**An Introduction to Cognitive Neuroscience**

**1. Definition**

Cognitive neuroscience is the field of study linking the brain and other aspects of the nervous system to cognitive processing and, ultimately, to behavior. The brain is the organ in our bodies that most directly controls our thoughts, emotions, and motivations (Rockland, 2000).

**2. Cognition in the Brain: The Anatomy and Mechanisms of the Brain**

The brain has three major regions: forebrain, midbrain, and hindbrain. These labels do not correspond exactly to locations of regions in an adult or even a child’s head. Rather, the terms come from the front-to-back physical arrangement of these parts in the nervous system of a developing embryo.



**Figure (01): Structures of the Brain (Sternberg, 2000)**

The following table sums up the major structures of the Brain and their functions





**Table (01): Major structures and Functions of the Brain (Sternberg, 2000)**

**3. Cerebral Cortex and Localization of Function**

 The cerebral cortex forms the outer layer of the two halves of the brain—**the left** and **right cerebral hemispheres** (Galaburda & Rosen, 2003). Although the two hemispheres appear to be quite similar, they function differently. **The left cerebral hemisphere** is specialized for some kinds of activity whereas **the right cerebral hemisphere** is specialized for other kinds. For example, receptors in the skin on the right side of the body generally send information through the medulla to areas in the left hemisphere in the brain. The receptors on the left side generally transmit information to the right hemisphere. Similarly, the left hemisphere of the brain directs the motor responses on the right side of the body. The right hemisphere directs responses on the left side of the body. **The following figure shows clearly the functional areas of the cortex.**

 However, not all information transmission is contralateral—from one side to another (contra-, “opposite”; lateral, “side”). Some ipsilateral transmission—on the same side—occurs as well. For example, odor information from the right nostril goes primarily to the right side of the brain. About half the information from the right eye goes to the right side of the brain, the other half goes to the left side of the brain.

 In addition to this general tendency for contralateral specialization, the hemispheres also communicate directly with one another. The corpus callosum is a dense aggregate of neural fibers connecting the two cerebral hemispheres (Witelson, Kigar, & Walter, 2003). It allows transmission of information back and forth. Once information has reached one hemisphere, the corpus callosum transfers it to the other hemisphere.

If the corpus callosum is cut, the two cerebral hemispheres—the two halves of the brain—cannot communicate with each other (Glickstein & Berlucchi, 2008). Although some functioning, like language, is highly lateralized, most functioning—even language—depends in large part on integration of the two hemispheres of the brain.The following figure shows clearly the functional areas of the cortex.



**Figure (02): the Functional areas of the Cortex (Sternberg, 2000)**

**4. Lobes of the Cerebral Hemispheres**

For practical purposes, four lobes divide the cerebral hemispheres and cortex into four parts. They are not distinct units. Rather, they are largely arbitrary anatomical regions divided by fissures. Particular functions have been identified with each lobe, but the lobes also interact. The four lobes, named after the bones of the skull lying directly over them are: **the frontal, parietal, temporal,** and **occipital lobes**.



**Figure (03):** Four Lobes of the Brain (Sternberg, 1998)

**4.1. The frontal lobe**

It is toward the front of the brain and associated with motor processing and higher thought processes, such as abstract reasoning, problem solving, planning, and judgment (Stuss & Floden, 2003). It tends to be involved when sequences of thoughts or actions are called for. It is critical in producing speech. The prefrontal cortex, the region toward the front of the frontal lobe, is involved in complex motor control and tasks that require integration of information over time (Gazzaniga, Ivry, & Mangun, 2002).

**4.2. The parietal lobe**

It is at the upper back portion of the brain and associated with somatosensory processing. It receives inputs from the neurons regarding touch, pain, temperature sense, and limb position when you are perceiving space and your relationship to it—how you are situated relative to the space you are occupying (Culham, 2003). The parietal lobe is also involved in consciousness and paying attention. If you are paying attention to what you are reading, your parietal lobe is activated.

**4.3. The temporal lobe**

It is directly under your temples and associated with auditory processing (Murray, 2003) and comprehending language. It is also involved in your retention of visual memories. For example, if you are trying to keep in memory then your temporal lobe is involved. The temporal lobe also matches new things you see to what you have retained in visual memory.

**4.4. The occipital lobe**

It is associated with visual processing (De Weerd, 2003b). The occipital lobe contains numerous visual areas, each specialized to analyze specific aspects of a scene, including color, motion, location, and form (Gazzaniga, Ivry, & Mangun, 2002). When you go to pick strawberries, your occipital lobe is involved in helping you find the red strawberries in between the green leaves.

