13

The Nervous System: Neural Tissue

PowerPoint® Lecture Presentations prepared by
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Introduction

• Nervous System Characteristics
  • Controls and adjust the activity of the body
  • Provides swift but brief responses
Introduction

• The nervous system includes:
  • **Central Nervous System (CNS)**
    • Associated with the brain and the spinal cord
  • **Peripheral Nervous System (PNS)**
    • Associated with the tissue outside the CNS
An Overview of the Nervous System

- The Peripheral Nervous System (PNS) can be subdivided into:
  - **Afferent**: Brings sensory information toward the CNS
    - Which can be further subdivided into *somatic* and *visceral*
  - **Efferent**: Carries motor commands away from the CNS
    - Which can be further subdivided into *somatic nerves* and *autonomic nerves*
Figure 13.1 The Nervous System

CENTRAL NERVOUS SYSTEM
- Brain
- Spinal cord

PERIPHERAL NERVOUS SYSTEM
- Peripheral nerves
An Overview of the Nervous System

• The Peripheral Nervous System (PNS)
  • Afferent
    • **Sensory** portion: monitors skeletal muscles and joints
    • **Visceral** portion: monitors smooth muscles, cardiac muscle, and other internal organs
  • Efferent
    • **Somatic nerves**: controls skeletal muscle contraction
    • **Autonomic nerves**: controls internal organ activities
An Overview of the Nervous System

• The Peripheral Nervous System (PNS)
  • The autonomic nerves can be further subdivided to form:
    • **Parasympathetic nerves**: cause pupil constriction, decrease heart rate, and tense the urinary bladder (for example)
    • **Sympathetic nerves**: cause pupil dilation, increase heart rate, and relax urinary bladder (for example)
Figure 13.2 A Functional Overview of the Nervous System

CENTRAL NERVOUS SYSTEM
(brain and spinal cord)

Information processing

Sensory information within afferent division

PERIPHERAL NERVOUS SYSTEM

Motor commands within efferent division

Includes

Somatic nervous system

Autonomic nervous system

Parasympathetic division

Sympathetic division

Skeletal muscle

Receptors

Special sensory receptors (provide sensations of smell, taste, vision, balance, and hearing)

Somatic sensory receptors (monitor skeletal muscles, joints, skin surface; provide position sense and touch, pressure, pain, and temperature sensations)

Visceral sensory receptors (monitor internal organs, including those of cardiovascular, respiratory, digestive, urinary, and reproductive systems)

Effectors

- Smooth muscle
- Cardiac muscle
- Glands
Cellular Organization in Neural Tissue

- Neural tissue consists of two cell types:
  - **Neurons**
    - Nerve cells that are responsible for the transfer and processing of information in the nervous system
    - Consist of a soma, axon, and dendrites
  - **Neuroglia**
    - Supporting cells
    - Protect the neuron
Figure 3.23a  Histology of Neural Tissue

Diagrammatic view of a representative neuron

- Brain
- Spinal cord
- Cell body
- Axon
- Nucleus of neuron
- Nucleolus
- Dendrites
Cellular Organization in Neural Tissue

- Functions of Neuroglia
  - Provide the framework for the neural tissue
  - Maintain the intercellular environment
  - Act as phagocytes
  - Over 100 billion
  - Roughly five times the number of neurons
  - Also called glial cells
  - Have the ability to reproduce
Cellular Organization in Neural Tissue

• Neuroglia Cells
  • Neuroglia cells of the CNS
    • Astrocytes
    • Oligodendrocytes
    • Microglia
    • Ependymal cells
  • Neuroglia cells of the PNS
    • Satellite cells
    • Schwann cells
Figure 13.4 The Classification of Neuroglia

**Peripheral Nervous System**
- **Satellite cells**: Surround neuron cell bodies in ganglia; regulate $O_2$, $CO_2$, nutrient, and neurotransmitter levels around neurons in ganglia.
- **Schwann cells**: Surround all axons in PNS; responsible for myelination of peripheral axons; participate in repair process after injury.

