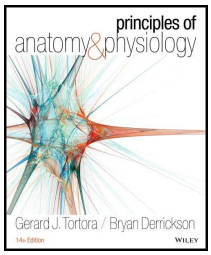


Principles of Anatomy and Physiology

14th Edition

CHAPTER 12
Nervous Tissue

Introduction

The purpose of the chapter is to:

1. Understand how the nervous system helps to keep controlled conditions within limits that maintain health and homeostasis
2. Learn about the different branches of the nervous system
3. Identify and describe the various types of cells that are found in nervous tissue

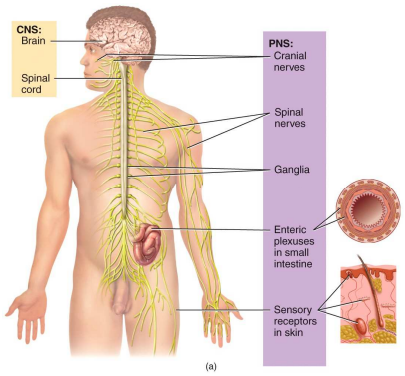
Nervous System Overview

Interactions Animation:

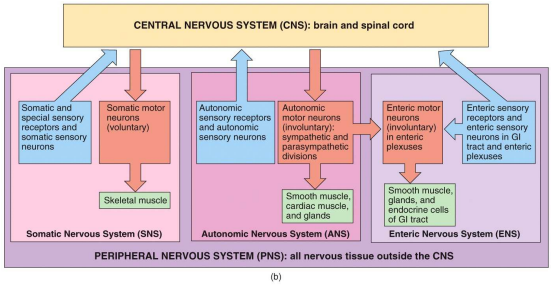
- Introduction to Structure and Function of the Nervous System

You must be connected to the Internet and in Slideshow Mode to run this animation.

Layout of the Nervous System



Organization of the Nervous System



Functions of the Nervous System

Sensory

- Sense changes through sensory receptors

Motor

- Respond to stimuli

Integrative

- Analyze incoming sensory information, store some aspects, and make decisions regarding appropriate behaviors

Histology of the Nervous System: Neurons vs. Neuroglia

Nervous Tissue

Anatomy Overview:

- Nervous Tissue

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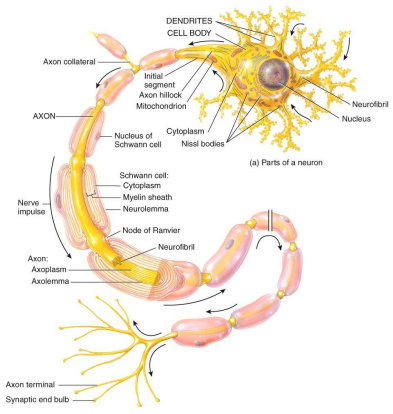
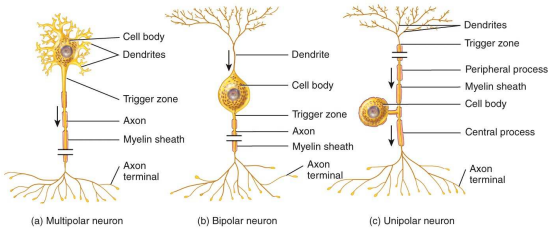
Neurons

Neurons

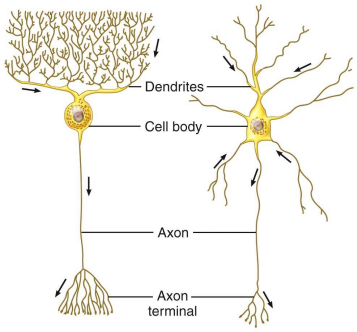
- Electrically excitable
- Cellular structures



