CONSCIOUSNESS, THE BRAIN AND BEHAVIOR
In Physiology Today

(a) Awake

NREM (slow-wave) sleep

Stage 1

Stage 2

Stage 3

Stage 4

(b) REM (paradoxical) sleep

Time
What the Brain Does

• The nervous system determines states of consciousness and produces complex behaviors
• Any given neuron may have as many as 200,000 synapses with other neurons
• Brain activity
  – States of consciousness
  – Conscious experiences
  – Motivation and emotion
  – Learning and memory
  – Spatial awareness and language
States of Consciousness

Consciousness includes 2 distinct concepts

• States of consciousness
  – The waking state
  – Drowsy
  – Sleep
  – Coma
  – Brain death

• Conscious experiences
  – Thoughts
  – Feelings
  – Perceptions
  – Ideas
  – Dreams
  – Reasoning
States of Consciousness

• Defined 2 ways
  1. By behavior
     – Maximum attentiveness to coma
  2. Measured by pattern of brain activity
     – Electrical activity of neurons in the brain recorded
     – Electroencephalogram (EEG)
EEG

• Electrical activity of cortical neurons is measured by electrodes placed on the scalp
  – Electrical potential differences between different points on the scalp
  – EEG patterns are mostly due to graded potentials
    • Summed postsynaptic potentials
    • Activity from hundreds to thousands of neurons just below the electrode
EEG

• The majority of the activity is measured from pyramidal cells of the cortex
• Records postsynaptic potentials from the dendrites

Pyramidal cells use glutamate as their excitatory NT and GABA as their inhibitory NT
EEG

- **Amplitude**
  - Measured as \( \mu V \)
    - Range 0.5 – 100 \( \mu V \)
  - High amplitude
    - many neurons are activated simultaneously
    - Synchronous firing
  - Low amplitude
    - Fewer neurons are activated
    - Asynchronous firing

- **Frequency**
  - Measured in Hz
    - Cycles per second
    - Range 1-40 Hz
  - Lower frequency
    - Less responsive states
    - Sleep
  - Higher frequency
    - Increased alertness
• Typical EEG
• Recorded from the parietal or occipital lobe
• Awake, relaxed person
• 4 seconds of activity
• Duration of a single wave 50 msec
The Waking State

• Alpha rhythm
  – Most prominent EEG wave pattern of an awake, relaxed adult whose eyes are closed
  – Decreased levels of attention
  – Subject feels relaxed and happy
The Waking State

- Beta rhythm
  - Attentive to an outside stimulus
  - Thinking about something
  - Low amplitude, higher frequency
Sleep

• EEG wave patterns change during sleep

• Becoming drowsy
  – Decrease in alpha-wave amplitude and frequency

• Asleep
  – Slower frequency higher amplitude wave patterns
  – Theta rhythms
  – Delta rhythms
  – Changes in
    • Posture
    • Ease of arousal
    • Motor output
    • Threshold for sensory stimuli

If sleep is SO important... Then why does school start so early?
# Sleep

## NREM
- Non rapid eye movement behind a closed eyelid
- Slow wave sleep
  - Waves are **high amplitude, low frequency**
- 4 stages
  - Each stage is characterized by an EEG pattern with a slower frequency and higher amplitude than the preceding one

## REM
- Rapid eye movement behind a closed eyelid
- Paradoxical sleep
  - Sleeper is difficult to arouse despite having EEG characteristics of the awake, alert state
- Dreaming occurs
NREM Sleep

• Progression from stage 1-4
• Process reverses itself
• Instead of waking up, move into REM sleep
NREM Sleep

- Sleep continues in the cyclical pattern, if uninterrupted
  - 1,2,3,4 then 4,3,2,1 episode of REM sleep then repeats
  - Lasts 90-100 minutes

- Average total nights sleep comprises 4-5 cycles

Purple bars are periods of REM sleep
NREM Sleep

• As a person moves from drowsiness to stage 1 sleep
  – Muscles become more relaxed as sleep progresses
    • Except ocular and respiratory muscles
• Pulsatile release from anterior pituitary
  – Growth hormone
  – Gonadotropins \( (FSH, LH) \)
• Decrease in blood pressure, heart rate, respiratory rate
REM Sleep

• REM sleep is 20-25% of a young adults total sleep time
  – Declines with age
• Duration of REM sleep increases toward the end of an undisturbed night
• Characterized by increase and irregularity
  – Blood pressure
  – Heart rate
  – Respiratory rate
• Muscle twitches may occur (face and limbs)
Why Do We Sleep

• A homeostatic requirement

• Importance of sleep
  – Learning and memory
  – Brain experiences reactivation of neural pathways stimulated during the prior awake state
  – Dampens overall neural activity which, in turn, strengthens synapses in pathways involved in learning and memory
Lack of Sleep

