Functional Brain Systems

Three functional brain systems illustrate the relation between the organizational principles and the structural components of the human brain:

1. **Thalamocortical system**

2. **Basal ganglia system**

3. **Limbic System**

1. Thalamocortical system

- The connection between the thalamus, the cerebral cortex, and certain related structures

- Comprises 3 Thalamocortical systems (each with different pattern of functional circuity):
  - Sensory System,
  - Motor System,
  - Association System.

Primary Sensory systems

- Somatosensory
- Visual
- Auditory
- Olfactory
- Gustatory

Somatosensory system

- **Six somatosensory modalities**

  [Light touch, Pressure, Pain, Temperature, Vibration, Proprioception (position)]

- **The peripheral receptor organs generate coded neural impulses that travel proximally along the sensory nerve axons to the spinal cord – Brain stem – thalamus – post-central gyrus (sensory strip or cortex (parietal lobe).**

The Visual System

- **Visual images are transduced into neural activity within the retina transmitted along the visual pathways and processed in highly specialized nerve cells in the visual cerebral cortex.**
- **Cortical visual abnormalities include:**

➢ **Prosopagnosia: inability to recognize faces**

➢ **Visual Agnosia: Inability to identify and draw items**

➢ **Colour Agnosia: Inability to recognize a colour**

➢ **Colour Anomia: Inability to name a colour.**

Auditory System

- Sounds produce air pressure changes and lead to neural impulse generation travelling to the brain stem - to the thalamus – to the primary auditory cortex
- Cortical auditory abnormalities:
  - Word deafness: Inability to recognize speech despite intact hearing
  - Sound agnosia: Inability to recognize non-verbal sounds such as horns or animal sounds in the presence of intact hearing

Olfactory system

- Smell is associated with sexual and reproductive responses.
- Human can recognize 10,000 different odors.
- Olfactory signals skip the thalamus and project directly to the frontal lobe and limbic system (especially pyriform cortex).
- Olfactory cues stimulate strong emotional responses and evoke powerful memories.

Gustatory System

- Taste receptors stimulate gustatory nerves that transmit impulses to nucleus solitarius in brain stem and end in medial temporal lobe.

- Detection and discrimination of foods involve a combination of:

  taste + olfaction + touch + vision + hearing.

- Human discriminates 4 broad classes of taste stimuli: sweet, sour, bitter and salty.

Motor System

- Movements are planned and produced in cortical association areas in consultation with the basal ganglia and cerebellum and executed by the UMN
- The motor cerebral cortex (pre-central gyrus) directs their smooth execution
- The UMN regulates the LMN activity.
- The LMN controls movement of body

Cerebellum

- Modulates tone of agonistic and antagonistic muscles by predicting relative contraction needed for smooth motion.

- Coarse intentional movement and tremor result from lesions in the cerebellum.

Association System

- In most behaviors, sensory systems project to association areas, where sensory information interpreted in terms of internally determined memories, motivation and drives.

- The exhibited behavior results from a plan of action determined by the association components and carried out by the motor systems.

2. Basal Ganglia System

- A collection of nuclei grouped together on the basis of their interconnections
- Play an important role in:
  - regulating movement
  - cognitive functions