 ***Projection areas*** are the areas in the lobes in which sensory processing occurs. These areas are referred to as projection areas because the nerves contain sensory information going to (projecting to) the thalamus. It is from here that the sensory information is communicated to the appropriate area in the relevant lobe. Similarly, the projection areas communicate motor information downward through the spinal cord to the appropriate muscles via the peripheral nervous system (PNS).

**5. Neuronal Structure and Function**

 Individual neural cells, called neurons, transmit electrical signals from one location to another in the nervous system (Carlson, 2006). The greatest concentration of neurons is in the neocortex of the brain. The neocortex is the part of the brain associated with complex cognition. This tissue can contain as many as 100,000 neurons per cubic millimeter (Churchland & Sejnowski, 2004). The neurons tend to be arranged in the form of networks, which provide information and feedback to each other within various kinds of information processing (Vogels, Rajan, & Abbott, 2005). Neurons vary in their structure, but almost all neurons have four basic parts, as illustrated in Figure (04). These include **a soma** (cell body), **dendrites**, **an axon**, and **terminal buttons**.



**Figure (04):** The composition of a Neuron (Sternberg, 1998)

**5.1. The soma**

It contains the nucleus of the cell (the center portion that performs metabolic and reproductive functions for the cell), is responsible for the life of the neuron and connects the dendrites to the axon.

**5.2. The dendrites**

They are branchlike structures that receive information from other neurons, and the soma integrates the information. Learning is associated with the formation of new neuronal connections. Hence, it occurs in conjunction with increased complexity or ramification in the branching structure of dendrites in the brain.

**5.3. The axon**

It is a long, thin tube that extends (and sometimes splits) from the soma and responds to the information, when appropriate, by transmitting an electrochemical signal, which travels to the terminus (end), where the signal can be transmitted to other neurons. Axons are of two basic, roughly equally occurring kinds, distinguished by the presence or absence of myelin. Myelin is a white, fatty substance that surrounds some of the axons of the nervous system, which accounts for some of the whiteness of the white matter of the brain.

1. **Myelinated axons** (in that they are surrounded by a myelin sheath): This sheath, which insulates and protects longer axons from electrical interference by other neurons in the area, also speeds up the
2. **Unmyelinated axons:** they are smaller and shorter (as well as slower) than the myelinated axons. As a result, they do not need the increased conduction velocity myelin provides for longer axons (Giuliodori & DiCarlo, 2004).

 In fact, transmission in myelinated axons can reach 100 meters per second (equal to about 224 miles per hour). Moreover, myelin is not distributed continuously along the axon. It is distributed in segments broken up by **nodes of Ranvier**. **Nodes of Ranvier** are small gaps in the myelin coating along the axon, which serve to increase conduction speed even more by helping to create electrical signals, also called action potentials, which are then conducted down the axon. The degeneration of myelin sheaths along axons in certain nerves is associated with multiple sclerosis, an autoimmune disease. It results in impairments of coordination and balance. In severe cases this disease is fatal.

**5.4. The terminal buttons**

 They are small knobs found at the ends of the branches of an axon that do not directly touch the dendrites of the next neuron. Rather, there is a very small gap, the synapse. The synapse serves as a juncture between the terminal buttons of one or more neurons and the dendrites (or sometimes the soma) of one or more other neurons (Carlson, 2006). Synapses are important in cognition.

**6. Brain Disorders**

A number of brain disorders can impair cognitive functioning.

**6.1. Stroke**

 Strokes occur when the flow of blood to the brain undergoes a sudden disruption. People who experience stroke typically show marked loss of cognitive functioning. The nature of the loss depends on the area of the brain that is affected by the stroke. There may be paralysis, pain, numbness, a loss of speech, a loss of language comprehension, impairments in thought processes, a loss of movement in parts of the body, or other symptoms.

**6.2. Brain Tumors**

 Brain tumors, also called neoplasms, can affect cognitive functioning in very serious ways. Tumors can occur in either the gray or the white matter of the brain. Tumors of the white matter are more common (Gazzaniga, Ivry, & Mangun, 2009). Following are the most common symptoms of brain tumors.

• Headaches (usually worse in the morning)

• Nausea or vomiting

• Changes in speech, vision, or hearing

• Problems balancing or walking

• Changes in mood, personality, or ability to concentrate

• Problems with memory

• Muscle jerking or twitching (seizures or convulsions)

• Numbness or tingling in the arms or legs

**6.3. Head Injuries**

Head injuries result from many causes, such as a car accident, contact with a hard object, or a bullet wound. Head injuries are of two types:

* **In closed-head injuries**: the skull remains intact but there is damage to the brain, typically from the mechanical force of a blow to the head. Slamming one’s head against a windshield in a car accident might result in such an injury.
* **In open-head injuries**: the skull does not remain intact but rather is penetrated, for example, by a bullet.