2.1 The Nervous System

Functions of the nervous system:

(1) Processes incoming information,
(2) Integrates incoming information,
(3) Influences and directs reactions to incoming information.

2.1.1 Divisions of the Nervous System

The nervous system is divided into the central nervous system and the peripheral nervous system:

Central Nervous System

Brain  Spinal Cord

Peripheral Nervous System

Somatic  Autonomic

Sympathetic  Parasympathetic

All nerves encased in bone make up the central nervous system.
The central nervous system is responsible for processing information and directing actions.

The **peripheral nervous system** is made up of all nerves that are not encased in bone, and its main function is to carry messages to and from the central nervous system.

The **somatic division** of the peripheral nervous system carries messages inward to the central nervous system from the sensory organs (by means of **afferent** or **sensory neurons**) and outward from the central nervous system (by means of **efferent** or **motor neurons**) to the muscles for action. A reflex arc occurs when an afferent message travels to the spinal cord and an efferent message for action immediately returns to the muscle, bypassing the brain.

The **autonomic division** of the peripheral nervous system is responsible for involuntary functions of the body. This autonomic nervous system is divided into the **sympathetic** (known as the “fight or flight” branch; activates the body for emergencies) and **parasympathetic** (quiets the body and conserves energy) branches:

<table>
<thead>
<tr>
<th>Sympathetic Branch</th>
<th>Parasympathetic Branch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dilates pupils</td>
<td>Constricts pupils</td>
</tr>
<tr>
<td>Inhibits tears</td>
<td>Stimulates tears</td>
</tr>
<tr>
<td>Inhibits salivation</td>
<td>Increases salivation</td>
</tr>
<tr>
<td>Activates sweat glands</td>
<td>Decreases heart rate</td>
</tr>
<tr>
<td>Increases heart rate</td>
<td>Constricts blood vessels</td>
</tr>
<tr>
<td>Increases respiration</td>
<td>Decreases respiration</td>
</tr>
<tr>
<td>Inhibits digestion</td>
<td>Stimulates digestion</td>
</tr>
<tr>
<td>Releases adrenaline</td>
<td>Contracts bladder</td>
</tr>
<tr>
<td>Stimulates glucose release</td>
<td>Stimulates elimination</td>
</tr>
<tr>
<td>Relaxes bladder</td>
<td>Stimulates sexual arousal</td>
</tr>
<tr>
<td>Inhibits elimination</td>
<td></td>
</tr>
<tr>
<td>Inhibits genitals</td>
<td></td>
</tr>
</tbody>
</table>
2.1.2 Neurons

Neurons are specialized cells that transmit information from one part of the body to another. Nerves are bundles of neurons. The function of most neurons is to receive information from other neurons and to pass this information on.

Structural features of neurons:

Soma – The cell body of the neuron.

Dendrites – The branching projections of neurons that receive information from other neurons and conduct information toward the cell body.

Axon – The long, thin fiber that transmits information away from the cell body of a neuron toward other neurons.

Myelin Sheath – An insulating material that encases some axons and permits faster transmission of information. Prevents neurons from communicating randomly.

Synapse – The small space between neurons where communication takes place.

Terminal Buttons – Small knobs at the end of axons that secrete chemicals.

Synaptic Cleft – A microscopic gap between the terminal button of one neuron and the cell membrane of another. The place where chemicals are released.

2.1.3 Communication within the Nervous System

The nervous system is considered an electrochemical system. Communication within a neuron is electrical; communication between neurons is chemical.

Neurons are filled with and surrounded by electrically charged molecules called ions. A neuron at rest has an ion distribution that makes the axon more negatively charged than the outside of the nerve cell. Resting potential is the stable, negative charge of an inactive neuron and is the term used to describe the difference in electrical potential between the
Figure 2.1 A Typical Nerve Cell

- **Terminal Buttons** (secrete neurotransmitters)
- **Axon Terminals** (contains neurotransmitters)
- **Axon** (transmits signal away from soma)
- **Myelin Sheath** (insulates)
- **Node of Ranvier** (small gaps in myelin sheath)
- **Nucleus** (directs manufacturing of substances necessary for cell life)
- **Dendrites** (receive information)
- **Cell Body (soma)**
outside and the inside of a resting nerve cell. Under these conditions the soma and axon are said to be polarized. The brief change in electrical charge that is caused by a dendrite being stimulated or depolarized and by the resultant inflow of positively charged sodium ions is called an action potential. A spike is a nerve impulse generated by the neuron reaching action potential. After the firing of an action potential comes the refractory period when no further action potentials can fire.

