THE NERVOUS SYSTEM

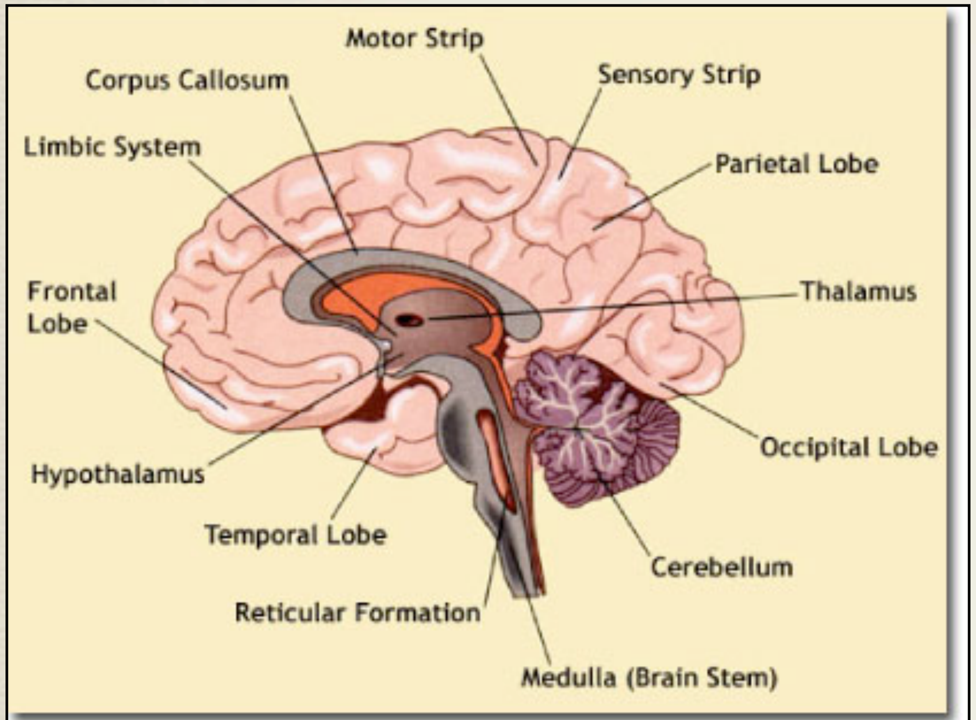
Biology 12 Human Systems

The brain, pituitary gland and neuroendocrine link

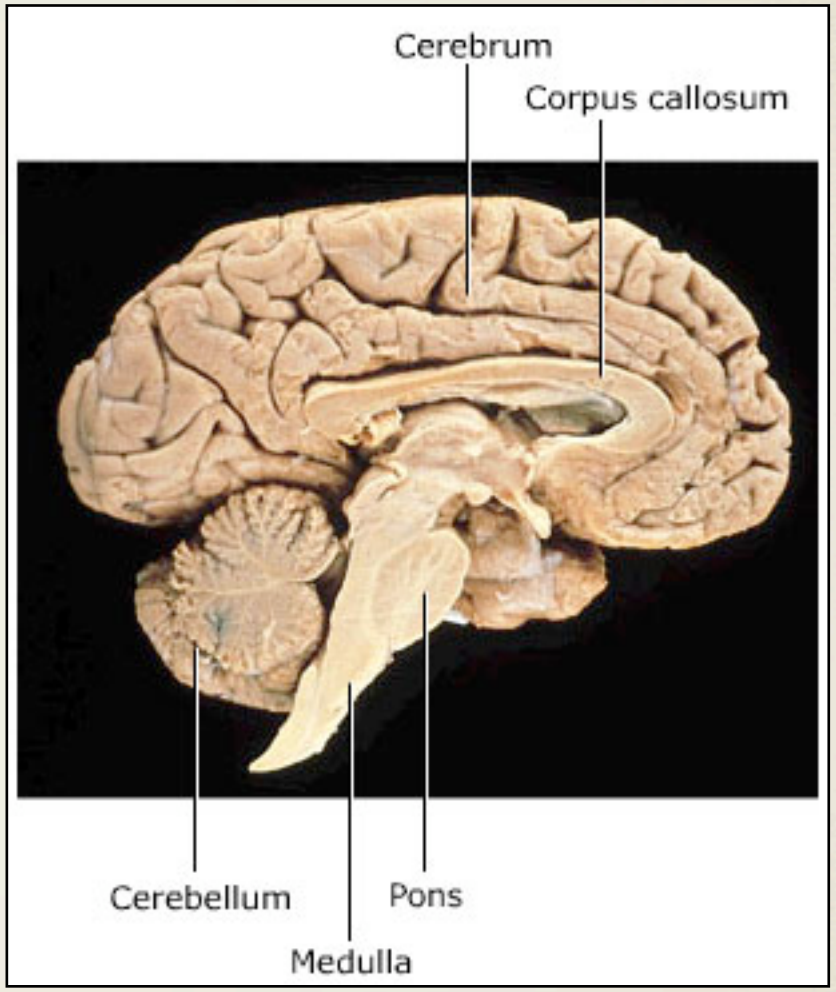
The Structure and Function of the Human Brain

- The human brain is part of the **central** nervous system
- It is made of billions of cells called **neurons**
- Each **neuron** is able to conduct nerve **impulses** across gaps called **synapses**
- The human brain consists of a number of parts which can be distinguished **structurally** and **functionally**

The Brain



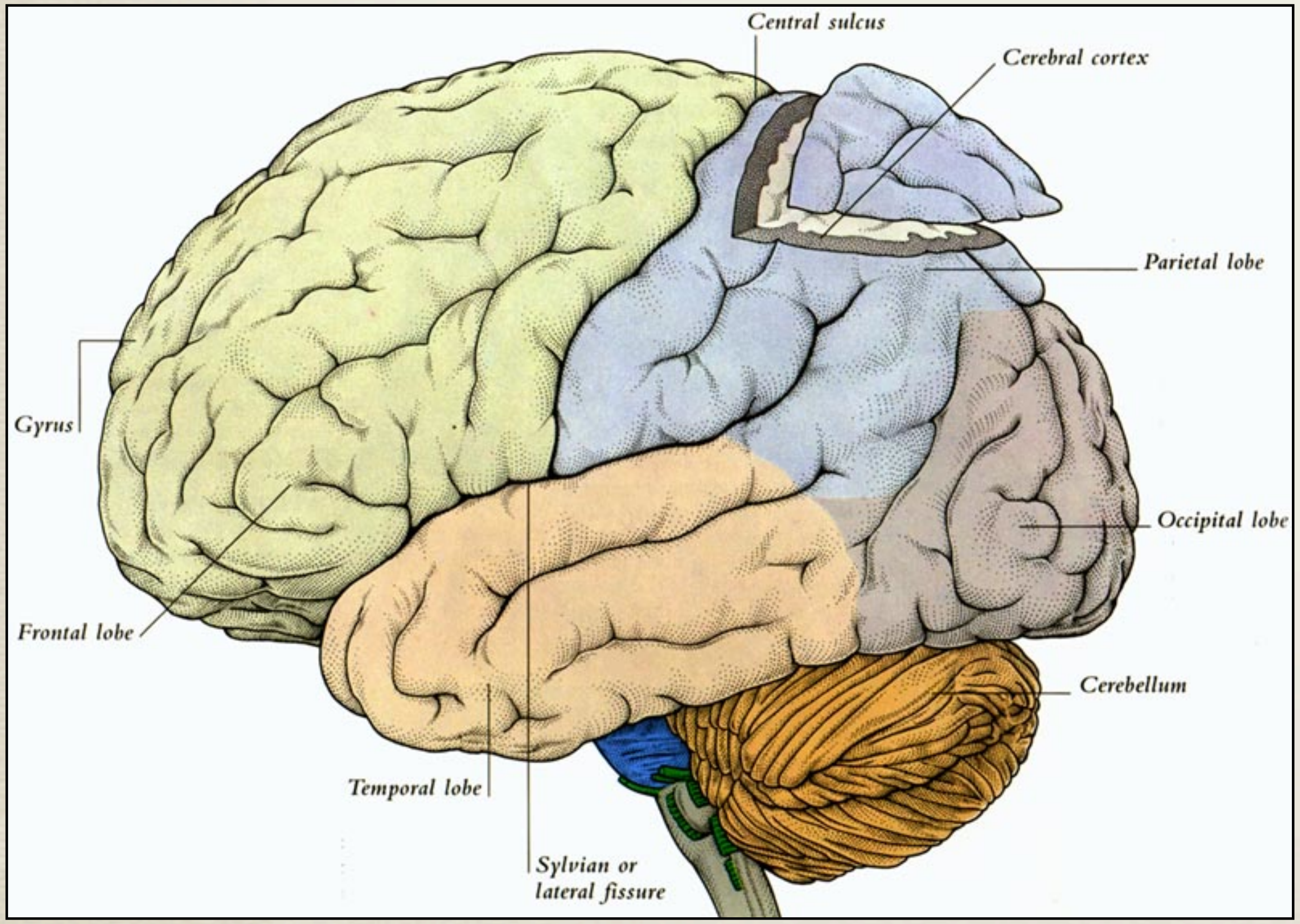
Brief Brain Anatomy

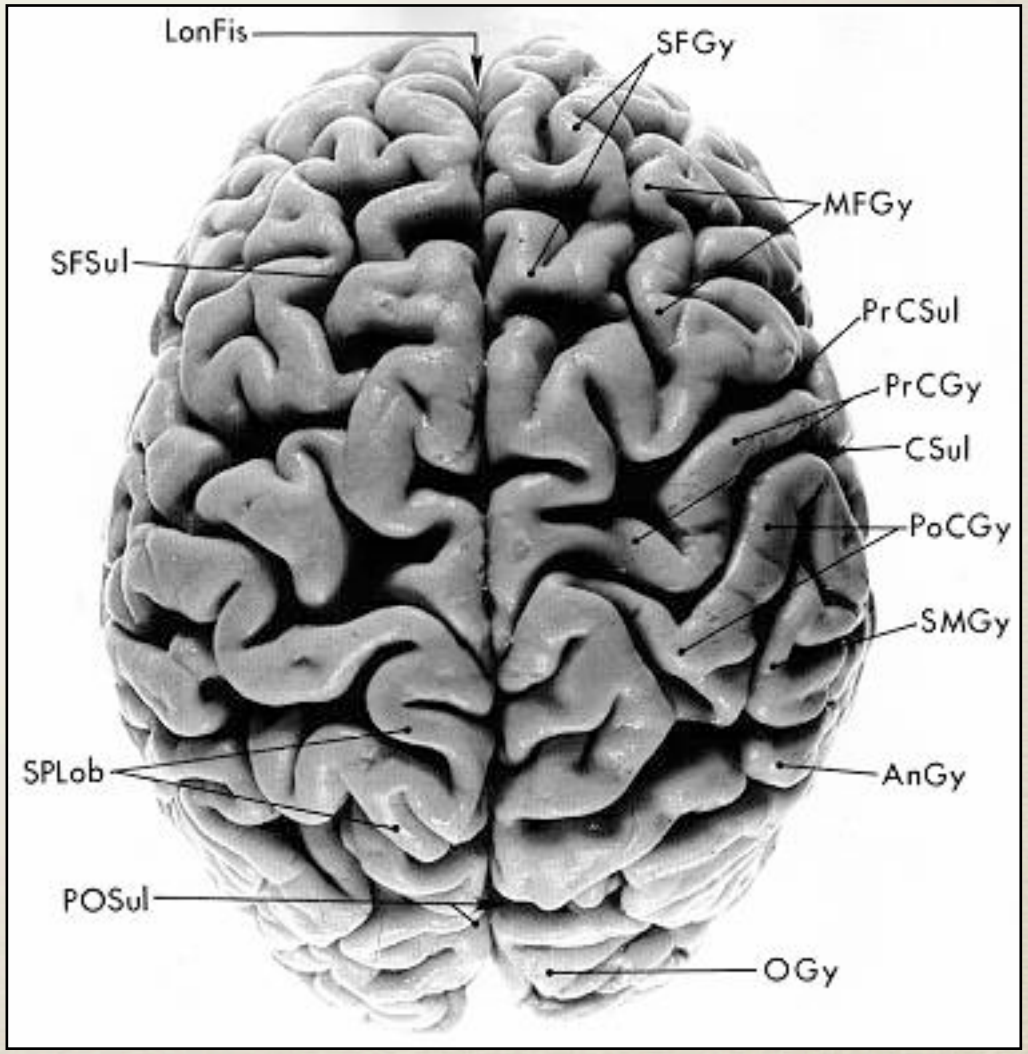


The Cerebrum

1. **The Cerebrum**

- The cerebrum is the largest part of the brain and is divided into the **left and right cerebral hemispheres**
- The surface of the **cerebrum** is called the **cerebral cortex**





