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Presents

Course Title:

Basic Cognitive Processes

By: Dr. Ark Verma,
Assistant Professor of Psychology,
Department of Humanities & Social Sciences,
IIT Kanpur

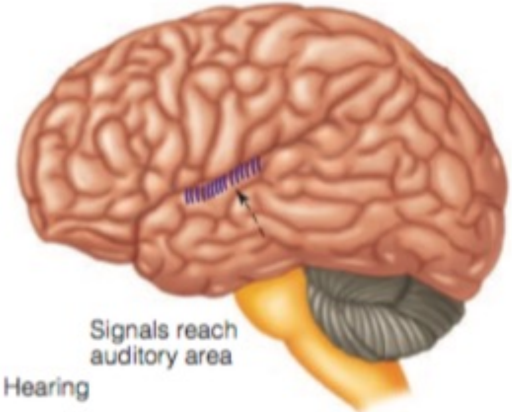
Lecture 09: Basic Concepts in Cognitive Neuroscience

What is Cognitive Neuroscience?

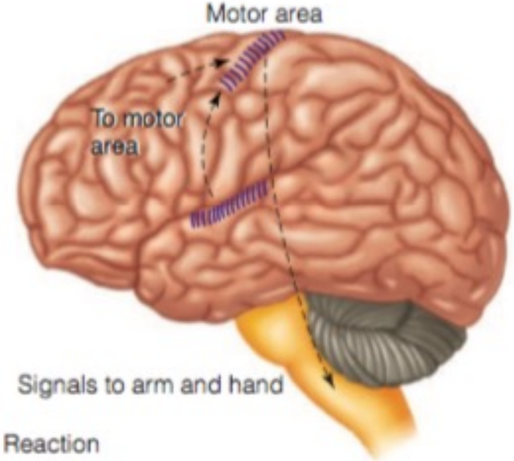
- Cognitive Neuroscience is the study of the physiological basis of cognition.

FIGURE 2.1 Some of the physiological processes that occur as Juan turns off his alarm. (a) Sound waves are changed to electrical signals in the ear and are sent to the brain. (b) Signals reaching the auditory areas of the brain—which are located inside the brain, under the hatched area—cause Juan to hear the alarm. (c) After Juan hears the alarm, signals are sent to the motor area. The two arrows pointing up symbolize the fact that these signals reach the motor area along a number of different pathways. Signals are then sent from the motor area to muscles in Juan's arm and hand so he can turn off the alarm.

(a) Sound to electricity



(b) Hearing



(c) Reaction

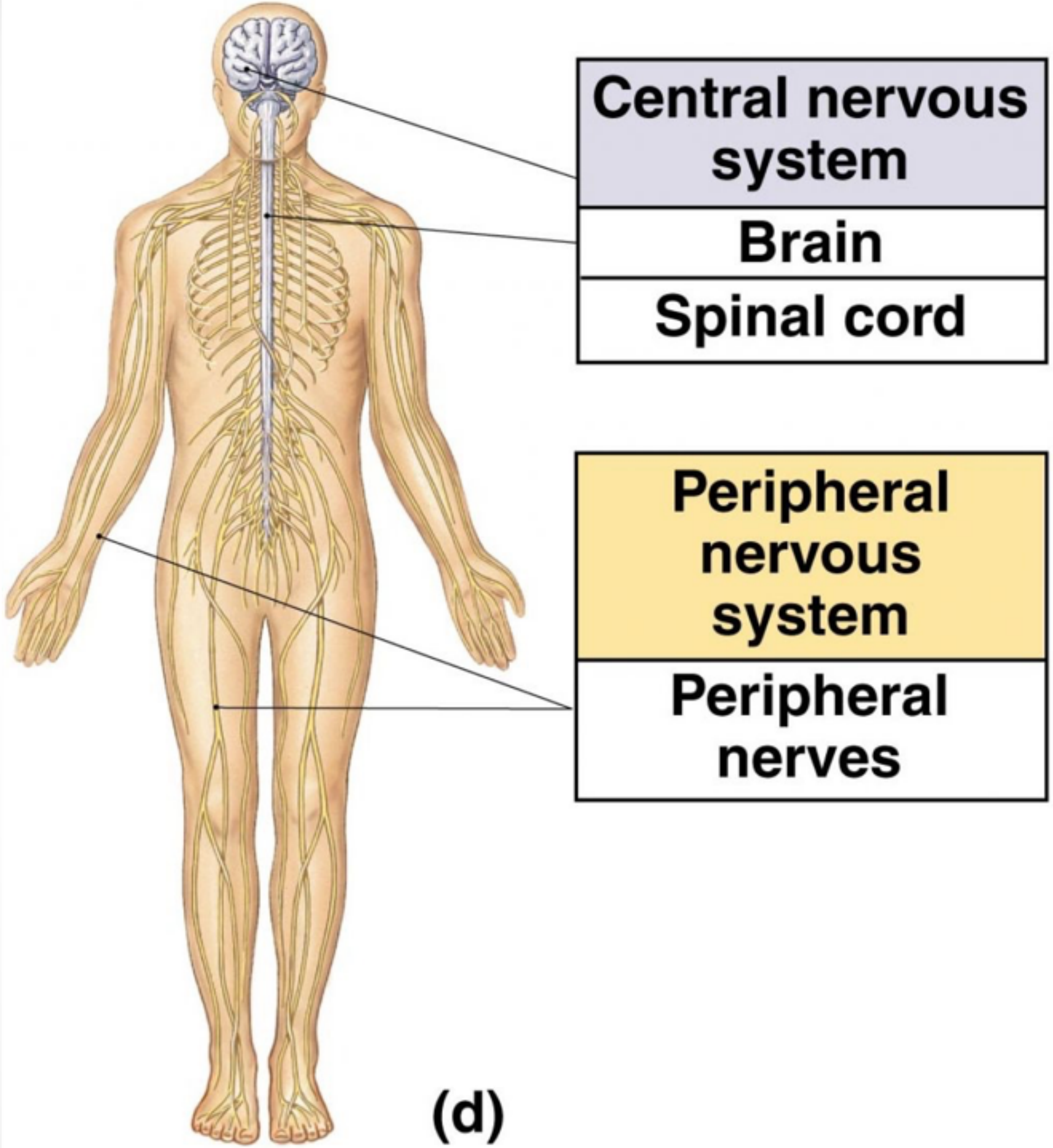
What do we do?