The firing of a neuron or action potential is an all or none proposition. This means that the neuron will fire an action potential of a high magnitude independent of the size of the original stimulus. In other words, if there is no stimulus, there will be no action potential. If there is a stimulus, weak or strong, there will be an action potential.

A neuron passes its message on to another neuron by releasing chemical neurotransmitters into the synapse. A presynaptic neuron sends the neural message and a postsynaptic neuron receives the message. A neurotransmitter can stimulate a postsynaptic neuron only at specific receptor sites on its dendrites and soma. Receptor sites respond to only one type of neurotransmitter. This lock and key model means that specific neurotransmitters work only at specific kinds of synapses. Neurons that respond to the same neurotransmitter form a neurotransmitter system.

Neurotransmitters may excite or inhibit the next neuron. Stimulation of an excitatory synapse makes the neuron more likely to respond; stimulation of an inhibitory synapse makes production of an action potential less likely.

Examples of neurotransmitters include:

<table>
<thead>
<tr>
<th>Neurotransmitter (Abbreviation)</th>
<th>Function</th>
<th>Associated Disorders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetylcholine (ACh)</td>
<td>Excitatory neurotransmitter related to movement of all muscles as well as arousal, attention, anger, aggression, sexuality and thirst.</td>
<td>Memory loss in patients with Alzheimer’s disease.</td>
</tr>
</tbody>
</table>
Biological Basis of Behavior

<table>
<thead>
<tr>
<th>Neuron Transmitter</th>
<th>Function</th>
<th>Disease/Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dopamine (DA)</strong></td>
<td>Produces both excitatory and inhibitory postsynaptic potentials that control posture and movement.</td>
<td>Parkinson’s disease; Schizophrenia</td>
</tr>
<tr>
<td><strong>Gamma-aminobutyric acid (GABA)</strong></td>
<td>Inhibits central nervous system and regulates anxiety and movement.</td>
<td>Anxiety disorders; Huntington’s disease</td>
</tr>
<tr>
<td><strong>Glutamate (Glu)</strong></td>
<td>Major excitatory neurons in central nervous system; important for learning and memory.</td>
<td>Memory loss; Alzheimer’s disease</td>
</tr>
<tr>
<td><strong>Norepinephrine (NE)</strong></td>
<td>Important for psychological arousal, mood changes, sleep, and learning.</td>
<td>Bipolar mood disorder</td>
</tr>
<tr>
<td><strong>Serotonin (5-HT)</strong></td>
<td>Regulates sleep, mood, appetite, and pain.</td>
<td>Depression</td>
</tr>
</tbody>
</table>

**Antagonists** are drugs that inhibit neurotransmission. **Agonists** are drugs that stimulate neurotransmission.

**Endorphins** and **neuromodulators** are chemicals that act at the synapse of neurons. Endorphins are **neuropeptides** (made from **amino acids**) and occur naturally in the brain. They decrease a person’s sensitivity to pain. **Neuromodulators** do not carry neural messages directly, instead they can either increase or decrease the activity of specific neurotransmitters.

**Problem Solving Example:**

**Q** Distinguish between the central and peripheral nervous systems with respect to their function and location.

**A** The central and peripheral nervous systems can be distinguished in terms of location and basic functions. The central nervous system
The Brain

The Brain system (or CNS) includes the brain and the spinal cord. The brain is, of course, located within the skull and the spinal cord is encased in the bony spinal column which runs down the center of the back. The peripheral nervous system (PNS), on the other hand, consists of nerve fibers which run from the CNS to the periphery, i.e., the hands, feet, internal organs, etc. It includes all parts of the nervous system not encased in the bony skull and spine.

