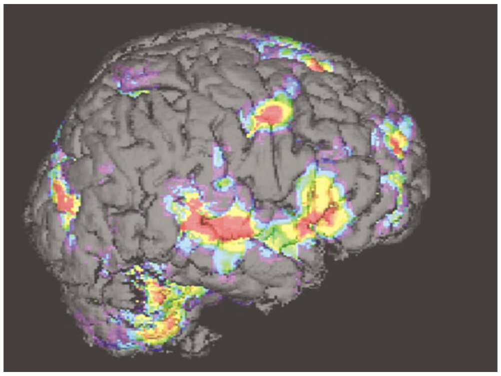


CHAPTER 48 & 49: NERVOUS SYSTEMS

AP Biology 2013

1

OVERVIEW

- Human brain consists of an estimated 100 billion neurons. Each neuron may communicate with thousands of other neurons that function in specialized circuits dedicated to different tasks
- All animals except sponges have some type of nervous system
- Cone snail kills prey with venom that disables neurons (nerve cells that transfer information)
- Neurons use two types of signals: electrical (long-distance), chemical (short distance)
- Processing information takes place in simple clusters of neurons called ganglia or a more complex structure called a brain

Fig. 48.1

2

INFORMATION PROCESSING

- Three stages: sensory input, integration, and motor output
- Sensory neurons - transmit information from sensors that detect external stimuli and internal conditions
- Interneurons -part of the CNS that receives and integrates sensory information
- Motor neurons - send motor output signals to the effector cells
- Central nervous system (CNS) - brain and nerve cord where integration takes place
- Peripheral nervous system (PNS) - carries information into and out of CNS

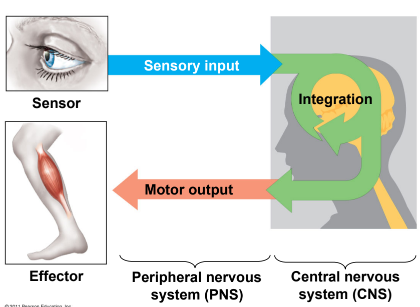


Fig. 48.3

3

NEURON STRUCTURE

- Most organelles are located in the cell body
- Dendrites - highly branched extensions that receive signals from other neurons
- Axon - longer extension that transmits signals to other cells at synapses
  - May be covered in a myelin sheath

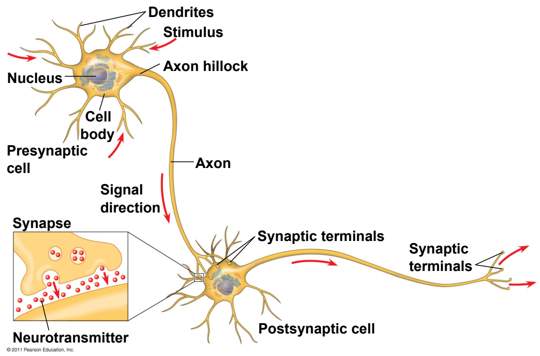
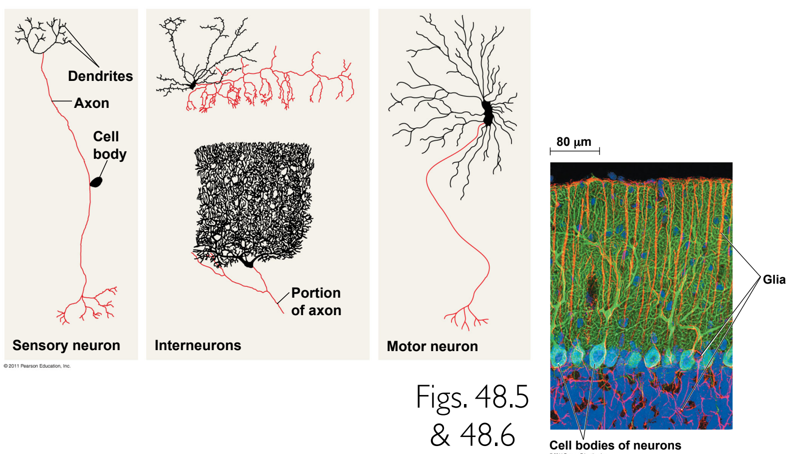