- We will study the brain's various structures & their relationship with human cognitive processes.

- We will try & figure out how such an investigation can contribute towards developing a theory of human cognition.

Organisation of the Nervous System

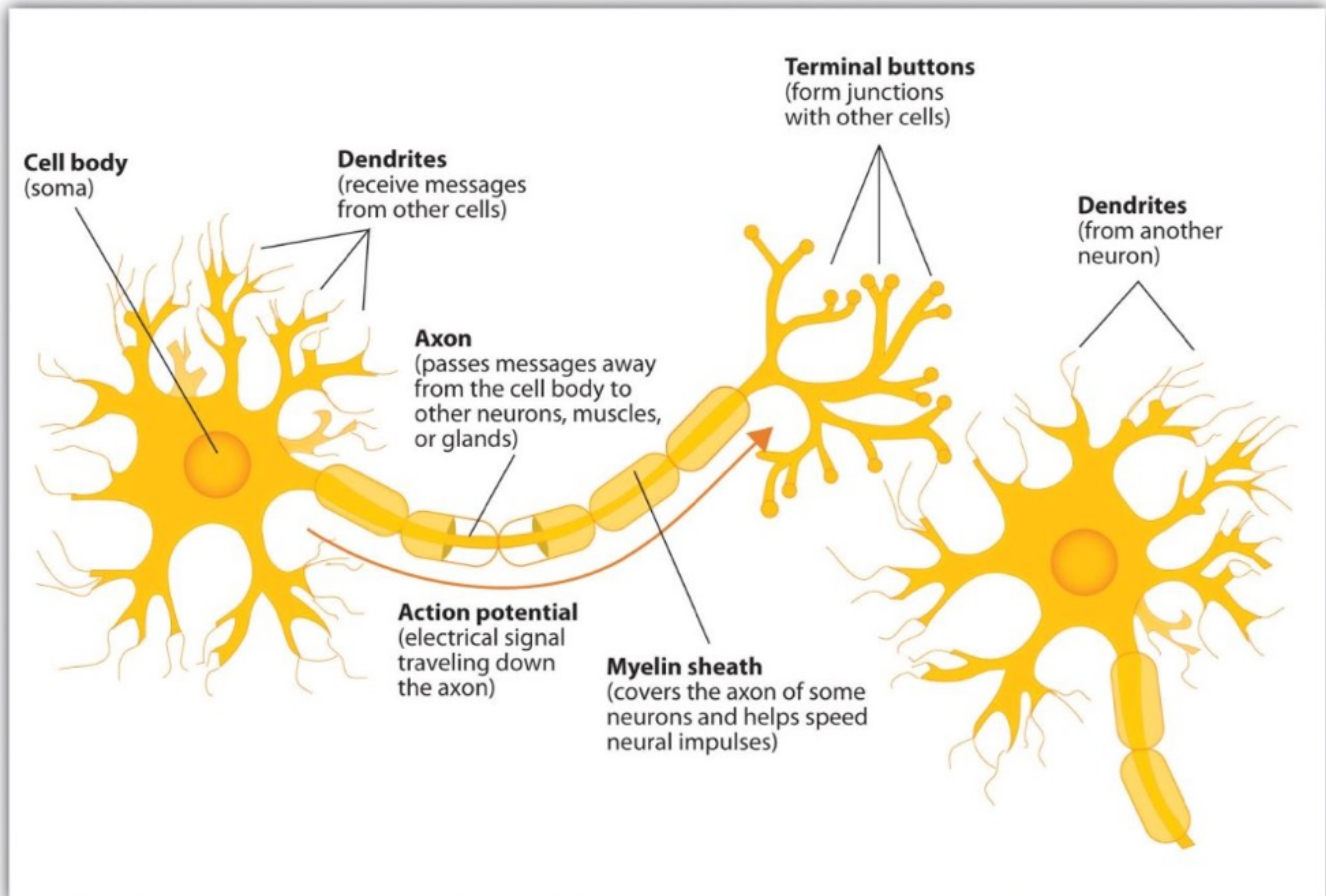
- The ***nervous system***, i.e. a collection of hundreds of billions of specialised and interconnected cells through which messages are sent between the brain and the rest of the body.
  - the ***central nervous system*** (*CNS*), made up of the brain and the spinal cord, and
  - the ***peripheral nervous system*** (*PNS*), the neurons that link the CNS to our skin, muscles and the glands.
  - a large part of our behaviour is also controlled by the ***endocrine system***, the chemical regulator of the body that consists of the glands that secrete hormones, influencing behaviour.