• Impairs immune function

• Causes cognitive deficits
  – Intellect
    • Reasoning
    • Perception
    • Intelligence
    • Learning

• Less effective memory retention
Circadian Rhythms

• Circadian rhythms are an average of 8 hours of sleep and 16 hours awake
• Hypothalamus and the brain stem drive cyclical changes
• Neurons of brainstem give rise to axons that branch to synapse with wide areas of the brain
  – Called the *reticular activating system* (RAS)
Circadian Rhythms

• Alternating reciprocal activity of different RAS neurons cause shifts from one state to another

• The waking state
  – Neurons that release NE and Serotonin dominate

• Sleep
  – NREM
    • Intermediate activity of NE, Serotonin and ACh
  – REM
    • Cholinergic neurons are dominant

>30 NTs have been identified that affect sleep
Hypothalamus Control of Circadian Rhythms

- Preoptic area
  - GABAergic neurons
  - Promotes slow wave sleep (NREM 3-4)
  - Inhibits center in hypothalamus that stimulates wakefulness
    - Inhibits histamine

- Suprachiasmatic nucleus
  - Stimulates the production of **melatonin** by the pineal gland
  - Timing of sleep/wake cycles relative to periods of light/dark
Motivation

• Primary motivated behavior
  – Related to homeostasis
  – Body needs are satisfied
  – Example: getting a drink of water when you are thirsty

• Secondary motivated behavior
  – Not all motivated behavior relates to homeostasis
  – Deciding what type of soda to drink
  – Influenced by incentives (cravings, habit, learning, intellect and emotions)
Emotion

• Physiological basis of emotion
  – Emotional behavior
    • The hormonal, autonomic and outward expressions and displays of response to the stimulus
  – Inner emotions
    • The conscious experience such as feelings of love, fear, anger, joy, anxiety, hope, etc.
Emotion

- Emotional behavior
  - Limbic system
  - Cerebral cortex
- Amygdala and association cortex are central to most emotional states
Learning

• Learning
  – Acquisition and storage of information
  – Rewards and punishments crucial to learning

• Memory
  – Relatively permanent storage of learned information
  – Brain processes, stores and retrieves information in different ways to suit different needs
Memory

- **Memory encoding**
  - The physiological events that lead to memory formation

- **Declarative memory**
  - Retention and recall of conscious experiences that can be put into words

- **Procedural memory**
  - Memory of how to do things
  - Learned emotional responses (fear, Pavlov’s dog)
Memory

• Short-term memory
  – Registers and retains information from seconds to minutes after its input
  – Working memory

• Long-term memory
  – Stored for days to years and recalled at a later time
  – Consolidation is the conversion of short-term to long-term memory
  – Focusing attention is essential for memory-based skills
  – The longer the span of attention in working memory, the better the ability to do things (practice makes perfect)
Memory

- Long-term potentiation
  - Certain synapses undergo a long-lasting increase in their effectiveness when they are heavily used
  - High frequency action potentials
  - Stimulates the post-synaptic neuron for a longer amount of time
  - Both AMPA and NMDA receptors activated simultaneously
Memory

- Hormones, consequences of our experiences affect our memories of them
  - Hormones normally released in stressful or mildly stimulating experiences
  - Opioid peptides interfere with learning and memory when the lesson involves pain
    - Inhibit learning by decreasing the emotional component of the learning experience (fear, anxiety)
    - Decrease the motivation necessary for learning
Cerebral Dominance

Each hemisphere of the brain has anatomical, chemical, functional specializations.
Left Brain, Right Brain

• **Left Hemisphere**
  – The left brain is the logical brain responsible for words, logic, numbers, analysis, lists, linearity and sequence. It controls the right side of your body.

• **Right Hemisphere**
  – The right brain is the creative brain and is responsible for rhythm, spatial awareness, color, imagination, daydreaming, holistic awareness and dimension. It controls the left side of your body.

• **Corpus Callosum**
  – The corpus callosum is a thick band of nerve fibers which connect the brain cells in one hemisphere to those in the other hemisphere. The two hemispheres keep up a continuous conversation via this neural bridge.
Male vs. Female Brain

- **Female Brain:** larger regions
  - parts of the frontal lobe
    - problem-solving and decision-making
  - Limbic system structure
    - regulating emotions
  - White matter

- **Male Brain:** larger regions
  - Parietal cortex, which is involved in
    - space perception
  - Amygdala
    - sexual and social behavior
  - Gray matter
Language

• A complex code that involves
  – Listening
  – Seeing
  – Reading
  – Speaking

• Centers for language function in the left hemisphere

• Cerebellum important in speaking and writing
  – Involve coordinated muscle contractions

• Males and females use different areas for language and processing (different strategies)