Fig. 48.4

NEURON SHAPE

- Shape of a neuron reflects its input and output interactions



Figs. 48.5 & 48.6

ION CHANNELS

- Across the membrane, every cell has a voltage (called membrane potential)
  - Inside of the cell is negative to the outside
  - Resting potential is the potential of a neuron that is not transmitting
    - Depends on the ionic gradients

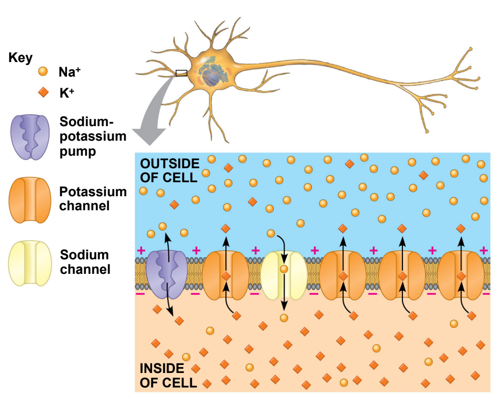


Fig. 48.7

ION CHANNELS

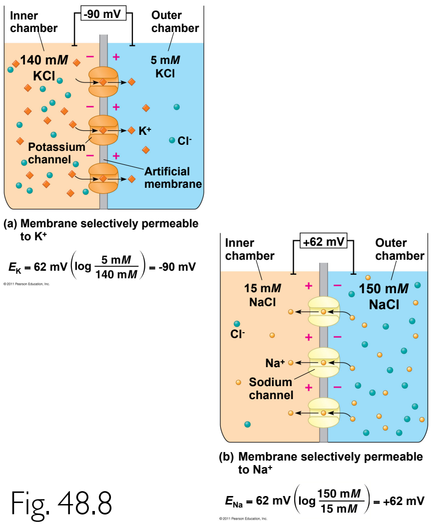


Fig. 48.8

- Concentration of Na^+ is higher in the extracellular fluid than in the cytosol, while the opposite is true for K^+.
- A neuron that is not transmitting signals contains many open K^+ channels and fewer open Na^+ channels in its plasma membrane.
- The diffusion of K^+ and Na^+ through these channels leads to separation of charges across the membrane, producing resting potential.
- Gated ion channels open or close in response to a change in membrane potential.

7

ACTION POTENTIALS

- If a cell has gated ion channels, its membrane potential may change in response to stimuli that open or close the channels.
- Stimuli either trigger hyperpolarization (increase in magnitude of the membrane potential) or depolarization (reduction of the magnitude of the membrane potential)
- A signal strong enough to produce a depolarization that reaches the threshold triggers a stronger response (**action potential**)
- Action potential - brief **all-or-nothing** depolarization of a neuron's plasma membrane; type of signal that carries information along axons

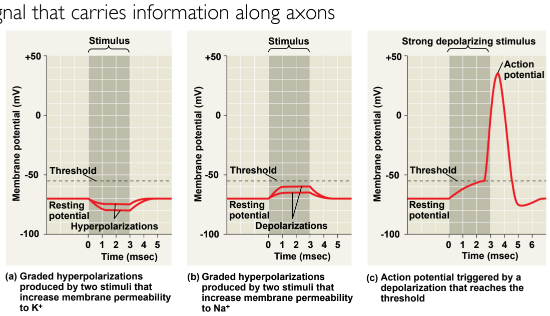


Fig. 48.10

8

- Both voltage-gated Na^+ channels and voltage-gated K^+ channels are involved in the production of action potential
  - When a stimulus depolarizes the membrane, Na^+ channels open, allowing Na^+ to diffuse into the cell
  - As the action potential subsides, K^+ channels open, and K^+ flows out of the cell
  - A refractory period follows during which a second action potential cannot be initiated.

