To survive, human beings must be able to perform three interrelated activities: sensing events, or stimuli; processing stimuli; and responding to stimuli.

- **Stimulus:**
- **Receptors:**

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The activities of sensing, processing, and responding are coordinated and controlled by the nervous system, which has two major divisions: the central nervous system (CNS) and the peripheral nervous system (PNS).

- **CNS:**
- **PNS:**
Divisions of the Nervous System

- Central Nervous System
  - Brain
  - Spinal cord
- Peripheral Nervous System
  - Somatic
  - Autonomic
    - Sympathetic
    - Parasympathetic

The Nervous System

- Somatic nervous system:
  - afferent (sensory) nerves
  - efferent (motor) nerves

The Nervous System

- Autonomic nervous system:
  - sympathetic nervous system
  - parasympathetic nervous system.
The Nervous System

- The CNS
- The spinal cord serves as the body’s “information superhighway.”
- We’ll talk about the brain in a bit…

The Nervous System

- Reflexes:

The Endocrine System

- Endocrine system
  - hormones.
- Pineal gland:
The Endocrine System

- Endocrine system:
  - Ductless glands that regulate growth, reproduction, metabolism, mood, and some behavior
- Hormones:
  - Chemical messengers secreted into the bloodstream

The Endocrine System

- Pancreas:
- Hypothalamus:
- Pituitary gland:
- Thyroid gland:
- Gonads—ovaries in women and testes in men:
- Adrenal glands:

Neurons: Basic Cells of the Nervous System

- The cells that make up the nervous system are called neurons.
- Neurons are composed of:
  - dendrites that receive signals from adjacent neurons,
  - a cell body or soma,
  - an axon that transmits signals, and
  - terminal buttons that contain neurotransmitters.
One of the major differences among neurons is found in their axons. Some axons are surrounded by a **myelin sheath**, which is a fatty protein substance. Myelin:

- **Nodes of Ranvier**
- **Glial cells**

Because a neural signal is sent from one neuron to the next through the terminal buttons of the axons, the most common arrangement is for a neuron’s terminal buttons to be near, but not touching, the receptive dendrites of neighboring neurons.

- The membrane on the side that sends the message is the **presynaptic membrane**, while the membrane on the receiving side of the synapse is the **postsynaptic membrane**.
Neurons: Basic Cells of the Nervous System

- The most common arrangement at the end of an axon consists of a terminal button to send the signal, a dendrite to receive the signal, and the gap between the two, which is the synapse.
- **Neurotransmitters:**

The Synapse

When the electrical signal reaches the terminal buttons, it causes the vesicles in the terminal button to release a chemical signal in the form of a neurotransmitter into the synapse.

As the neurotransmitter enters the synapse, it contacts the postsynaptic membrane (usually the dendrite) of the next neuron.
The neuron that is receiving the neurotransmitter may become more likely to transmit the message to subsequent neurons; this process is called **excitation**. In other instances, the neuron that receives the neurotransmitter becomes less likely to transmit the message to subsequent neurons; this process is called **inhibition**.

**Neurons: Basic Cells of the Nervous System**

- Dopamine:
- Serotonin:
- Acetylcholine:
- Glutamate:
- GABA (gamma-aminobutyric acid):
- Norepinephrine (which is also a hormone):

Synapses must be cleared, and cleared rapidly, before additional signals can be transmitted. The synapse is cleared in one of two ways, depending on the particular neurotransmitter involved.

- **Breakdown**:
- **Reuptake**:
Neurons: Basic Cells of the Nervous System

- Most drugs exert their effects by influencing the operation of a neurotransmitter: Some drugs increase the effectiveness of neurotransmitters; other drugs reduce their effectiveness.
  - agonists.
  - antagonists.

Agonists

![Illustration of agonists]
Antagonists

Neurons: Basic Cells of the Nervous System

- Neuromodulators:
  - Endorphins:

Neurons: Basic Cells of the Nervous System

- The Neural Signal:
  - Neurons are electrically charged:
  - Resting state:
    - resting potential:
Neurons: Basic Cells of the Nervous System

• When a neurotransmitter enters the synapse, it may result in either:
  • depolarization (the neuron becomes less negatively charged) or
  • hyperpolarization (the neuron becomes more negatively charged).

