

Chapter 2 Outline

I. Introduction: Neuroscience and Behavior

Biological psychology (also called *biopsychology* or *psychobiology*) is the scientific study of the biological bases of behavior and mental processes. Biological psychology makes important contributions to **neuroscience**—the scientific study of the nervous system.

II. The Neuron: The Basic Unit of Communication

1. Communication throughout the nervous system takes place via **neurons**, cells that are highly specialized to receive and transmit information from one part of the body to another.
2. The human nervous system is made up of other types of specialized cells, called **glial cells**, which support neurons by providing structural support and nutrition, removing cell wastes, and enhancing the communication between neurons.
3. There are three basic types of neurons.
 - a. **Sensory neurons** convey information from specialized receptor cells in the sense organs, the skin, and the internal organs to the brain.
 - b. **Motor neurons** communicate information to the muscles and glands of the body.
 - c. **Interneurons** communicate information between neurons; they are the most common type of neuron found in the human nervous system.

A. Characteristics of the Neuron -- Most neurons have three basic components.

1. The **cell body** (also called the *soma*) contains the nucleus, which provides energy for the neuron to carry out its functions.
2. **Dendrites** are short, branching fibers extending out from the cell body that receive information from other neurons or specialized cells.
3. The **axon** is a single, elongated tube that extends from the cell body and carries information from the neuron to other neurons, glands, and muscles. Axons vary in length from a few thousandths of an inch to about four feet.
 - a. Many axons are surrounded by a **myelin sheath**, a white, fatty covering that insulates axons from one another and increases the

neuron's communication speed.

b. *Nodes of Ranvier* are small gaps in the myelin sheath.

B. Communication Within the Neuron: The All-or-None Action Potential -- In general, messages are gathered by the dendrites and cell body and then transmitted along the axon in the form of a brief electrical impulse called an action potential.

1. Each neuron has a **stimulus threshold**—a minimum level of stimulation

from other neurons or sensory receptors to activate it.

2. While waiting for sufficient stimulation to activate it, the neuron is *polarized*; that is, the axon's interior is more negatively charged than the fluid surrounding the axon. The **resting potential**, or the negative

electrical charge of the axon's interior, is -70 millivolts. It has more *sodium* ions outside and more *potassium* ions inside.

3. When sufficiently stimulated by other neurons or sensory receptors—that is, when the neuron reaches its stimulus threshold—the axon depolarizes, beginning the **action potential**.

a. Sodium ion channels open; sodium ions rush into the axon.

b. Then sodium channels close, and potassium ion channels open, allowing potassium ions to rush out of the axon.

c. Finally, potassium channels close.

d. This sequence of *depolarization* and ion movement continues in a self-sustaining fashion down the entire length of the axon.

e. The result is a brief positive electrical impulse ($+30$ millivolts) that progressively occurs at each segment down the axon—the *action potential*.

4. The **all-or-none law** is the principle that either a neuron is sufficiently stimulated and an action potential occurs or a neuron is not sufficiently stimulated and an action potential does not occur.

5. Following the action potential, a *refractory period* occurs during which the neuron is unable to fire. During this thousandth of a second or less, the neuron *repolarizes*, that is, it reestablishes the resting potential conditions.

6. Two factors affect the speed of the action potential.

- a. Axon diameter—thicker axons are faster.
- b. Myelin sheath—myelinated axons are faster.

C. Communication Between Neurons: Bridging the Gap

1. The point of communication between two neurons is called the **synapse**.

- a. The message-*sending* neuron is referred to as the *presynaptic neuron*.
- b. The message-*receiving* neuron is called the *postsynaptic neuron*.
- c. **Synaptic gap:** the tiny, fluid-filled space only five-millionths of an inch wide between the *axon terminal* of one neuron and the dendrite of the adjoining neuron.

2. Transmission of information between neurons occurs in one of two ways.

- a. Electrical: Ion channels bridge the narrow gap between neurons; communication is virtually instantaneous.
- b. Chemical: The presynaptic neuron creates a chemical substance (a *neurotransmitter*) that diffuses across the synaptic gap and is detected by the postsynaptic neuron (over 99 percent of the synapses in the brain use chemical transmission).

(1) An action potential arrives at the **axon terminals**; these branches at the end of the axon contain tiny pouches or sacs called **synaptic vesicles**, which contain special chemical messengers called **neurotransmitters**.