Central nervous system
Brain
Spinal cord
Peripheral nervous system
Peripheral nerves
(d)

Neurons: The Building Blocks of the Brain

- Cajal's discovery that individual units called neurons were the basic building blocks of the brain was the centrepiece of **neuron doctrine** - the idea that individual cells transmit signals in the nervous system, and these cells are not continuous with other cells as proposed by the nerve net theory.

Figure 3.2 Components of the Neuron



- ***cell body*** - contains mechanisms to keep the cell alive.
- ***dendrites*** - branches which emerge out of the cell body to receive signals from other neurons,
- ***axon*** - transmits signals to other neurons.
- for all neurons, there is a small gap between the end of the neuron's axon and the dendrites or cell body of another neuron. this gap is called a **synapse**.
- neurons are not connected indiscriminately to other neurons, but form connections only to specific neurons; to form **neural circuits.**

Communication of Neurons

- the nervous system operates using an *electrochemical process*.

- The neurons exist in an electrically charged environment, both inside & outside of the neurons exist electrically charged particles, called *ions*. Some of these are *positively charged* while others are *negatively charged*.

- When a neuron is inactive or resting, more of the "plus" charges exist outside the neutron and more "minus" charged charges exist inside; as a result the inside of each resting neuron in the brain has an electrical charge of about -70 mV.

- the electrical charge of an inactive neuron is called its ***resting potential.***

- however, the neurons are mostly busy:

  - messages arriving from other neurons raise & lower the resting potential.

  - if the electrical charge rises to about -50 mV, the neuron will reach its ***threshold*** or trigger point for firing.

  - when a neuron reaches its threshold, an ***action potential*** or ***nerve impulse*** sweeps down the axon at up to 200 miles per hour.

- ***What happens during an action potential***:

  - the axon membrane is pierced by tiny tunnels or holes called *ion channels*.

  - these tiny channels act like gates, which opens to allow the sodium ions to rush into the axon.

  - the channels open first near the soma, & then throughout the length of the axon as the action potential zips along.

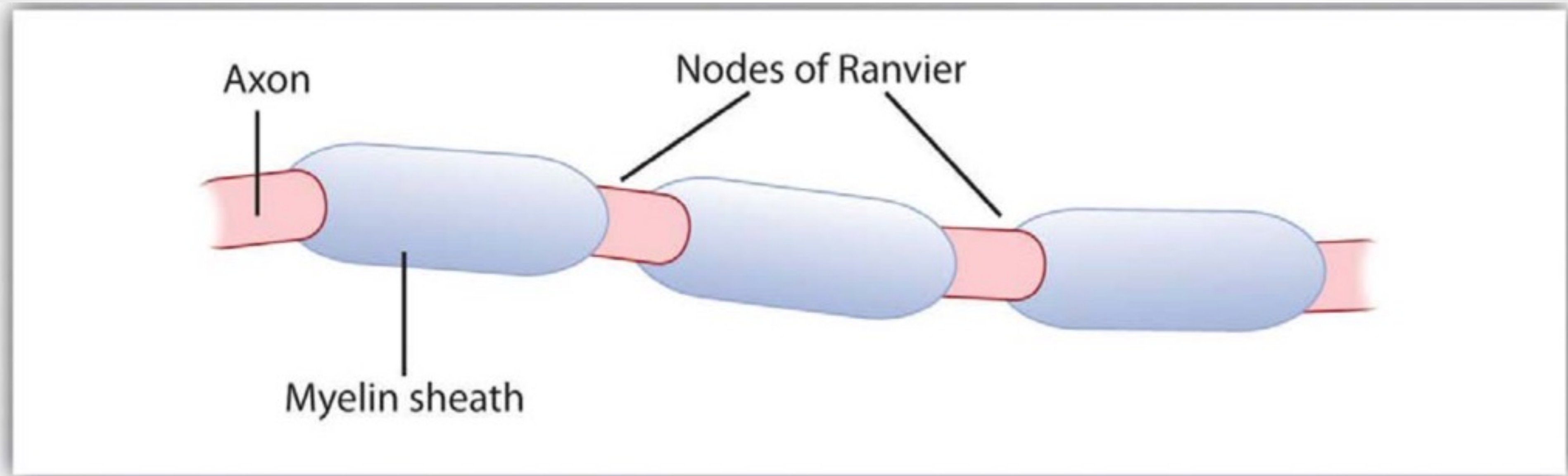
  - each action potential is an *all - or - nothing* event. So, a nerve impulse is first triggered near the soma, & then a wave of activity travels down the length of the axon.