Structural Classification of Neurons



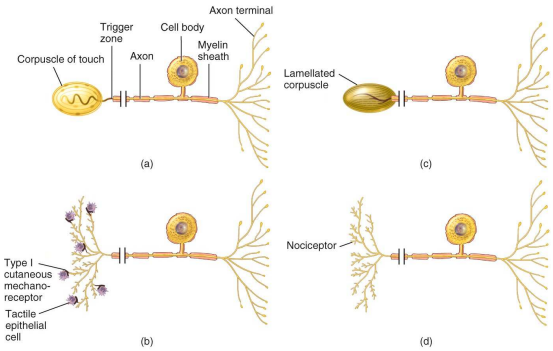
Examples of Dendritic Branching



Functional Classification of Neurons

- Sensory/afferent neurons
- Motor/efferent neurons
- Inter/association neurons

Examples of Sensory Receptors

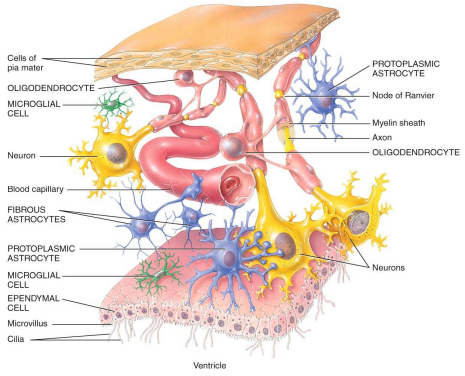


Neuroglia

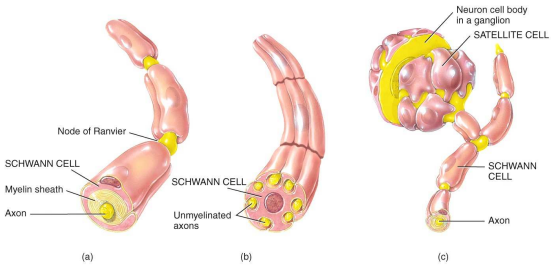
Neuroglia

- Not electrically excitable
- Make up about half the volume of the nervous system
- Can multiply and divide
- 6 kinds total (4 in CNS, 2 in PNS)

Neuroglia of the CNS

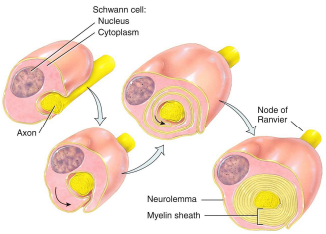


Neuroglia of the PNS



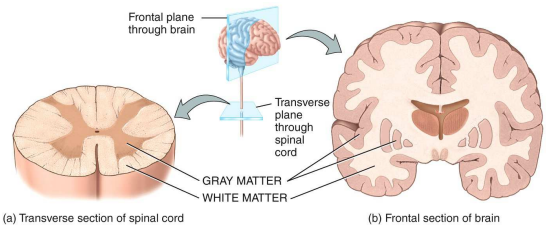
Myelination of Neurons

The myelin sheath is produced by Schwann cells and oligodendrocytes and it surrounds the axons of most neurons



(a) Transverse sections of stages in the formation of a myelin sheath

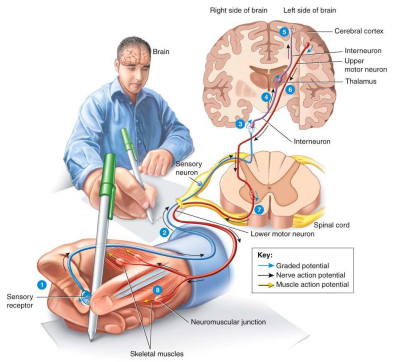
Gray Matter vs. White Matter



Electrical Signals in Neurons

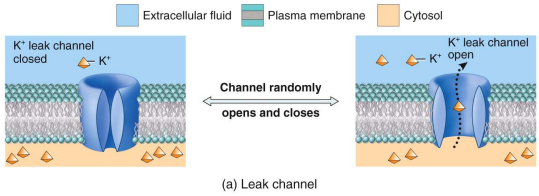
- Excitable cells communicate with each other via action potentials or graded potentials
- Action potentials (AP) allow communication over short and long distances whereas graded potentials (GP) allow communication over short distances only
  - Production of an AP or a GP depends upon the existence of a resting membrane potential and the existence of certain ion channels

Graded Potentials & Action Potentials



Ion Channels in Neurons

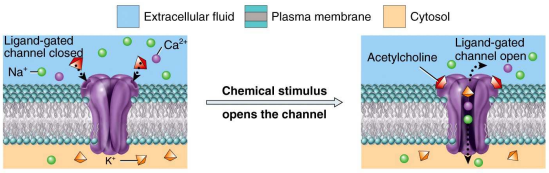
- Leakage channels alternate between open and closed
- K^+ channels are more numerous than Na^+ channels



(a) Leak channel

Ion Channels in Neurons

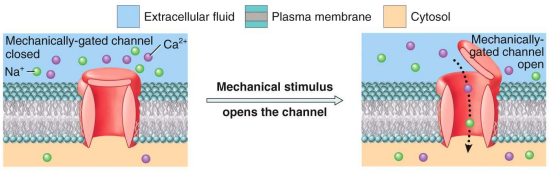
Ligand-gated channels respond to chemical stimuli (ligand binds to receptor)