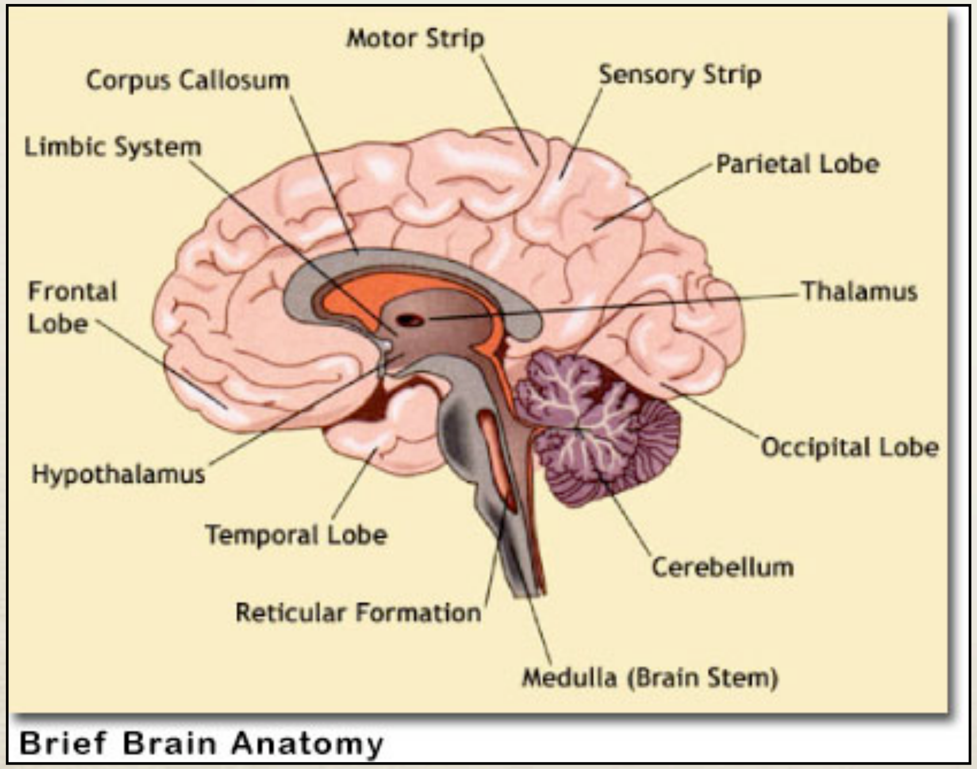
Functions of the cerebrum

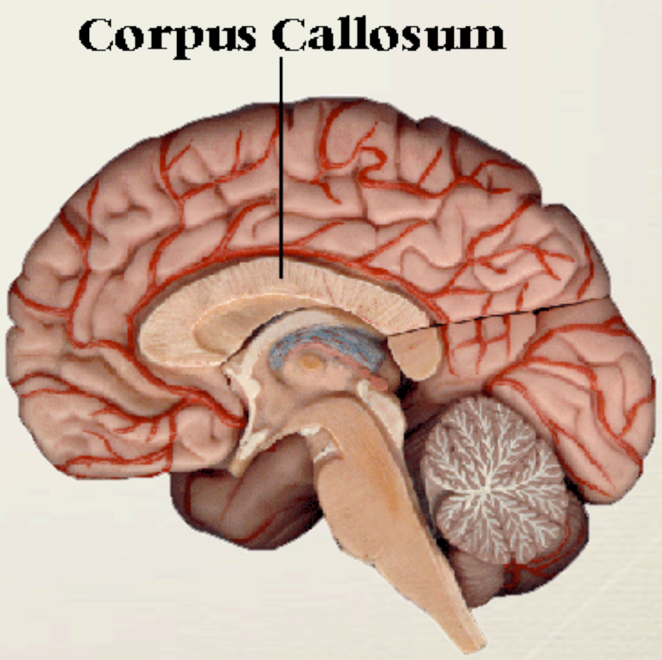
- Specific areas of the **cerebral cortex** have specific functions which include the following:
  - **Motor Areas-**
    Send impulses to **skeletal muscles** causing them to contract
  - **Sensory Areas-**
    Receive and interpret nerve impulses from **sensory organs**
  - **Association Areas-**
    Responsible for **higher order** mental functions such as **learning, memory, language** and **speech**

The Corpus Callosum

<u>The Corpus Callosum</u>

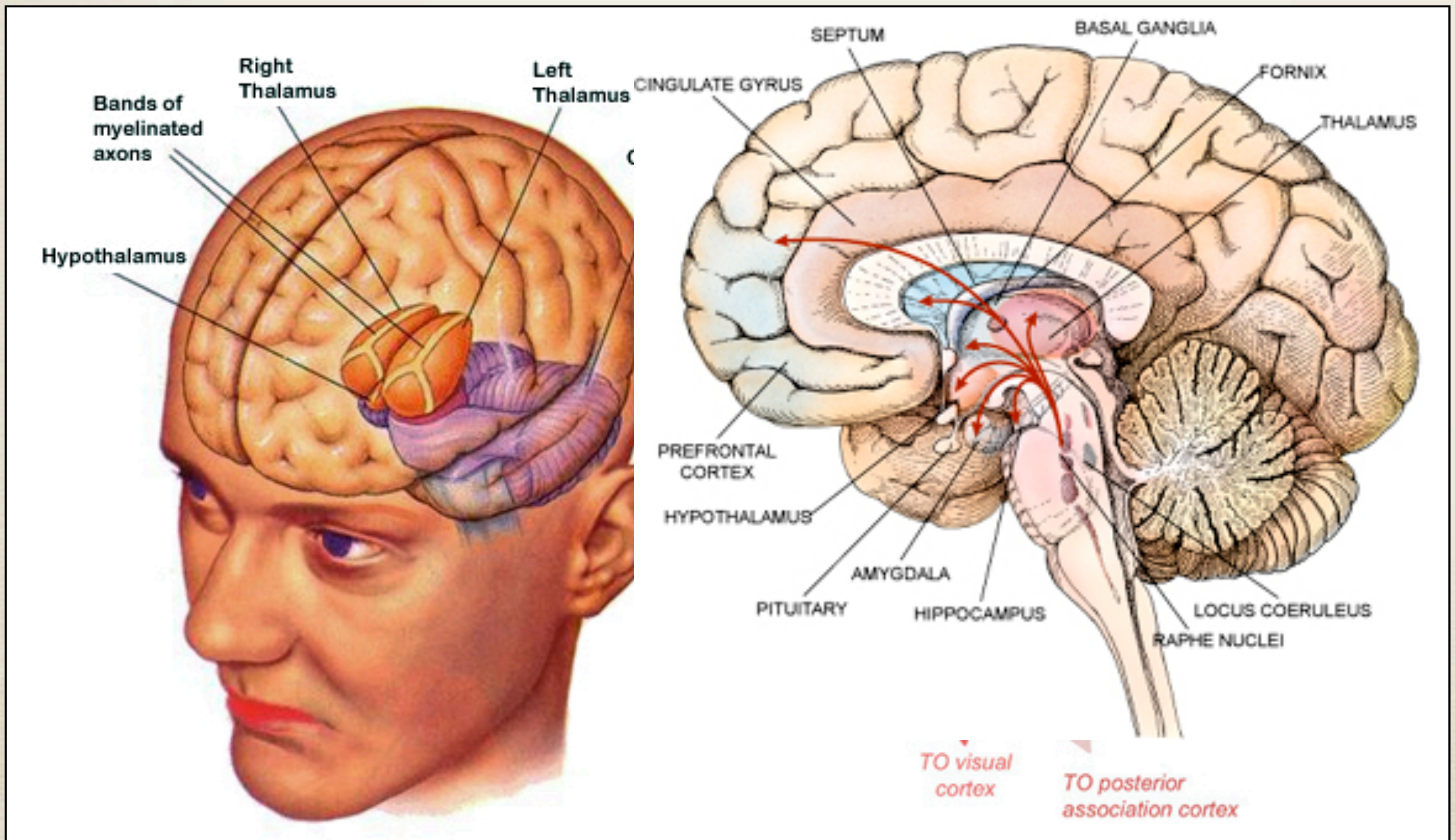
- The left and right cerebral hemispheres are connected by the **corpus callosum**
- It is a thick band of **nerve fibres** between the two hemispheres
- This structure allows nerve impulses to be transmitted between the two cerebral hemispheres





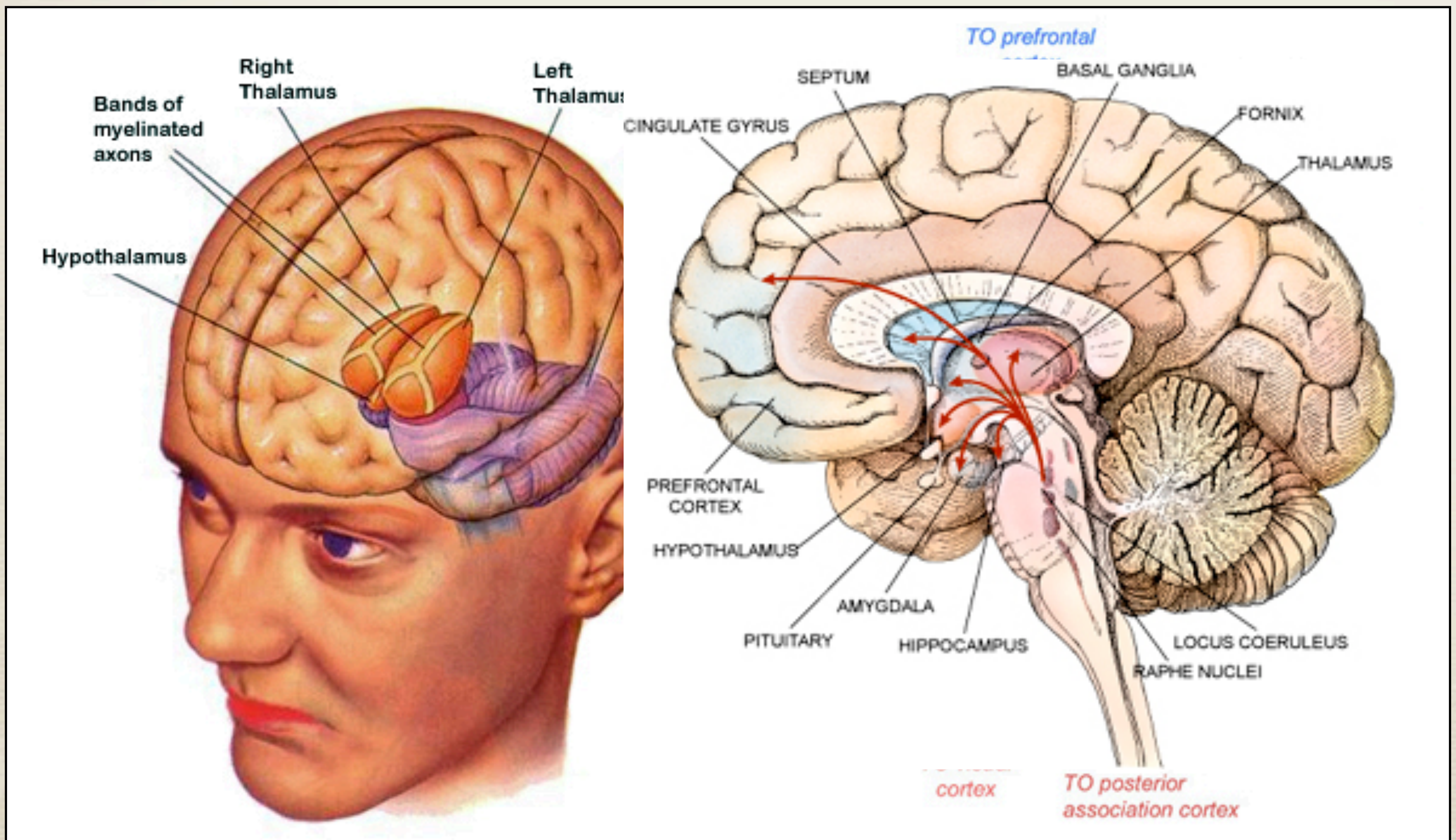
The Thalamus

- The thalamus receives **sensory information** from other parts of the body and **relays** them to appropriate locations in the **cerebral cortex** where they are interpreted



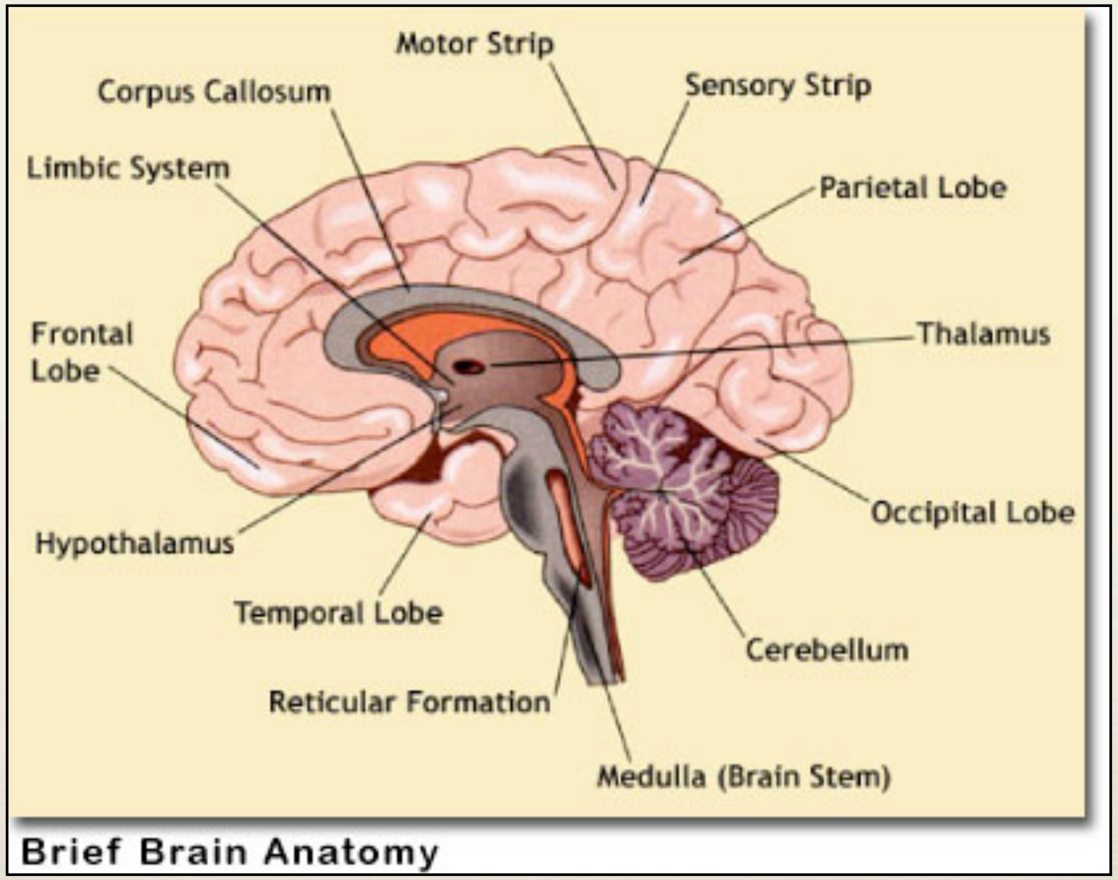
The Hypothalamus

- The hypothalamus is located just beneath the thalamus
- It helps to maintain **homeostasis** by regulating **hunger, sleep, thirst, body temperature** and **water balance**
- The hypothalamus is connected to and controls the **pituitary gland** (which releases MANY important hormones such as ADH, oxytocin, TSH, growth hormone, gonadotropic hormones etc)
- Therefore the hypothalamus is a link between the **nervous system** and the **endocrine system** called the **neuroendocrine link**



The Cerebellum

- The cerebellum is located in the lower, back portion of the brain, beneath the cerebrum
- The cerebellum receives **sensory info** from the ears, eyes, joints and muscles about the position of body parts
- It also receives **motor output** from the cerebral cortex
- After integrating this information, the cerebellum send messages to **skeletal muscles**
- Therefore maintaining **posture, balance** and ensuring that the muscles work together in a **coordinated** fashion