**Central Nervous System**
- **Oligodendrocytes**: Myelinate CNS axons; provide structural framework.
- **Astrocytes**: Maintain blood–brain barrier; provide structural support; regulate ion, nutrient, and dissolved-gas concentrations; absorb and recycle neurotransmitters; form scar tissue after injury.
- **Microglia**: Remove cell debris, wastes, and pathogens by phagocytosis.
- **Ependymal cells**: Line ventricles (brain) and central canal (spinal cord); assist in producing, circulating, and monitoring cerebrospinal fluid.
Cellular Organization in Neural Tissue

- **Neuroglia of the CNS**
  - **Astrocytes**
    - Have a large number of cytoplasmic processes
    - Control the chemical content of the interstitial environment
    - Maintain the *blood–brain barrier*
    - Isolate the neurons from general circulation
Cellular Organization in Neural Tissue

- **Neuroglia of the CNS**
  - **Oligodendrocytes**
    - Cytoplasmic extensions contact the somas or axons
    - Cytoplasmic extensions tie axons together in a sheath of myelin
  - **Microglia**
    - Phagocytic cells
    - Protect the neuron by removing waste and debris
Cellular Organization in Neural Tissue

• Neuroglia of the CNS
  • Ependymal cells
    • Line the ventricles of the brain
    • Line the central canal of the spinal cord
    • Monitor the CSF (cerebrospinal fluid) composition
    • Some ependymal cells secrete CSF
Figure 13.5 Histology of Neural Tissue in the CNS

- Gray matter
- White matter

- Neurons
- Myelinated axons
- Internode
- Myelin (cut)
- Axon
- Axolemma
- Myelin sheath gap
- Unmyelinated axon
- Basal lamina
- Capillary
- Ependymal cells
- Oligodendrocyte
- Astrocyte
- Microglial cell
- CENTRAL CANAL
Figure 13.6a The Ependyma

**Light micrograph showing the ependymal lining of the central canal**
Cellular Organization in Neural Tissue

- Neuroglia of the PNS
  - **Satellite cells**
    - Regulate the exchange of material between the cell body and the environment
  - **Schwann cells**
    - Also called *neurolemmocytes*
    - Form a myelin sheath
Figure 13.7 Satellite Cells and Peripheral Neurons

- Nerve cell body
- Nucleus
- Satellite cells
- Connective tissue
- Peripheral ganglion

LM × 25
A single Schwann cell forms the myelin sheath around a portion of a single axon. This situation differs from the way myelin forms inside the CNS. Compare with Figure 13.5.
A single Schwann cell can encircle several unmyelinated axons. Unlike the situation inside the CNS, every axon in the PNS has a complete neurolemmal sheath.
Cellular Organization in Neural Tissue

• Neuron Structure
  • Neurons consist of:
    • Axons
    • Soma (cell body)
    • Dendrites
    • Terminal boutons
### Figure 13.3 A Review of Neuron Structure

<table>
<thead>
<tr>
<th>Dendrites</th>
<th>Cell body</th>
<th>Axon</th>
<th>Terminal boutons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stimulated by environmental changes or the activities of other cells</td>
<td>Contains the nucleus, mitochondria, ribosomes, and other organelles and inclusions</td>
<td>Conducts nerve impulse (action potential) toward synaptic terminals</td>
<td>Affect another neuron or effector organ (muscle or gland)</td>
</tr>
</tbody>
</table>

- **Mitochondrion**
- **Nucleus**
- **Nucleolus**
- **Nissl bodies** (clusters of RER and free ribosomes)
- **Dendritic spines**
- **Axon hillock**
Cellular Organization in Neural Tissue

• Details of Neuron Structure
  • Soma consists of:
    • Nucleus
    • Nucleolus
    • Ribosomes (clusters are called Nissl bodies or chromatophilic substances – create gray matter)
    • Mitochondria
    • Golgi apparatus
    • Lack centrosomes – cannot reproduce
Cellular Organization in Neural Tissue

• Details of Neuron Structure
  • Axon (nerve fiber) consists of:
    • Axon hillock area
    • Axoplasm
    • Axon vesicles containing neurotransmitters
A neuron may innervate (1) other neurons, (2) skeletal muscle fibers, or (3) gland cells. Synapses are shown in boxes for each example. A single neuron would not innervate all three.
Cellular Organization in Neural Tissue

- Neuron Classification
  - Can be classified based on structure or function
  - **Structural classification**
    - Based on the placement of the cell body
    - Based on the number of processes extending from the cell body
  - **Functional classification**
    - Sensory
    - Motor
    - Interneuron (involved with both sensory and motor)
Cellular Organization in Neural Tissue

• Structural Classification of Neurons
  • Anaxonic
    • Has many processes but cannot differentiate between axons and dendrites
  • Bipolar
    • The cell body is between two axons
  • Pseudounipolar
    • The cell body is off to one side of the axon
  • Multipolar
    • Typically has a single axon and multiple dendrites
Figure 13.10  A Structural Classification of Neurons

<table>
<thead>
<tr>
<th>Anaxonic neuron</th>
<th>Bipolar neuron</th>
<th>Pseudounipolar neuron</th>
<th>Multipolar neuron</th>
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**Anaxonic neurons** have more than two processes, but axons cannot be distinguished from dendrites.

