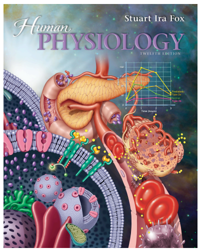
Connect Learn Succeed



Chapter 8

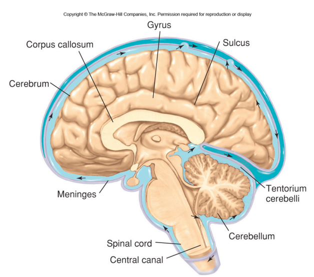
The Central Nervous System

Lecture PowerPoint

Central Nervous System

- Composed of the brain and spinal cord
  - Receives input from *sensory* neurons (stimulus) and directs activity of *motor* neurons (response) that innervate muscles and glands
  - Association neurons integrate sensory information and help direct the appropriate response to maintain homeostasis and respond to the environment.

Central Nervous System

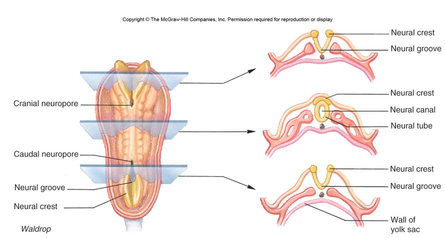


I. Structural Organization of the Brain

Early Embryonic Development

- From the ectoderm comes a groove that will become the neural tube around 20 days after conception. This will eventually become the CNS.
  - The inside of the tube becomes the ventricles in the brain.
- Between the neural tube and the developing epidermis, a neural crest forms. This will become PNS ganglia.

Early Embryonic Development



Embryonic Development

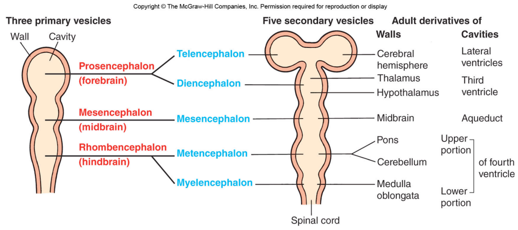
- By week 4 after conception, three distinct swellings are seen along the neural tube:
  - Prosencephalon (forebrain)
  - Mesencephalon (midbrain)
  - Rhombencephalon (hindbrain)

Embryonic Development

- By week 5, these *3 regions* differentiate into *5 regions*.
  - The forebrain divides into the *telencephalon* and *diencephalon*.
  - The hindbrain divides into the *metencephalon* and *myelencephalon.*
  - The mesencephalon remains the *mesencephalon*/ mibrain
- These terms are still used to describe regions of the adult brain.

Embryonic Development

- Weeks 4 and 5



Brain Fun Facts

- The adult brain has 100 billion neurons.
- It weighs about 1.5 kg (3−3.5 pounds).
- It receives 15% of the total blood flow to the body per minute.
- Scientists have demonstrated neurogenesis (the formation of new brain cells from stem cells *(there's hope!)*) can occur in adult brains within the hippocampus and near the ventricles (adjacent to ependymal cells).

II. The Cerebrum

Cerebrum

- Derived from the telencephalon
- Largest portion of the brain (80%)
- Responsible for higher mental functions
- Consists of a right and left cerebral hemisphere connected internally by the corpus callosum

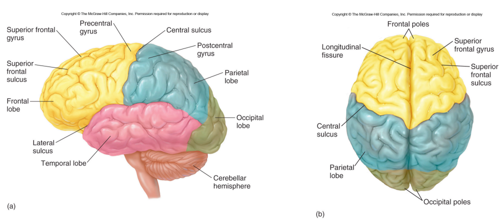
Cerebral Cortex

- The outer region of the cerebrum is composed of 2−4 mm gray matter with underlying white matter.
- Characterized by raised folds called gyri (gyrus) separated by depressed grooves called sulci (sulcus).
- Each hemisphere is divided by deep sulci into 5 lobes.

Lobes of the Cerebrum

- Frontal
- Parietal
- Temporal
- Occipital
- Insula (aka, Isle of Reil)

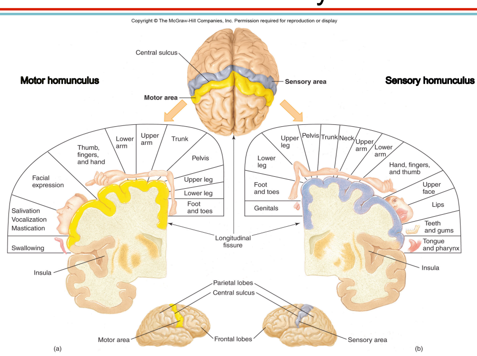
Lobes of the Cerebrum



Frontal and Parietal Lobes

- Separated by the central sulcus
- The precentral gyrus is located in the frontal lobe and is responsible for motor control. Information is carefully MAPPED OUT…
- The postcentral gyrus is in the parietal lobe and is responsible for somatesthetic sensation (coming from receptors in the skin, muscles, tendons, and joints). Information is carefully MAPPED OUT…

Maps of the Precentral and Postcentral Gyri



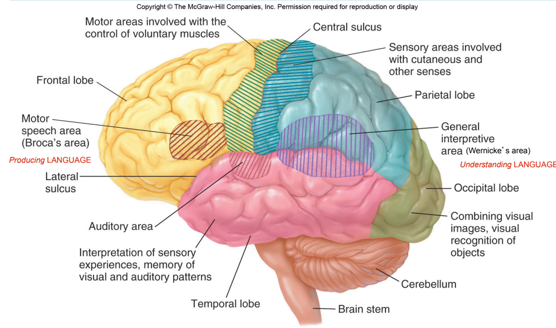
Maps can change

- Use-dependent cortical plasticity
  - Young brains are extremely adaptable and can repair damage and recover from disease, a process known as plasticity.
  - The adult brain (!!) can reorganize to accommodate environmental modifications and to compensate for lost function, a process known as plasticity.