The Brainstem

- The brainstem contains the **midbrain**, **pons** and **medulla oblongata**

Midbrain

- Acts as a relay station for information passing between the cerebrum and spinal cord or cerebellum

Pons

- It contains a bundle of nerves that act as a **bridge** between the cerebellum and the rest of the central nervous system
- It also assists the medulla oblongata in controlling **breathing rate**

Medulla Oblongata

- Contains a number of centres for regulating **heart beat, breathing,** and **vasoconstriction**
- It also contains the **reflex** centres for **coughing, vomiting, sneezing, hiccupping** and **swallowing**

Neuroendocrine Link

- The **Hypothalamus** is part of the **brain** and thus part of the **central nervous system**
- The **pituitary gland** is part of the **endocrine system** which produces and secretes **hormones** into the **blood**
- The **pituitary gland lies beneath,** and is **connected to** the **hypothalamus** by the **infundibulum**
- Therefore the hypothalamus and the pituitary provide a link between the nervous system and the endocrine system and are known as the **neuroendocrine link**

Hypothalamic Control of the Anterior Pituitary

- The **anterior pituitary** produces and stores a number of hormones
- These include:
  - Growth hormone (GH)
  - Gonadotropic Hormones (FSH and LH)
  - Prolactin (PRL)
  - Adrenocorticotropin hormone (ACTH)
  - Thyroid stimulating hormone (TSH)

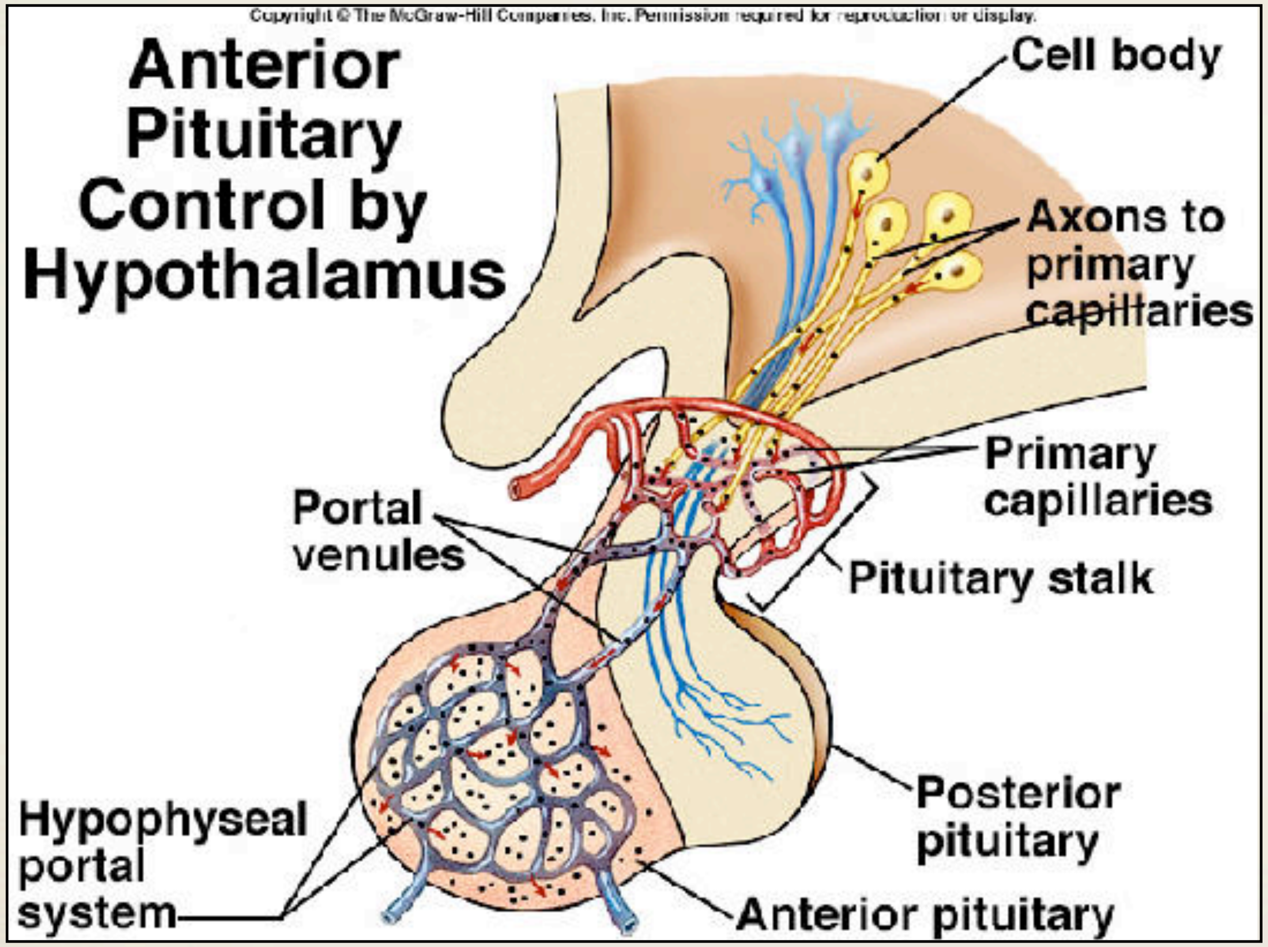
Hypothalamic Control of the Anterior Pituitary

- The release of these hormones from the anterior pituitary is controlled by **hypothalamic-releasing** and **hypothalamic-inhibiting** hormones from the hypothalamus
- **Neurosecretory cells** in the hypothalamus secrete these hormones which travel down **nerve axons** to the anterior pituitary where they enter a capillary bed
- These hormones are then carried by a **portal system** to another capillary bed where they stimulate the anterior pituitary to secrete its hormones into the **blood**

In Other Words...There is always a messenger

Ex.

- Thyroid releasing hormone TRH is produced by the neuroendocrine cells of the hypothalamus
- It travels from the hypothalamus into the capillary bed of the anterior pituitary
- It stimulates the anterior pituitary to release thyroid stimulating hormone TSH into the blood



Hypothalamic Control of the Anterior Pituitary

- The **posterior pituitary secretes** the hormones **ADH** and **oxytocin** into the blood
- These hormones are **produced** by **neurosecretory cells** in the **hypothalamus**
- **ADH** and **oxytocin** travel down the **axons** of the **neurosecretory cells** of the hypothalamus into the posterior pituitary
- These hormones are stored in the posterior pituitary until **nerves** from the **hypothalamus** send a signal to the posterior pituitary that they need to be released

In other words...Pituitary holds a bunch of hormones until the hypothalamus tells it to release them.

Hypothalamic Control of the Anterior Pituitary

Eg:

- ADH is produced by the neurosecretory cells of the hypothalamus
- ADH travels into the posterior pituitary where it is stored until the posterior pituitary receives a nerve signal from the hypothalamus

Anterior Hormones

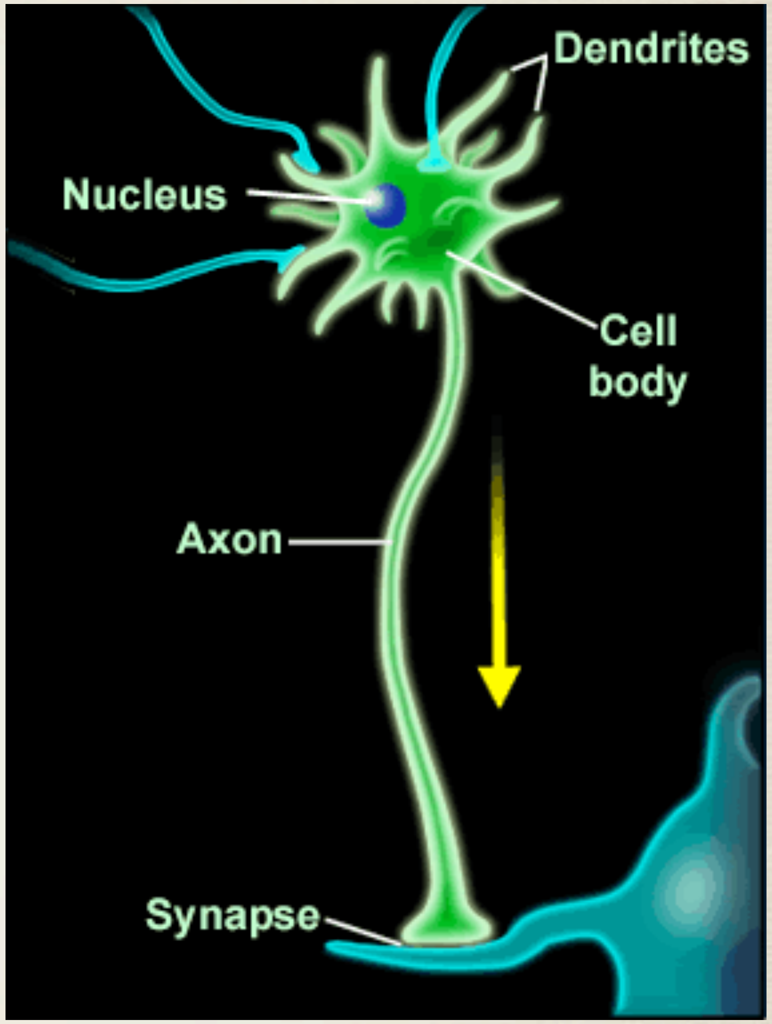
- The anterior pituitary produces, and when stimulated by the hypothalamus, releases a number of hormones into the blood
- These include:
  - **Growth Hormone GH**
    - ♣ Growth hormone causes growth in humans by stimulating protein synthesis
  - **Prolactin PRL**
    - ♣ Causes the mammary glands of the breast to develop and produce milk
  - **Follicle Stimulating Hormone FSH**
    - ♣ Stimulates female ovaries to produce gametes and sex hormones
  - **Leutinizing Hormone LH**
    - ♣ Causes ovulation and stimulates the ovaries to produce hormones
  - **Adrenocorticotropic Hormone ACTH**
    - ♣ Stimulates the adrenal glands to secrete cortisol
  - **Thyroid stimulating Hormone TSH**
    - ♣ Stimulates the thyroid gland to release

Posterior Hormones

- The posterior pituitary secretes the two hormones ADH and oxytocin which are produced by the neuroendocrine cells of the hypothalamus
- Their functions are:
  - **Antidiuretic Hormone ADH**
    - ♣ Causes the kidneys to reabsorb water from the urine into the blood
  - **Oxytocin**
    - ♣ Causes the muscles of the uterus to contract during childbirth
    - ♣ Release milk during breast feeding

Neurons

- Most neurons (nerve cells) consist of 3 parts:
  - **Cell body**
  - **Axons**
  - **Dendrites**
- The neuron cell body contains most of the cells organelles including the nucleus
- The **dendrites** carry the nerve impulse **toward** the cell body
- The **axon** carries the nerve impulse away from the cell body



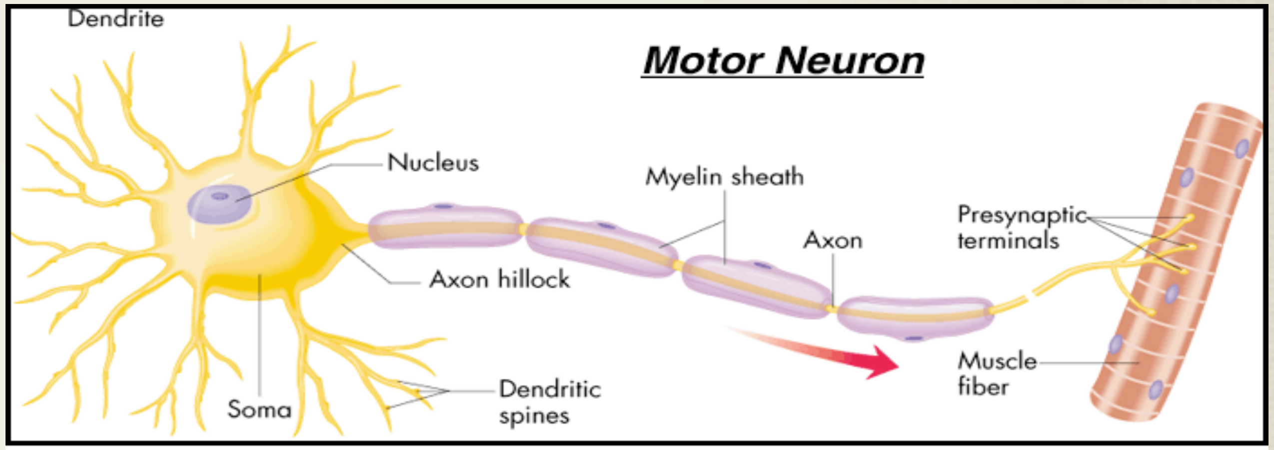
Types of Neurons

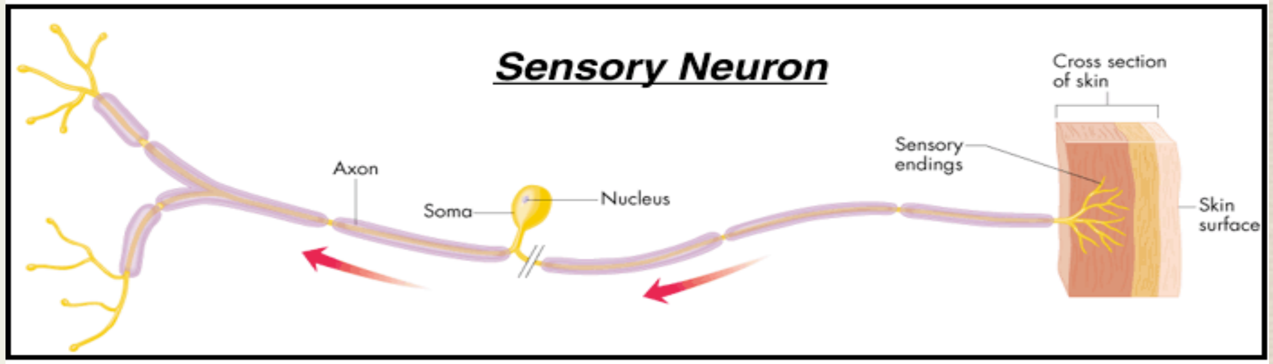
- There are three major types of neurons:
  - **Sensory Neurons**
  - **Motor Neurons**
  - **Interneurons**

- **Sensory neurons**
  - Carry nerve impulses from a **receptor** to the central nervous system

