Nervous Tissue

Neurons

Neural communication

Nervous Systems
What is the function of nervous tissue?

- **Maintain homeostasis & respond to stimuli**
  - **Sense & transmit** information **rapidly**, to *specific* cells and tissues, about the changing internal & external environment.
  - **Interpret** stimuli.
  - Send directions for **response**
Organization

- Ganglia
- Nerves with giant axons
- Brain
- Arm
- Eye
- Mantle
- Nerve

Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.
Cells & structures of nervous systems

- **Neurons**: integrate & transmit information (electrical signals) from one cell to another.
  - Sensory
  - Interneurons
  - Motor

- **Glial cells**: support, protect and provide nutrients to neurons

- **Ganglia or brains**: clusters of interacting neurons
Flow of information

Sensor → Sensory input → Integration → Motor output → Effector

Peripheral nervous system (PNS) → Central nervous system (CNS)
Flow of information

Afferent sensory neuron

Sensory input

Integration

Interneuron

Efferent motor neuron

Peripheral nervous system (PNS)

Central nervous system (CNS)
• Dendrites
• Cell body
• Axon hillock
• Axon
• Glial cells
  – Myelin sheath
• Nodes of Ranvier
• Synaptic terminals
Multipolar Neurons

400X

A

B

C

100X
Purkinje cells

400X

100X
Connection: The Synapse

- Synaptic vesicles: hold & release neurotransmitters
- Presynaptic membrane: vesicles merge & release neurotransmitters
- Synaptic cleft: space
- Postsynaptic membrane: encrusted with receptor proteins
Cell membrane provides mechanism for signal initiation & propagation

- Electrical signals travel along neurons via the exchange of ions across the cell membrane.
  - How does its structure allow a separation of ions?
  - Which ions are in greater concentration **inside** the cell? **Outside** the cell?
  - How does this provide a means of signal propagation?
**Electrochemical gradient**

- A charge difference exists, like between poles of a battery.
- **Intracellular**: high concentration of $K^+$ ions & negatively charged proteins
- **Extracellular**: high concentration of $Na^+$ & $Cl^-$ ions
Membrane is loaded with gated ion channels

- Note the chemical gradients.
- Cell @ rest; Gated channels closed
Two gradients =

• The sum of the chemical and electrical forces acting across the membrane = Electrochemical gradient (AKA membrane potential)

• Measured in milliVolts (mV)
  – Resting transmembrane potential ~ -70mV

• What is the effect of this gradient?
  – Na⁺ wants IN
  – K⁺ wants OUT
A variety of signals can open or close gated channels

- **Chemically** regulated: Respond to particular chemicals
- **Voltage** regulated: respond to changing membrane potential
- **Mechanically** regulated

All will produce graded potentials

- If graded potential produces large enough depolarization, an *Action* Potential will fire
Graded Potentials depolarize membrane

- Depolarization causes $\text{Na}^+$ gates to open.
- $\text{Na}^+$ rushes in, pushing other $+$ ions into neighboring regions.
Graded potentials create **Action Potential (AP)**

- **AP** = signal that travels through neurons.
- Propagated change in the transmembrane potential that affect an **entire** neuron & results in release of a neurotransmitter.
- **ALL OR NOTHING** response.
1. AP generates local currents (depolarizations)
   1. these depolarize the plasma membrane immediately adjacent to the AP
2. When local depolarizations reach **threshold**, a new AP is produced adjacent to original

3. In this manner, AP is **propagated** along entire axon
Measuring changes in potential

- Cell @ rest; Gated channels closed
Depolarization

• Stimulus arrives!
• $\text{Na}^+$ channels open & $\text{Na}^+$ rushes IN; \textbf{Depolarization}
Repolarization

- Slow opening $K^+$ channels open & $K^+$ rushes OUT;
Animations

• Gated Channels McGraw Hill
• Blackwell Action Potential
Factors influencing propagation speed

- **Myelination** – Schwann cells *insulate* membrane
- **Diameter** – Large diameter offers *less resistance* to ion flow
  - PM slows ions more than cytosol
Axon fiber types: structure determines function

- Type A: myelinated; 4 – 20 μm; 120 m/s
- Type B: myelinated; 2 – 4 μm; 18 m/s
- Type C: unmyelinated; <2 μm; 1 m/s

Which type carries position and balance info to CNS, and motor commands to skeletal muscles?
1. A
2. B
3. C
Action Potentials are transduced and transferred @ synapses

Signal Transduction:
Electrical -> chemical
-> electrical
A chemical synapse

- Voltage-gated Na\(^+\) & Ca\(^{2+}\) channels
- Secretory vesicles stuffed with neurotransmitter molecules
- As AP arrives, what channels are opening?
- Ca\(^{2+}\) influx causes vesicles to fuse with PM.
A chemical synapse

- Neurotransmitters diffuse across cleft, bind to chemical-gated channels, causing them to open.
- Ions diffuse across membrane (along conc. gradient), produce a depolarization, in this case, and AP is reinitiated.
- AChE degrades ACh
Synaptic transmission

• **HHMI Synaptic Transmission**
• **Chemical Synapse**

• **Excitatory**: post-synaptic cell is depolarized
  – Na\(^+\) channels open = **depolarization**

• **Inhibitory**: post-synaptic cell is hyperpolarized
  – K\(^+\) or Cl\(^-\) channels open = **hyperpolarization**

• Like Endocrine system, *receptors determine behavior of target cell.*
Neurotransmitters

• Acetylcholine ACH
  – Excitatory; inhibitory at cardiac muscle cells

• Amines
  – Serotonin, dopamine – modulates mood, sleep, attentiveness in CNS
  – epinephrine, norepinephrine – excitatory in PNS

• Amino Acids used in CNS
  – GABA
    • Inhibitory
  – Glutamate
    • Excitatory

• Neuropeptides – pain and pain modulation

• Gases – NO and CO
Nervous System Diversity

**Neurons**
- (a) Hydra (cnidarian)
- (b) Sea star (echinoderm)

**Bundled nerves**
- (c) Planarian (flatworm)
- (d) Leech (annelid)

**Ganglia, Nerve cords & Brains**
- (e) Insect (arthropod)
- (f) Chiton (mollusc)
- (g) Squid (mollusc)
- (h) Salamander (vertebrate)
Nerve C. S.

A = Schwann cells
B = Axons
CNS

Brain & Spinal cord

Afferent Sensory Nerves

Efferent Motor Nerves

PNS

Autonomic Nervous System

Sympathetic Effectors
- Glands
- Cardiac Muscle
- Adipocytes

Parasympathetic Effectors
- Glands
- Smooth Muscle
- Adipocytes

Somatic Nervous System

Skeletal Muscles
Simple Reflex Arc
The brain develops from three primary regions: the forebrain, midbrain, and hindbrain. The forebrain includes the telencephalon and diencephalon. The midbrain is part of the brainstem and includes the mesencephalon. The hindbrain includes the metencephalon and myelencephalon, which further develop into the cerebellum and medulla oblongata, respectively.

(a) Embryo at 1 month
(b) Embryo at 5 weeks
(c) Adult