Organization & Functions of the Nervous System
Chapter 3

Central Nervous System
Peripheral Nervous System
Development and Change in the Nervous System
Overview

Nervous System

Peripheral Nervous System
(Nerves & Ganglia)

Central Nervous System
(Tracts & Nuclei)

Somatic Nervous System

Autonomic Nervous System

Brain
Spinal Cord

Sympathetic Nervous System
Parasympathetic Nervous System
## The Central Nervous System

### Table 3.1: Terms for Axons and Cell Bodies

<table>
<thead>
<tr>
<th></th>
<th>Peripheral NS</th>
<th>Central NS</th>
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<tbody>
<tr>
<td>Bundle of axons</td>
<td>Cranial Nerves, Spinal Nerves</td>
<td>Tract</td>
</tr>
<tr>
<td>Group of cell bodies</td>
<td>Ganglion</td>
<td>Nucleus</td>
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The Central Nervous System

Figure 3.3: Central Nervous System Development

- Brain develops from a hollow, tubular structure
  - Upper tube develops into
    - Forebrain
    - Midbrain
    - Hindbrain
  - 3 weeks: all equal in size
  - 11 weeks: forebrain becomes the largest part
- Lower tube becomes the spinal cord
- Gray Matter consists of unmyelinated cell bodies. White matter is neurons whose axons are myelinated.
The Central Nervous System
The Forebrain – Cortex . Figure 3.5: The Forebrain

- Largest part of the brain.
  - **Cerebral hemispheres** separated by **longitudinal fissure**.
  - Thalamus
  - Hypothalamus
- **Cortex** is wrinkled to increase surface area.
  - Ridge: **gyrus**
  - Groove: **Central sulcus** separates it and parietal lobe.
  - Layers and columns of cell bodies.
The 6-layered structure of the cortex. Columnar arrangement.
The Central Nervous System
The Forebrain – Cortex

Do intelligent individuals have bigger brains?

- Brain size is mostly related to body size, because larger bodies require larger brains.
  - Examples: Elephants and sperm whales have brains that are 5-6 times larger than humans.
- Among humans, there is a small and highly variable correlation between brain size and intelligence (discussed later in text)
The Central Nervous System
The Forebrain – Cortex - Figure 3.7

- Two key features characterize more “intelligent” species.
  - Cortex has more convolutions.
  - Cerebral hemispheres are larger in proportion to other brain areas.
- Increasing complexity from spinal cord to hindbrain to midbrain to forebrain.

- Armadillo
- Monkey
- Chimpanzee
The Central Nervous System

The Forebrain – Direction and Orientation. Figure 3.9

- Directions (relative to other structures)
  - Dorsal vs. Ventral
  - Anterior vs. Posterior
  - Lateral vs. Medial
  - Superior vs. Inferior

- Planes of section
  - Coronal (L/M and D/V)
  - Sagittal (A/P and D/V)
  - Horizontal (A/P and L/M)
The Central Nervous System
The Forebrain – Cortex. Figure 3.8: Lobes and Cortical Areas
The Central Nervous System
The Forebrain – Cortex. Figure 3.8: Lobes and Cortical Areas

• **Frontal Lobe**
  • Movement and complex human capabilities.
  • **Motor cortex** found on the **precentral gyrus** controls voluntary movement
  • **Broca’s area** is important for speech production.
  • **Prefrontal cortex** involved in planning, impulse control, and decision making
    • **Lobotomy** is the surgical destruction of the prefrontal cortex
    • **Psychosurgery** treats cognitive and emotional disorders
    • Damage here may lead to depression
The Central Nervous System
The Forebrain – Cortex. Figure 3.8: Lobes and Cortical Areas

- **Parietal lobe**
  - Important for body sensations, attention, perception, and spatial localization.