- **Motor Neurons**
  - Carry nerve impulses from the central nervous system to an **effector** (eg-muscle)

- **Interneurons**
  - They are found completely within the central nervous system
  - They act as a link between sensory neurons and motor neurons





Nerves and Bundles

Nerves

- Bundles of neurons
- The type and function of a nerve depends on what type of neurons it contains
- There are **sensory nerves, motor nerves** and **mixed nerves**

Ganglia

- Ganglia (ganglion singular) are groups of neuron cell bodies that lie within the peripheral nervous system (ie: outside the central nervous system)

Divisions of the Nervous System

- The two major divisions of the nervous system are the **central nervous system** and the **peripheral nervous system**

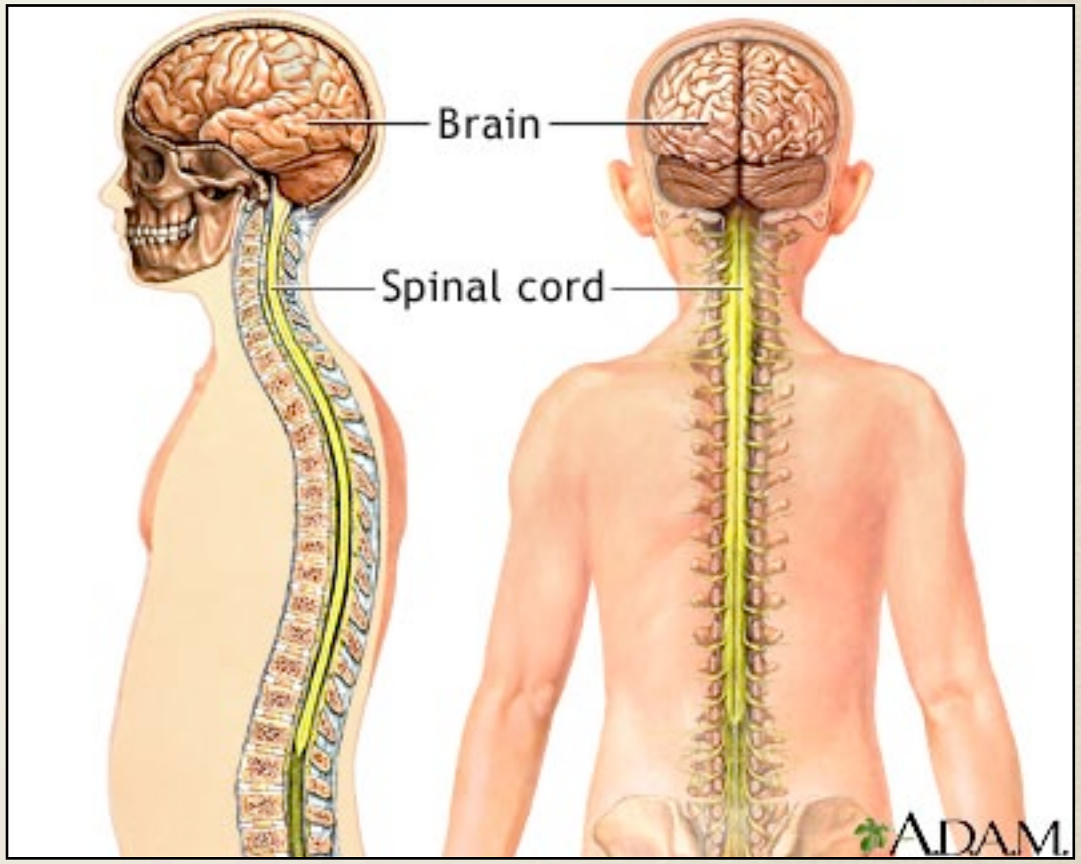
- Nervous System
  - Central Nervous System (Brain & Spinal Cord)
  - Peripheral Nervous System
    Cranial Nerves
    Spinal Nerves
    - Autonomic
      Automatic/Involuntary
      - Sympathetic
      - Parasympathetic
    - Somatic
      Reflex

The **peripheral nervous system** can be further divided into the **somatic nervous system** and the **autonomic nervous system**

- The **autonomic nervous system** consists of two divisions called the **sympathetic system** and the **parasympathetic system**

Central Nervous System

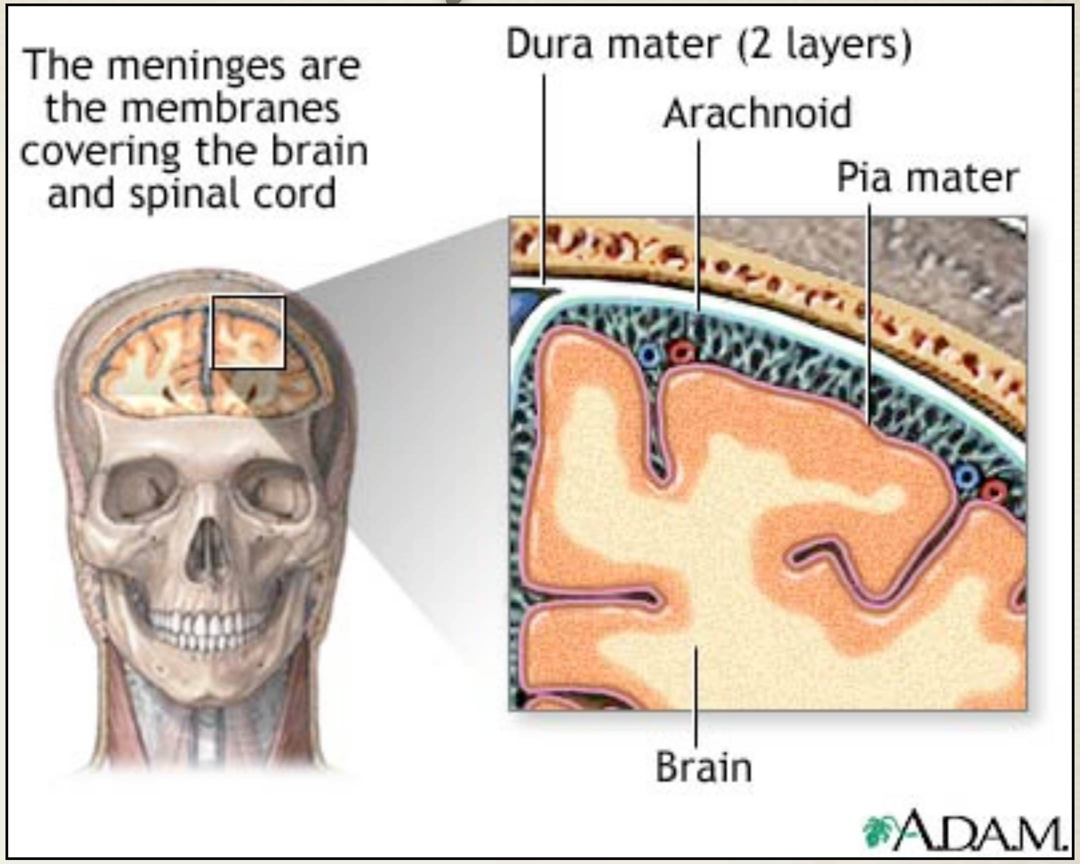
- The central nervous system consists of the **brain** and **spinal cord**
  - The **brain** is encased in the skull and serves as the overall control for the nervous system
  - The **spinal cord** is surrounded by **vertebrae** and extends down the back of the neck, thorax and abdomen. It provides a link between the brain and the peripheral nerves which radiate out form the spinal cord

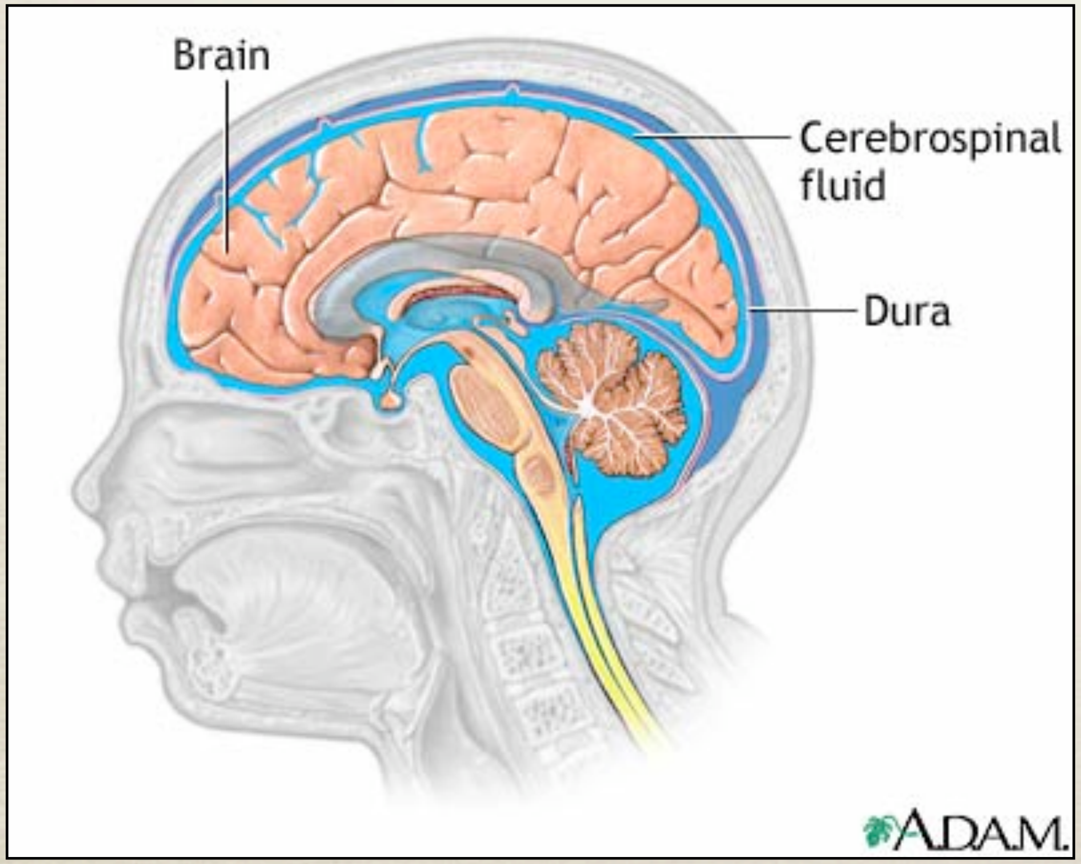


Central Nervous System

- Both the brain and the spinal cord are surrounded by membranes called **meninges**

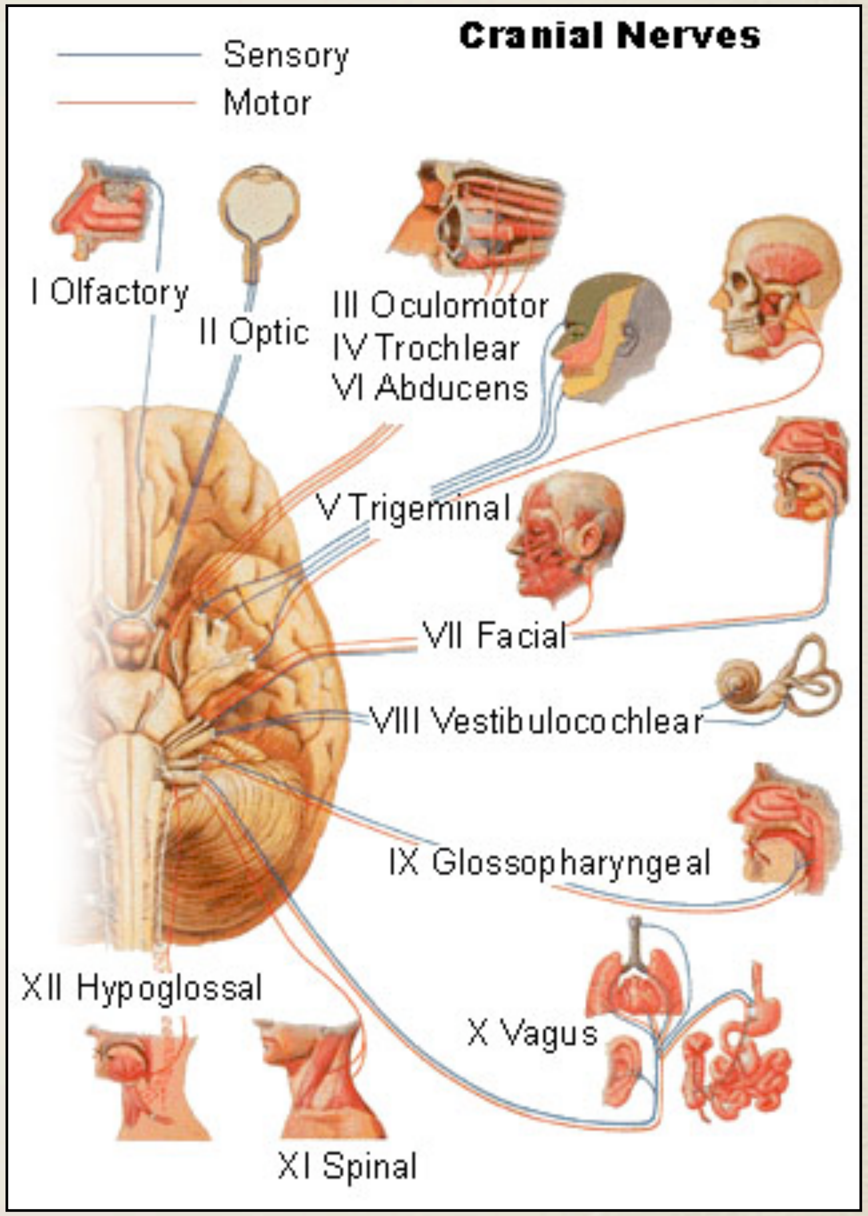
- The spaces between the **meninges** contain **cerebrospinal fluid** which **cushions** and **protects** the central nervous system