(2) The synaptic vesicles release the neurotransmitters into the synaptic gap.

(3) **Synaptic transmission** is the process through which neurotransmitters are released by one neuron, cross the synaptic gap, and affect surrounding neurons by attaching to *receptor sites* on their dendrites.

(4) After synaptic transmission, the following may occur.

(a) **Reuptake:** the process by which neurotransmitter molecules detach from a postsynaptic neuron and are reabsorbed

by a presynaptic neuron so they can be recycled and used again.

(b) Enzymatic destruction or breakdown.

(5) Each neurotransmitter has a chemically distinct, different shape. For a neurotransmitter to affect a neuron, it must perfectly fit the receptor site.

3. Excitatory and inhibitory messages -- A neurotransmitter communicates either an *excitatory* message or an *inhibitory* message to a postsynaptic neuron.

a. An excitatory message *increases* the likelihood that the neuron will activate; an inhibitory message *decreases* the likelihood that it will activate. The postsynaptic neuron will depolarize only if the net result is a sufficient number of excitatory messages.

b. Depending on the *receptor* site to which it binds, the same neurotransmitter can have an inhibitory effect on one neuron and an excitatory effect on another neuron.

c. On the average, each neuron in the brain communicates directly with 1,000 other neurons.

D. Neurotransmitters and Their Effects -- Researchers have linked abnormal levels of specific neurotransmitters to various physical and behavioral problems.

1. Important Neurotransmitters

a. **Acetylcholine** stimulates muscles to contract and is important in memory, learning, and general intellectual functioning. Levels of acetylcholine are severely reduced in people with *Alzheimer's disease*.

b. **Dopamine** is involved in movement, attention, learning, and pleasurable or rewarding sensations.

c. Degeneration of neurons that produce dopamine in one brain area causes *Parkinson's disease*. Symptoms of Parkinson's disease can be alleviated by a drug called *L-dopa*, which converts to dopamine in the brain.

d. Excessive brain levels of dopamine are sometimes involved in the hallucinations and perceptual distortions that characterize *schizophrenia*. Some antipsychotic drugs work by blocking dopamine receptors and reducing dopamine activity in the brain.

e. **Serotonin** is involved in sleep, moods, and emotional states, including depression. Antidepressant drugs such as *Prozac* increase the availability of serotonin in certain brain regions.

f. **Norepinephrine** activates neurons throughout the brain, assists in the body's response to danger or threat, and is involved in learning and memory retrieval.

Norepinephrine dysfunction is also involved in some mental disorders, especially depression.

g. **GABA (gamma-aminobutyric acid)** usually communicates an inhibitory message to other neurons, reducing brain activity. Antianxiety medications work by increasing GABA activity.

2. **Endorphins:** Regulating the Perception of Pain

a. Pert & Synder (1973) discovered the brain contains receptor sites specific for opiates.

b. Endorphins are chemicals released by the brain in response to stress or trauma.

c. Endorphins are associated with the pain-reducing effects of *acupuncture*.

3. Focus on Neuroscience: Is "Runner's High" an Endorphin Rush?

a. "Runner's high," the rush of endorphins experienced after sustained aerobic exercise, was the subject of an experiment by Boecker et al., using a PET scan to detect a chemical that binds to opioid receptors.

b. The experiment provided the first real evidence that "runner's high" is at least partly due to the release of endorphins in the brain.

E. How Drugs Affect Synaptic Transmission -- Many drugs, especially those that affect moods or behavior, work by interfering with the normal functioning of neurotransmitters in the synapse.

1. Drugs may increase or decrease the amount of neurotransmitter released by neurons.

2. Drugs may affect the length of time the neurotransmitter remains in the synaptic gap, either increasing or decreasing the amount available to the postsynaptic receptor.

3. Drugs may prolong the effects of the neurotransmitter by blocking

its reuptake by the sending neuron.

4. Drugs can mimic specific neurotransmitters.

5. Drugs can mimic or block the effect of a neurotransmitter by fitting into receptor sites and preventing the neurotransmitter from acting.

III. The Nervous System and the Endocrine System: Communication Throughout the Body -- The **nervous system** is the complex, organized communication network of neurons; its two main divisions are the *central nervous system* and the *peripheral nervous system*. In the peripheral nervous system, **nerves** are made up of large bundles of neuron axons.