Temporal, Occipital, and Insula

- Temporal lobe: auditory centers; olfactory cortex; short-term memory
- Occipital lobe: vision and coordination of eye movements (along with midbrain)
- Insula: integration of sensory information with visceral responses; receives olfactory, gustatory, auditory, and pain information

Functional Regions of the Cerebrum



Functions of the Cerebrum

Table 8.1 | Functions of the Cerebral Lobes

Lobe	Functions
Frontal	Voluntary motor control of skeletal muscles; personality; higher intellectual processes (e.g., concentration, planning, and decision making); verbal communication
Parietal	Somatesthetic interpretation (e.g., cutaneous and muscular sensations); understanding speech and formulating words to express thoughts and emotions; interpretation of textures and shapes
Temporal	Interpretation of auditory sensations; storage (memory) of auditory and visual experiences
Occipital	Integration of movements in focusing the eye; correlation of visual images with previous visual experiences and other sensory stimuli; conscious perception of vision
Insula	Memory; sensory (principally pain) and visceral integration

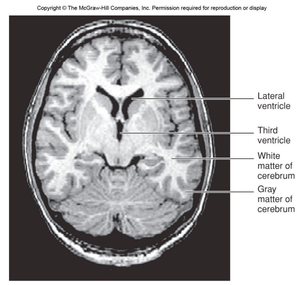
Mirror Neurons

- Found in frontal and parietal lobes: integrate sensory and motor neural activity
- Connected through the insula to emotion centers in the brain
- May be involved in the ability to learn social skills and language
- Have been implicated in *autism*

Visualizing the Brain and Its Activity

- X-ray computed tomography (CT): looks at soft tissue absorption of X-rays
- Positron emission tomography (PET): radioactively labeled deoxyglucose injected into the blood; emits gamma rays in active tissues
  - Used to monitor cancer
  - Used to study brain metabolism, drug distribution in the brain, and changes in blood flow following activity
- Magnetic resonance imaging (MRI): Protons in tissues are aligned by powerful magnets. The chemical composition of different tissues results in differences in proton alignment.
  - Can be amplified using MRI contrast agents injected before imaging
  - Shows clear definition between gray matter, white matter, and cerebrospinal fluid

Visualizing the Brain and Its Activity: MRI



From W.T. Carpenter and R.W. Buchanan, "Medical Progress: Schizophrenia" in New England Journal of Medicine, 330:685, 1994, fig 1A.

Visualizing the Brain and Its Activity

- *Functional* magnetic resonance imaging (fMRI): visualizes increased neuronal activity in different brain regions indirectly by looking at blood flow
  - Release of the neurotransmitter glutamate increases vasodilation of blood vessels in the area.

Visualizing the Brain and Its Activity

- *Electroencephalogram (EEG)*: Electrodes on the scalp detect *synaptic* potentials produced by cell bodies and dendrites in the cerebral cortex.
- Four patterns are usually seen (patterns are described by frequency of the waves in cycles per sec or Hertz (Hz) and amplitude of the waves):
  1. Alpha waves: active, relaxed brain. Seen most in frontal and parietal lobes (10-12 Hz, high amplitude, with spindles)
  2. Beta waves: produced with visual stimulation and mental activity. Seen most in frontal lobe (13-25 Hz, smaller amplitude, with spindles)
  3. Theta waves: seen during sleep; most from occipital and temporal lobes (5-8 Hz)
  4. Delta waves: also seen in sleep, from all over the cerebrum

EEG Patterns

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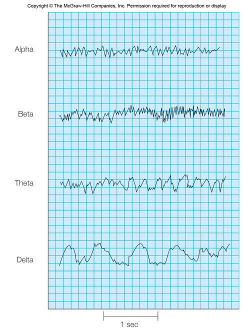
2. Beta waves: produced with visual stimulation and mental activity. Seen most in frontal lobe (13-25 Hz, smaller amplitude, with spindles)

3. Theta waves: seen during sleep; most from occipital and temporal lobes (5-8 Hz) [when recorded in awake adults, can signify problems]

4. Delta waves: also seen in sleep, from all over the cerebrum (1-5 Hz) [when recorded in awake adults, can signify problems]

EEG



Sleep

- Two recognized categories:
  - REM: rapid eye movement; state when dreams occur. *Beta* waves are seen here.
  - Non-REM: also called resting sleep; divided into four stages, determined by EEG waves seen. Stages 3 and 4 are often called slow-wave sleep, characterized by *delta* waves.

Sleep

- When people first fall asleep, they enter non-REM sleep and progress through the four stages.
- Next, a person ascends back up the stages of non-REM sleep to REM sleep.
- This cycle repeats every 90 minutes, and most people go through five cycles per night.
- If allowed to awaken naturally, people usually do so during REM sleep.