Peripheral Nervous System

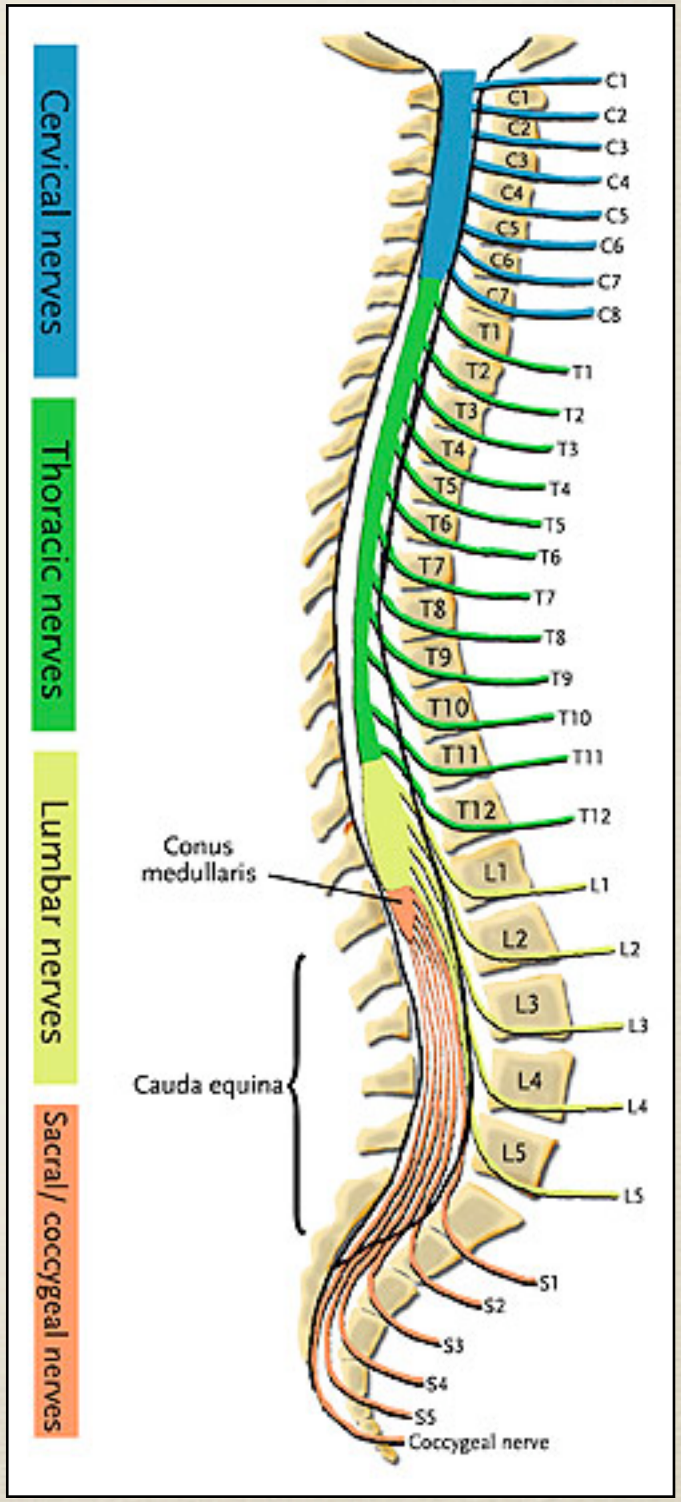
- The peripheral nervous system consists of nerves which radiate out from the central nervous system
- Nerves which are attached to the brain are called **cranial nerves** (there are 12 pairs of these)



Peripheral Nervous System

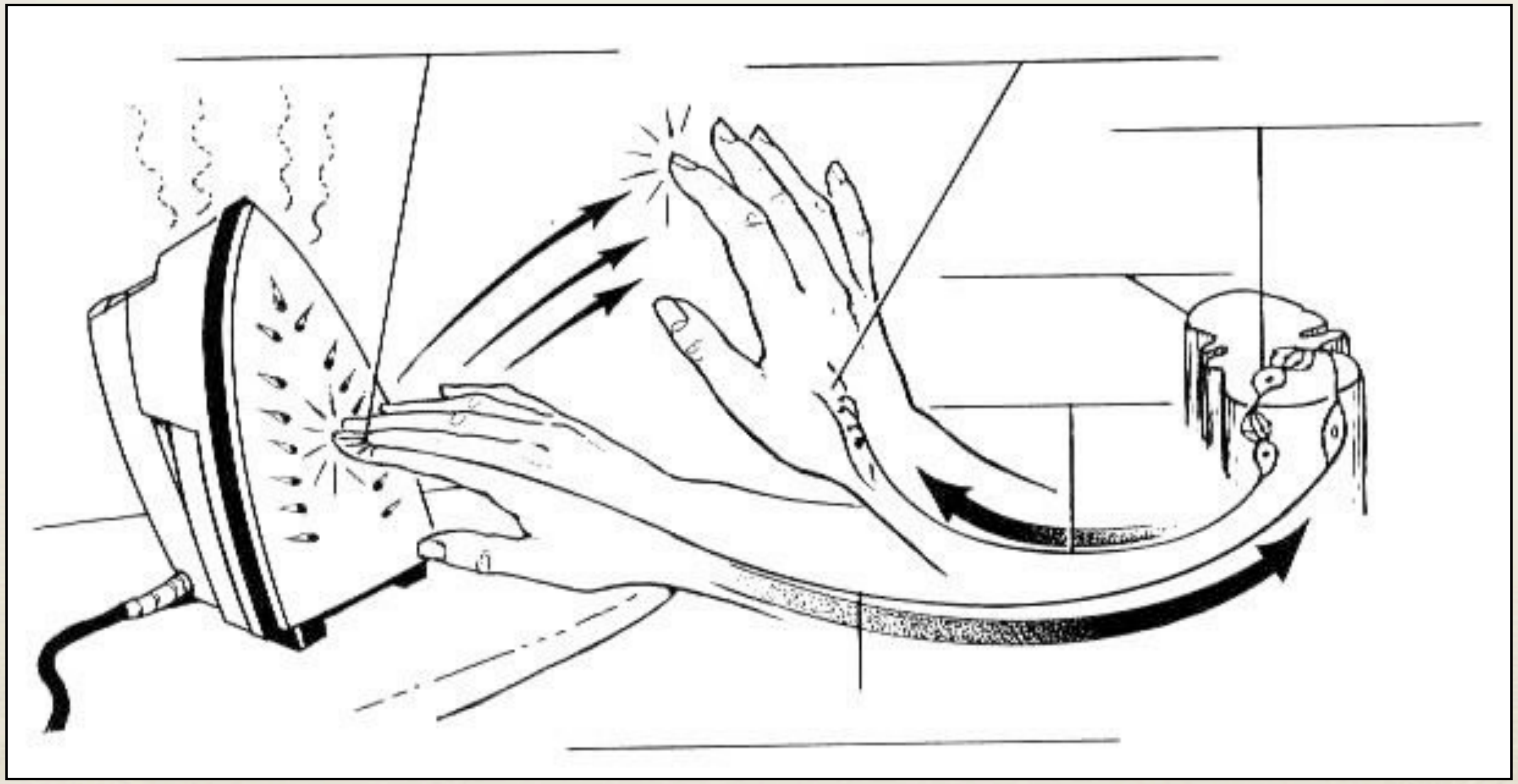
- Nerves which are attached to the spinal cord are called **spinal nerves** (there are 31 pairs of these)

- The peripheral nervous system is further divided into the **somatic nervous system** and the **autonomic nervous system**



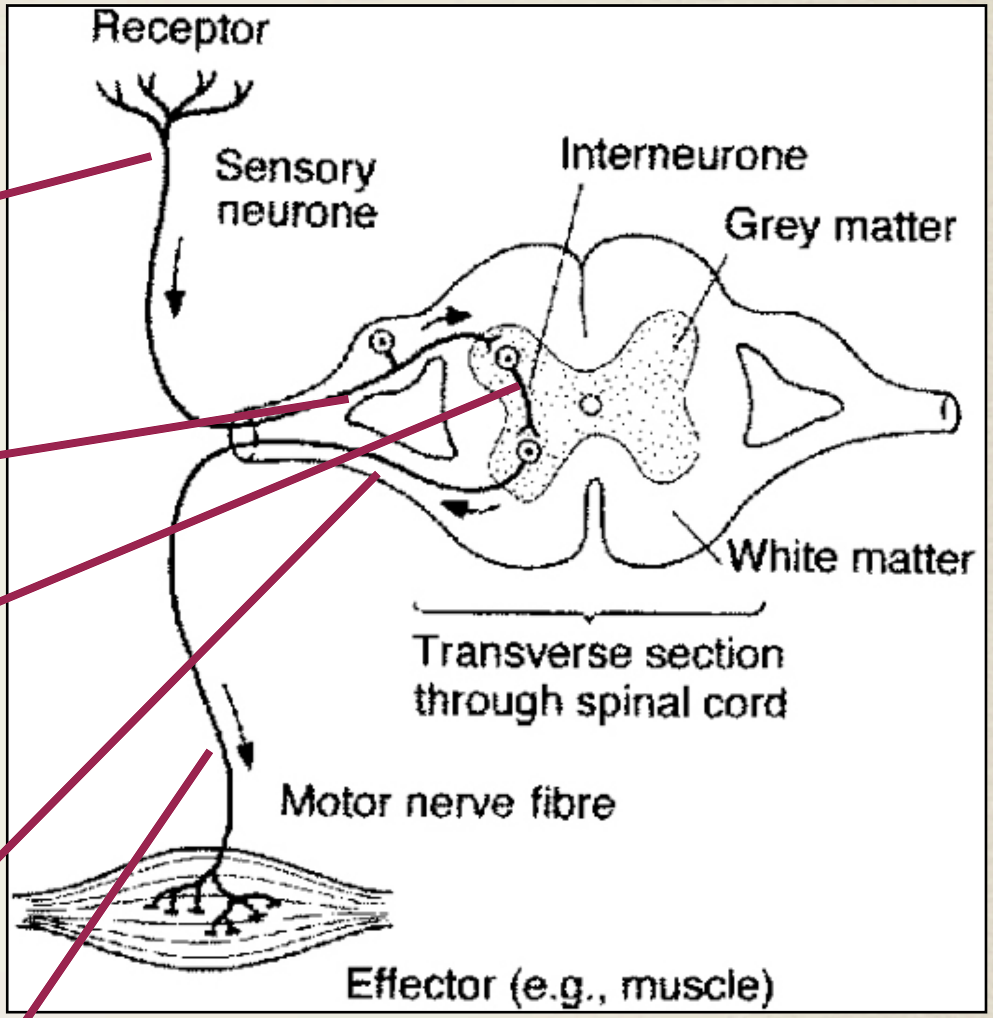
Somatic Nervous System

- The somatic nervous system includes the nerves that are associated with **sensory receptors (**including those in the skin) and **skeletal muscles**
- The sensory receptors allow detection of external and internal **stimuli** while the skeletal muscles act as **effectors** and thus allow for responses to stimuli



Somatic Nervous System

- The main function of the somatic nervous system is the **reflex arc** which involves the following:
  - A **sensory receptor** detects a stimulus and initiates an impulse in a **sensory neuron**
  - The **sensory neuron** carries the impulse through the **dorsal root ganglion** and into the **spinal cord**
  - Within the **spinal cord** the impulse is passed onto one or more **interneurons** which are found in the grey matter (middle) of the spinal cord
  - The **interneurons** convey the impulse to a **motor neuron** which conducts the impulse out of the spinal cord via the **ventral root gangion**
  - The **motor neuron** then carries the impulse to an **effector** muscle which responds to the original stimulus

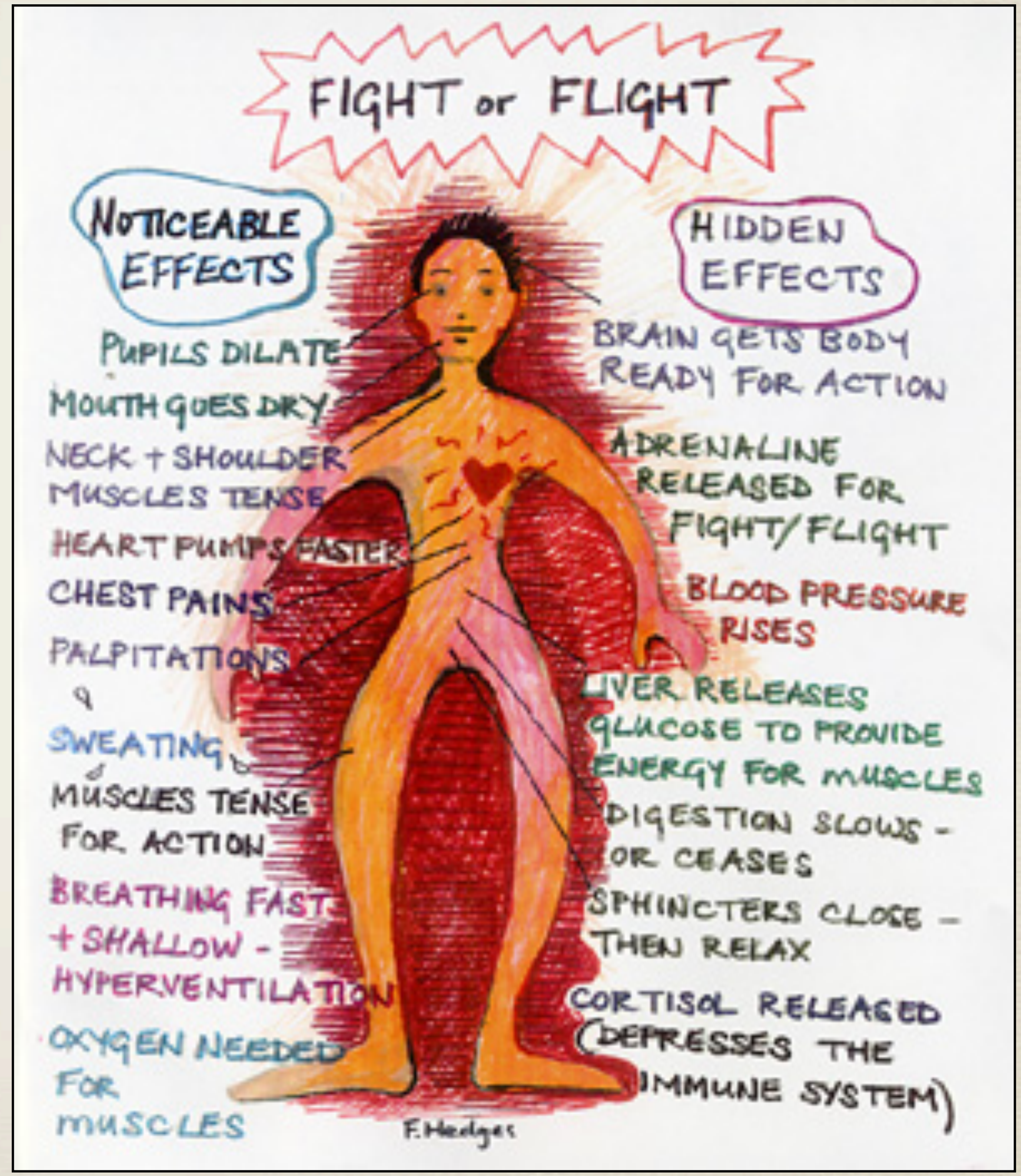


Autonomic Nervous Sytem

- The autonomic nervous system consists of nerves that control the **internal organs** and **smooth muscle**
- The responses of the autonomic nervous system are typically **automatic** and do not involve conscious control
- The two divisions of the autonomic nervous system are the **sympathetic** and the **parasympathetic systems**
- These two divisions have the following characteristics in common:
  - The are both **involuntary**
  - They both innervate **all internal organs** and **smooth muscle**
  - They both utilize a pathway that consists of **two neurons** and one **ganglion**