Neurons: Basic Cells of the Nervous System

• Action potential:

The Brain: A Closer Look

• In the 1800s, German physician and anatomist Franz Joseph Gall developed the pseudoscience phrenology ("science of the mind").
The Brain: A Closer Look

- In 1861, the French physician Paul Broca used a technique for understanding the brain—the *clinical or case study method*.
- Broca’s area:

The Brain: A Closer Look

- Phineas Gage’s story is one of the most famous cases of survival from massive brain injury.
- Gage, a railroad foreman, was working with explosives in Cavendish, Vermont, on September 13, 1848, trying to clear a railroad right-of-way through granite bedrock.

The Brain: A Closer Look

- The stereotaxic instrument holds the head in a fixed position and allows an electrode (a fine piece of specially-treated wire) to be inserted into a specified area of a patient’s brain.
In 1929, Hans Berger developed the electroencephalograph (EEG):

Brain waves (identified by Greek letters) are distinguished by their frequency, which is measured in cycles per second (called hertz and abbreviated Hz), and their amplitude (the height of the wave on the EEG record), which reflects strength. Brain researchers have labeled a number of different types of brain waves; each is generally associated with a particular state of consciousness.

Alpha waves:
The Brain: A Closer Look

• Beta waves:

The Brain: A Closer Look

• Theta waves:

The Brain: A Closer Look

• Delta waves:
The advent of computers has led to major advances in the study of the brain.

- Positron emission tomography (PET):
- Computerized axial tomography (CT or CAT):
- Magnetic resonance imaging (MRI):
- Functional magnetic resonance imaging (fMRI):

The brain is divided into the hindbrain, midbrain, and forebrain.
The major components of the hindbrain are the medulla, the pons, and the cerebellum.

From an evolutionary perspective, these are the oldest parts of the brain, and they have important survival functions.

The medulla (short for medulla oblongata):

The pons:

The cerebellum:
Together, the hindbrain and midbrain are known as the **brain stem** because they form the stem, or stalk, on which the remainder of the brain rests.

**The midbrain:**
Psychologists have found that this complex network of fibers, known as the **reticular formation**, is very important in controlling our level of arousal or alertness.

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The **forebrain:**
These two halves or hemispheres are connected by a wide band of fibers known as the **corpus callosum** (“hard body”).

The two hemispheres of the forebrain communicate with each other through the corpus callosum.

**The cerebral cortex (cerebrum):**
The Brain: A Closer Look
- Deep down in the brain—below the cortex—is the **basal ganglia**:
- The **limbic system**:

Major Components of the Limbic System

The Brain: A Closer Look
- The **thalamus**:
- Each cerebral hemisphere has four specific areas, called **lobes**—the frontal, temporal, parietal, and occipital lobes.
The Brain: A Closer Look

- The frontal lobes:
- The major responsibility of the parietal lobes:

The Brain: A Closer Look

- The temporal lobes:
- The occipital lobes:

Neuroscientists have focused on the brain structures responsible for language as well as the problems that develop when these areas are damaged.

- Broca's area:
- Wernicke's area:
The term **aphasia** refers to a loss of the ability to speak or understand written or spoken language. Damage to Broca’s area results in nonfluent aphasia.

In 1874, the German neurologist Carl Wernicke (1848–1905) identified a second brain area that plays a significant role in language. Damage to Wernicke’s area results in language problems called fluent aphasia.

Broca’s and Wernicke’s aphasias are the two most common, but there are other types. For example, **optic aphasia**:
Apraxias are deficits in nonverbal skills. Apraxias involve damage to the right hemisphere. Dressing apraxia: Constructional apraxia:

In addition to apraxias, the right hemisphere controls prosody, the ability to express emotion. People suffering from motor aprosodia:

In the early 1960s, two neurosurgeons, Philip Vogel and Joseph Bogen, discovered that cutting the corpus callosum reduced seizures in untreatable epileptic patients. Even though we do not know exactly why this operation controls seizures, it is still performed as a last resort in severe cases of epilepsy.
Research by Nobel Prize winner Roger Sperry and his colleague Michael Gazzaniga showed that in people with a severed corpus callosum, the two hemispheres appeared to be doing different things.

Studies of split brain patients support the conclusion that the left hemisphere…

Although the right hemisphere…

Neuroplasticity of the brain.