The CNS and PNS can also be distinguished in terms of function. The PNS serves mainly as a relay route for information travelling between the central nervous system and the rest of the body. It consists basically of two types of nerves. The first includes the afferent nerves which run from the body to the spinal cord. The second type are the motor or efferent nerves which leave the CNS to travel back to the rest of the body.

The CNS functions as an integrative center. This means that it organizes, collates, and stores information sent to it by the PNS. It consists basically of bundles of nerve fibers composed of axons and dendrites, called pathways, and groups of cell bodies called centers. Pathways are specific in that they transmit only certain types of information to the appropriate centers.

The PNS can also perform some integrative activity. This activity occurs in groups of cell bodies called ganglia. The most important integrative centers of the PNS are two series of ganglia located alongside the spinal column. These are the sympathetic ganglia and the sensory or dorsal root ganglia.

2.2 The Brain

Gray matter refers to the neurons in the brain without myelin. White matter in the brain consists of myelinated neurons.

The cerebral cortex is the outer surface of the brain surrounding the cerebral hemispheres. It contains small grooves called sulci and large grooves called fissures and bulges between adjacent sulci or fissures called gyri. The cerebral cortex processes all perceptions and complex
thoughts. In evolutionary terms, it is the most recently developed brain structure.

The brain can be divided into the **hindbrain**, the **midbrain**, and the **forebrain**.

### 2.2.1 The Hindbrain

The **hindbrain** is located in the bottom portion of the brain and is an extension of the spinal cord. In evolutionary terms, it is the oldest portion of the brain.

The **major components of the hindbrain** are:

**Medulla** – The oblong structure at the top of the spinal cord that
controls many vital life-support functions such as breathing, heart rate, and blood pressure.

**Pons** – Located above the medulla. Connects the lower brain regions with higher brain regions. The pons is important for sleep, dreaming, and arousal. Pons means “bridge.”

**Cerebellum** – Located at the rear of the brain and controls movement, coordination, balance, muscle tone, and learning motor skills. Resembles a miniature version of the cerebrum.

**Reticular Activating System (RAS)** – Monitors the general level of activity in the hindbrain and maintains a state of arousal. Keeps the brain awake even during sleep. The RAS is part of the reticular formation, which extends to the upper border of the midbrain.

### 2.2.2 The Midbrain

The **midbrain** continues upward from the pons portion of the hindbrain and lies between the hindbrain and the forebrain.

The midbrain **relays sensory information** from the spinal cord to the forebrain.

The upper portion of the **reticular activating system** is located in the midbrain.

### 2.2.3 The Forebrain

Not only does the **forebrain** make up the largest part of the brain, it is also the most highly developed portion of the brain.

The **major components of the forebrain** are:

**Cerebrum** – The largest part of the forebrain and responsible for complex mental activities. Its outer surface is the **cerebral cortex** and is divided into two **cerebral hemispheres**. Contains four major lobes: the **frontal lobe** that controls voluntary movement and includes the **motor cortex**; the **parietal lobe** that contains the primary **somatosensory area** that manages skin senses; the **occipital lobe** is located in the back of the
head and contains the visual cortex; and the temporal lobe contains the auditory cortex and is located on each side of the head above the temples.

**Limbic System** – Related structures that control emotion, motivation, and memory. Contains amygdala and hippocampus.

**Corpus Callosum** – Enormous communication network that connects the right and left cerebral hemispheres.

**Thalamus** – Relays and translates information from all of the senses, except smell, to higher levels in the brain.

**Hypothalamus** – Plays a major role in the regulation of basic biological drives and controls autonomic functions such as hunger, thirst, and body temperature. Regulates the pituitary gland.

### 2.2.4 Hemispheres of the Brain

The cerebrum is divided into two hemispheres known as the right and left cerebral hemispheres. The main interconnection between the two hemispheres of the brain is a large set of axons called the corpus callosum.