**Bipolar neurons** have two processes separated by the cell body.

**Pseudounipolar neurons** have a single elongate process with the cell body situated to one side.

**Multipolar neurons** have more than two processes; there is a single axon and multiple dendrites.
Cellular Organization in Neural Tissue

• Functional Classification of Neurons
  • Sensory
    • Sends information from the PNS to the CNS
    • Somatic sensory and visceral sensory
  • Motor
    • Sends information from the CNS to the periphery
  • Interneurons
    • Situated between the motor and sensory neurons
    • Analyze sensory input and coordinate motor outputs
    • Can be excitatory or inhibitory
Cellular Organization in Neural Tissue

• Functional Classification of Neurons (cont.)
  • **Sensory neurons**
    • Pick up information from **receptors** and send it to the CNS
  • **Motor neurons**
    • Send information to the **effectors** of the periphery or organs
Figure 13.2 A Functional Overview of the Nervous System

CENTRAL NERVOUS SYSTEM (brain and spinal cord)

Information processing

Sensory information within afferent division

PERIPHERAL NERVOUS SYSTEM

Motor commands within efferent division

Includes

Somatic nervous system

Autonomic nervous system

Parasympathetic division

Sympathetic division

EFFECTORS

Skeletal muscle

- Smooth muscle
- Cardiac muscle
- Glands

RECEPTORS

Somatic sensory receptors (monitor skeletal muscles, joints, skin surface; provide position sense and touch, pressure, pain, and temperature sensations)

Visceral sensory receptors (monitor internal organs, including those of cardiovascular, respiratory, digestive, urinary, and reproductive systems)

Special sensory receptors (provide sensations of smell, taste, vision, balance, and hearing)
There are three major types of receptors:

- **Exteroceptors**
  - Provide information about the external environment such as:
    - Touch, temperature, pressure, sight, smell, and hearing

- **Proprioceptors**
  - Monitor position and movement of the body

- **Interoceptors**
  - Monitor internal organ activity
Figure 13.11  A Functional Classification of Neurons

**RECEPTORS**
- Interoceptors
- Exteroceptors
- Proprioceptors

**EFFECTORS**
- **Skeletal muscles**
  - Skeletal muscle fibers
- **Visceral effectors**
  - Smooth muscles
  - Glands
  - Cardiac muscle
  - Adipose tissue

**PERIPHERAL NERVOUS SYSTEM**
- Afferent fibers
- Sensory neurons in peripheral ganglia
- Efferent fibers
- Visceral motor neurons in peripheral motor ganglia
- Postganglionic fibers
- Preganglionic fibers

**CENTRAL NERVOUS SYSTEM**
- Somatic motor neurons
- Visceral motor neurons in CNS
- Interneurons

Blue lines = Somatic (sensory & motor)
Red lines = Visceral (sensory & motor)
Neural Regeneration

- Neural Regeneration
  - Steps involved in the limited ability to repair
    - Schwann cells grow into the cut area
    - Axons begin to grow into the Schwann cells
The Nerve Impulse

• A nerve impulse is the **action potential** of a nerve
• The action potential is due to the **exchange of ions** across the membrane
• The ability to conduct the impulse is known as **excitability**
• A **stimulus** is anything that causes an action potential to occur
• The stimulus has to overcome the **threshold level** of that particular neuron
• The threshold level is the amount of stimuli required to create the action potential
The Nerve Impulse

- The “speed” of the impulse depends on:
  - Presence of a myelin sheath
    - Fast impulse
  - Lack of a myelin sheath
    - Slow impulse
  - Axon with a large diameter
    - Fast impulse
    - Up to 140 m/sec
  - Axon with a small diameter
    - Slow impulse
    - Less than 1 m/sec
Synaptic Communication