Sympathetic Nervous System

- The Sympathetic division of the peripheral nervous system is used to respond to **emergency situations**
- It is also known as the **flight or fight** response
- Like all autonomic pathways, it consists of two neurons and a ganglion
- The ***preganglionic neuron*** *is* ***short*** while the ***postganglionic neuron*** *is long*
- The **neurotransmitter** used in the sympathetic pathway is **nor ephinepherine**
- The sympathetic nervous system prepares the body for emergencies by:
  - **Increasing heart rate**
  - **Increasing breathing rate**
  - **Dialation of the bronchi**
  - **Dilation of the pupils**
  - **Decreasing rate of digestion**

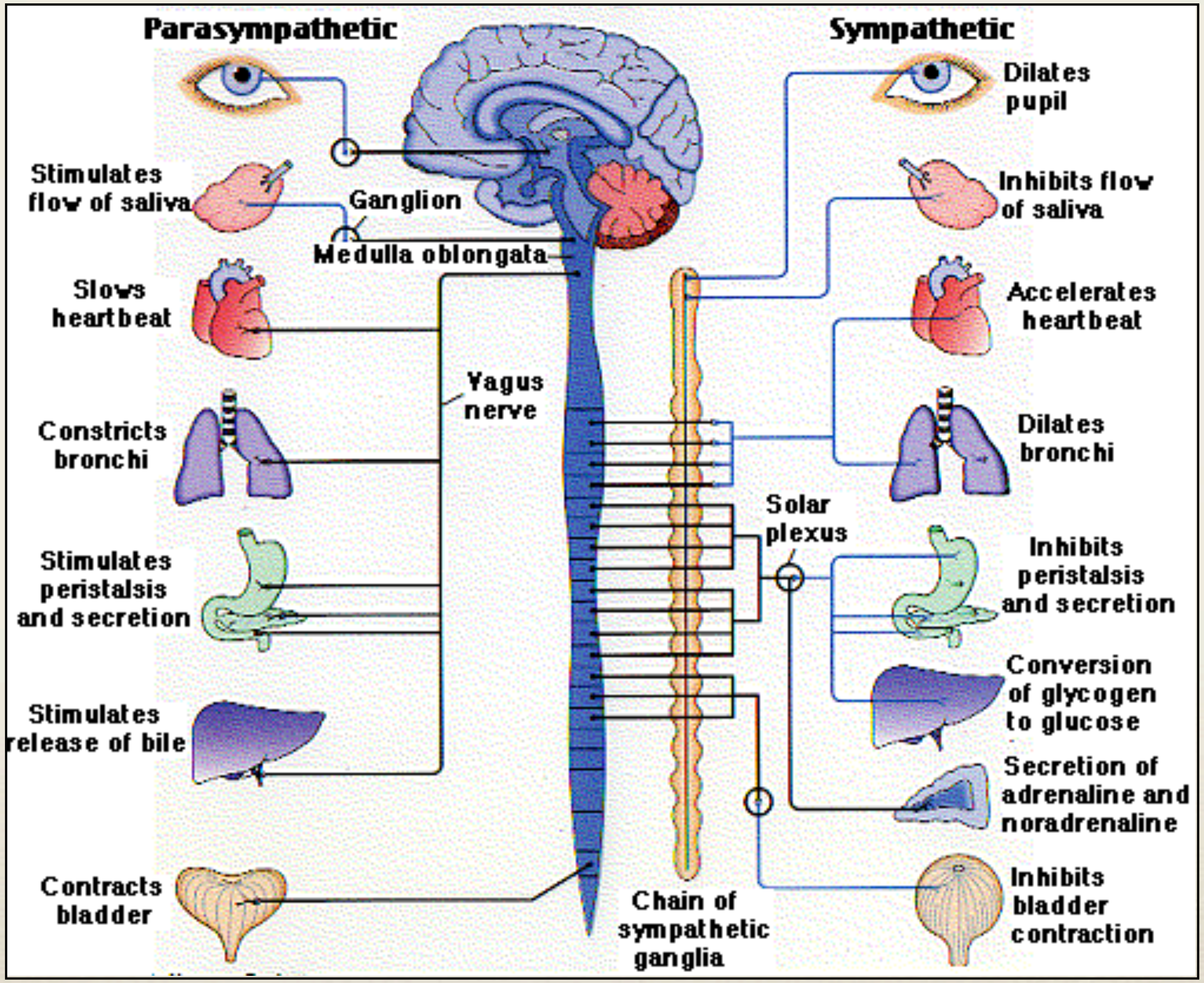


Parasympathetic Nervous System

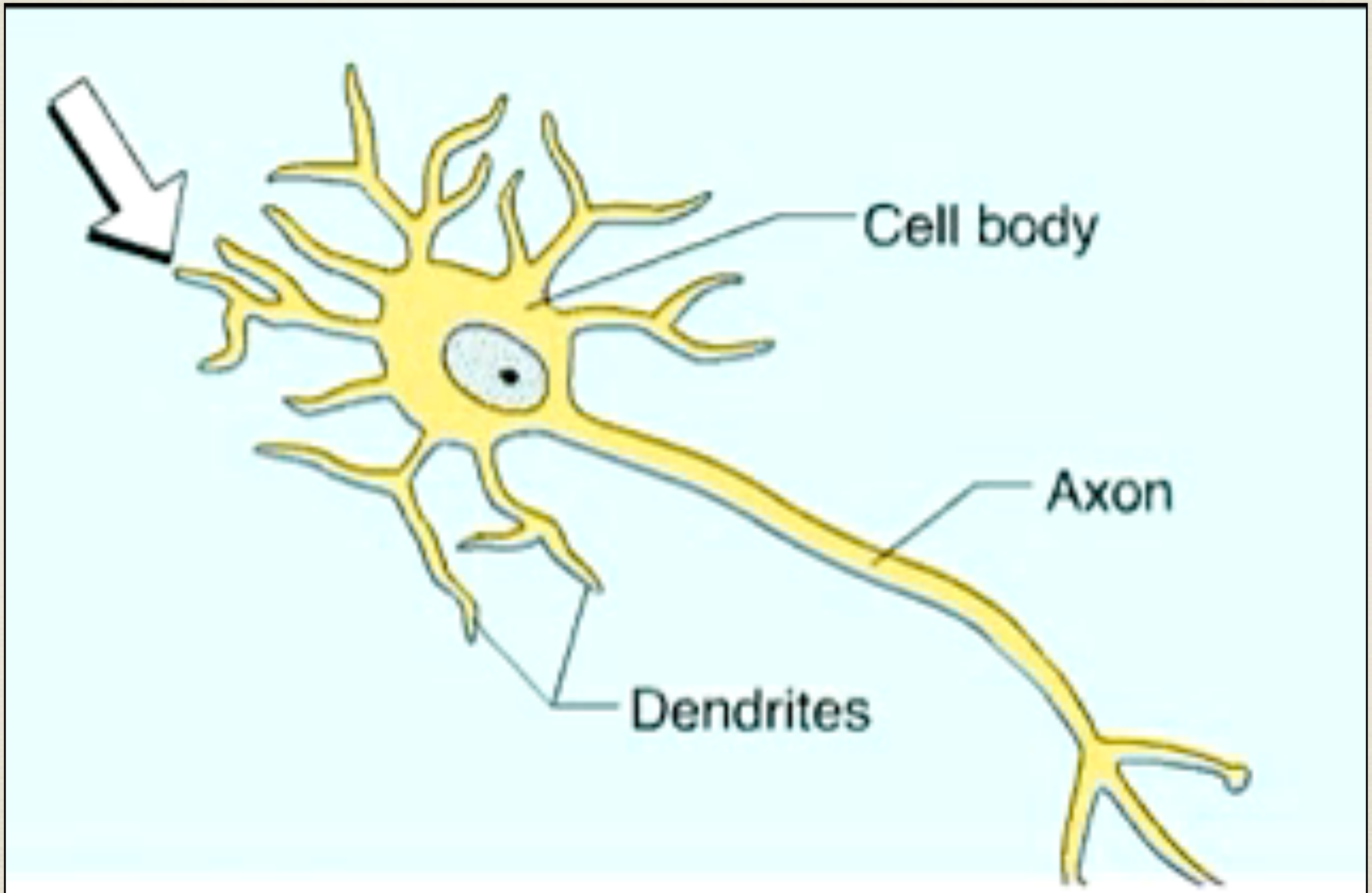
- The **parasympathetic** division of the peripheral nervous system promotes the **relaxed state** of the body
- Like all autonomic pathways it consists of two neurons and a ganglion
- The ***preganglionic*** *fibre is* ***long***, while the ***postganglionic*** *fibre is* ***short***
- The main neurotransmitter used in this pathway is **acetylcholine** **(important role in enhancement of sensory perception)**
- The parasympathetic pathway promotes the relaxed state by:
  - **Decreasing heart rate**
  - **Decreasing breathing rate**
  - **Constricting the bronchi**
  - **Constricting the pupils**
  - **Increasing digestion**

Comparison

- Thus, in many ways, the **sympathetic** and **parasympathetic** divisions of the autonomic nervous system are **opposite** to each other in their effects on the body