- after each nerve impulse, the cell briefly dips below its resting level and becomes less willing or ready to fire. This negative after-potential occurs because potassium (K+) ions flow out of the neuron while the membrane gates are open.

- ***Saltatory Conduction***: the axons of some neurons are coated with a fatty layer called *myelin*, small gaps in the myelin help nerve impulses move faster.

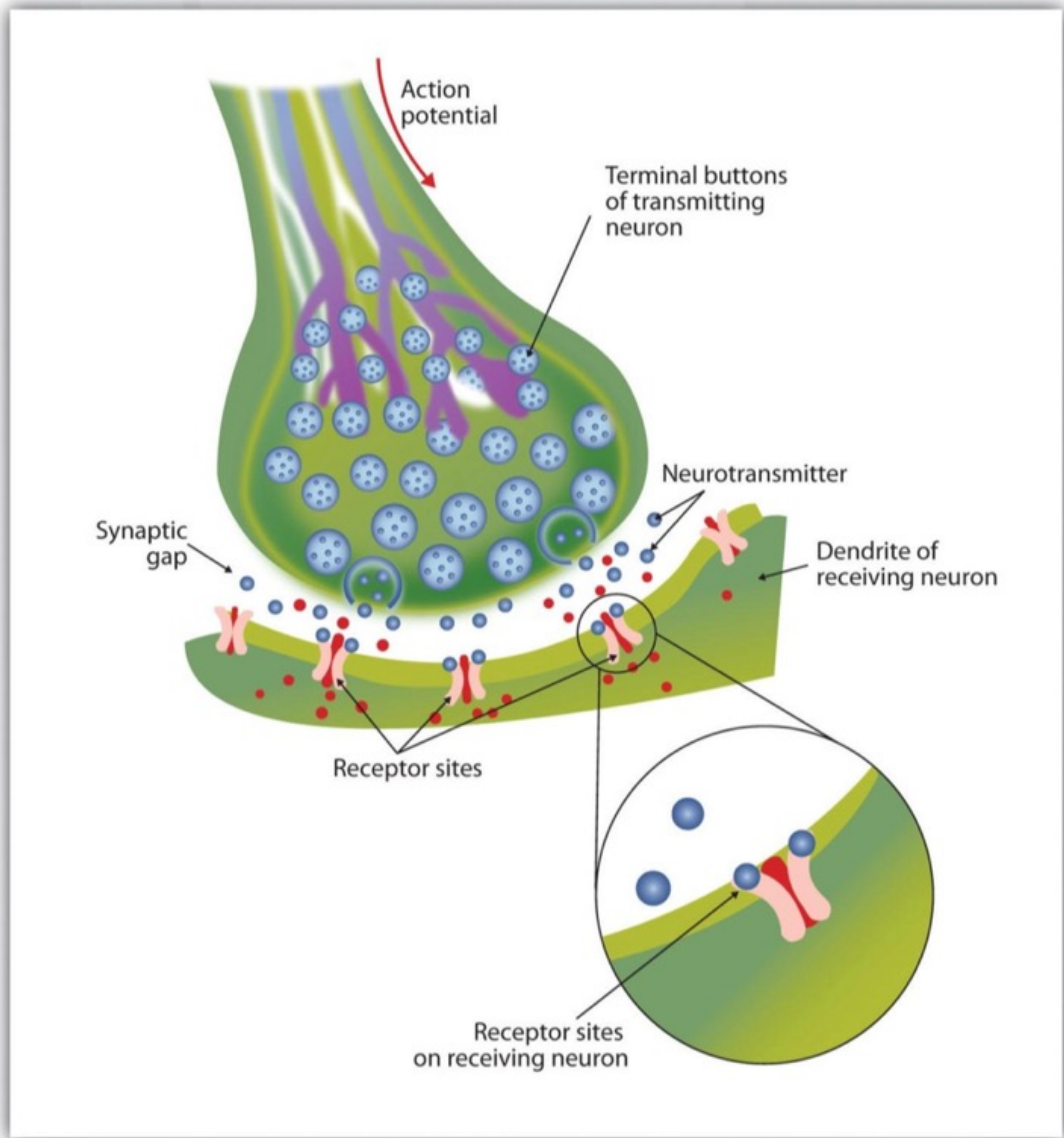
- instead of passing down the entire length of the axon, the action potential jumps from gap to gap, a process called *saltatory conduction.*

- when the myelin layer is damaged, a person may suffer from numbness, weakness or paralysis. in fact, that is what happens in **multiple sclerosis**, a disease that occurs when the immune system attacks & destroys the myelin in a person's brain (Khan et al., 2010).