• A synapse is the junction between:
  • The axon of one neuron and the dendrite of another neuron (axodendritic)
  • The axon of one neuron and the soma of another neuron (axosomic)
  • The axon of one neuron and the axon of another neuron (axoaxonic)
  • The axon of a neuron and a muscle (neuromuscular)
  • The axon of a neuron and a gland (neuroglandular)
A neuron may innervate (1) other neurons, (2) skeletal muscle fibers, or (3) gland cells. Synapses are shown in boxes for each example. A single neuron would not innervate all three.
Synaptic Communication

- At a synaptic terminal, a nerve impulse triggers events at a synapse that transfers information across the synapse.
- This transfer process is accomplished by:
  - **Vesicular synapses** (chemical synapses)
    - Involve a neurotransmitter
  - **Nonvesicular synapses**
    - Involve the flow of ions
Figure 13.13a The Structure of a Synapse

Diagrammatic view of a vesicular synapse between two neurons.
Synaptic Communication

• **Vesicular synapse** events
  • Impulses are conveyed in one direction only
  • Sequence of events:
    • An action potential arrives at the presynaptic membrane
    • This triggers the release of a neurotransmitter from the axon vesicles
    • The neurotransmitter diffuses across the synapse
    • The neurotransmitter binds to the postsynaptic membrane
    • This binding action causes a change in the permeability of the postsynaptic membrane
    • This change in permeability results in an action potential of the next neuron
Synaptic Communication

• **Nonvesicular synapse** events
  • Impulses can be conveyed in any direction
  • Sequence of events:
    • The presynaptic membrane of one neuron is tightly bound to the postsynaptic membrane of another neuron
    • This binding permits the passage of ions from one neuron to the next
Neuron Organization and Processing

• Neurons can be organized into smaller organized groups called neuronal pools
• The neuronal pools are identified by their neural circuitry such as:
  • Divergence
  • Convergence
  • Serial processing
  • Parallel processing
  • Reverberation
Neuron Organization and Processing

• **Divergence**
  - The spread of information from one neuron to several neurons
  - Permits broad distribution of a specific input
  - Information enters the CNS and then spreads to the brain and spinal cord at the same time

• **Convergence**
  - Information going from several neurons to a single neuron
  - Movements of the diaphragm muscle are involuntary, but yet at times we can move the diaphragm muscle voluntarily
Neuron Organization and Processing

• **Serial processing**
  • Information going from one neuron to the next in a sequence
  • Information going to one part of the brain then, to another part, and then to another part, etc.

• **Parallel processing**
  • Several neurons are processing the information at the same time
  • If you step on a nail, you typically move your foot, shout “ouch,” and dance a bit, all at the same time
Neuron Organization and Processing

- Reverberation
  - Collateral axons extend back toward the origin of the impulse to cause an enhancement or a continuation of the impulse
<table>
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**Divergence**, a mechanism for spreading stimulation to multiple neurons or neuronal pools in the CNS.

**Convergence**, a mechanism providing input to a single neuron from multiple sources.

**Serial processing**, in which neurons or pools work in a sequential manner.

**Parallel processing**, in which individual neurons or neuronal pools process information simultaneously.

**Reverberation**, a feedback mechanism that may be excitatory or inhibitory.
Anatomical Organization of the Nervous System

- The organization of the neurons in the CNS and PNS is not random
  - Organization in the CNS
    - A collection of cell bodies in one area creates gray matter
    - Bundles of axons in an area create white matter; these are called tracts and columns
  - Organization in the PNS
    - The cell bodies are found in ganglia
    - Axons are bundled together to form spinal nerves and cranial nerves
Figure 13.15 Anatomical Organization of the Nervous System

PERIPHERAL NERVOUS SYSTEM

GRAY MATTER
- Ganglia: Collections of neuron cell bodies in the PNS

WHITE MATTER
- Nerves: Bundles of axons in the PNS

CENTRAL NERVOUS SYSTEM

GRAY MATTER ORGANIZATION
- Neural Cortex: Gray matter on the surface of the brain
- Nuclei: Collections of neuron cell bodies in the interior of the CNS
- Higher Centers: The most complex centers in the brain

WHITE MATTER ORGANIZATION
- Tracts: Bundles of CNS axons that share a common origin and destination
- Columns: Several tracts that form an anatomically distinct mass

PATHWAYS
- Centers and tracts that connect the brain with other organs and systems in the body
- Ascending (sensory) pathway
- Descending (motor) pathway