A. The Central Nervous System

1. The **central nervous system** includes the brain and the spinal cord, which are suspended in *cerebrospinal fluid* for protection.

2. **Spinal reflexes** are simple, automatic behaviors that are processed in the spinal cord.

3. One of the simplest spinal reflexes involves a three-neuron loop of rapid communication—a *sensory neuron* that communicates sensation to the spinal cord, an *interneuron* that relays information within the spinal cord, and a *motor neuron* leading from the spinal cord that signals muscles to react.

B. The Peripheral Nervous System -- The **peripheral nervous system** comprises all the nerves outside the central nervous system; its two subdivisions are the somatic nervous system and the autonomic nervous system.

1. The **somatic nervous system** communicates sensory information received by sensory receptors along sensory nerves *to* the central nervous system and carries messages *from* the central nervous system along motor nerves to perform voluntary muscle movements.

2. The **autonomic nervous system** regulates *involuntary* functions such as heartbeat, blood pressure, breathing, and digestion; its two branches are the *sympathetic nervous system* and *parasympathetic nervous system*.

a. The **sympathetic nervous system** produces rapid physiological arousal in response to perceived threats or emergencies. These bodily changes collectively represent the *fight-or-flight response*—they physically prepare you to fight or flee from a

perceived danger.

b. The **parasympathetic nervous system** conserves and maintains the body's physical resources.

C. The Endocrine System -- The **endocrine system** is made up of glands located throughout the body that secrete hormones into the bloodstream. Communication in the endocrine system takes place much more slowly than in the nervous system.

1. **Hormones** are chemical messengers secreted into the bloodstream primarily by endocrine glands. They interact with the nervous system and affect internal organs and body tissues. Some of the processes they regulate are metabolism, growth rate, digestion, blood pressure, and sexual development and reproduction.

2. A brain structure called the *hypothalamus* serves as the main link between the nervous system and the endocrine system. It directly regulates the release of hormones by the pituitary gland.

3. The **pituitary gland**, a pea-sized gland just under the brain, controls hormone production in other endocrine glands. It also produces some hormones directly, such as *growth hormone* and *prolactin*.

4. A set of glands called the **adrenal glands** is involved in the human stress response.

a. The **adrenal cortex**, the outer portion of each adrenal gland, also interacts with the *immune system*.

b. The **adrenal medulla**, the inner portion of the adrenal glands, secretes *epinephrine* (or *adrenaline*) and *norepinephrine*.

5. The **gonads**, or sex organs, are the *ovaries* in females and *testes* in males. These sex hormones regulate sexual development, reproduction, and sexual behavior.

IV. A Guided Tour of the Brain

1. Science Versus Pseudoscience: Phrenology

a. In the early 1800s, Franz Gall developed **phrenology**, which was based on the idea that specific skull locations were associated with various personality characteristics, moral character, and intelligence.

b. Although later shown to be a pseudoscience, phrenology triggered

scientific interest in the possibility of **cortical localization**

(or *localization of function*)—the idea that specific psychological and mental functions are localized in specific brain areas.

A. The Dynamic Brain: Plasticity and Neurogenesis

Plasticity is the brain's ability to change structure and function. Until the mid-1960s, it was believed that the brain's physical structure was *hard-wired* or fixed for life.

1. **Functional plasticity** is the brain's ability to shift functions from damaged to undamaged areas.
2. **Structural plasticity** is a phenomenon in which brain structures physically change in response to environmental influences.
3. Focus on Neuroscience: Juggling and Brain Plasticity
 - a. Research by Draganski et al. (2004) provides evidence that learning a new skill produces structural changes in the brain.
 - b. Participants in a study, divided into “jugglers” and “nonjugglers,” were given MRI brain scans to detect changes over time.

B. Neurogenesis

1. **Neurogenesis** is the development of new neurons after birth.
 - a. Research by Gould (1998) showed generation of new neurons every day in the *hippocampus* in adult marmoset monkeys.
 - b. Further research by Eriksson and Gage (1998) on adult cancer patients provided the first evidence that the human brain has the capacity to generate new neurons.

C. The Brainstem: Hindbrain and Midbrain Structures

The **brainstem** is made up of the *hindbrain* and the *midbrain*, which are located at the base of the brain.