Severe epilepsy may be treated by cutting the corpus callosum which results in a split brain.

The left hemisphere controls the right side of the body and the right hemisphere controls the left side of the body.

Although both hemispheres are capable of carrying out most tasks, the left hemisphere is often more active in verbal and logical tasks and the right hemisphere usually specializes in spatial, artistic, and musical tasks.

The brain can be monitored using certain devices:

**PET scanning (positron emission tomography)** creates a visual image of functioning in various parts of the brain by tracing chemical activity.

**MRI (magnetic-resonance imaging) scanner** is another imaging technique that provides clear pictures of the structural anatomy.
and chemistry of the brain by passing a strong magnetic field through the person’s head.

**CAT scan (computerized axial tomography)** presents a picture of the human brain by passing X-ray beams through the head at various angles.

**EEG (electroencephalograph)** records the electrical activity of the brain.

### Problem Solving Example:

**Q** What are the three main divisions of the brain? Which major areas does each contain?

**A** The human brain is considered to have three major divisions; these are the hindbrain, midbrain, and forebrain.

The hindbrain is located at the base of the brain near the beginning of the spinal cord – just above the back of the neck. It contains the major ‘primitive’ parts of the brain. That is, as man evolved and developed a more complex portion of the brain, this essential portion of the brain stayed much the same, while additional layers were added on to it. The hindbrain includes three major parts – the cerebellum, the pons, and the medulla oblongata. The cerebellum functions in coordinating movements, the pons serves among other functions to connect the two halves of the cerebellum. The medulla is the center for control of breathing and heart rate.

The midbrain lies on top of the hindbrain. It consists of an upper portion called the tectum, and a lower part, the tegmentum. The tectum functions in the visual (sight) and auditory (hearing) systems. The tegmentum contains part of our sleep and arousal system and contains centers for eye movements.

The forebrain is the “highest” portion of the brain, both physically and in degree of complexity. Its major parts include the cerebral cortex, thalamus, hypothalamus, the basil ganglia, and the limbic system. The cortex and thalamus function in perception, thinking, and learning. The
hypothalamus and limbic systems are important in the control of motivation and emotion. The basil ganglia plays a part in motor control, the extrapyramidal motor system, and emotion. The cerebral cortex is the most complex component of the forebrain, and thus of our entire brain. It is the center of most of our higher order cognitive processes.

### 2.3 Hormones and the Endocrine System

The endocrine system is a system of glands that release chemical messengers called hormones which are carried by the bloodstream to target organs.

#### Major glands of the endocrine system:

<table>
<thead>
<tr>
<th>Gland</th>
<th>Hormones Secreted</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adrenal Cortex</td>
<td>Steroids</td>
<td>Regulates salt and carbohydrate metabolism.</td>
</tr>
<tr>
<td>Adrenal Medulla</td>
<td>Adrenaline</td>
<td>Prepares body for action.</td>
</tr>
<tr>
<td></td>
<td>Noradrenaline</td>
<td></td>
</tr>
<tr>
<td>Gonads</td>
<td>Estrogen</td>
<td>Affects reproductive organs, sexual behavior, and physical development.</td>
</tr>
<tr>
<td></td>
<td>Progesterone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Testosterone</td>
<td></td>
</tr>
<tr>
<td>Hypothalamus</td>
<td>Neurosecretions</td>
<td>Controls the pituitary gland.</td>
</tr>
<tr>
<td>Pancreas</td>
<td>Insulin</td>
<td>Regulates sugar metabolism.</td>
</tr>
<tr>
<td></td>
<td>Glucagon</td>
<td></td>
</tr>
<tr>
<td>Pituitary Gland</td>
<td>Thyrotropin</td>
<td><strong>Master gland;</strong> controls growth and other glands.</td>
</tr>
<tr>
<td></td>
<td>Oxytocin</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Corticotrophin</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Prolactin</td>
<td></td>
</tr>
<tr>
<td>Thyroid Gland</td>
<td>Thryroxine</td>
<td>Regulates metabolism.</td>
</tr>
<tr>
<td></td>
<td>Calcitonin</td>
<td></td>
</tr>
</tbody>
</table>
Hormones and the Endocrine System

Problem Solving Example:

Q Define a hormone. How would you go about proving that a particular gland is responsible for a specific function?