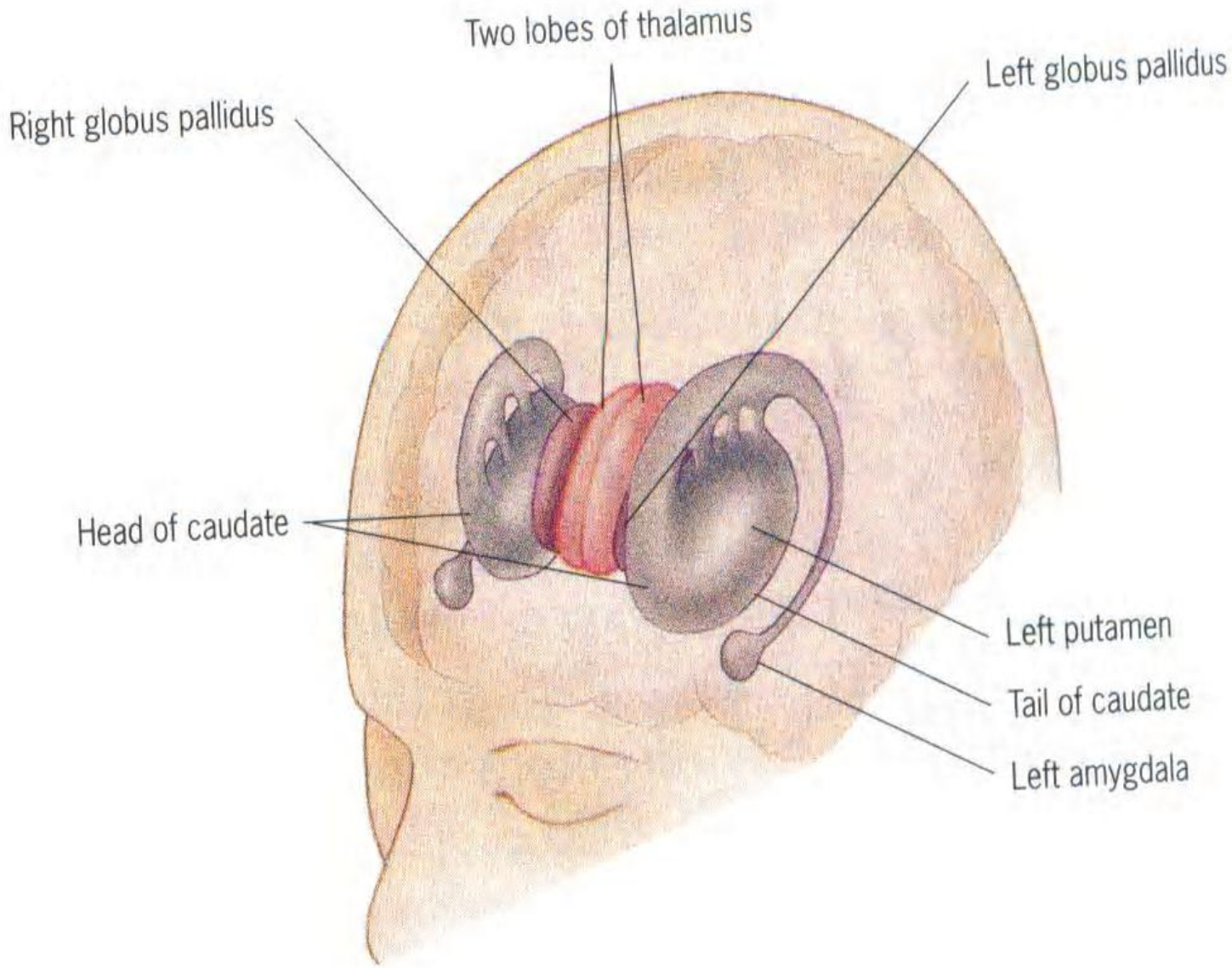
2. Basal Ganglia System

- **Major components:**

1. **Caudate**
2. **Lentiform nucleus = putamen + Globus pallidus (pallidum or paleo striatum)**
3. **Subthalamic nucleus**
4. **Substantia nigra**

[Striatum = all the above nuclei]

Basal Ganglia



Basal Ganglia

- The caudate influences associative (cognitive) processes.
- The globus pallidus involved in the regulation of voluntary movement
- Lesions of substantia nigra lead to rigidity and tremor as in Parkinson's disease with depression
- Subthalamic nucleus lesions yield ballistic

3. The Limbic System

[Limbic = Latin word "Limbus" (for border) applied by "*Pierre Broca*" more than 100 years ago]

- **Limbic system applied by "MacLean" to describe the circuity that relates certain forebrain structures (hippocampus and amygdala) and their connections with the hypothalamus and its output pathway (that control autonomic, somatic, and endocrine functions)**

- **Involved in the experience and expression of emotions, behaviour and long term memory.**
- **Limbic structures are closely associated with the olfactory structures.**

Structures of the Limbic System

- **Amygdala:** Involved in signaling the cortex of motivationally significant stimuli such as those related to **reward and fear** in addition to **social functions** such as **mating**.
- **Hippocampus:** Required for the formation of long-term memories.
- **Parahippocampus gyrus:** is part of the hippocampus Plays a role in the formation of spatial memory.
- **Cingulate gyrus:** Autonomic functions regulating heart rate, blood pressure, and cognitive and attentional processing.

Structures of the Limbic System (cont…)

- **Hypothalamus**: Regulates the autonomic nervous system via hormone production and release.