1. The **hindbrain** connects the spinal cord with the rest of the brain. In the hindbrain, incoming sensory messages cross over to the other side of the brain, and outgoing motor messages cross over to the other side of the body. This is referred to as *contralateral organization*.

Three structures make up the hindbrain: the medulla, the pons, and the cerebellum.

- a. The **medulla** lies directly above the spinal cord and controls vital autonomic functions such as breathing, heart rate, and digestion.
- b. The **pons** lies just above the medulla. Large bundles of axons on both sides of the pons connect it to the cerebellum. Information from other brain regions higher up in the brain is relayed to the cerebellum via the pons.
- c. The **cerebellum** bulges out behind the pons; it is involved in the control of balance, muscle tone, coordinated muscle movements, and the learning of automatic movements and motor skills.
- d. The **reticular formation** (or the *reticular activating system*) is a network of neurons at the core of the medulla and the pons.
The neurons project up to higher brain regions and down to the spinal cord. The reticular formation plays an important role in regulating attention and sleep.

2. The midbrain

- a. The **midbrain** is an important relay station and contains centers important to the processing of auditory and visual sensory information before sending them to higher brain centers.
- b. The **substantia nigra** is an area of the midbrain that is involved in motor control and contains a large concentration of dopamine-producing neurons.

D. The Forebrain

The **forebrain**, or *cerebrum*, is the largest and most complex brain region.

1. The **cerebral cortex** is the grayish, quarter-inch-thick, wrinkled outer portion of the forebrain that is sometimes described as being composed of *gray matter*. Extending inward from the cerebral cortex are white myelinated axons, sometimes referred to as *white matter*, that connect the cerebral cortex to other brain regions.
 - a. The cerebral cortex is divided into two **cerebral hemispheres**.

b. The **corpus callosum** is a thick band of axons that connects the two hemispheres of the cerebral cortex and serves as the primary communication link between them.

c. Each cerebral hemisphere is divided into four regions, or *lobes*.

(1) The *temporal lobe*, located near the temples, is the primary receiving area for auditory information (*primary auditory cortex*).

(2) The *occipital lobe*, at the back of each cerebral hemisphere, is the primary receiving area for visual information (*primary visual cortex*).

(3) The *parietal lobe*, located above the temporal lobe, processes bodily, or *somatosensory*, information, including touch, temperature, pressure, and information from receptors in the muscles and joints. A band of tissue on the parietal lobe, called the *somatosensory cortex*, receives information from touch receptors in different parts of the body. Body parts are represented in proportion to their sensitivity to somatic sensations.

(4) The *frontal lobe*, the largest lobe of the cerebral cortex, is located behind and above the eyes; it is involved in planning, initiating, and executing voluntary movements. The movements of different body parts are represented in a band of tissue on the frontal lobe called the *primary motor cortex*.

d. The bulk of the cerebral cortex consists mostly of *association areas*, which are generally thought to be involved in processing and integrating sensory and motor information.

2. In Focus: The Curious Case of Phineas Gage

a. In 1848, Phineas Gage, a railroad crew foreman, was impaled through the skull by an iron rod in a freak accident, yet miraculously survived. However, the accident profoundly affected his personality

b. In 1994, modern X-rays and brain-modeling techniques used on Gage's skull confirmed damage to the frontal lobe and associated behavioral effects.

3. The **limbic system** is a group of forebrain structures that form a border around the brainstem and are involved in emotion, motivation, learning, and memory.

a. The **hippocampus** is a large structure embedded in the temporal lobe that plays a role in the ability to form new memories of events and information. Neurogenesis takes place in the adult hippocampus.

b. The **thalamus** is a rounded mass of cell bodies that processes and distributes motor and sensory (except for smell) information going to and from the cerebral cortex. It is thought to be involved in regulating levels of awareness, attention, motivation, and emotional aspects of sensations.

c. The **hypothalamus** is a peanut-sized structure that regulates both divisions of the autonomic nervous system and behaviors related to survival, such as eating, drinking, frequency of sexual activity, fear, and aggression.

(1) One area of the hypothalamus, the *suprachiasmatic nucleus (SCN)*, plays a key role in regulating daily sleep–wake cycles and other rhythms of the body.

(2) The hypothalamus produces both neurotransmitters and hormones that directly influence the *pituitary gland*.

d. The **amygdala** is an almond-shaped clump of neuron cell bodies that is involved in a variety of emotional response patterns, including fear, anger, and disgust. It is also involved in learning and in memory formation, especially emotional memories.