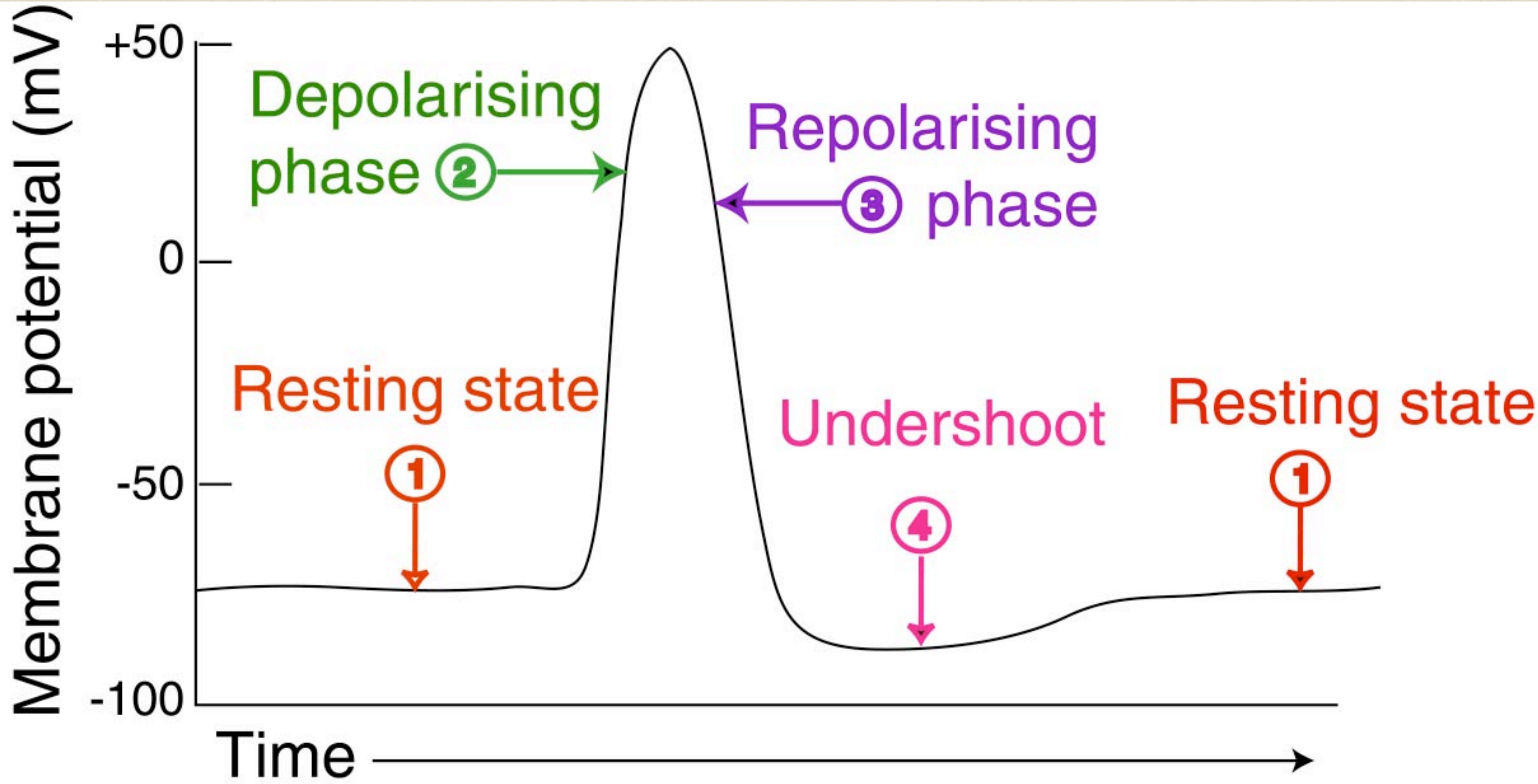


Nerve Impulse



Nerve Impulses & Action Potentials

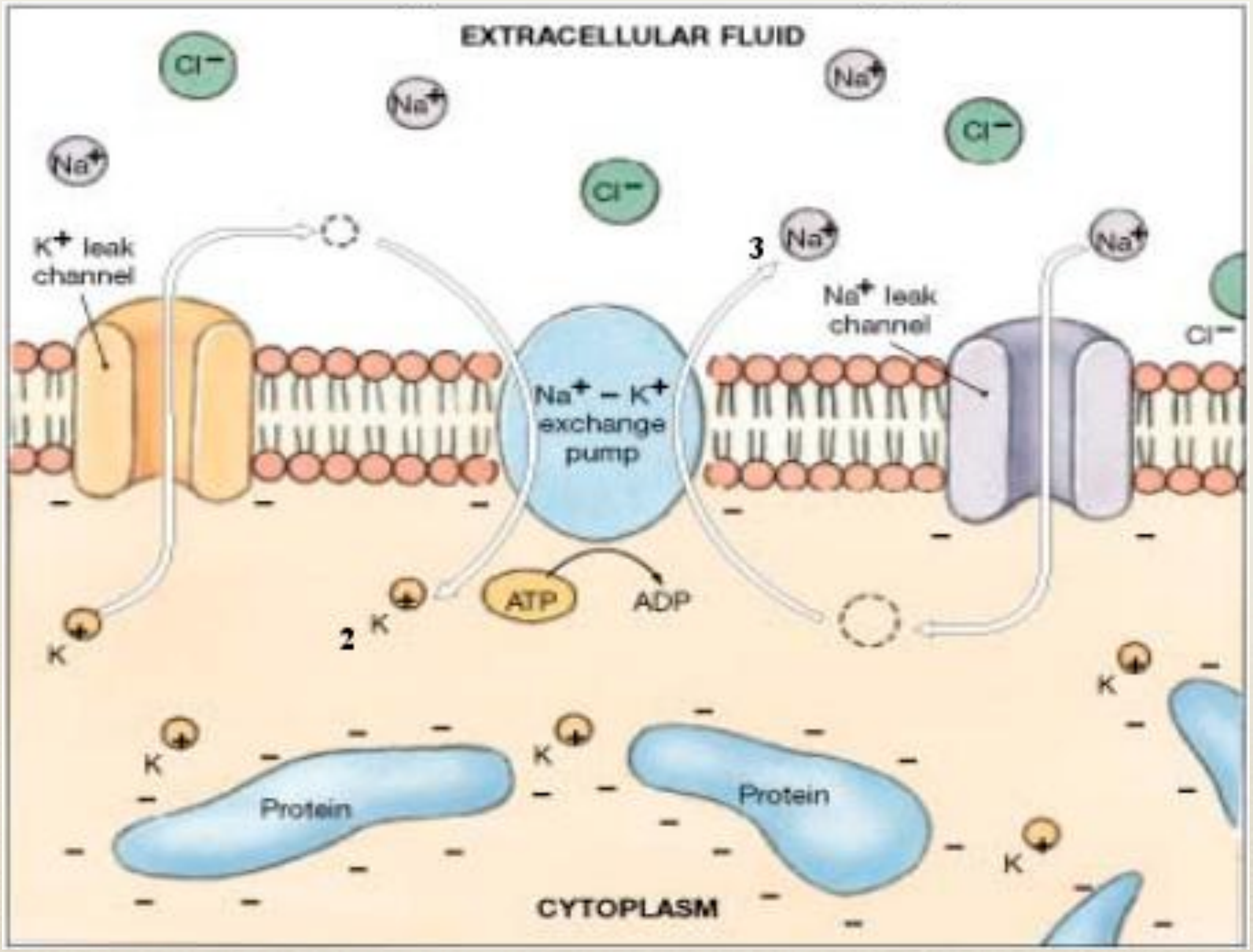
- Neurons are specifically designed to conduct nerve impulses
- Nerve impulses are only conducted when the neuron has recovered from conducting its last nerve impulse and is sufficiently stimulated to conduct a new one
- Neurons can exhibit three states:
    - **Resting Potential**
        - ♣ The state during which no impulse is being conducted although the neuron is capable of doing so
    - **Action Potential**
        - ♣ The state during which the neuron is actively conducting a nerve impulse
    - **Refractory Period**
        - ♣ The state during which the neuron is unable to conduct nerve impulses as it is recovering from its last impulse



Membrane potential (mV)
+50
0
-50
-100
Depolarising phase 2
Repolarising 3 phase
Resting state 1
Undershoot 4
Resting state 1
Time

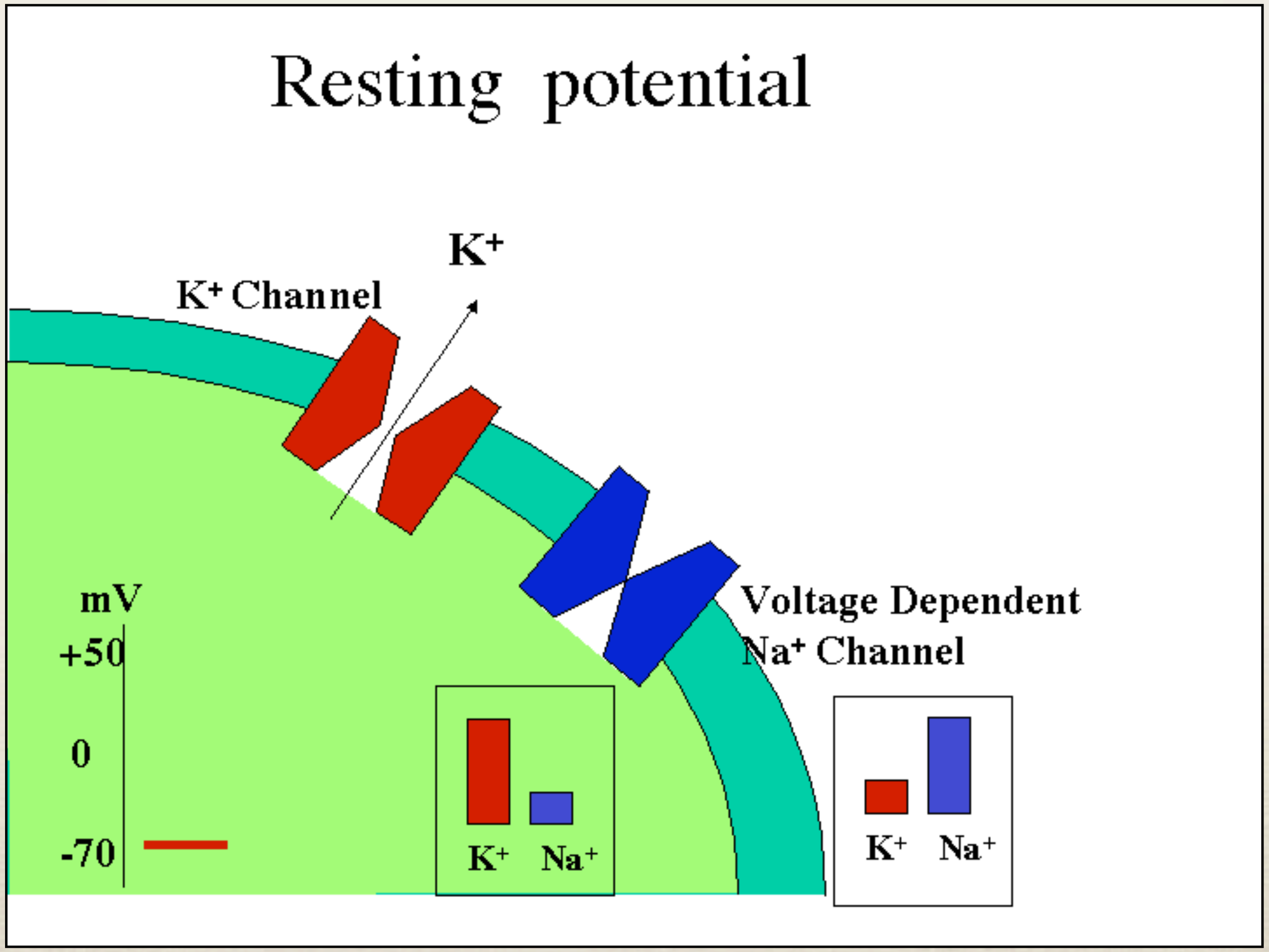
Resting Potential

- ♣ Resting potential is the state of the neuron when no impulse is being conducted
- During resting potential there is a difference in **ion displacement** on either side of the neuron cell membrane
  - There are more **Na^+ ions** on the **outside** than on the inside
  - There are more **K^+ ions** on the **inside** than on the outside
  - There are many large **negatively charged organic ions** on the inside of the cell



Resting Potential

- Due to this difference in ion displacement across the cell membrane, there is a **charge difference** across the cell membrane called the **electrical potential**
- The electrical potential when the neuron is at rest is called the **resting potential**
- The resting potential is **-65mV** since the inside of the cell is negative relative to the outside of the cell



Resting Potential

This difference in ion displacement and thus the resting potential of the neuron is maintained by the **Na^+/K^+ pump**

- This pump uses energy to actively pump **Na^+ ions** to the **outside** of the cell and **K^+ ions** to the **inside** of the cell
- The neuron cell membrane also has special proteins called **Na^+ gates** and **K^+ gates**
- These gates are **closed** during the resting state of the neuron, preventing large amounts of Na^+ and K^+ from moving across the cell membrane

Action Potential

- An action potential occurs when a nerve is conducting a nerve impulse
- In order for an action potential to occur, the neuron must receive sufficient stimulation to open enough **Na^+ gates** to reach the **threshold level**
- If the threshold level is reached, other **Na^+ and K^+** gates will be stimulated to **open**
- This results in a self propagating wave of Na^+ and K^+ gates opening along the length of the neuron and an action potential and nerve impulse occur
- This is an **all or none** response as it only occurs if the **threshold level** is reached

Action Potentials

- Action potentials can be divided into two phases:
  - **Depolarization**
  - **Repolarization**

Depolarization

- If a neuron receives sufficient stimulation to reach the threshold, successive **Na^+ gates** along the entire neuron will **open**
- The opening of these gates allows **Na^+ ions** to move **into the neuron**
- This causes the **membrane potential** to change from **negative (-65mV)** to **positive (+40mV)**
- At the end of the depolarization, the **Na^+ gates close**

Action Potentials

- In response to the depolarization, successive **K^+ gates** along the length of the neuron
- The opening of these gates allows **K^+ ions** to move **out of the neuron**
- This causes the **membrane potential** to return to **negative (-65mV)**
- Following repolarization, the **K^+ gates** close slowly

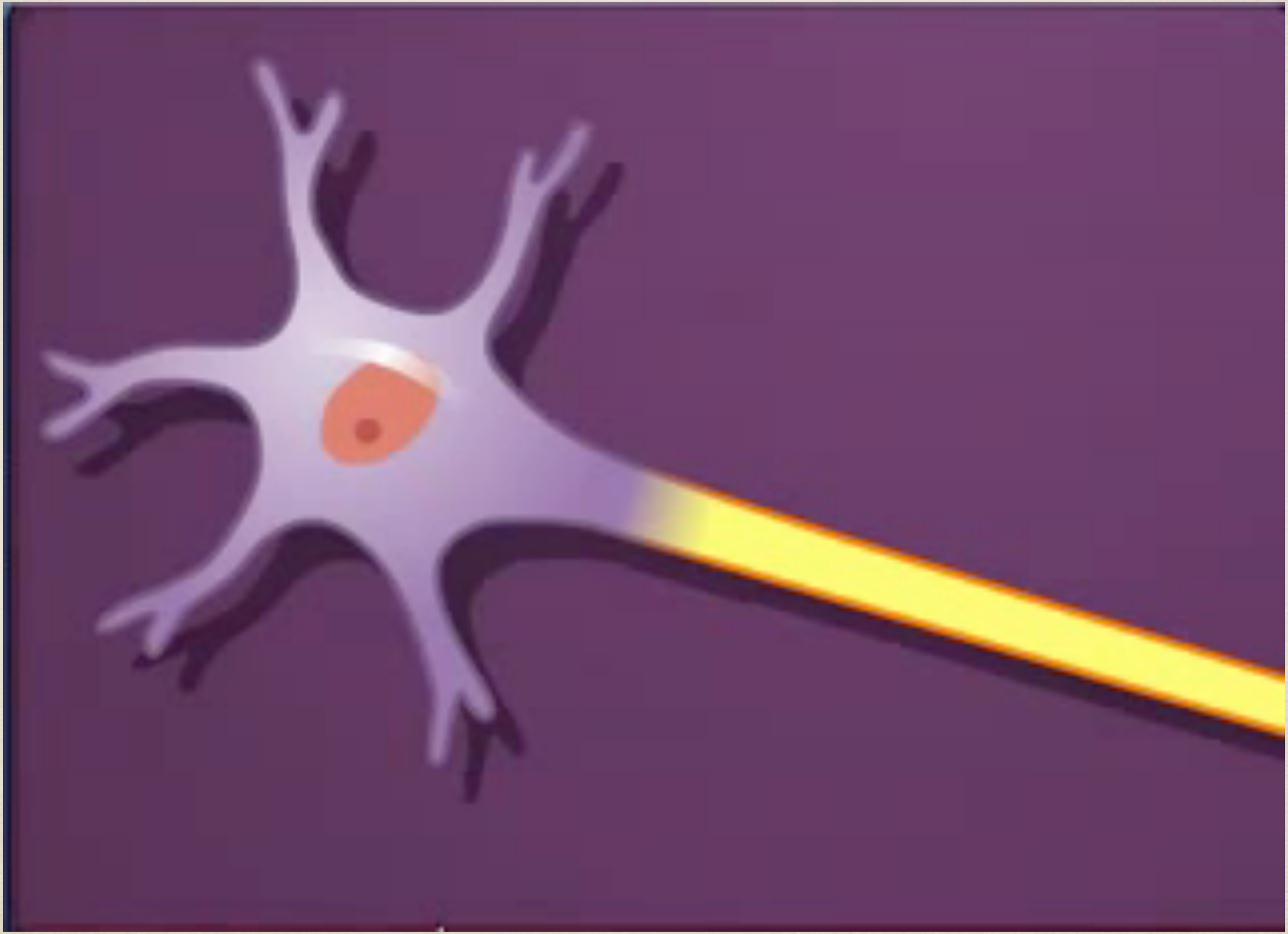
- During the conduction of a nerve impulse, each successive portion of the neuron's **axon** will undergo an **action potential** consisting of **depolarization** followed by **repolarization**

- Thus, the **nerve impulse** is the movement of an **action potential** down the neuron cell axon

Refractory Period

- Immediately following an action potential, a neuron is unable to conduct a nerve impulse until it has recovered because its **Na^+ gates won't open**
- During the refractory period, the following events are occurring:
  - The **K^+ gates** are closing
  - The **Na^+/K^+ pump** is returning Na^+ ions to the outside of the cell and K^+ ions to the inside of the cell
  - The membrane potential is returning to its **resting potential**
- Once the refractory period is complete, the neuron is ready to conduct another nerve impulse