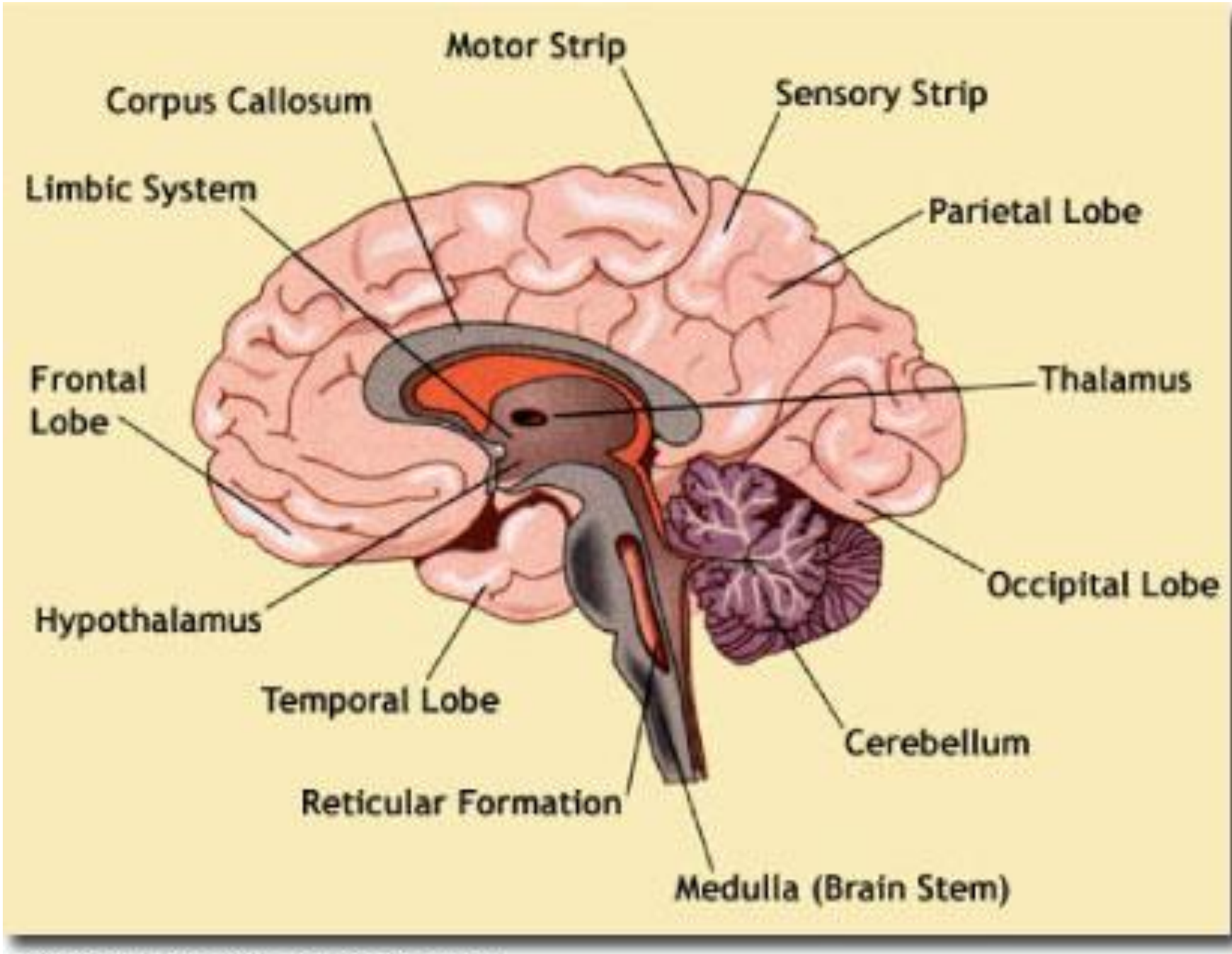
Affects and regulates:

- blood pressure,
- heart rate,
- Hunger,
- Thirst,
- Sexual arousal,
- Sleep/wake cycle