(b) Ligand-gated channel

Ion Channels in Neurons

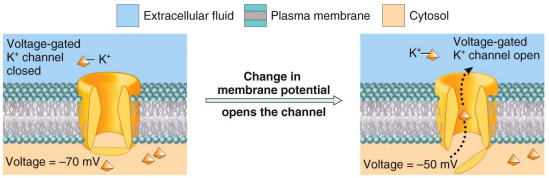
Mechanically-gated channels respond to mechanical vibration or pressure stimuli



(c) Mechanically-gated channel

Ion Channels in Neurons

Voltage-gated channels respond to direct changes in membrane potential



(d) Voltage-gated channel

Ion Channels in Neurons

TABLE 12.1

Ion Channels in Neurons

TYPE OF ION CHANNEL	DESCRIPTION	LOCATION
Leak channels	Gated channels that randomly open and close.	Found in nearly all cells, including dendrites, cell bodies, and axons of all types of neurons.
Ligand-gated channels	Gated channels that open in response to binding of ligand (chemical) stimulus.	Dendrites of some sensory neurons such as pain receptors and dendrites and cell bodies of interneurons and motor neurons.
Mechanically-gated channels	Gated channels that open in response to mechanical stimulus (such as touch, pressure, vibration, or tissue stretching).	Dendrites of some sensory neurons such as touch receptors, pressure receptors, and some pain receptors.
Voltage-gated channels	Gated channels that open in response to voltage stimulus (change in membrane potential).	Axons of all types of neurons.

Membrane Potentials

Interactions Animation:

- Membrane Potentials

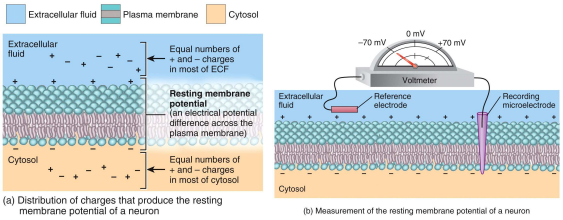
You must be connected to the Internet and in Slideshow Mode to run this animation.

Resting Membrane Potential

The membrane of a non-conducting neuron is positive outside and negative inside. This is determined by:

1. Unequal distribution of ions across the plasma membrane and the selective permeability of the neuron's membrane to Na^+ and K^+
2. Most anions cannot leave the cell
3. Na^+/K^+ pumps

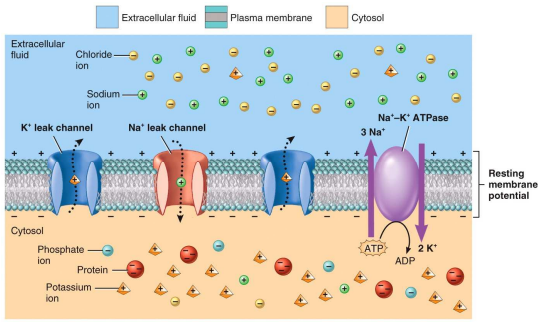
Resting Membrane Potential: Voltage Difference



(a) Distribution of charges that produce the resting membrane potential of a neuron

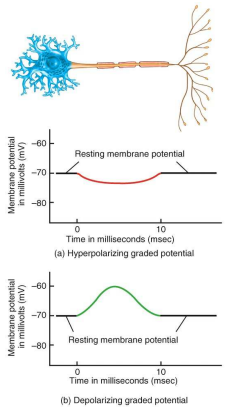
(b) Measurement of the resting membrane potential of a neuron

Factors Contributing to Resting Membrane Potential



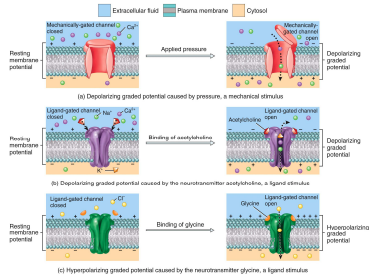
Graded Potentials

Small deviations in resting membrane potential



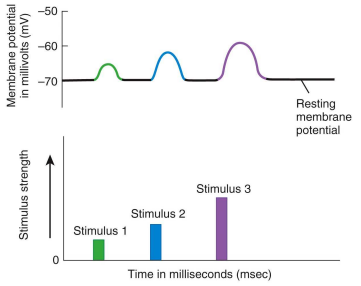
Graded Potentials

A graded potential occurs in response to the opening of a mechanically-gated or ligand-gated ion channel