V. Specialization in the Cerebral Hemispheres

Although the left and right hemispheres are very similar in appearance, they are not identical in structure or function.

A. Language and the Left Hemisphere: The Early Work of Broca and Wernicke

Cortical localization, as noted in the box on phrenology, refers to the idea that particular areas of the human brain are associated with particular functions.

1. **Pierre Paul Broca** was a French surgeon and neuroanatomist who, in the 1860s, discovered an area on the *lower left frontal lobe* of the cerebral cortex that, when damaged, produces great difficulties in speaking but no loss of comprehension. Today, this area is known as *Broca's area*.

2. **Karl Wernicke** was a German neurologist who, in the 1870s, discovered an area on the *left temporal lobe* of the cerebral cortex that, when damaged, produces meaningless or nonsensical speech and difficulties in verbal or written comprehension. Today, this is known as *Wernicke's area*.

3. **Lateralization of function** is the notion that one hemisphere exerts more control over the processing of a particular psychological function (e.g., speech and language functions are *lateralized* on the left hemisphere).

4. **Aphasia** refers to the partial or complete inability to articulate ideas or understand spoken or written language due to brain injury or damage.

a. People with *Broca's aphasia* find it difficult or impossible to produce speech, but their comprehension of verbal or written words is relatively unaffected.

b. People with *Wernicke's aphasia* can speak, but they often have trouble finding the correct words and have great difficulty comprehending written or spoken communication.

5. Critical Thinking: "His" and "Her" Brains?

a. Some researchers argue that gender differences in cognitive abilities and personality characteristics are due to differences in brain structure, organization, and function.

b. Both hormones and genes seem to influence gender differences in brain development

c. Men's brains tend to be larger, have a higher percentage of white matter (which is evenly distributed throughout the brain), and have more cerebrospinal fluid. Women's brains have a higher

percentage of gray matter, have a greater concentration of white matter in the corpus callosum, and display more cortical complexity.

d. Men and women seem to use their brains equally, but differently. A recent study found that some of the brain regions correlated with intelligence were more prominent in women and some were more prominent in men.

e. Studies of gender differences should be examined critically, keeping in mind that male and female brains are much more alike than they are dissimilar.

B. Cutting the Corpus Callosum: The Split Brain

1. A **split-brain operation** is a surgical procedure that involves cutting the corpus callosum in order to stop or reduce epileptic seizures.

2. **Roger Sperry** was an American psychologist and neuroscientist who did pioneering research on hemispheric specialization using split-brain patients.

a. Typical Sperry experiment

(1) Sperry projected the image of an object to the left of the midpoint on a screen; the image was sent to the right nonverbal hemisphere.

(2) If a split-brain subject was asked to *verbally* identify the image flashed on the screen, he could not do so. However, the split-brain subject's right hemisphere still processed the information and expressed itself *nonverbally*: *the subject was able to pick up the correct object with his left hand.*

b. Sperry's experiments reconfirmed the specialized language abilities of the left hemisphere.

c. Results from other brain research

(1) The left hemisphere is superior in language abilities, speech, reading, and writing.

The right hemisphere is more involved in verbal emotional expression and visual-spatial tasks that involve deciphering complex visual clues; it also excels in recognizing faces and emotional facial cues, reading maps, copying designs, and drawing; it

also shows a higher degree of specialization for appreciating or responding to music.

d. In the normal brain, the left and right hemispheres function in an integrated fashion, constantly exchanging information.

C. Science Versus Pseudoscience: Brain Myths

Six questions about myths are answered, including “Do we use only 10 percent of our brain?” and “Are we left-brained or right-brained?”

VI. Application: An Enriched Environment

A. Studies first conducted in the 1960s demonstrated that rats raised in enriched environments produce *more synaptic connections* between brain neurons, whereas impoverished environments decrease synaptic connections.

B. The human brain also seems to benefit from enriched, stimulating environments—the brains of university graduates were found to have up to 40 percent more synaptic connections than the brains of high school dropouts.

C. Studies show that the best protection against developing Alzheimer’s disease is engaging in intellectually stimulating hobbies.

D. In humans, a mentally stimulating, intellectually challenging environment is associated with enhanced cognitive functioning. Even in late adulthood, remaining mentally active can help prevent or lessen mental decline.