Section 10.1 – Coordination

Body systems cannot work in isolation and must therefore be integrated in a coordinated fashion.

Principles of coordination

In mammals, there are two main forms of coordination:

1.) **The nervous system –** Uses nerve cells that can pass electrical impulses along their length. The result is the secretion of chemicals by the target cells called ***neurotransmitters*.** The response is quick, yet short lived and only acts on a localised region of the body.
2.) **The hormonal system –** Chemicals are transported in the blood plasma which then reach target certain cells, thus stimulating them to carry out a function. The responses due to secretion of hormones often act over a longer period of time, yet are slower to act.

Chemical mediators

Nervous and hormonal forms of communication are only useful at coordinating the activities of the whole organism. At the cellular level they are complimented by **chemical mediators.**
Chemical mediators are secreted by individual cells and affect other cells in the immediate vicinity.
A common example of this type of coordination is the inflammation of certain tissues when they are damaged or exposed to foreign agents.

Two examples of chemical mediators are:

1.) **Histamine –** Stored in white blood cells and is secreted due to the presence of antigens. Histamine causes dilation of blood vessels, increased permeability of capillaries and therefore swelling the infected area.
2.) **Prostaglandins** – Found in cell membranes and cause dilation of small arteries and arterioles. They release due to injuries and increase the permeability of capillaries. They also affect blood pressure and neurotransmitters. In doing so they relieve pain.

Hormonal system	**Nervous system**
Communication by chemicals	Communication by nervous impulses
Transmission takes place in the blood	Transmission is by neurons
Transmission is generally slow	Transmission is very rapid
Hormones travel to all areas of the body, but target only certain tissues/organs	Nerve impulses travel to specific areas of the body
Response is widespread	Response is localised
Effect may be permanent/long lasting/ irreversible	Effect is temporary and reversible

Plant growth factors

Plants respond to external stimuli by means of plant growth factors (plant hormones)
Plant growth factors:

- Exert their influence by affecting growth
- Are not produced by a particular organ, but are instead produced by all cells
- affect the tissues that actually produce them, rather than other tissues in a different area of the plant.

One plant hormone called **indoleacetic acid (IAA)** causes plant cells to elongate

Control of tropisms by IAA

IAA is used to ensure that plant shoots grow towards a light source.

1.) Cells in the tip of the shoot produce IAA, which is then transported down the shoot.
2.) The IAA is initial transported to all sides as it begins to move down the shoot
3.) Light causes the movement of IAA from the light side to the shaded side of the shoot.
4.) A greater concentration of IAA builds up on the shaded side of the shoot
5.) The cells on the shaded side elongate more due to the higher concentration of IAA
6.) The shaded side of the root therefore grows faster, causing the shoot to bend towards the source of light

IAA can also effect the bending of roots towards gravity. However in this case it slows down growth rather than speeds it up.
IAA decreases root growth and increases shoot growth

Section 10.2 – Neurons

Specialised cells adapted to rapidly carry electrochemical changes (nerve impulses) from part of the body to another

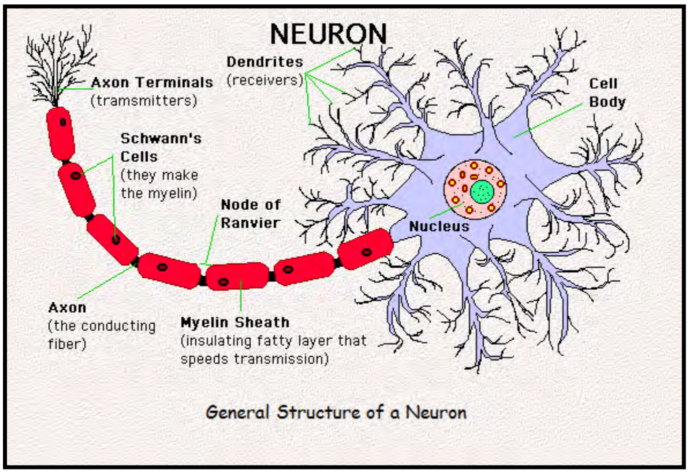
Neuron structure

Cell body

- Nucleus
- Large amounts of rough endoplasmic reticulum to produce neurotransmitters

Dendrons

- Extensions of the cell body sub-divided into dendrites
- Carry nervous impulses to the cell body



General Structure of a Neuron

Axon

- A single long fibre that carries nerve impulses away from the cell body

Schwann cell

- Surrounds the axon
- Protection/electrical insulation/phagocytosis. Can remove cell debris and are associated with nerve regeneration.

Myelin sheath

- Made up from the Schwann membrane which produces myelin (a lipid)
- Some neurons are unmyelinated and carry slower nerve impulses

Nodes of Ranvier

- The gaps between myelinated areas
- 2 – 3 micrometers long and occur every 1 – 3mm

Sensory Neuron

- Transmit impulses from a receptor to an intermediate neuron or motor neuron
- One Dendron towards the cell body, one axon away from the cell body

Motor neuron

- Transmit impulses from the sensory/intermediate neuron to an effector
- Long axon, many short dendrites

Intermediate neuron

- Transmit impulses between neurons
- Numerous short processes

Section 10.3 – The nerve impulse

A nerve impulse is not an electrical current! It is a self-propagating wave of electrical disturbance that travels along the surface of an axon membrane.