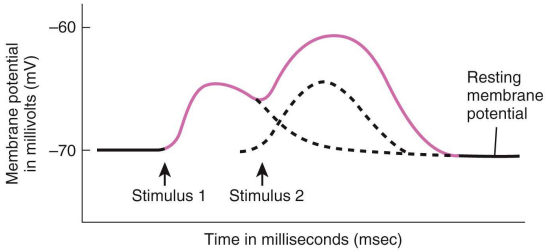
Graded Potentials: Stimulus Strength

The amplitude of a graded potential depends on the stimulus strength



Graded Potentials: Summation

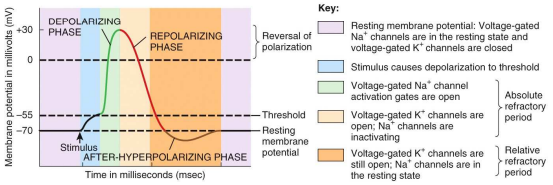
Graded potentials can be add together to become larger in amplitude



Action Potentials

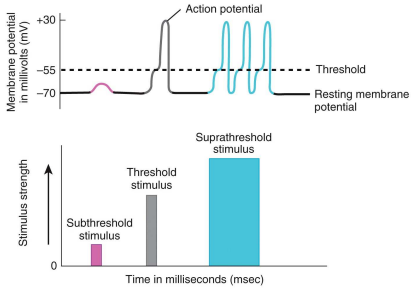
An action potential is a sequence of rapidly occurring events that decrease and eventually reverse the membrane potential (depolarization) and eventually restore it to the resting state (repolarization)

Action Potentials

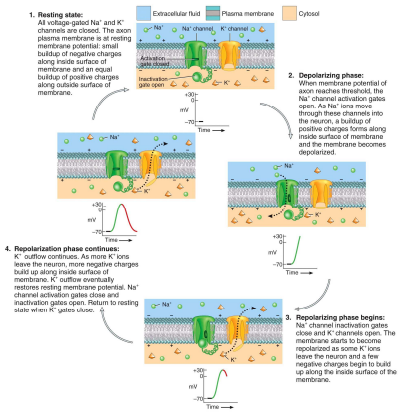


Action Potentials: Stimulus Strength

Action potentials can only occur if the membrane potential reaches threshold



Action Potentials: the Status of Na^+ and K^+ Voltage-Gated Channels



Comparison of Graded & Action Potentials

TABLE 12.2

Comparison of Graded Potentials and Action Potentials in Neurons

CHARACTERISTIC	GRADED POTENTIALS	ACTION POTENTIALS
Origin	Arise mainly in dendrites and cell body.	Arise at trigger zones and propagate along axon.
Types of channels	Ligand-gated or mechanically-gated ion channels.	Voltage-gated channels for Na^+ and K^+.
Conduction	Decremental (not propagated); permit communication over short distances.	Propagate and thus permit communication over longer distances.
Amplitude (size)	Depending on strength of stimulus, varies from less than 1 mV to more than 50 mV.	All or none; typically about 100 mV.
Duration	Typically longer, ranging from several milliseconds to several minutes.	Shorter, ranging from 0.3 to 2 msec.
Polarity	May be hyperpolarizing (inhibitory to generation of action potential) or depolarizing (excitatory to generation of action potential).	Always consist of depolarizing phase followed by repolarizing phase and return to resting membrane potential.
Refractory period	Not present; summation can occur.	Present; summation cannot occur.

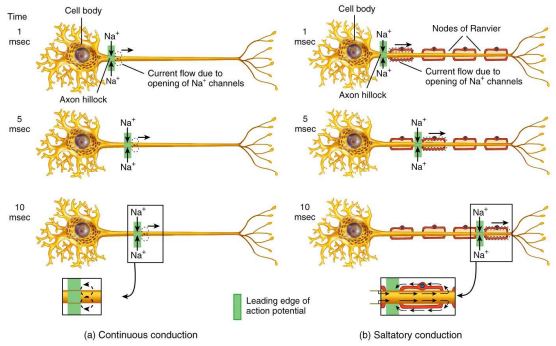
Propagation of Action Potentials

Interactions Animation:

- Propagation of Nerve Impulses

You must be connected to the Internet and in Slideshow Mode to run this animation.