REM Sleep

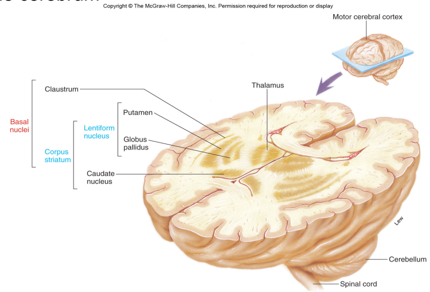
- Some brain regions are more active during REM sleep than during the waking state.
  - The limbic system (involved in emotion) is very active during REM sleep.
  - Breathing and heart rate may be very irregular.

Non-REM Sleep

- As you fall asleep, neurons decrease their firing rates, decreasing blood flow and energy metabolism.
  - (During REM sleep, HIGER blood flow to selected brain regions occurs, even more than when awake!)
- Breathing and heart rate are very regular.
- Non-REM sleep may allow repair of metabolic damage done to cells by free radicals and allow time for the neuroplasticity mechanisms needed to store memories.

Basal Nuclei

Masses of gray matter located deep in the white matter of the cerebrum



Basal Nuclei: Corpus Striatum

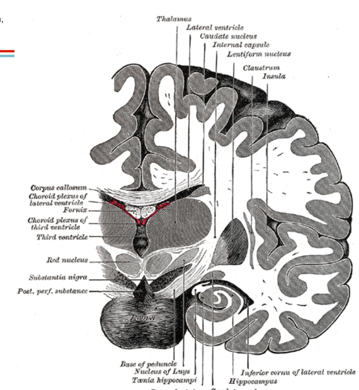
- Composed of:
  - Caudate nucleus, and the
  - Lentiform nucleus, which is made up of:
    - Putamen
    - Globus pallidus
- These nuclei influence movement in circuits involving the motor cortex, thalamus, substantia nigra (midbrain) and subthalamic nucleus (diencephalon).

Basal Nuclei: Corpus Striatum

- The neurons from motor regions of the frontal lobe release glutamate (stimulatory) on the putamen. The putamen then releases GABA (inhibitory) on other regions of the basal nuclei.
- The globus pallidus sends GABA-releasing (inhibitory) neurons to the thalamus, which sends excitatory axons to the motor cortex of the cerebrum.
- This completes a motor circuit...
- This circuit *stimulates appropriate movements and inhibits unwanted movement.*

Coronal brain section
through thalamus, anterior midbrain, hippocampus, and basal nuclei/basal ganglia

Nucleus of Luys = Subthalamic Nucleus



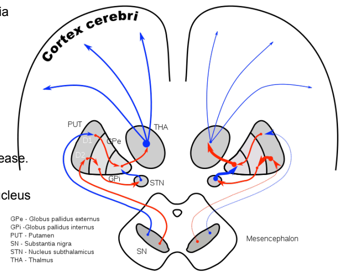
Basal ganglia motor circuit

Subthalamic nucleus and substantia nigra are often included in the basal ganglia.

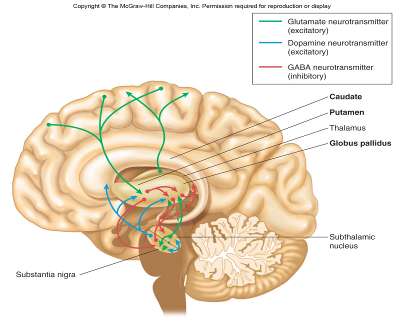
Lesion of subthalamic nucleus (stroke) => Hemiballismus.

Lesion of substantia nigra (degeneration)=> Parkinson's Disease.

Lesion/degeneration of caudate nucleus => Huntington;s Disease.



The Motor Circuit and Neurotransmitters involved



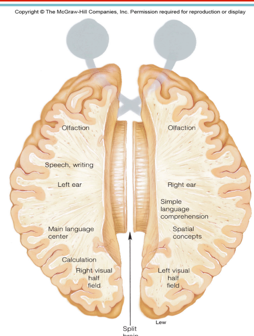
Cerebral Lateralization

- Each side of the precentral gyrus controls movements on the *contralateral* (opposite) side of the body.
- Somesthetic sensation from each side of the body projects to *contralateral* sides of the postcentral gyrus.
- Communication between the sides occurs through the *corpus callosum*; this is severed in severe forms of epilepsy.

Cerebral Lateralization

- Some tasks seem to be performed better by one side of the brain than the other.
  - Right hemisphere: visual-spatial tasks, recognizing faces, composing music, arranging blocks, reading maps
  - Left hemisphere: Language, speech, writing, calculations

Cerebral Lateralization



Language

- Most of the knowledge of how the brain controls language has come from studying people with language problems (producing language or understanding language) called aphasias.
- Two areas are identified as important :
  - Broca's area
  - Wernicke's area

….. Both on the LEFT side of the brain in most people.

Broca's Area

- Located in left inferior frontal gyrus
- Controls motor aspects of speech
  - Interestingly, other actions of the tongue, lips, and larynx are not affected; only the production of speech is affected.
  - Broca's aphasia involves slow, poorly articulated speech. There is no impairment in understanding.

Wernicke's Area

- Located in left superior temporal gyrus
- Controls *understanding* of words.
- Information about *written* words is sent by the occipital lobe, about *spoken* words by the auditory cortex.