Axon
Nodes of Ranvier
Myelin sheath

- ***Synapses and Neurotransmitters*:**
  - in contrast to nerve impulses, communicated between neurons is chemical in nature.
  - the microscopic space between two neutrons, over which the messages pass is called a ***synapse*.**
  - when an action potential reached the tips of the axon terminals, ***neurotransmitters*,** are released into the synaptic gap.
  - these are chemicals that alter activity in neurons.

- neurotransmitters travel across the synaptic space between the terminal button of one neutron and the dendrites of another neuron where they bind to the dendrites in the neighbouring neurons.
- different terminals release different neurotransmitters and different dendrites are particularly sensitive to different neurotransmitters.
- the dendrites will admit the neurotransmitters only if they are the right shape to fit in the receptor sites on the receiving neuron, the mechanism resembling that of a lock & key.



Action potential
Terminal buttons of transmitting neuron
Neurotransmitter
Synaptic gap
Dendrite of receiving neuron
Receptor sites
Receptor sites on receiving neuron

- When neurotransmitters are accepted by the receptors on the receiving neurons, their effects may be either *excitatory* or *inhibitory.*

- if the receiving neuron is able to accept more than one neurotransmitter, then it will be influenced by the excitatory or inhibitory processes of each.

- the summation of the two influences, governs the behaviour of the particular neuron.

Table 3.1 The Major Neurotransmitters and Their Functions

Neurotransmitter	Description and function	Notes
Acetylcholine (ACh)	A common neurotransmitter used in the spinal cord and motor neurons to stimulate muscle contractions. It's also used in the brain to regulate memory, sleeping, and dreaming.	Alzheimer's disease is associated with an undersupply of acetylcholine. Nicotine is an agonist that acts like acetylcholine.
Dopamine	Involved in movement, motivation, and emotion, Dopamine produces feelings of pleasure when released by the brain's reward system, and it's also involved in learning.	Schizophrenia is linked to increases in dopamine, whereas Parkinson's disease is linked to reductions in dopamine (and dopamine agonists may be used to treat it).
Endorphins	Released in response to behaviors such as vigorous exercise, orgasm, and eating spicy foods.	Endorphins are natural pain relievers. They are related to the compounds found in drugs such as opium, morphine, and heroin. The release of endorphins creates the runner's high that is experienced after intense physical exertion.
GABA (gamma-aminobutyric acid)	The major inhibitory neurotransmitter in the brain.	A lack of GABA can lead to involuntary motor actions, including tremors and seizures. Alcohol stimulates the release of GABA, which inhibits the nervous system and makes us feel drunk. Low levels of GABA can produce anxiety, and GABA agonists (tranquilizers) are used to reduce anxiety.

The Organisation of the Brain

- There a number of ways to conceptualise the structure of the brain.
  - based on location:
    - the ***hindbrain***, which includes all the structures located in the posterior part.
    - the ***midbrain***, located in the middle of the brain &
    - the ***forebrain***, which includes the structures located in the front part of the brain.

- based on function:
    - *the central core* or ***brainstem****,* which regulates our most primitive behaviours, such as coughing, sneezing etc. & primitive behaviours which are under voluntary control as vomiting, sleeping, eating, drinking, temperature regulation & sexual behaviour.
        - It includes all the structures in the hindbrain & midbrain & two structures in the forebrain viz. the hypothalamus & thalamus.
    - ***the limbic system****,* which controls our emotions
    - ***the cerebellum****,* which regulates our higher intellectual processes.