ACTION POTENTIALS

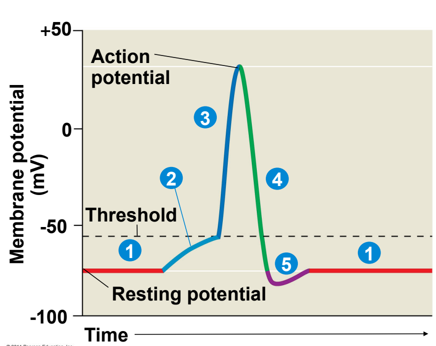
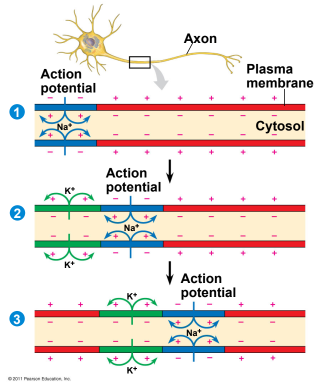


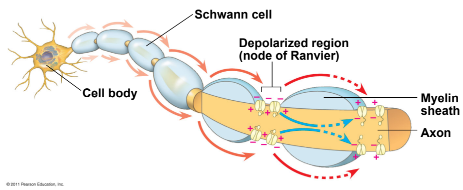
Fig. 48.11

9

ACTION POTENTIALS

- Can travel long distances
- Action potential is generated at the axon hillock where an electrical current depolarizes the neighboring region of the axon
- The speed increases with the diameter of the axon
- In vertebrates axons are myelinated which causes the speed of an action potential to increase
  - Action potential jumps between the nodes of Ranvier in a process called saltatory conduction

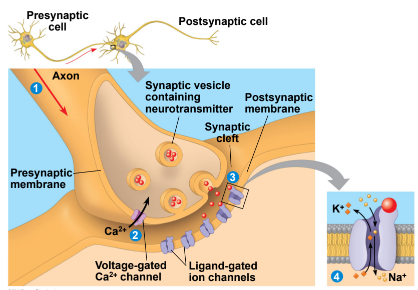


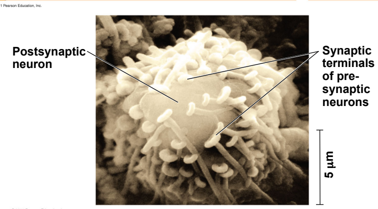


Figs. 48.12 & 48.14

NEURONS COMMUNICATE AT SYNAPSES

- Electrical synapse - electrical current flows directly from one cell to another via a gap junction
- Chemical synapse - a presynaptic neuron releases chemical neurotransmitters which are stored in the synaptic terminal
- When the action potential reaches the terminal neurotransmitters are released into the synaptic cleft where they bind to ligand-gated ion channels
  - Binding of neurotransmitters causes ion channels to open generating a postsynaptic potential





Figs. 48.15 & 48.16

POSTSYNAPTIC POTENTIALS

- After release, neurotransmitters diffuse out of the synaptic cleft and may be taken up by surrounding cells and degraded.
  - Excitatory postsynaptic potentials (EPSPs) - most neurons have many synapses so a single EPSP is too small to trigger an action potential in the postsynaptic neuron
  - Inhibitory postsynaptic potentials (IPSPs) - can counter the effect of an EPSP

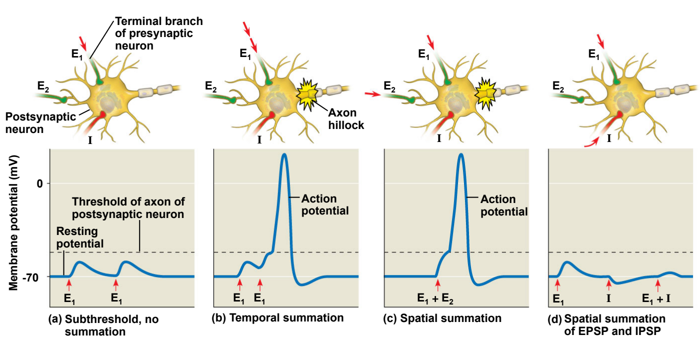
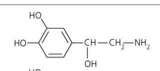
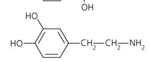
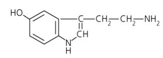


Fig. 48.17

NEUROTRANSMITTERS

- Same neurotransmitter can produce different effects in different types of cells
  - Acetylcholine - one of the most common in both vertebrates and invertebrates; can be inhibitory or excitatory
  - Biogenic amines - epinephrine, norepinephrine, dopamine, and serotonin (active in the CNS and PNS)
  - Neuropeptides - endorphins which impact perception of pain
  - Amino acids and peptides
  - Gasses - nitric oxide and carbon monoxide (regulators in the PNS)