- **Primary somatosensory cortex** on the postcentral gyrus processes skin senses, body position, and movement

- Know how to describe where this is located
The Central Nervous System
The Forebrain – Cortex. Figure 3.8: Lobes and Cortical Areas

- Parietal association areas
  - get info from primary areas
  - combine information from body senses and vision;
  - identify objects by touch, determine the location of the limbs, and locate objects in space.
- Posterior parietal cortex damage causes neglect of objects, people, and activity on the opposite side.
  - Usually on the right side.
  - The patient will be unaware of the condition.
The Central Nervous System
The Forebrain – Cortex. Figure 3.8: Lobes and Cortical Areas

- **Temporal** separated from frontal and parietal lobes by the lateral fissure
  - Contains the *auditory cortex*, language, auditory and visual association areas.
- **Wernicke’s area** is involved in language comprehension and production.
  - Damage results in meaningless speech and poor comprehension of written and spoken communication.
- **Inferior temporal cortex** is concerned with visual identification.
  - Damage causes difficulty in recognizing objects and familiar faces.
The Central Nervous System
The Forebrain – Cortex. Figure 3.8: Lobes and Cortical Areas

- **Occipital** is posterior lobe of brain
  - Primary **Visual cortex** contains a map of visual space
    - adjacent receptors in the eye send information to adjacent points in the visual cortex
  - Secondary visual areas that process individual components of a scene
    - Color, movement, and form.
The Central Nervous System
The Forebrain. Figure 3.13: Other Brain Areas

- **Thalamus**
  - Sensory processing, arousal

- **Hypothalamus**
  - Emotions and motivations
  - Controls endocrine system and the Autonomic N.S.

- **Pineal gland**
  - Descartes’ “seat of the soul”
  - Regulates daily rhythms (melatonin) & sleep

- **Structures**
  - Corpus callosum
  - Ventricles
The Central Nervous System

The Forebrain. Figure 3.15: The Ventricles

- During development, the hollow interior of the nervous system becomes the **ventricles**
  - Filled with **cerebrospinal fluid (CSF)**
    - carries material from the blood vessels to the CNS
    - transports waste materials out of the CNS
  - **Hydrocephalus** - too much CSF in brain

[Figures and diagrams related to the ventricles and cerebrospinal fluid]
The Central Nervous System

Figure 3.16: The Midbrain and Hindbrain

**Midbrain**
- Secondary roles in vision, audition, movement. Parts include the
  - Superior colliculi
  - Inferior colliculi
  - Reticular formation
- Not on figure:
  - Substantia nigra
  - Ventral tegmental area
The Central Nervous System

Figure 3.16: The Midbrain and Hindbrain

- **Hindbrain**
  - Basic functions.
- **Medulla**
- **Pons**
  - Part of the *reticular formation*
- **Cerebellum**
  
  coordinates speed and direction of body movements
The Spinal Cord: Figure 3.17

- The **spinal cord** is a cable of sensory neurons that carry sensory information to the brain, and motor neurons that carry commands to the muscles and organs.
  - Sensory neurons enter through the **dorsal root** (1)
  - Motor neuron axons leave through the **ventral root** (3, 4)
  - Interneurons connect sensory and motor neurons, or and brain (5, 6)
- **Reflex** - sensory neuron to interneuron to motor neuron. (2)
The Central Nervous System

Figure 3.18: Protecting the Central Nervous System

- **Cerebrospinal fluid cushions and ‘floats’ the brain.**
  - Meninges: three layers
    - Dura (tough outside)
    - Arachnoid (BBB)
    - Pia (on brain surface)
- **Blood-brain barrier:** protective layer of endothelial cells between the blood and the brain
  - Gases and fat-soluble substances can pass through, but other materials must go through the cells
The Peripheral Nervous System

Figure 3.19: The Nervous System

- **Contents**
  - Cranial nerves on the underside of the brain:
  - Spinal nerves that connect to the sides of the spinal cord at each vertebra;

- **Subsystems**
  - **Somatic nervous system**
    - Motor and sensory neurons that allow us to sense and react to the environment
  - **Autonomic nervous system (ANS)**
    - Controls smooth muscle, glands, heart, and other organs.
The Peripheral Nervous System