Continuous vs. Saltatory Conduction



Factors that Affect Propagation Speed

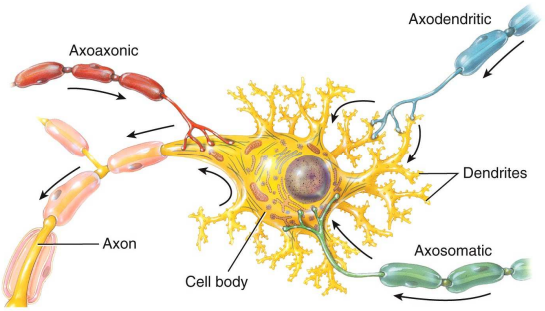
- Axon diameter
- Amount of myelination
- Temperature

Signal Transmission at Synapses

A synapse is the junction between neurons or between a neuron and an effector

- Electrical Synapse
  - Gap junctions connect cells and allow the transfer of information to synchronize the activity of a group of cells
- Chemical Synapse
  - One-way transfer of information from a presynaptic neuron to a postsynaptic neuron

Synapses Between Neurons



Events at the Synapse

Interactions Animation:

- Events at the Synapse

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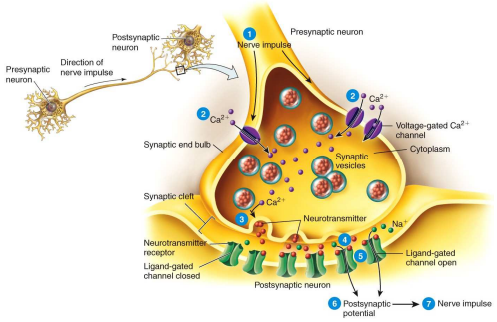
Signal Transmission at a Chemical Synapse



Postsynaptic Potentials

Excitatory postsynaptic potentials

- A depolarizing postsynaptic potential

Inhibitory postsynaptic potentials

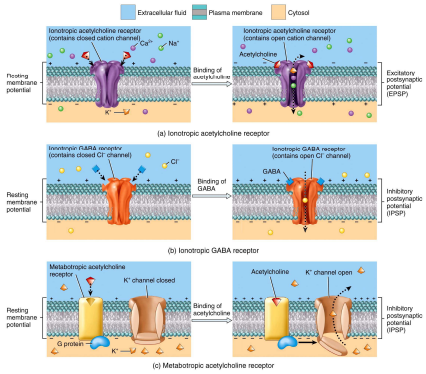
- A hyperpolarizing postsynaptic potential

A postsynaptic neuron can receive many signals at once

Structure of Neurotransmitter Receptors

- Neurotransmitters at chemical synapses cause either an excitatory or inhibitory graded potential
- Neurotransmitter receptors have two structures
  - Ionotropic receptors
  - Metabotropic receptors

Ionotropic & Metabotropic Receptors



Removal of Neurotransmitter

Neurotransmitter can be removed from the synaptic cleft by:

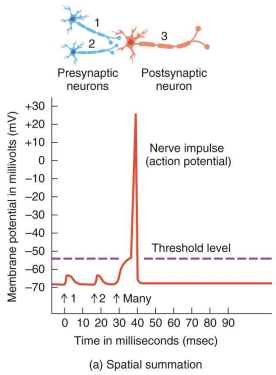
1. Diffusion
2. Enzymatic degradation
3. Uptake into cells

Summation

If several presynaptic end bulbs release their neurotransmitter at about the same time, the combined effect may generate a nerve impulse due to summation