Table 48.2 Major Neurotransmitters

Neurotransmitter	Structure
Acetylcholine	$H_3C-C(=O)-O-CH_2-CH_2-N^+(CH_3)_3$
Amino Acids	
GABA (gamma-aminobutyric acid)	$H_2N-CH_2-CH_2-CH_2-COOH$
Glutamate	$H_2N-CH(COOH)-CH_2-CH_2-COOH$
Glycine	H_2N-CH_2-COOH
Biogenic Amines	
Norepinephrine	
Dopamine	
Serotonin	
Neuropeptides (a very diverse group, only two of which are shown)	
Substance P	Arg—Pro—Lys—Pro—Gln—Gln—Phe—Phe—Gly—Leu—Met
Met-enkephalin (an endorphin)	Tyr—Gly—Gly—Phe—Met
Gases	
Nitric oxide	N=O

NERVOUS SYSTEM ORGANIZATION

- Nerve net - series of interconnected nerve cells
- Nerves - bundles of axons of multiple nerve cells

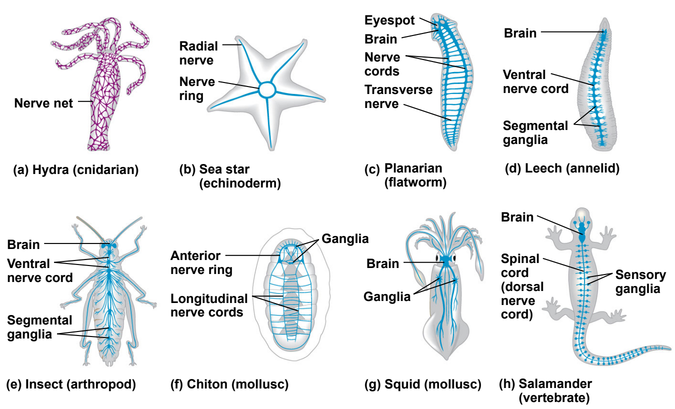


Fig. 49.2

ORGANIZATION OF VERTEBRATE NERVOUS SYSTEM

- Spinal cord conveys information from and to the brain
- Spinal cord also produces reflexes (body's automatic response to a stimulus

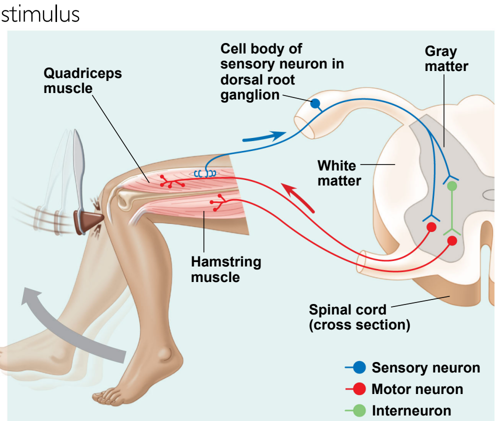
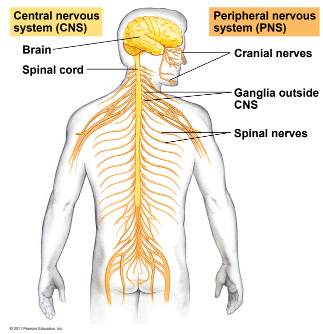
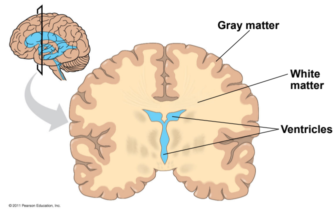


Fig. 48.4

VERTEBRATE NERVOUS SYSTEM

- Cephalization and distinct CNS and PNS
- Brain provides integrative power that allows for complex behavior
- Spinal cord integrates simple responses to stimuli and conveys information to and from the brain
- Central canal of the spinal cord and four ventricles of the brian are hollow because they are derived from the dorsal embryonic nerve cord and filled with cerebrospinal fluid

