Nervous Tissue and Neurophysiology

Objectives
• Describe the two major divisions of the nervous system and their characteristics.
• Identify the structures/functions of a typical neuron.
• Describe the location and function of neuroglia.
• Explain how resting potential is created and maintained.
• Describe the events in the generation and propagation of an action potential.
• Define the structure/function of a synapse.
• List the major types of neurotransmitters and neuromodulators.
• Explain the processing of information in neural tissue.

Nervous system overview
• Nervous system
  • Provides swift, brief responses to stimuli to control homeostasis (hand off a hot stove)
  • Communicates via action potentials along neurons
• Endocrine system
  • Adjusts metabolic operations and directs long-term changes
  • Communicates via hormones in the bloodstream. Growth and development
• Nervous system includes
  • All the neural tissue of the body
  • Basic unit = neuron

Divisions of the nervous system
• CNS (Central Nervous system)
  • Brain and spinal cord
• PNS (Peripheral Nervous system)
  • Neural tissue outside CNS
  • Afferent division brings sensory information from receptors to CNS
  • Efferent division carries motor commands to effectors
    • Efferent division includes somatic nervous system and autonomic nervous system
**Organization**

Nervous System

- Central Nervous System
  - Brain
  - Spinal Cord

- Peripheral Nervous System
  - Afferent
    - Periphery to CNS
  - Efferent
    - CNS to Periph.
    - Autonomic
      - CNS to Skeletal
    - Somatic
      - Glands, Smooth & Cardiac Muscle
    - Sympathetic
      - During Stress
    - Parasympathetic
      - During Normal Functioning

**Neuron structure**

- Perikaryon – cytoplasm surrounding the nucleus
  - Neurofilaments, neurotubules, neurofibrils
- Soma
- Dendrites
- Axon
- Axon hillock
- Collaterals with telodendria
- Synaptic terminals (knob)

**The Anatomy of a Multipolar Neuron**

**Synapse**

- Site of intercellular communication
- Neurotransmitters released from synaptic knob of presynaptic neuron

**Neuron classification**

- Anatomical
  - Anaxonic
  - Unipolar
  - Bipolar
  - Multipolar
Functional

• Sensory neurons (afferent)
  • deliver information from exteroceptors, interoceptors, or proprioceptors about external and internal environmental changes
• Motor neurons (efferent)
  • Responds by initiating muscular contractions or glandular secretions
• Interneurons (association neurons)
  • Located entirely within the CNS
  • Distributes and interprets sensory input and coordinate motor output

Neuroglia of the central nervous system

• Ependymal cells
  • Related to cerebrospinal fluid
• Astrocytes
  • Largest and most numerous
• Oligodendrocytes
  • Myelination of CNS axons – White matter of CNS
• Microglia
  • Phagocytic cells

Neuroglia of the peripheral nervous system

• Satellite cells
  • Surround neuron cell bodies within ganglia
• Schwann cells
  • Ensheaths axons in the PNS. Forms myelin sheath

Neurophysiology: Ions and Electrical Signals

The transmembrane potential

• Electrochemical gradient
  • Sum of all chemical and electrical forces acting across the cell membrane
  • Sodium-potassium exchange pump stabilizes resting potential at ~70 mV

Changes in the transmembrane potential

• Membrane contains
  • Passive (leak) channels that are always open
  • Active (gated) channels that open and close in response to stimuli

Three types of active channels

• Chemically regulated channels (binding to a neurotransmitter)
• Voltage-regulated channels (change in transmembrane potential as in action potentials)
• Mechanically regulated channels – respond to physical distortion (touch, pressure)
Graded potential
- A change in potential that decreases with distance
  - Localized depolarization or hyperpolarization

Action Potential
- Appears when region of excitable membrane depolarizes to threshold (-60mV)
- Voltage-regulated Na⁺ channels open – Na⁺ ions flood into cell
- Transmembrane potential rises to +30mV via positive feedback
- Voltage-gated K⁺ channels open, and K⁺ ions exit cell
- Voltage-gated Na⁺ channels close at +30mV
- Repolarization K⁺ positive charges exit cell and Na⁺ positive cease entering cell
- K⁺ channels start to close a –70mV, but are slow
- Repolarization continues until –90mV causing hyperpolarization

Steps involved
- Membrane depolarization and sodium channel activation
- Sodium channel inactivation
- Potassium channel activation
- Return to normal permeability

Characteristics of action potentials
- Generation of action potential follows all-or-none principle
- Refractory period lasts from time action potential begins until normal resting potential returns
- Continuous propagation
  - Spread of action potential across entire membrane in series of small steps – Relatively slow and characteristic of unmyelinated neuron.
- Salutatory propagation
  - Action potential spreads from node to node, skipping internodal membrane – Much faster and a characteristic of myelinated neuron.

Axon classification
- Type A fibers, Type B fibers, Type C fibers
  - Based on diameter, myelination, and propagation speed

General properties of synapses
- Chemical synapses
  - Most common
  - Excitatory neurotransmitters cause depolarization and promote action potentials
  - Inhibitory neurotransmitters cause hyperpolarization and suppress action potentials
Cholinergic synapses
- Release acetylcholine (ACh), the most common and best understood neurotransmitter

Other neurotransmitters
- Adrenergic synapses release norepinephrine (NE)
- Other important neurotransmitters include
  - Dopamine
  - Serotonin
  - GABA (gamma aminobutyric acid)

Alteration of Synaptic Conduction
  Botulism (Clostridium botulinum)
  - Food poisoning from improperly canned or cooked foods
  - The toxin from this organism inhibits release of acetylcholine (ACh)
  - Inhibits muscle contraction=weak, pupils dysfunction, dysphagia
  - Victims suffocate from no contraction of diaphragm

Crack Cocaine
  - Affects neurotransmitters: dopamine, norepinephrine, serotonin
  - These regulate mood & motor functions
  - Crack interferes w/ inactivation & return of neurotransmitters to presynaptic neuron
  - Resulting buildup results in feelings of euphoria
  - Can also result in high HR, high BP, convulsions, insomnia
  - Neurotransmitter shortages may result in depression

Information processing
- Simplest level of information processing occurs at the cellular level
  - Excitatory and inhibitory potentials are integrated through interactions between postsynaptic potentials

Postsynaptic potentials
- EPSP (excitatory postsynaptic potential) = depolarization
  - EPSP can combine through summation
    - Temporal summation or Spatial summation
- IPSP (inhibitory postsynaptic potential) = hyperpolarization
- Most important determinants of neural activity are EPSP/IPSP interactions

Presynaptic inhibition
- GABA release at axoaxonal synapse inhibits opening calcium channels in synaptic knob
  - Reduces amount of neurotransmitter released when action potential arrives