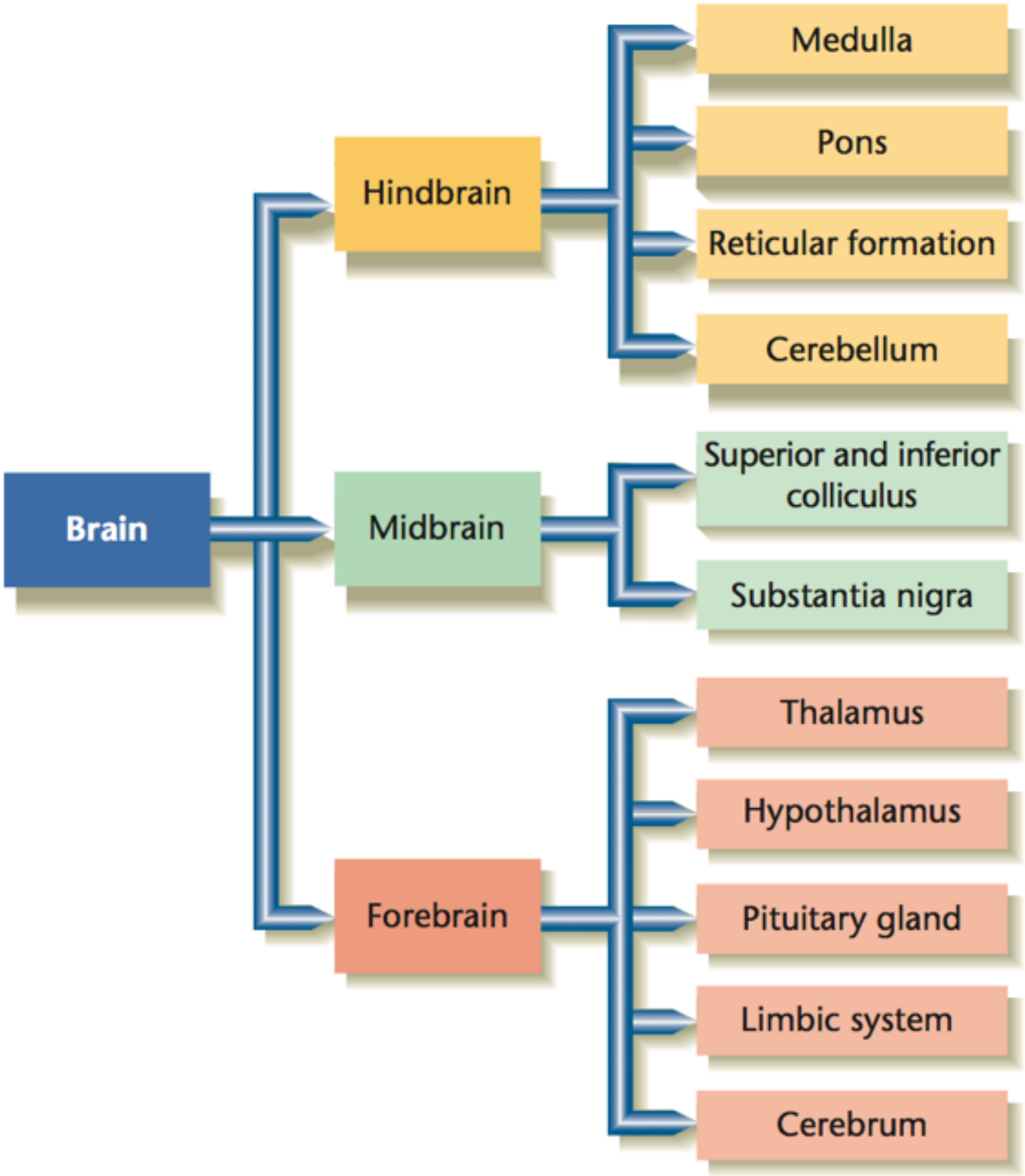
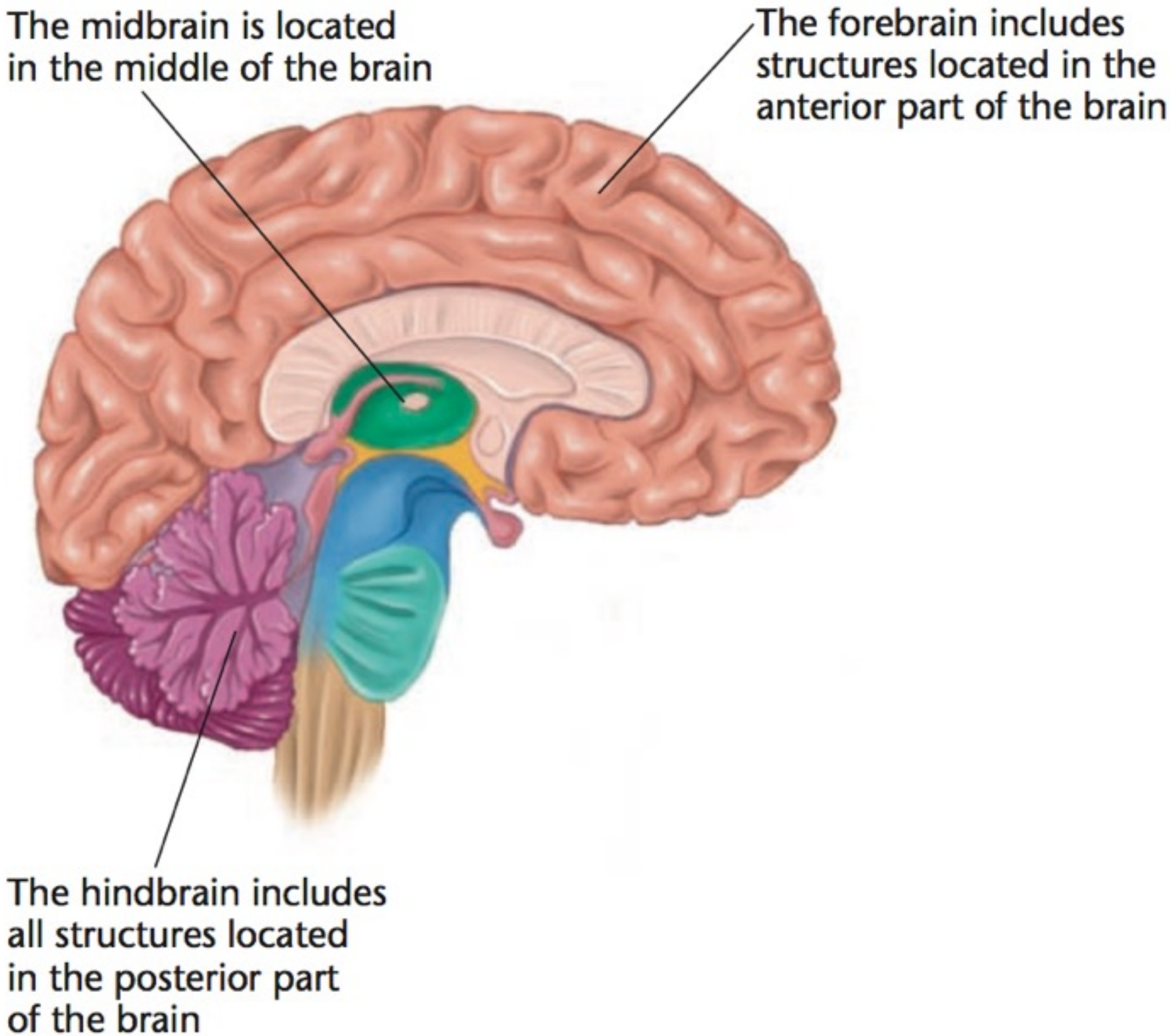