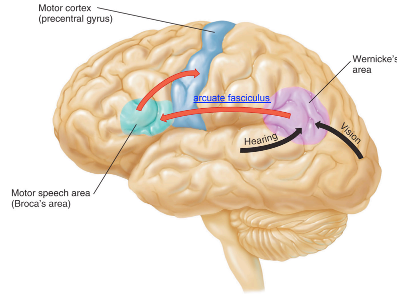
- Wernicke's aphasia involves production of rapid speech with no meaning, called "word salad." Language (spoken and written) comprehension is destroyed.

Speech

- To speak, word comprehension originates in Wernicke's area and is sent to Broca's area along the arcuate fasciculus, a tract of white matter.

- Broca's area then sends information to the motor cortex to direct movement of appropriate muscles.

Speech



Angular Gyrus

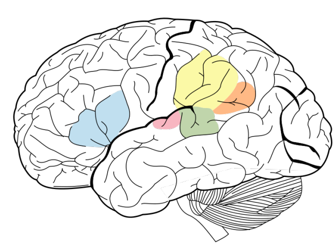
- Located at the junction between the parietal, occipital, and temporal lobes

- Center for integration of sensory information

- Damage here also produces aphasias involved in reading and writing

Language areas

- Diagram of human brain showing surface gyri and the primary auditory cortex
- Angular gyrus (orange)
- Supramarginal gyrus (yellow)
- Broca's area (blue)
- Wernicke's area (green)
- Primary auditory cortex (pink)



Angular gyrus….other functions…?

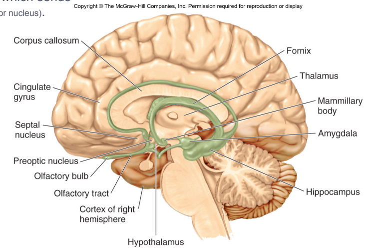
- **Out-of-body experiences**
  - Recent experiments have demonstrated the possibility that stimulation of the angular gyrus is the cause of out-of-body experiences. Stimulation of the angular gyrus in one experiment caused a woman to perceive a phantom existence behind her. Another such experiment gave the test subject the sensation of being on the ceiling. This is attributed to a discrepancy in the actual position of the body, and the mind's perceived location of the body.
- **Mathematics**
  - Since 1919, brain injuries to the angular gyrus have been known to often cause arithmetic deficits. Functional imaging has shown that while other parts of the parietal lobe bilaterally are involved in approximate calculations due to its link with spatiovisual abilities, the left angular gyrus together with left Inferior frontal gyrus are involved in exact calculation due to verbal arithmetic fact retrieval and when this is greater, a person's mathematical abilities are also greater.

The Limbic System

- Group of brain regions responsible for *emotional drives* (older part of brain; limbus means "border" or "ring")
  - Areas of the cerebrum included in limbic system: cingulate gyrus, amygdala, hippocampus, septal nuclei, anterior insula
  - Plus the hypothalamus and thalamus (in the diencephalon) are also part of this system

The Limbic System

The fornix connects the hippocampus to the hypothalamus (mammillary bodies), which sends neurons to the thalamus (anterior nucleus).



The thalamus sends neurons to the cingulate gyrus, which sends neurons to the hippocampus, completing the circuit.

Limbic System

- Once called the *rhinencephalon, or "smell brain*," because it also deals with olfaction.
- There are few synaptic connections between the limbic system and the cerebral cortex, which is why it is hard to control your emotions.

Limbic System

- Emotions controlled by the limbic system:
  - Aggression: areas in the amygdala and hypothalamus
  - Fear: amygdala and hypothalamus
  - Hunger/satiety: hypothalamus
  - Sex drive: the whole system
  - Goal-directed behaviors: hypothalamus and other regions (reward center?)

Memory

- Studies of people with amnesia reveal that *areas of the temporal lobe, hippocampus, caudate nucleus, and dorsomedial thalamus are involved in memory.*

In addition:

- …The *amygdala* is important in learning fear responses.
- …The *prefrontal cortex* may be involved in working memory (a very short-term memory, more diffusely located).

Types of Memory

- Short-term memory: recent events; transferred to long-term memory through process of *memory consolidation*
  - Memory consolidation occurs in the medial temporal lobe, hippocampus, and amygdala.
    - If remove left medial temp. lobe, cannot consolidate short-term verbal memories
    - If remove right medial temp. lobe, cannot consolidate short-term non-verbal (visual)memories
  - Sleep is needed for optimum memory consolidation.
- Long-term memory: requires actual structural change

Types of Memory

- Long-term memory can be classified into:
  - Nondeclarative (implicit--- implied): memory of simple skills, *how* to do things
  - Declarative (explicit--- clearly expressed): memory of things that can be verbalized. People with amnesia have impaired declarative memory, further broken into:
    - Semantic memory: facts
    - Episodic memory: events

Categories of Memory

Table 8.3 | Categories of Memories and the Major Brain Regions Involved

Memory Category	Major Brain Regions Involved	Length of Memory Storage	Examples
Episodic memory (explicit, declarative)	Medial temporal lobes, thalamus, fornix, prefrontal cortex	Minutes to years	Remembering what you had for breakfast, and what vacation you took last summer
Semantic memory (explicit, declarative)	Inferior temporal lobes	Minutes to years	Knowing facts such as what city is the capital, your mother's maiden name, and the different uses of a hammer and a saw
Procedural memory (explicit or implicit; nondeclarative)	Basal ganglia, cerebellum, supplementary motor areas	Minutes to years	Knowing how to shift gears in a car and how to tie your shoelaces
Working memory	Words and numbers: prefrontal cortex, Broca's area, Wernicke's area Spatial: prefrontal cortex, visual association areas	Seconds to minutes	Words and numbers: keeping a new phone number in your head until you dial it Spatial: mentally following a route

Source: Modified from: Budson, Andrew E. and Bruce H. Price."Memory dysfunction." *New England Journal of Medicine 352* (2005): 692–698.