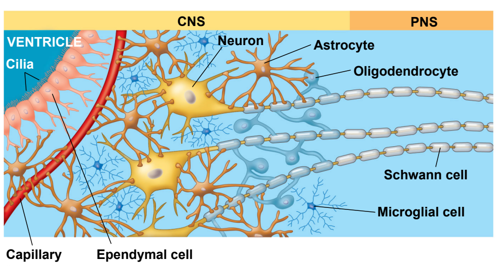




Figs. 49.4 & 49.5

SUPPORTING CELLS

- Gilia - essential for structural integrity of the nervous system and for normal functioning neurons
  - Astrocytes - provide structural support for neurons and regulate extracellular concentrations of ions and neurotransmitters in the CNS
  - Oligodendrocytes (CNS) and Schwann cells (PNS) - are gila that form the myelin sheaths around axons of many vertebrate neurons



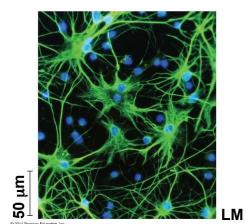


Fig. 49.6

PERIPHERAL NERVOUS SYSTEM

- PNS transmits information to and from the CNS
- Cranial nerves originate in the brain and terminates in the organs of the head
- Spinal nerves originates in the spinal cord and extend the parts of the body below the head
- PNS is divided into two functional components:
  - Motor system - carries signals to skeletal muscles
  - Autonomic nervous systems - regulates the internal environment in an involuntary manner; divided into the sympathetic, parasympathetic, and enteric divisions

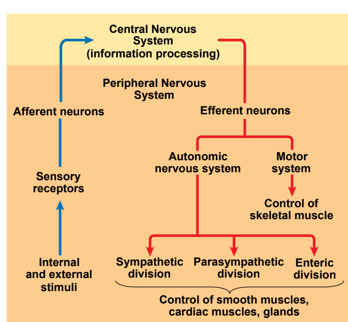
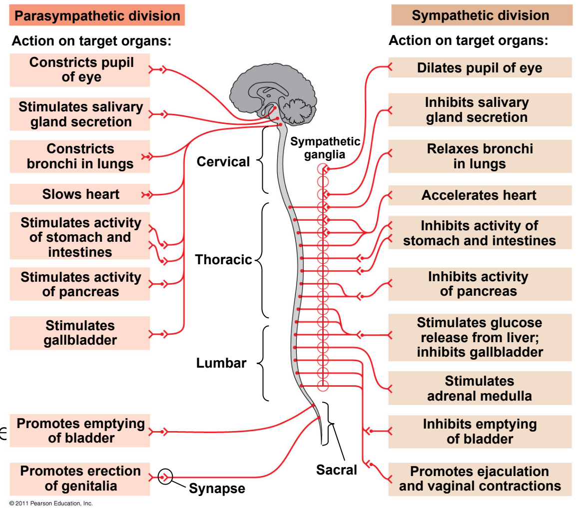


Fig. 49.7

AUTONOMIC NERVOUS SYSTEM

Fig. 49.8

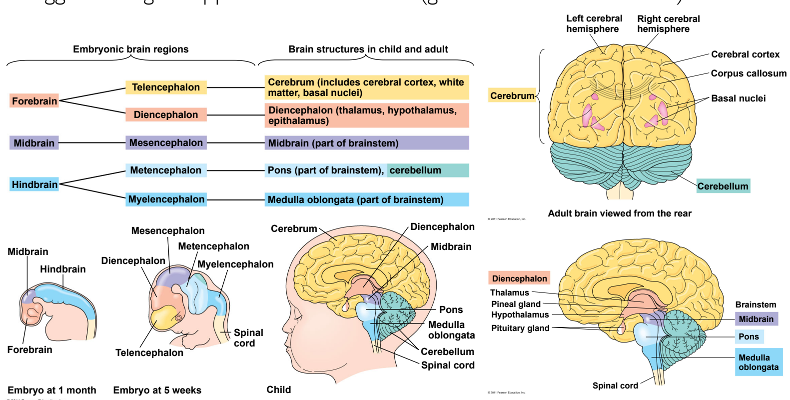
- Sympathetic and parasympathetic are antagonistic
- Sympathetic - fight-or-flight
- Parasympathetic - return to self-maintenance functions
- Enteric - controls activity of digestive tract, pancreas, and gallbaldder