A The endocrine system constitutes the second great communicating system of the body, with the first being the nervous system. The endocrine system consists of ductless glands which secrete hormones. A hormone is a chemical substance synthesized by a specific organ or tissue and secreted directly into the blood. The hormone is carried via the circulation to other sites of the body where its actions are exerted. Hormones are typically carried in the blood from the site of production to the site(s) of action, but certain hormones produced by neuro-secretory cells in the hypothalamus act directly on their target areas without passing through the blood. The distance travelled by hormones before reaching their target area varies considerably. In terms of chemical structure, hormones generally fall into two categories: steroids and amino acid derivatives. The latter ranges in size from small molecules containing several peptides to very large proteins. Hormones serve to control and integrate many body functions such as reproduction, organic metabolism and energy balance, and mineral metabolism. Hormones also regulate a variety of behaviors, particularly sexual behaviors.

To determine whether a gland is responsible for a particular function or behavior, an investigator usually begins by surgically removing the gland and observing the effect upon the animal. The investigator would then replace the gland with one transplanted from a closely related animal, and determine whether the changes induced by removing the gland can be reversed by replacing it. When replacing the gland, the experimenter must be careful to ensure that the new gland becomes connected with the vascular system of the recipient. This must be done so that secretions from the transplanted gland can enter the blood of the recipient. Finally, the experimenter may make an extract of the gland and purify it to determine its chemical structure. Very often the chemical structure of a substance is very much related to its function. Studying the chemical structure may enable the investigator to deduce
a mechanism by which the gland-extract functions on a molecular level. The investigator may also inject the purified gland-extract into an experimental animal devoid of such a gland, and see whether the injection effected replacement of the missing function or behavior. Some hormonal chemicals have additive effects.

The investigator may inject a dosage of the purified gland-extract to an intact animal to observe if there was any augmentation of the particular function or behavior under study.

Quiz: Biological Basis of Behavior

1. All of the following are functions of the sympathetic branch of the autonomic nervous system EXCEPT

   (A) Constricts pupils
   (B) Inhibits tears
   (C) Inhibits salivation
   (D) Increases heart rates

2. The cell body of the neuron is the

   (A) soma.
   (B) dendrites.
   (C) axon.
   (D) synapse.
Quiz: Biological Basis of Behavior

3. Communication within a neuron is ________; communication between neurons is ________.
   (A) electrical; electrical
   (B) chemical; chemical
   (C) chemical; electrical
   (D) electrical; chemical

4. What neurotransmitter(s) is/are associated with Alzheimer’s Disease?
   (A) Acetylcholine
   (B) Glutamate
   (C) Both A and B.
   (D) None of the above.

5. The neurotransmitter that regulates sleep, mood, appetite, and pain is
   (A) glutamate.
   (B) dopamine.
   (C) acetylcholine.
   (D) serotonin.

6. In evolutionary terms, the oldest part of the brain is the
   (A) hindbrain.
   (B) midbrain.
   (C) forebrain.
   (D) There is no oldest part of the brain.
7. The most highly developed portion of the brain is
   (A) hindbrain.
   (B) midbrain.
   (C) forebrain.
   (D) Both (A) and (B).

8. The upper portion of the reticular activating system is located in
   (A) hindbrain.
   (B) midbrain.
   (C) forebrain.
   (D) Both (B) and (C).

9. The gland that controls the pituitary gland is
   (A) adrenal cortex.
   (B) gonads.
   (C) pancreas.
   (D) hypothalamus.

10. The gland that secretes estrogen, progesterone, and testosterone is
    (A) adrenal cortex.
    (B) gonads.
    (C) pancreas.
    (D) hypothalamus.
1. (A)  
2. (A)  
3. (D)  
4. (C)  
5. (D)  
6. (A)  
7. (C)  
8. (B)  
9. (D)  
10. (B)