Synaptic Changes in Memory

- Short-term memory involves a *recurrent (or reverberating) circuit,* where neurons synapse on each other in a circle.
  - Interruption of the circuit destroys the memory. => There was no structural change.
- Long-term memory requires a relatively permanent change in neuron chemical structure and synapses (requires protein synthesis).

Synaptic Changes in Memory

- Long-term potentiation (LTP) in the hippocampus is a good example of memory storage mechanism via synaptic learning.
  - Synapses that are stimulated at a high frequency exhibit increased excitability.
  - In these synapses, glutamate is secreted by the presynaptic neuron.
  - The postsynaptic neuron has both AMPA and NMDA receptors for glutamate.

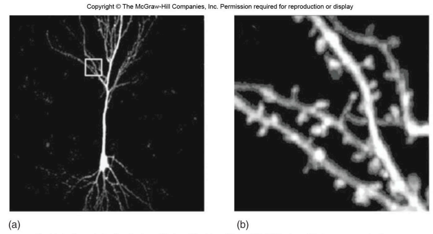
Synaptic Changes in Memory

- The mechanism:
  - Glutamate binds to AMPA receptor, allowing Na^+ in.
  - This depolarizes the cell and activates NMDA receptor channels (which were inactive due to a Mg^+ blocking the pore).
  - NMDA allows Ca^{2+} and Na^+ in.
  - The Ca^{2+} binds to a protein called calmodulin, which in turn activates an enzyme called CaMKII (calcium/calmodulin-dependent protein kinase II).

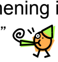
Synaptic Changes in Memory

- CaMKII causes more AMPA receptors to fuse to the plasma membrane. This alone strengthens the synapse–> it becomes more sensitive to glutamate release.
- It also promotes the growth of dendritic spines with AMPA receptors inserted.

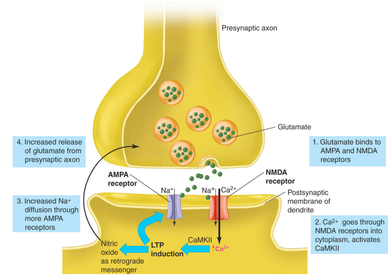
Synaptic Changes in Memory



Synaptic Changes in Memory

- A <u>retrograde</u> messenger (likely NO) is released into the synapse, and the presynaptic axon is changed so that <u>more</u> glutamate can be released.
- Endocannabinoids (also retrograde) may lift inhibition from GABA-releasing neurons on the synapse, further strengthening it (called "depolarization-induced suppression of inhibition"  .

Synaptic Changes in Memory



Neural Stem Cells in Learning

- Neural stem cells have been found in the hippocampus, and scientists suspect that <u>*neurogenesis is part of learning*</u>.
- In mice, physical activity and an enriched environment promote neurogenesis.
- Aging and stress reduce neurogenesis.

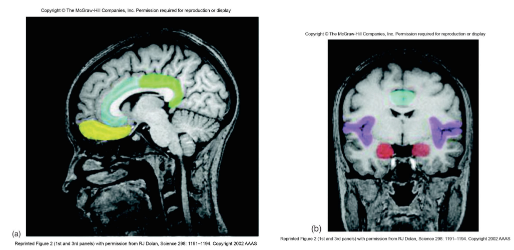
Emotions and Memory

- Emotions sometimes strengthen and other times weaken memory formation.
  - If the memory has an emotional component, the amygdala is involved in memory formation.
  - Stress impairs memory formation in the hippocampus and working memory function of the prefrontal cortex.
  - Posttraumatic stress disorder may result in hippocampal atrophy.

Emotions and Memory

- The amygdala and hippocampus also have receptors for *stress* hormones, such as cortisol.
  - It is thought that cortisol may <u>strengthen</u> emotional memory formation via the amygdala but <u>weaken</u> hippocampal memory formation and memory retrieval (PTSD?).

Brain Regions Involved in Emotion and Memory



a. Yellow = prefrontal cortex; mint green = cingulate gyrus
b. Purple = insula; mint green = cingulate gyrus; red = amygdala

Prefrontal Cortex functions…

- Orbitofrontal region:
  - ability to consciously experience pleasure and reward
  - receives input from all the senses and the limbic system
  - damage here results in severe impulsive behavior.
- Lateral prefrontal area:
  - motivation, sexual desire, and cognitive functions
- In general, judgement, motivation, interpersonal skills, memory, curiosity– found here.