Figure 2.10 **Organization of the Brain.**


The midbrain is located in the middle of the brain
The forebrain includes structures located in the anterior part of the brain
The hindbrain includes all structures located in the posterior part of the brain

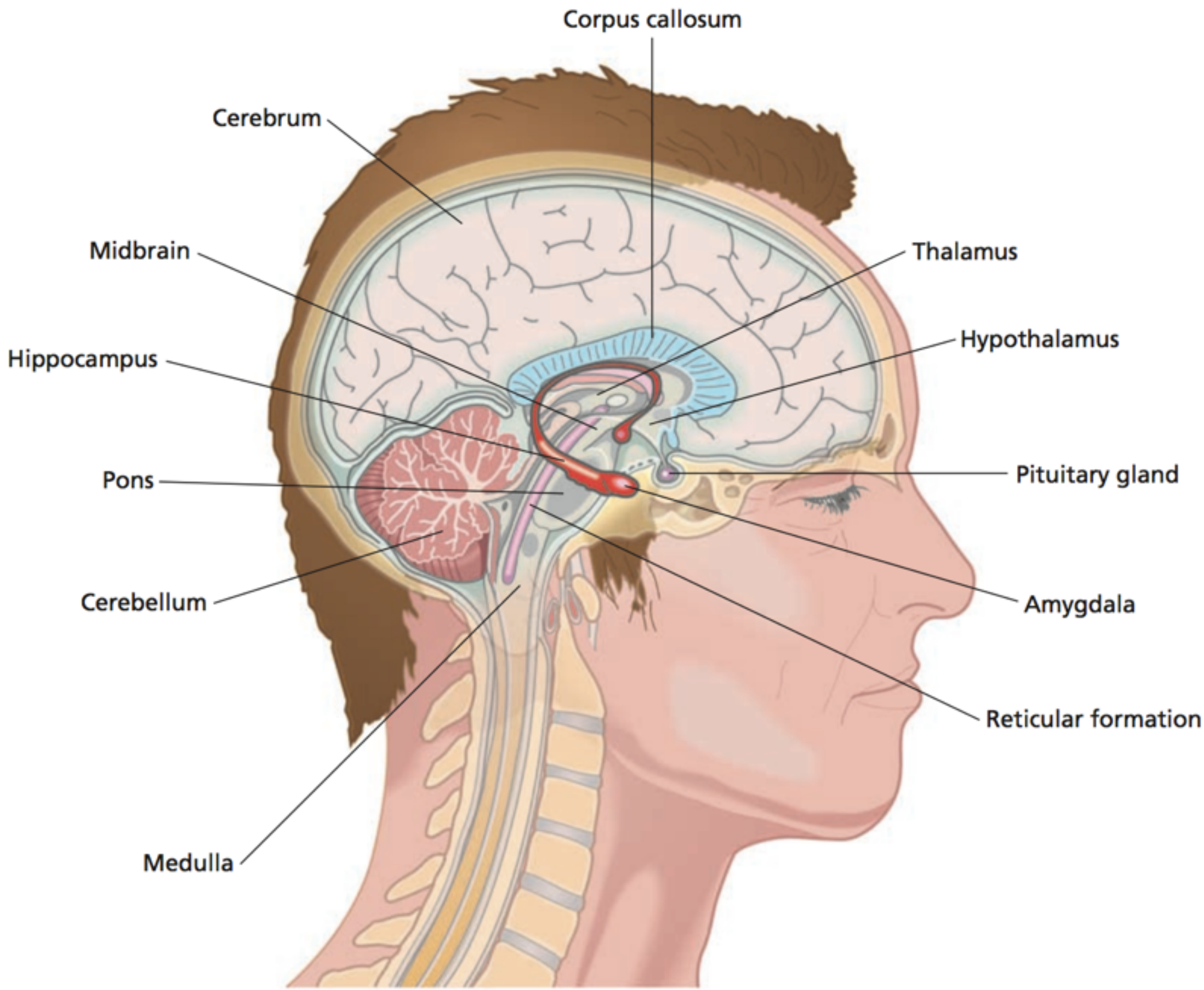


Figure 2.11 The main structures of the human brain.