Review



Saltatory Conduction

- Most neurons in humans are enclosed in a **lipid** coat formed by **Schwann cell membranes** which are wrapped around the neuron
  - As the Schwann cells contain **myelin** in their cell membranes, these neurons are referred to as **myelinated**

Saltatory Conduction

- In **myelinated neurons** an action potential **does not** occur along the sections of the neuron wrapped in **myelin** since the **ions** are unable to cross the nerve cell membrane in these regions
- However, the myelin coat is **interrupted** at regular intervals along the length of the neuron by gaps called **nodes of Ranvier** where an action potential **can** occur
- Thus, in **myelinated neurons** the action potential **jumps** from one **node of Ranvier** to the next in a process called **salutatory conduction**

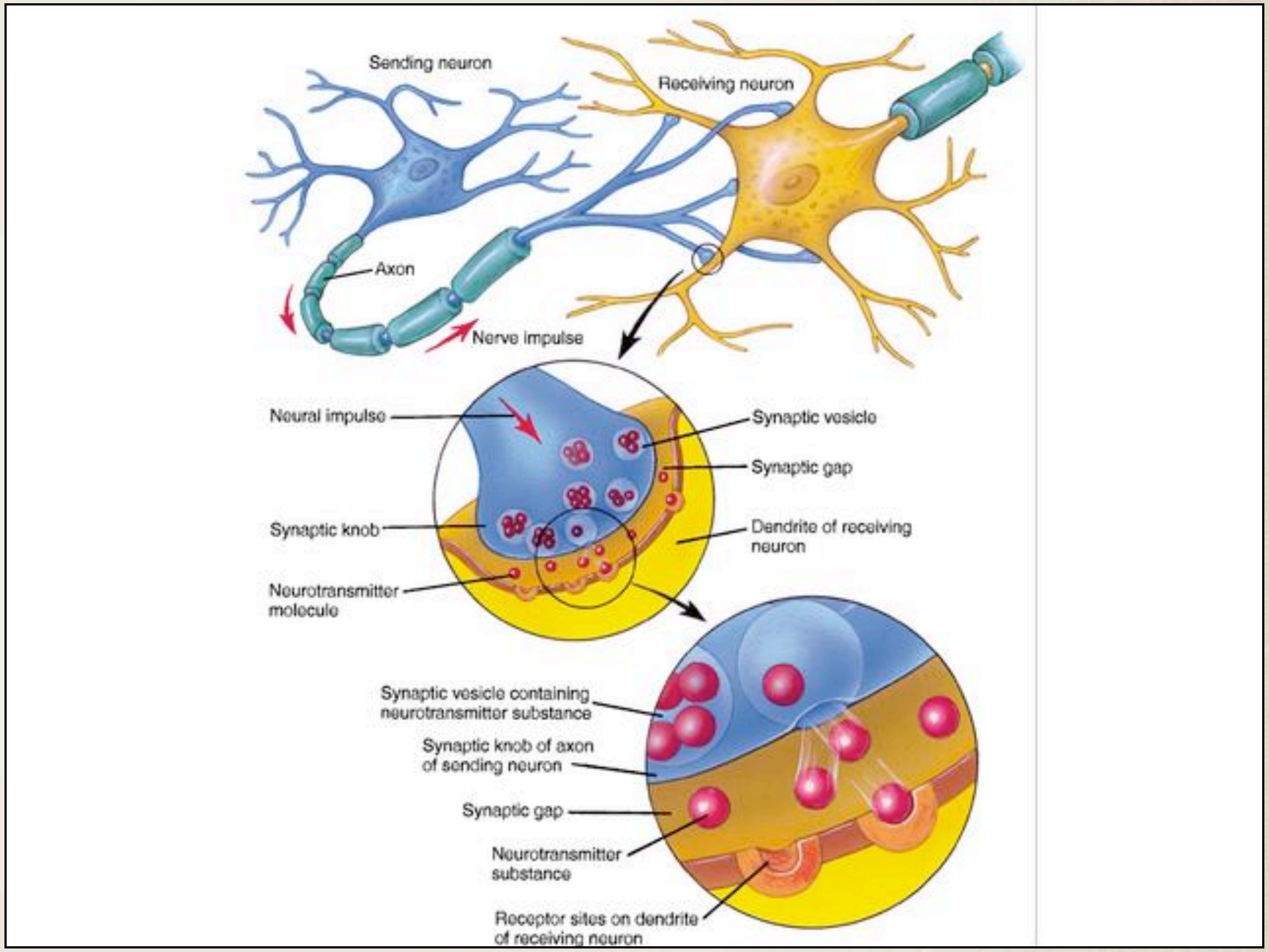
- **Saltatory conduction** is very **fast**, allowing the nerve impulse to travel quickly
- In u**nmyelinated neurons**, the action potential must pass through each point along the neuron cell membrane which makes the conduction of nerve impulses relatively **slow**

Synaptic Transmission

- Successive neurons in a pathway are usually separated by a gap called a **synaptic cleft**
- Thus, for a nerve impulse to be transferred from one neuron to the next, a series of events must take place in the neuron before the synaptic cleft to pass the impulse to the neuron after the synaptic cleft

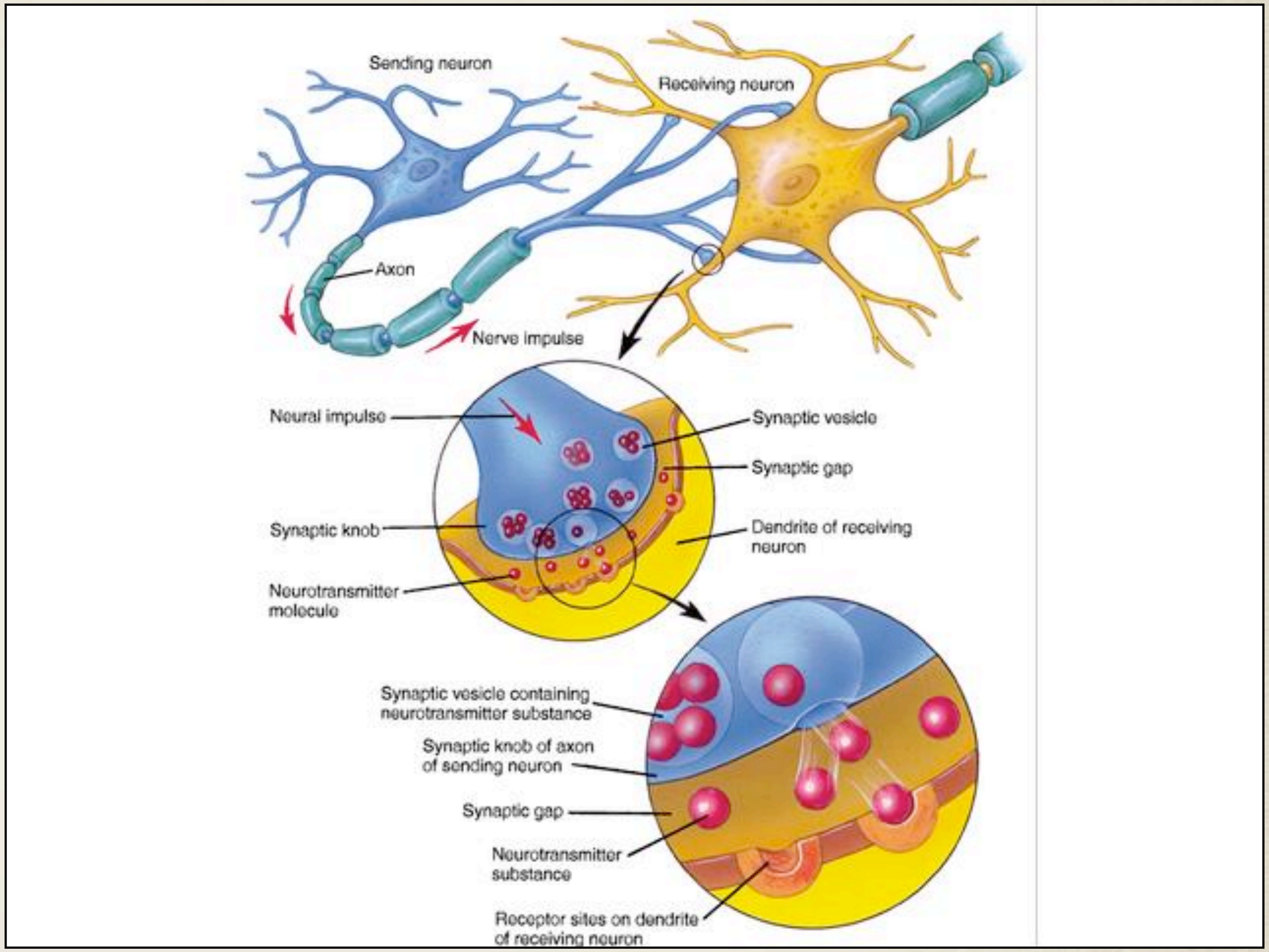
Synapse Structure

- The neuron **before** the synaptic cleft is called the **presynaptic neuron**
- The ends of the axon of the presynaptic neuron are swollen to form **axon bulbs**
- The membrane surrounding the axon bulbs is called the **presynaptic membrane**
- Within the axon bulbs are **vesicles** containing molecules of **neurotransmitters**
  - Examples of neurotransmitters are acetylcholine and norepinepherine



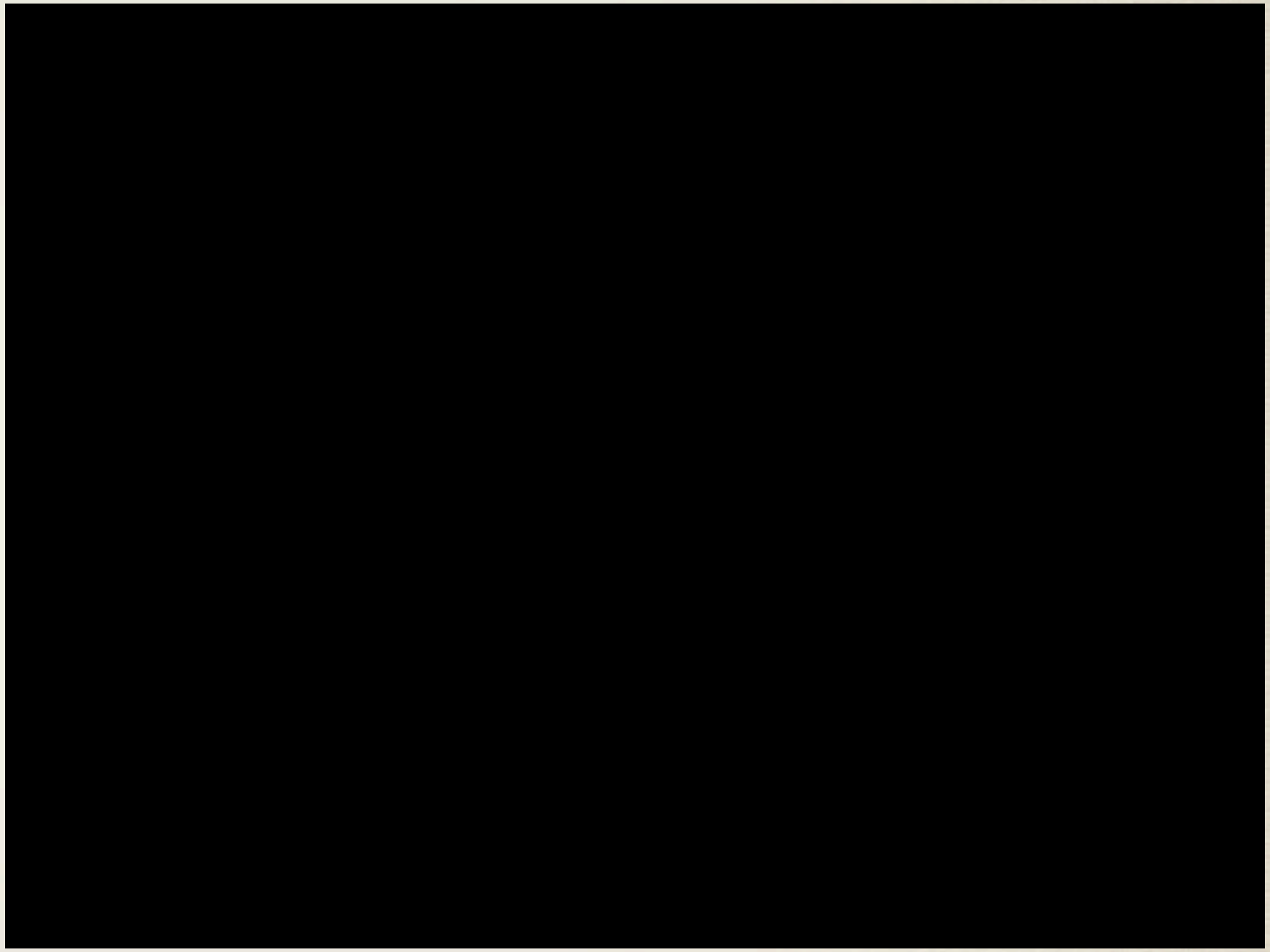
Synapse Structure

- The axon bulbs lie close to, but do not touch, the membrane of the next neuron
- The neuron after the synaptic cleft is called the **postsynaptic** neuron
- The membrane of the postsynaptic neuron is called the **postsynaptic membrane**
- The postsynaptic membrane has special **receptors** which stick out into the synaptic cleft and act as **binding sites** for **neurotransmitters**



Transmission Across the Synapse

- When an action potential arrives at the axon bulb of the presynaptic neuron it causes the membrane to become very **permeable** to **Ca^{2+} ions**
- The **Ca^{2+} ions** diffuse from the synaptic cleft **into** the axon bulb
- The increase in positive charge stimulates the **vesicles** to fuse with the cell membrane of the axon bulb
- The vesicles **release** their **neurotransmitter molecules** into the synaptic cleft
- The **neurotransmitter molecules** diffuse across the synaptic cleft and bind to **receptor proteins** on the postsynaptic membrane



Transmission Across the Synapse

- Binding of **neurotransmitters** to **receptor proteins** opens a channel which allows **Na^+ ions** to enter the postsynaptic neuron
- If enough neurotransmitters bind to the postsynaptic membrane, the membranes **threshold** will be reached and an **action potential** will occur in the postsynaptic neuron

Note-

- The stimulation of the post synaptic neuron by neurotransmitter molecules does not continue indefinitely
- In some cases, the synapse contains specific enzymes which will degrade neurotransmitter molecules after a short time