Prefrontal Lobe

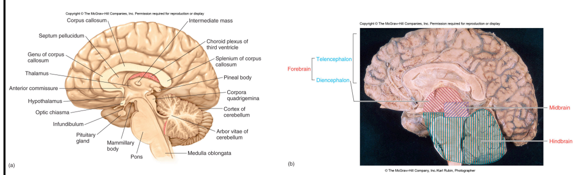
- The tale of Phineas Gage (1848); prefrontal lobotomies
- Subsequent studies, on patients with prefrontal injuries, have shown that the patients verbalized what the most appropriate social responses would be under certain circumstances. Yet, when actually performing, they instead pursued behavior that is aimed at immediate gratification despite knowing the longer-term results would be self-defeating.
- The interpretation of this data indicates that not only are skills of comparison and understanding of eventual outcomes harbored in the prefrontal cortex but the prefrontal cortex (when functioning correctly) *controls the mental option to delay immediate gratification* for a better or more rewarding longer-term gratification result. This ability to wait for a reward is one of the key pieces that define optimal executive function of the human brain.

III. Diencephalon

Diencephalon

- Part of the forebrain that includes the epithalamus, thalamus, hypothalamus, and part of the pituitary gland

Diencephalon



Epithalamus

- Contains the choroid plexus over the third ventricle where cerebrospinal fluid is produced
- Also contains the pineal gland, which secretes the hormone melatonin that helps regulate circadian rhythms

Thalamus

- Relay center through which most sensory information is passed to the cerebrum
- Promotes a state of arousal from sleep and alertness

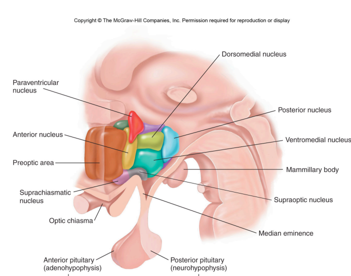
Hypothalamus

- Very important for maintaining homeostasis and regulating the autonomic system.
- Contains centers for:
  - Hunger/satiety and thirst
  - Regulation of body temperature
  - Regulation of sleep and wakefulness
  - Sexual arousal and performance
  - Emotions of fear, anger, pain, and pleasure
  - Control of the endocrine system (controls pituitary secretions)

Regions of the Hypothalamus

- Certain regions of the hypothalamus are known to control particular functions:
  - Lateral region: hunger
  - Medial region: satiety
  - Preoptic-anterior: shivering, hyperventilation, vasodilation, sweating
  - Supraoptic: produces antidiuretic hormone (ADH), which helps control urine formation
  - Paraventricular: produces the hormone oxytocin (OT), which stimulates childbirth

Regions of the Hypothalamus



Regulation of the Pituitary Gland by the Hypothalamus

- ADH and oxytocin are transported along the hypothalamo-hypophyseal tract (through axons) to the posterior pituitary gland, where they are stored until needed.
- The hypothalamus also produces releasing hormones and inhibiting hormones that are transported along the hypothalamo-hypophyseal portal system (through blood vessels) to the anterior pituitary to regulate the secretion of pituitary hormones.

Regulation of Circadian Rhythms by the Hypothalamus

- Suprachiasmatic nucleus (SCN) of the hypothalamus (the "master clock"): contains about 20,000 "clock cells" with activity that oscillates every 24 hours
  - Entrained by information about day length via tracts from cells in the retinas
  - Controls the secretion of melatonin from the pineal gland
  - Other circadian clock genes found in other organs as well

IV. Midbrain and Hindbrain

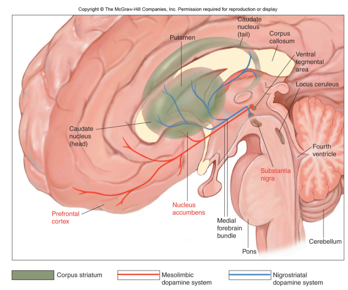
Midbrain

- Also called the mesencephalon. Includes:
  - Superior colliculi: visual reflexes
  - Inferior colliculi: auditory reflexes
    - [sup. and inf. coll. = 'corpora quadrigemina']
  - *Cerebral peduncles*
  - *Red nucleus*: connects the cerebrum and cerebellum; involved in motor coordination
  - *Substantia nigra*: important part of the motor circuit; part of the dopaminergic nigrostriatal system

Midbrain

- Ventral tegmental area (VTA): Part of the dopaminergic mesolimbic system that sends neurons to the limbic system and nucleus accumbens in the forebrain
- Involved in the behavioral reward system and has been implicated in addiction (nicotine, heroin, morphine, cocaine, amphetamine, ethanol) and psychiatric disturbances

Dopaminergic Pathways



Hindbrain

- Also called the rhombencephalon
- Composed of the metencephalon (pons and cerebellum) and myelencephalon (medulla oblongata)

Metencephalon

- Composed of the pons and cerebellum
- The pons houses sensory and motor tracts heading from/to the spinal cord.
  - The trigeminal, abducens, facial, and vestibulocochlear nerves arise from the pons
  - Two respiratory control centers are found here:
    - Apneustic
    - Pneumotaxic

Cerebellum

- Receives input from proprioceptors in joints, tendons, and muscles
- Works with the basal nuclei and motor cortex to coordinate movement
  - Fibers from the cerebellum pass through the red nucleus to the thalamus and then to the motor cortex

Cerebellum

- The cerebellum is needed for motor learning and the proper timing and force required to move limbs in a specific task.
- The cerebellum influences motor coordination through inhibition on the motor cortex.
- Other possible cerebellar functions include:
  - Acquisition of sensory data
  - Memory
  - Emotion
  - Involved in conditions such as schizophrenia and autism

Myelencephalon

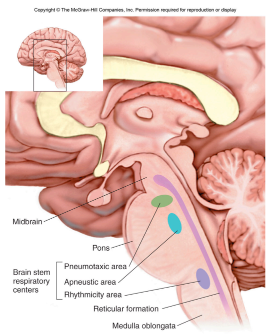
- Made up of the medulla oblongata
- All ascending and descending tracts between the brain and spinal cord pass through the medulla.
  - Tracts cross sides in the pyramids.
  - Cranial nerves VIII, IX, X, XI, and XII come off the medulla.