Parts of the brain

- ***The Hindbrain*** sits on the top of the spinal cord, & it is crucial for basic life functions.
  - Medulla: the first slight enlargement of the spinal cord as it enters the skull is the medulla, a narrow structure that controls breathing and some reflexes that help maintain upright posture.
  - Pons: above the medulla is the pons, important for the control of attentiveness, as well as the timing of sleep. At this point, the major nerve tracts coming up from the spinal cord cross over so that the right side of the brain is connected to the left side of the body and the left side of the brain is connected to the left side of the body.

- ***Reticular formation***: a network of neural circuits that extends from the lower brainstem up to the thalamus in the forebrain, & the transversing some of the other central core structures is called reticular formation.

  - this network of neurons acts to control arousal.

  - the reticular formation also plays a role in our ability to focus attention on particular stimuli.

  - all of the sense receptors have nerve fibres that feed into the reticular system, which appears to act as a filter. it allows some sensory messages to pass to the cerebral cortex while blocking others.

- ***Cerebellum***: attached to the rear of the brain stem slightly above the medulla is a convoluted structure called the cerebellum.
  - it is primarily concerned with the coordination of movement.
  - specific movements may be initiated at higher levels, but the coordination of those movements depends on the cerebellum.
  - damage to the cerebellum results in jerky, uncoordinated movements.

- it is also important for learning new motor responses.

- direct neural connections between the cerebellum and frontal parts of the brain are involved in languages, planning, & reasoning.

- cerebellum may also play a role in the control & coordination of higher mental processes also.

- ***The Midbrain***: the midbrain is relatively small in humans & found just above the pons & surrounded by the forebrain.

    - Superior & inferior colliculus: the midbrain consists of two small structures, which are important for relaying sensory information to the brain & for movement control.

    - Substantia nigra: located just above the midbrain is the substantia nigra, a crucial part of the dopamine-containing pathway (also known as the reward pathway). This structures deteriorates in Parkinson's disease.

- ***The Forebrain***:

  - In humans the forebrain is relatively large, and covers the midbrain & parts of the hindbrain.

  - a large part of it, the cerebrum is especially more developed in humans than in any other organism.

  - the outer layer of the cerebrum is called the cerebral cortex (or simply cortex), from the Latin word for ‘bark’.

  - the other structures of the forebrain (the thalamus, the hypothalamus & the areas comprising the limbic system) are found just beneath the cerebrum & are referred to as subcortical structures.

- Thalamus: located just above the midbrain inside the cerebral hemispheres are two egg shaped groups of nerve cell nuclei, the thalamus.

- it acts as a sensory relay station, directing incoming information from the sense receptor (such as vision & hearing) to the cerebrum.

- ***Hypothalamus***: the hypothalamus is a much smaller structure, located just below the thalamus.
  - centers in the hypothalamus regulate eating, drinking & sexual behaviour.
  - the hypothalamus is involved maintaining homeostasis by exerting control over the autonomic nervous system.
  - *homeostasis* is a term that refers to the level of functioning that is characteristic of a healthy organism, such as normal body temperature, herat rate, & blood pressure.

- When an organism is under stress, homeostasis is disturbed, & processes are set in motion to correct this lack of equilibrium. e.g. if we are too warm, we perspire and if we are too cool, we shiver.
    - both these processes tend to restore normal temperature and are controlled by the hypothalamus.
- the hypothalamus also plays an important role in the sensation of emotions and in our response to stress producing situations.
- mild electrical stimulation of certain areas in the hypothalamus produces feelings of pleasure; stimulation of adjacent regions produces unpleasant sensations.

- Pituitary Gland: the pituitary glans is the most important part of a system of glands called the endocrine system; the hypothalamus controls the endocrine system and thus the production of hormones.

- Limbic System: around the central core of the brain and closely interconnected with the hypothalamus is the limbic system, a set of structures that impose additional control over some of the instinctive behaviours regulated by the central core.

  - the hippocampus: a part of the limbic system, the hippocampus plays a special role in memory.

  - the amygdala, an almond shaped structure deep within the brain, is critical in emotions such as fear. e.g. monkeys with damage to the amygdala exhibit marked reduction in fear.

  - humans with such damage are unable to recognise facial expressions of fear of learn new fear responses.

To Sum Up…

- In this lecture we talked about the basic neural organisation that governs human behaviour.
- More specifically, we talked about the structure & function of neurons.
- Also, we talked about the basic organisation principles of the brain.