- **Thalamus**: The "relay station" to the cerebral cortex

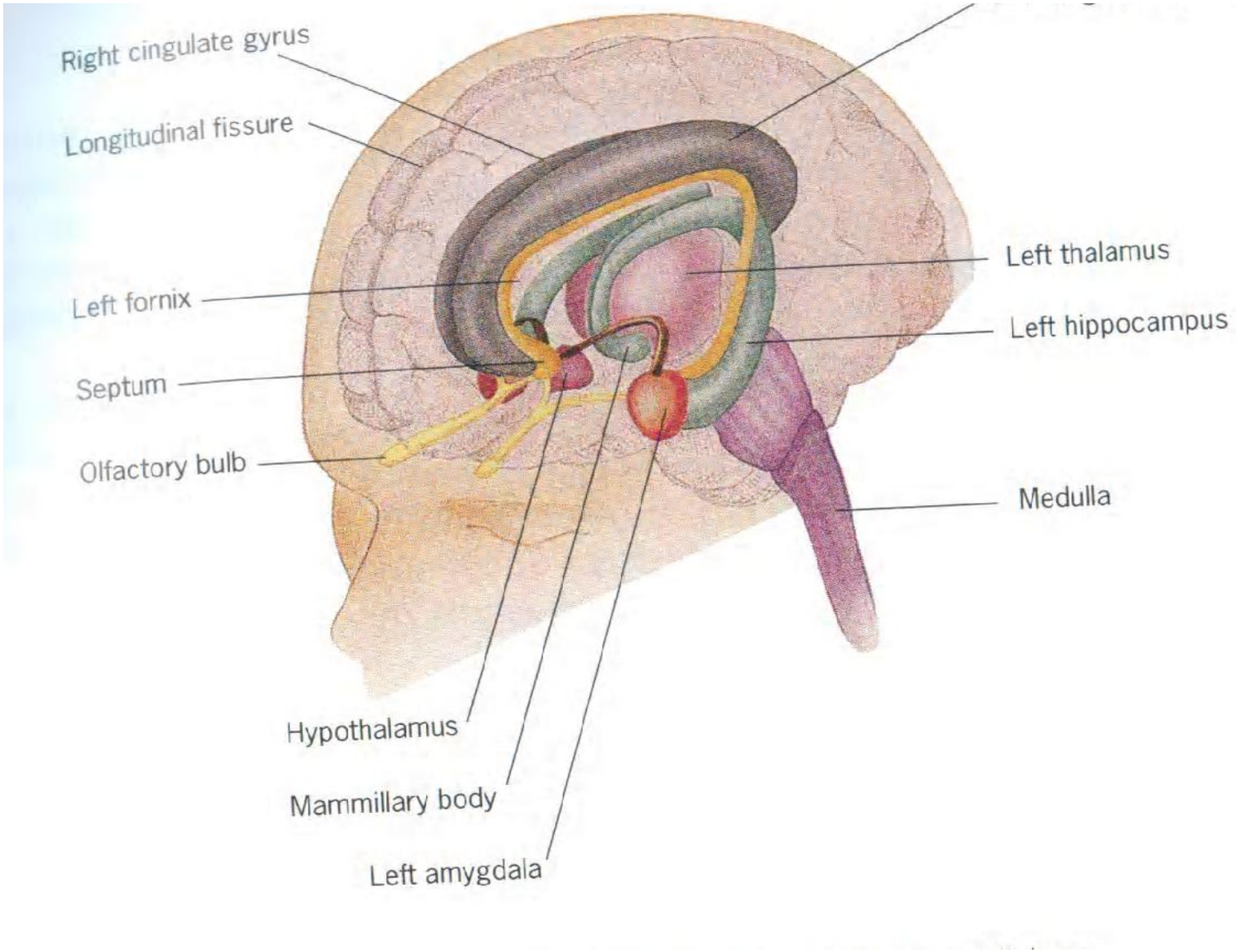
Other Limbic Structures

- **Mamillary body**: Important for the formation of memory
- **Pitutary gland**: secretes hormones regulating homeostasis
- **Dentate gyrus**: contributes to new memories and to regulate happiness (Pleasure Centre).
- **Entorhinal cortex and pyriform cortex**: Receive smell input in the olfactory system.
- **Olfactory bulb**: Olfactory sensory input
- **Nucleus accumbens**: Involved in reward, pleasure, and addiction



Brief Brain Anatomy

The Limbic System



Autonomic System (ANS)

- Monitors the basic functions necessary for life.
- Consists of sensory and motor divisions (fibers).

Sensory Component (fibers):

Transmit the activity of visceral organs, blood pressure, cardiac output, blood glucose

Autonomic System (ANS) cont.. .

Motor Component (Fibres):

- Sympathetic and parasympathetic divisions.
- Innervate the same organs.
- Antagonistic roles.
- The sympathetic fibers controls heart rate and respiration.
- The parasympathetic fibers slow the heart

Autonomic System (ANS) (cont..)