Medulla Oblongata

- Contains nuclei required for regulation of breathing and cardiovascular response = vital centers

– Vasomotor center controls blood vessel diameter.
– Cardiac control center controls heart rate.
– Rhythmicity center helps areas in the pons control breathing.

Medulla Oblongata



Reticular Activating System

- To fall asleep, we must tune out sensory stimuli. When awake, we are alert to sensory stimuli.
- This depends on the activation and inhibition of the reticular activating system (RAS).
  - Includes the pons and reticular formation of the midbrain

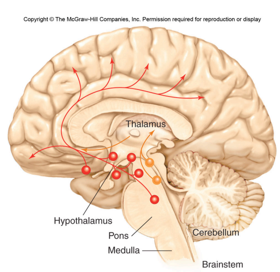
Reticular Activating System

- Arousal from sleep and alertness:
  - Neurons from the pons release ACh on the thalamus. This enhances passing of sensory information to the cerebrum.
  - Neurons from the hypothalamus and basal forebrain release monoamines onto the cerebrum, further enhancing alertness.
  - Neurons from the lateral hypothalamic area release arousing polypeptide hormones.
    - Loss of these neurons leads to narcolepsy.

Reticular Activating System

- Sleep
  - Neurons from the ventrolateral preoptic nucleus of the hypothalamus release GABA onto other areas of the RAS.
  - This inhibits the RAS and allows sleep.
  - This activity is increased with depth of sleep.

Structures of the RAS



V. Spinal Cord Tracts

Spinal Cord

- Composed of white matter surrounding a gray matter core
  - The gray matter is arranged with a left and right dorsal horn and a left and right ventral horn.

Spinal Cord

- The white matter is composed of ascending and descending fiber tracts.
  - Arranged into six columns called funiculi
  - Ascending tracts are given the prefix spino- with a suffix that indicates the brain region it synapses on.
  - Descending tracts are given the suffix -spinal, and the prefix indicates the brain region they came from.

Ascending Tracts

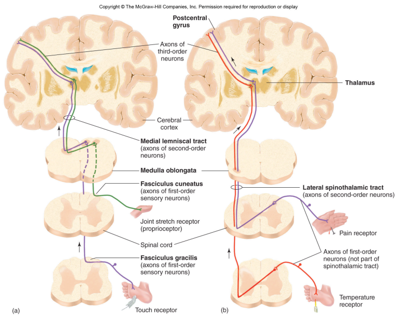
- Convey sensory information from receptors in the skin, muscles, joints, and organs
  - Crossover of information (contralateral) may occur in the spinal cord or in the medulla

Ascending Tracts

Table 8.4 | Principal Ascending Tracts of Spinal Cord

Tract	Origin	Termination	Function
Anterior spinothalamic	Posterior horn on one side of cord but crosses to opposite side	Thalamus, then cerebral cortex	Conducts sensory impulses for crude touch and pressure
Lateral spinothalamic	Posterior horn on one side of cord but crosses to opposite side	Thalamus, then cerebral cortex	Conducts pain and temperature impulses that are interpreted within cerebral cortex
Fasciculus gracilis and fasciculus cuneatus	Peripheral afferent neurons; ascends on ipsilateral side of spinal cord but crosses over in medulla	Nucleus gracilis and nucleus cuneatus of medulla; eventually thalamus, then cerebral cortex	Conducts sensory impulses from skin, muscles, tendons, and joints, which are interpreted as sensations of fine touch, precise pressures, and body movements
Posterior spinocerebellar	Posterior horn; does not cross over	Cerebellum	Conducts sensory impulses from one side of body to same side of cerebellum; necessary for coordinated muscular contractions
Anterior spinocerebellar	Posterior horn; some fibers cross, others do not	Cerebellum	Conducts sensory impulses from both sides of body to cerebellum; necessary for coordinated muscular contractions

Ascending Tracts



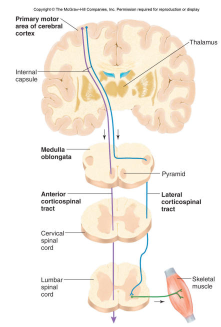
Descending Tracts

- Two major groups:
  1. Corticospinal (& corticobulbar) or pyramidal tract: descends directly without synaptic interruption from the cerebral cortex to the spinal cord
     - Cell bodies of these neurons are located mainly in the precentral gyrus and superior frontal gyrus, and some (10%) in the supplementary motor cortex (and, surprisingly, some cell bodies of the axons in this tract are in the POSTcentral gyrus).