Figure 3.19: The Nervous System

- **Two branches**
  - **Sympathetic Nervous System** (fight-flight)
    - activates the body in ways that help it cope with demands, such as emotional stress and physical emergencies
    - Stimulants mimic these effects
    - has most of its ganglia in the sympathetic ganglion chain.
  - **Parasympathetic Nervous System**
    - Slows activity of organs, increases digestion
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Stages of Development. Figure 3.23: Neuronal Proliferation and Migration

1. Proliferation
   - Neurons divide and multiply in ventricular zone (neurogenesis)
   - new cells multiply at 250,000 per minute

2. Migration
   - Neurons move up radial glial cells towards final locations
Development & Change in N. S.

Stages of Development: Figure 3.24: Neuronal Growth Cone

3. **Circuit formation**
   - Developing neurons grow towards target tissues
   - Use **growth cones** and form functional connections

4. **Circuit pruning**
   - Synaptic **plasticity**
     - Active synapses strengthened
     - Inactive ones removed
   - Decreases with age
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Figure 3.25: Fetal Alcohol Syndrome

- Mother’s use of alcohol during brain development.
  - Brain smaller and malformed with dislocated neurons
  - Cortical neurons do not migrate correctly into columns
  - Some neurons migrate too far.
- Exposure to ionizing radiation affects both proliferation and migration.

A: mouse cortex arranged in vertical columns
B: alcohol-exposed cortex fails to form columns
Development & Change in N. S.

Figure 3.26: Brain reorganization

• Stimulation continues to shape synaptic construction and reconstruction throughout life.

• Much of this involves reorganization.
  • Shift in connections that changes the area’s function
  • Provides compensation for peripheral changes
  • Reorganization is not always beneficial
Development & Change in N. S.
Damage and Recovery

• **Stroke** due to internal forces
  • Caused by artery blockage (ischemic) or rupture (hemorrhagic).
  • Damage is due to oxygen and glucose deprivation, excitotosis, and edema (swelling).
  • A leading cause of death and disability in the U.S.

• **Traumatic Brain Injury (TBI)** due to external forces
  • Caused by a blow to the head, penetration, or sudden acceleration or deceleration.
  • Even trauma that does not produce concussion can result in brain changes typically seen in Alzheimer’s patients.
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Limitations on Recovery

- **Regeneration** is the regrowth of severed axons.
  - Myelin provides a guide tube for the neuron to grow through, and the axon is guided to its destination much as in development. Myelination continues until the early 20s.
  - Occurs in the amphibian brain and in the mammalian PNS.
  - In the mammalian CNS, glia produce scar tissue and growth inhibitors, and immune cells may also interfere.

- **Neurogenesis**
  - It appears to support learning (in the hippocampus) and odor discrimination (in the olfactory bulbs).
  - No evidence neurogenesis contributes to self repair.
  - However, neurogenesis does increase in damaged brains, and there is some hope this could be enhanced as a means of recovery.
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Compensation and Reorganization

**Compensation**
- Uninjured tissue takes over functions of lost areas
  - Presynaptic neurons sprout more terminals to form additional synapses.
  - Postsynaptic neurons add more receptors.
  - Silent side branches from adjacent neurons become active within minutes of injury.

**Reorganization**
- Functions are taken over by other, more distant areas.
- Typically, compensation is by an adjacent area, but it can involve the other hemisphere.
- Reorganization generally more effective early in life.
- In the mature brain we get reorganization of existing connections.
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CNS Repair

• Possibilities
  • Neuron growth enhancers
  • Providing guide tubes or scaffolding
  • Counteracting regrowth inhibitors

• Stem Cells seem like they could be an ideal means of neural repair.
  • Embryonic stem cells can be multipurpose tools because they are pluripotent.
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Application- Mending the Brain with Computer Chips

• Temporarily anesthetized a monkey’s arm at the elbow.

• The BrainGate device records from 96 locations in the motor cortex.