DEVELOPMENT OF BRAIN

- Brain develops from the forebrain, midbrain, and hindbrain
- Week 5 - give brain regions form from original three
- Biggest changes happens in the forebrain (gives rise to the cerebrum)

Fig. 49.9

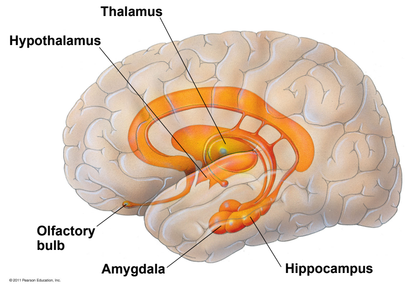


AROUSAL AND SLEEP

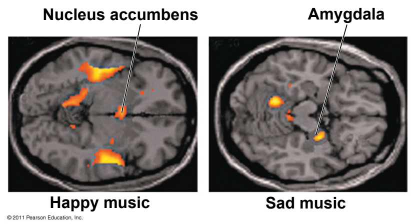
- Controlled by brainstem
- Regulates the amount and type of information that reaches the cerebral cortex and affects alertness
- Hormone melatonin is released by the pineal glad and plays a role in bird and mammal sleep cycles
- Sleep is essential (may play a role in memory)
- Biological clock can direct gene expression and is usually synchronized to light and dark cycles

EMOTIONS

- Limbic system - ring of structures around the brainstem
- Includes three parts of the cerebral cortex: amygdala, hippocampus, and olfactory bulb
  - These structures interact with with the neocortex to mediate primary emotions and attach "feelings" to survival-related functions



Figs. 49.13 & 49.14



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LANGUAGE AND SPEECH

- Broca's area - area in frontal lobe that is active when speech is generated
- Wernicke's area - area in temporal lobe that is active when speech is heard
- Left hemisphere is more adept at language, math, logic
- Right hemisphere is stronger at pattern recognition, nonverbal thinking, and emotional processing

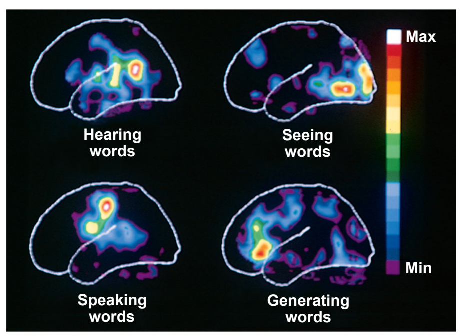


Fig. 49.16

23

CEREBRAL CORTEX

- Has four lobes: frontal, parietal, temporal, and occipital
- Somatosensory cortex and motor cortex - neurons are distributed according to the part of the body that generates sensory input or receives motor input
- Lateralization - competing functions segregate and displace each other in the cortex of left and right hemispheres
  - Left hemisphere - language, math, logical operations
  - Right hemisphere - pattern recognition, nonverbal thinking , and emotional processing

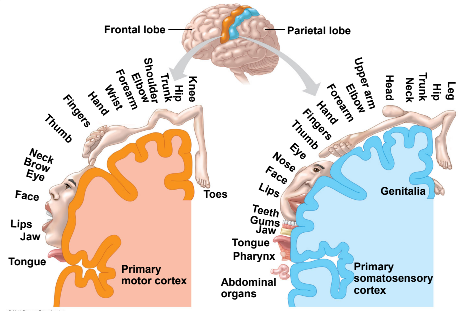


Fig. 49.17

24

MEMORY AND LEARNING

- Frontal lobes - site of short-term memory
    - Interact with hippocampus and amygdala to consolidate long-term memory
- Areas of the cerebral cortex are involved in the storing and retrieving of words and images
- Neural plasticity - describes ability of nervous system to be modified after birth

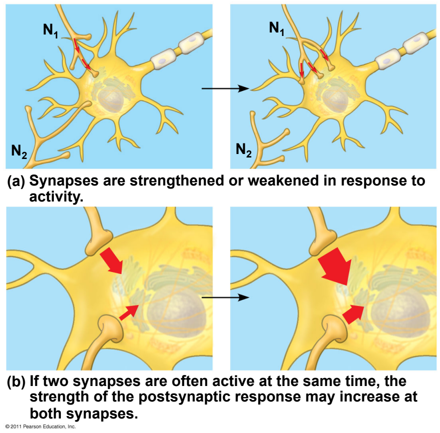


Fig. 49.19

25

MEMORY AND LEARNING

- Short-term memory - accessed via the hippocampus
- Long-term memory - stored in cerebral cortex
- Long-term potentiation - involves increase in strength of synaptic transmission