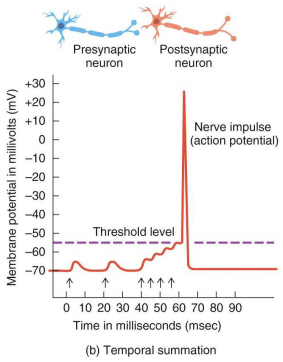
- Summation may be spatial or temporal

Spatial Summation



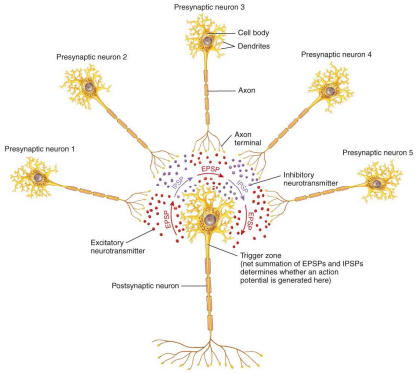
(a) Spatial summation

Temporal Summation



(b) Temporal summation

Summation of Postsynaptic Potentials

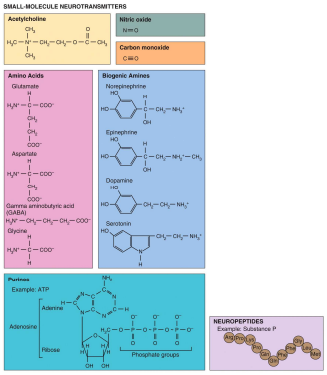


Neurotransmitters

Small molecule neurotransmitters

- Acetylcholine
- Amino acids
- Biogenic amines
- ATP and other purines
- Nitric oxide
- Carbon monoxide

Neurotransmitters



Neuropeptides

Neuropeptides

- Substance P
- Enkephalins
- Endorphins
- Dynorphins
- Hypothalamic releasing and inhibiting hormones
- Angiotensin II
- Cholecystokinin

Neuropeptides

TABLE 12.4

Neuropeptides

SUBSTANCE	DESCRIPTION
Substance P	Found in sensory neurons, spinal cord pathways, and parts of brain associated with pain; enhances perception of pain.
Enkephalins	Inhibit pain impulses by suppressing release of substance P; may have role in memory and learning, control of body temperature, sexual activity, and mental illness.
Endorphins	Inhibit pain by blocking release of substance P; may have role in memory and learning, sexual activity, control of body temperature, and mental illness.
Dynorphins	May be related to controlling pain and registering emotions.
Hypothalamic releasing and inhibiting hormones	Produced by hypothalamus; regulate release of hormones by anterior pituitary.
Angiotensin II	Stimulates thirst; may regulate blood pressure in brain. As a hormone, causes vasoconstriction and promotes release of aldosterone, which increases rate of salt and water reabsorption by kidneys.
Cholecystokinin (CCK)	Found in brain and small intestine; may regulate feeding as a "stop eating" signal. As a hormone, regulates pancreatic enzyme secretion during digestion, and contraction of smooth muscle in gastrointestinal tract.

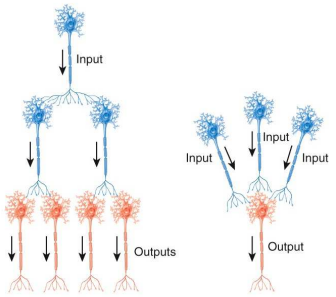
Neural Circuits

A neural circuit is a functional group of neurons that process specific types of information

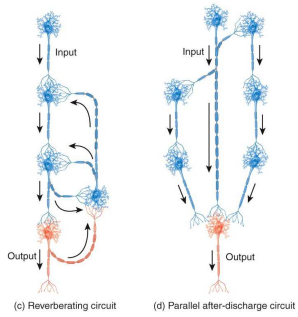
Types of circuits

- Simple series
- Diverging
- Converging
- Reverberating
- Parallel after-discharge

Neural Circuits: Diverging & Converging



Neural Circuits: Reverberating & Parallel After-Discharge



Regeneration & Repair of Nervous Tissue

Although the nervous system exhibits plasticity, neurons have a limited ability to regenerate themselves

- Plasticity – the capability to change based on experience
- Regenerate – the capability to replicate or repair

Neurogenesis in the CNS

In the CNS, there is little or no repair due to:

- Inhibitory influences from neuroglia, particularly oligodendrocytes
- Absence of growth-stimulating cues that were present during fetal development
- Rapid formation of scar tissue

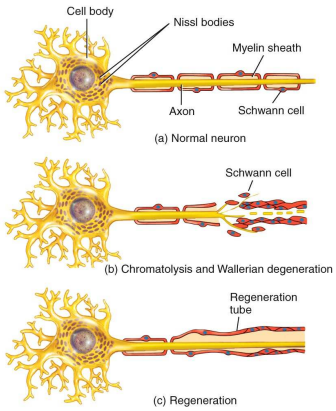
Damage and Repair in the CNS

In the PNS repair is possible if the cell body is intact, Schwann cells are functional, and scar tissue formation does not occur too rapidly

Steps involved in the repair process are:

- Chromatolysis
- Wallerian degeneration
- Formation of a regeneration tube

Damage and Repair in the CNS



End of Chapter 12