Descending Pyramidal Tracts

- 80−90% cross sides in the medulla pyramids and descend as lateral corticospinal tracts.
- Those that do not cross sides here descend as anterior corticospinal tracts and cross in the spinal cord.

Descending Pyramidal Tracts



Descending Tracts

2. Extrapyramidal tracts: originate in the brain stem and are controlled by the motor circuits of the corpus striatum, substantia nigra, and thalamus
   – Symptoms of Parkinson disease reveal the importance of these tracts for initiating body movements, maintaining posture, and controlling facial expression.

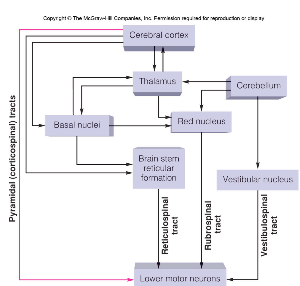
Extrapyramidal Tracts

– Reticulospinal tracts are the major descending extrapyramidal tracts.
  - These originate in the reticular formation of the brain stem. This area is stimulated or inhibited by neurons from the cerebellum, basal nuclei, and cerebrum.

– Vestibulospinal tracts arise from the vestibular nuclei.

– Rubrospinal tracts arise from the red nuclei.

Tracts Involved in the Control of Skeletal Muscles



VI. Cranial and Spinal Nerves

Cranial Nerves, I -XII

- Part of the PNS
- Nerves that arise directly from nuclei in the brain
- Twelve pairs, I-XII
- Most are mixed nerves with both sensory and motor neurons
- Those associated with vision, olfaction, and hearing are sensory only
  - Cell bodies of these neurons are not in the brain but in ganglia located near the sensory organ (i.e., retina, olfactory mucosa, and spiral ganglia).

Cranial Nerves

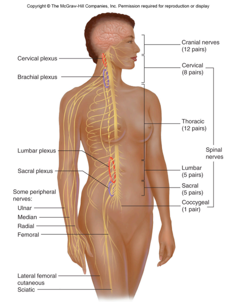
Table 8.6 | Summary of Cranial Nerves

Number and Name	Composition	Function
I Olfactory	Sensory	Olfaction
II Optic	Sensory	Vision
III Oculomotor	Motor	Motor impulses to levator palpebrae superioris and extrinsic eye muscles, except superior oblique and lateral rectus; innervation to muscles that regulate amount of light entering eye and that focus the lens
	Sensory: proprioception	Proprioception from muscles innervated with motor fibers
IV Trochlear	Motor	Motor impulses to superior oblique muscle of eyeball
	Sensory: proprioception	Proprioception from superior oblique muscle of eyeball
V Trigeminal		
Ophthalmic division	Sensory	Sensory impulses from cornea, skin of nose, forehead, and scalp
Maxillary division	Sensory	Sensory impulses from nasal mucosa, upper teeth and gums, palate, upper lip, and skin of cheek
Mandibular division	Sensory	Sensory impulses from temporal region, tongue, lower teeth and gums, and skin of chin and lower jaw
	Sensory: proprioception	Proprioception from muscles of mastication
	Motor	Motor impulses to muscles of mastication and muscle that tenses the tympanum
VI Abducens	Motor	Motor impulses to lateral rectus muscle of eyeball
	Sensory: proprioception	Proprioception from lateral rectus muscle of eyeball
VII Facial	Motor	Motor impulses to muscles of facial expression and muscle that tenses the stapes
	Motor: parasympathetic	Secretion of tears from lacrimal gland and salivation from sublingual and submandibular salivary glands
	Sensory	Sensory impulses from taste buds on anterior two-thirds of tongue; nasal and palatal sensation.
	Sensory: proprioception	Proprioception from muscles of facial expression
VIII Vestibulocochlear	Sensory	Sensory impulses associated with equilibrium
		Sensory impulses associated with hearing
IX Glossopharyngeal	Motor	Motor impulses to muscles of pharynx used in swallowing
	Sensory: proprioception	Proprioception from muscles of pharynx
	Sensory	Sensory impulses from pharynx, middle-ear cavity, carotid sinus, and taste buds on posterior one-third of tongue
	Parasympathetic	Salivation from parotid salivary gland
X Vagus	Motor	Contraction of muscles of pharynx (swallowing) and larynx (phonation)
	Sensory: proprioception	Proprioception from visceral muscles
	Sensory	Sensory impulses from taste buds on rear of tongue; sensations from auricle of ear; general visceral sensations
	Motor: parasympathetic	Regulation of many visceral functions
XI Accessory	Motor	Laryngeal movement; soft palate
		Motor impulses to trapezius and sternocleidomastoid muscles for movement of head, neck, and shoulders
	Sensory: proprioception	Proprioception from muscles that move head, neck, and shoulders
XII Hypoglossal	Motor	Motor impulses to intrinsic and extrinsic muscles of tongue and infrahyoid muscles
	Sensory: proprioception	Proprioception from muscles of tongue

Spinal Nerves

- Part of the PNS
- Nerves that arise directly from the spinal cord
- 31 pairs: 8 cranial, 12 thoracic, 5 lumbar, 3 sacral, 1 coccygeal
- All are mixed nerves that separate near the spinal cord into a dorsal root carrying sensory fibers and a ventral root carrying motor fibers.
  - The dorsal root ganglion houses the sensory neuron cell bodies.

Spinal Nerves



Reflex Arch