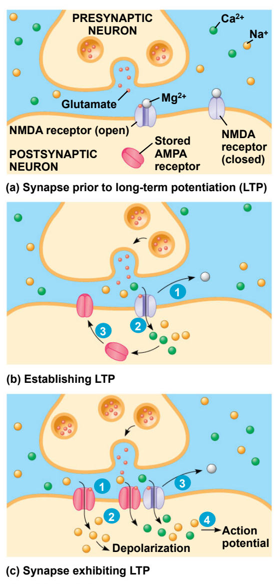


Fig. 49.20

26

STEM CELLS IN THE BRAIN

- Adult human brain contains neural stem cells
- Play a role in learning and memory

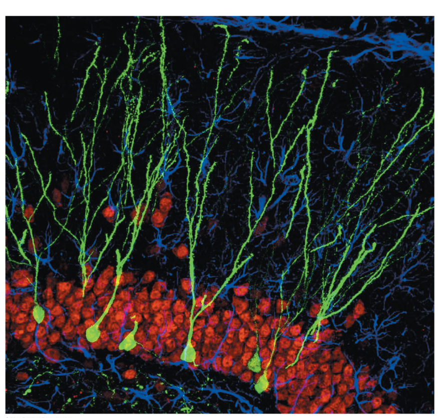


Fig. 49.21

27

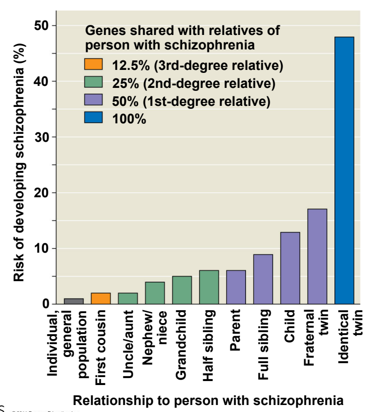
CNS INJURIES

- CNS (unlike PNS) cannot repair itself when damaged or diseased
- Receptor binding of adjacent nerve cells triggers a signal transduction pathway which may cause an axon to grow toward or away from the source of a signal
- Neural stem cells have the ability to differentiate into mature neurons and may hold promise for repairing damage

28

CNS DISORDERS

- Schizophrenia - (about 1% of world's population)
  - Characterized by hallucinations, delusions, blunted emotions
  - Treatments focus on brain pathways that use dopamine as a neurotransmitter
- Depression: bipolar disorder (manic and depressive phases) and major depression (persistent low mood)
  - Treatments involve drugs like Prozac and lithium
- Alzheimer's disease - mental deterioration characterized by confusion and memory loss
  - Caused by neurofibrillary tangles and plaques in the brain
- Parkinson's disease - caused by death of dopamine-secreting neurons; characterized by difficulty initiating movements



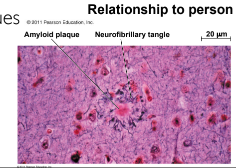


Fig.s 49.22 & 49.24

29

DRUG ADDICTION

- Some drugs are addictive because they increase activity of the brain's reward system
- Addictive drugs enhance the activity of the dopamine pathway
- Drug addiction leads to long-lasting changes in the reward circuitry that causes a craving for the drug

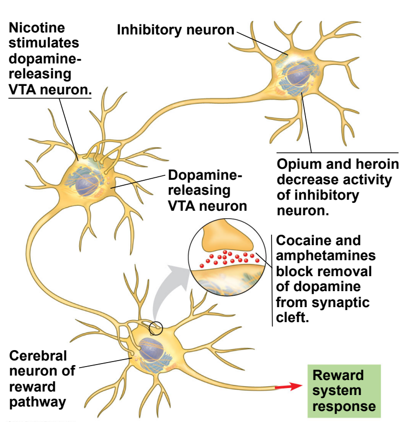


Fig. 48.23

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