the Brain

BEHAVIOR	AWAKE	NON-REM SLEEP	REM SLEEP
EEG	Low voltage, fast	High voltage, slow	Low voltage, fast
Sensation	Vivid, externally generated	Dull or absent	Vivid, internally generated
Thought	Logical, progressive	Logical, repetitive	Vivid, illogical, bizarre
Movement	Continuous, voluntary	Occasional, involuntary	Muscle paralysis; movement commanded by the brain but not carried out
Rapid eye movement	Often	Rare	Often

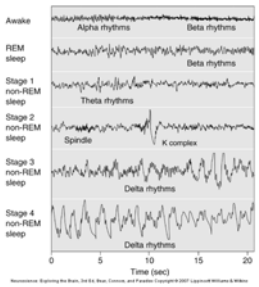
Sleep

- Physiological changes during non-REM and REM sleep



Sleep

- The Sleep Cycle



Sleep

- Why Do We Sleep?
  - Sleep
    - Mammals, birds, reptiles
    - Recovery time for brain
  - Theories of restoration
    - Restoration: Sleep to rest and recover, and prepare to be awake again
  - Theories of adaptation
    - Adaptation: Sleep to keep out of trouble, hide from predators

Sleep

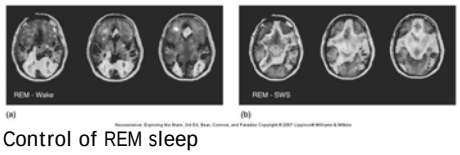
- Neural Mechanisms of Sleep
  - Basic Principles
    - Critical neurons→ Diffuse modulatory neurotransmitter systems
    - Noradrenergic and serotoninergic neurons: Fire during and enhance waking state
    - Cholinergic neurons: enhance REM events; active during waking
    - Diffuse modulatory system control rhythmic behaviors of thalamus→ controls cortical EEG→ sensory input flow to cortex blocked by slowed thalamic rhythms
    - Activity in descending branches of diffuse modulatory systems (e.g., inhibitory neurons)

Sleep

- Falling Asleep and Non-REM State
  - Sleep: Progression of changes ending in non-REM state
  - Non-REM sleep: Decrease in firing rates of most brain stem modulatory neurons using NE, 5-HT, ACh
  - Stages of non-REM sleep:
    - EEG sleep spindles
    - Spindles disappear
    - Replaced by slow, delta rhythms (less than 4 Hz)

Sleep

- Mechanisms of REM Sleep



- Control of REM sleep
  - Diffuse modulatory systems→ Pons
    - Decreased firing of neurons in locus coeruleus and raphe nuclei→ Concurrent sharp increase in ACh neuron activity
  - REM sleep behavior disorder: Act out dreams

Sleep

- Sleep-Promoting Factors
  - Muramyl dipeptide: isolated from the CSF of sleep-deprived goats, facilitates non-REM sleep
  - Interleukin-1: Synthesized in brain (glia, macrophages), stimulates immune system
  - Adenosine: Sleep promoting factor; released by neurons; may have inhibitory effects of diffuse modulatory systems
  - Melatonin: Produced by pineal gland, released at night-inhibited during the day (circadian regulation); initiates and maintain sleep; treat symptoms of jet lag and insomnia

Sleep

- Gene Expression During Sleeping and Waking
  - Comparison of gene expression in brains of awake and sleeping rats
  - 0.5% of genes showed differences of expression levels in two states
  - Increased in awake rats
    - Intermediate early genes
    - Mitochondrial genes
  - Increased in sleeping rats: protein synthesis- and plasticity-related genes
  - Changes specific to brain not other tissues

Circadian Rhythms

- Circadian rhythms
  - circa = approximately; dies = a day
  - Daily cycles of light and dark
  - Schedules of circadian rhythms vary among species
  - Physiological and biochemical processes in body: Rise and fall with daily rhythms
  - Daylight and darkness cycles removed, circadian rhythms continue
  - Brain clocks

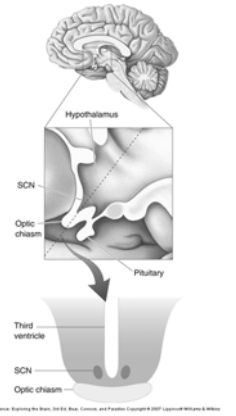
Circadian Rhythms

- Biological Clocks
- Free-run: Mammals completely deprived of zeitgebers settle into rhythm of activity and rest, period a little more or less than 24 hours
- Components of biological clock

Light-sensitive input pathway → Clock → Output pathway

Circadian Rhythms

- The Suprachiasmatic Nucleus: A Brain Clock
  - Small nucleus in the hypothalamus
  - Serves as biological clock



Circadian Rhythms

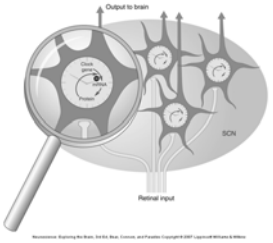
- A New Type of Photoreceptor
  - specialized type of ganglion cell in retina
    - Photoreceptor, but not rod or cone cell
    - Contains melanopsin, slowly excited by light
    - Synapses directly onto SCN neurons
  - SCN output axons: Parts of the hypothalamus, midbrain, diencephalons, use GABA as primary neurotransmitter, lesions disrupt circadian rhythms

Circadian Rhythms

- SCN Mechanisms
  - Intact SCN produces rhythmic message: Efferent axons use action potentials, SCN cell firing rate varies with circadian rhythm
  - Each SCN cell is a small clock
  - TTX does not disrupt their rhythmicity
    - Suggests that action potentials don't play a role

Circadian Rhythms

- SCN Mechanisms (Cont'd)
  - Molecular Clocks
    - Similar basis in humans, mice, flies, mold
    - Clock genes
      - Period (Per)
      - Timeless (Tim)
      - Clock



Concluding Remarks

- Rhythms
  - Ubiquitous in the mammalian CNS
  - Intrinsic brain mechanisms
  - Environmental factors
  - Interaction of neural processes and zeitgebers (like SCN clock)
  - Function of rhythms
    - Unknown but arise mainly as a secondary consequence
  - Sleep research
    - Little known about why we sleep to the function of dreams and sleep