The ANS is controlled by the hypothalamus that controls:

- appetite and obesity
- rage
- temperature
- blood pressure
- perspiration
- sexual drive

Reticular Formation

- A mesh of neurons extending from the spinal cord to thalamus in the ventral core of the brain stem
- Neurons are neither sensory nor motor.
- The reticular formation is involved in actions such as awaking/sleeping cycle, and filtering incoming stimuli.

- The ascending reticular activating system connects to areas in the thalamus, hypothalamus, and cortex.
- The descending reticular activating system connects to the cerebellum and sensory nerves.

Localization of Specific Brain Functions

Arousal:

- Is a physiological and psychological state of being awake or alert, or reactive to stimuli and readiness for action.
- It involves activation of the:

➢ Reticular activating system in the brain

➢ Autonomic nervous system

➢ Endocrine system

Localization of Specific Brain Functions

Arousal:

The arousal system is formed of five neural systems, based on the neurotransmitters, that originate in the brain stem and project to the cerebral cortex:

- **Acetylcholine**
- **Norepinephrine**
- **Dopamine**
- **Histamine**

Localization of Specific Brain Functions

Arousal:

- Arousal is important in regulating:
- Consciousness
- Attention
- Information processing

Localization of Specific Brain Functions (cont..)

Memory

- The process in which information is:
  - **Encoded or registered**: receiving, processing and combining of received information.
  - **Stored**: creation of a permanent record of the encoded information
  - **Retrieved**: recall or recollection: calling back the stored information
- The loss of memory is called **forgetfulness** or **amnesia**

Localization of Specific Brain Functions (cont..)

Memory

Three periods of memory:

- **Sensory (Immediate) – functions over a period of seconds**
- **Short term (recent or working memory) functions over a period of minutes to days**
- **Long term (Remote) – functions over a period of months to years:**

Localization of Specific Brain Functions (cont..)

Long-term Memory

- **Explicit (Conscious) Memory**

  Declarative (facts & events):

  - **Episodic (events, experiences)**
  - **Semantic (facts, concepts)**

- **Implicit (Unconscious) Memory**

  Procedural (skills, tasks)

Localization of Specific Brain Functions (cont..)

Memory

- Brain structures critical to the formation of memories:
  - Hippocampus contains cognitive maps, encoding, memory consolidation (process of converting short to long-term memory
  - Cerebellum plays a role in procedural memory
  - Amygdala involved in emotional learning and memory consolidation
  - Frontal lobes are important in working memory and prospective memory
  - Temporal lobe involved in autobiographical and

Localization of Specific Brain Functions (cont..)

Memory

- **Brain structures critical to the formation of memories:**
  - **Temporal lobe involved in autobiographical and recognition memory**
  - **Parietal lobes involved in verbal short term memory and focusing attention**
  - **Basal ganglia are associated with learning, unconscious memory processes (implicit memory)**
- ***Alzheimer and Pick disease are examples of memory disorders***

Language (cont..)

- 90% of people are Right handed.
- 99% of them have left hemisphere dominance for language
- 10% left handed
- 7% have left hemispheric dominance and 3% either mixed or right hemispheric dominance.
- Music is represented in the right hemisphere

Localization of Specific Brain Functions (cont..)

Language

- **Aphasias** are language disorders (inability to understand or produce language in the presence of normal articulation).
- **Broca's aphasia (non fluent aphasia):** Inability to form speech due to a lesion of inferior frontal lobe.
- **Wernicke's aphasia (fluent aphasia):** inability to comprehend speech due to a lesion of the left superior temporal lobe.
- **Developmental Dyslexia :**

Inability to learn in the context of adequate intelligence, motivation and education in children, due to right

Localization of Specific Brain Functions

Emotions

- Emotion is often defined as a complex state of feeling that results in physical and psychological changes that influence thought and behavior and actions.
- Emotions derive from the basic drives that all animals share feeding, sex, reproduction, pleasure, pain, fear, aggression)
- There are only two basic emotions that we all experience, love and fear. All other emotions are variations of these two emotions

Localization of Specific Brain Functions

Emotions

- Emotions derive from the basic drives that all animals share (feeding, sex, reproduction, pleasure, pain, fear, aggression)
- Human emotions are largely learned and include: affection, pride, guilt, pity, envy, and resentment
- Emotions are represented in the prefrontal cortex and the limbic system namely the amygdala

➢ Lesion of the left prefrontal area produces depression

➢ Lesion of right prefrontal produces laughter and euphoria

Thank You