Nerve impulse – temporary reversal of the electrical p.d across an axon membrane
The reversal is between two states
The resting potential - no nerve impulse transmitted
The action potential – nerve impulse transmitted

Resting potential

- Sodium/potassium are not lipid soluble and cannot cross the plasma membrane
- Transported via intrinsic proteins – ion channels
- Some intrinsic proteins actively transport potassium ions into the axon and sodium ions out. This is called the **sodium potassium pump**.

Sodium potassium pump

- 3 sodium ions pumped out for every 2 potassium ions pump in
- Most gated potassium channels remain open – potassium ions move out of the axon down their chemical gradient
- Most gated sodium channels remain closed

The action potential

- Temporary reversal of the charge of the membrane from (-65mV to +65mV). When the p.d is +65mV the axon is said to be depolarised
- Occurs because the ion channels open/close depending upon the voltage across the membrane
- When the generator potential is reached, sodium ion channels open and potassium close, allowing sodium to flood into the axon. Sodium being positively charged causes the axon to become more positive in charge

The passage of an action potential along an unmyelinated axon

- Stimulus – some voltage – gated ion channels open, sodium ions move in down electrochemical gradient
- Causes more sodium channels to open
- When the action potential reaches ~ +40mV sodium channels close
- Voltage – gated potassium channels open and begin repolarisation of the axon

Hyper – polarisation

- The inside of the axon becomes more negative than usual due to an "overshoot" in potassium ions moving out of the axon.
- Potassium channels close
- Sodium potassium pump re-established the -65mV resting potential

Section 10.5 – The speed of a nerve impulse

Factors affecting speed

1. **The myelin sheath –** Prevents the action potential forming in myelinated areas of the axon. The action potential jumps from one node of Ranvier to another (salutatory conduction) – this increases the speed of the impulse as less action potentials need to occur
2. **The greater the diameter of the axon the greater the speed of conductance** – due to less leakage of ions from the axon
3. **Temperature –** Higher temperature, faster nerve impulse. Energy for active transport comes from respiration. Respiration like the sodium potassium pump is controlled by enzymes.

Refractory period

After an action potential, sodium voltage-gated channels are closed and sodium cannot move into the axon. It is therefore impossible during this time for a further action potential to be generated.
This time period, called the refractory period serves two purposes:
It ensures that an action potential can only be propagated in one direction – An action potential can only move from an active region to a resting region.
It produces discrete impulses – A new action potential cannot be generated directly after the first. It ensures action potentials are separated from one another.
It limits the number of action potentials – action potentials are separated from one another, therefore there is a limited amount that can pass along a neuron in a given time.

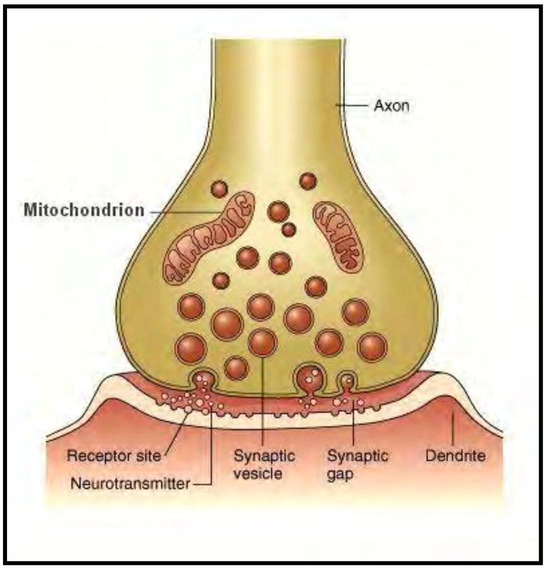
All or nothing principle

Nervous impulses are all or nothing responses
A stimulus must exceed a certain threshold value to trigger an action potential
A stimulus that exceeds the threshold value by a significant amount, will produce the same strength of action potential as if it has only just overcome the threshold value
A stimulus can therefore only produce one action potential
An organism can perceive different types of stimulus in two ways:
The number of impulses in a given time (larger stimulus, more impulses per second)
Having neurons with different threshold values – depending on which neurons are sending impulses, and how frequently impulses are sent, the brain can interpret the strength of the stimulus

Section 10.6/10.7 – Structure and function of the synapse / Transmission across a synapse

A synapse occurs where a dendrite of one neuron connects to the axon of another

Structure of a synapse



Synapses use neurotransmitters to send impulses between neurons
The gap between two neurons is called the synaptic cleft
The neuron that produces neurotransmitters is called the presynaptic neuron
The axon of the presynaptic neuron ends in a presynaptic knob
The presynaptic knob consists of many mitochondria and endoplasmic reticulum
These organelles are required to produce neurotransmitters which are stored in synaptic vesicles
Synaptic vesicles can fuse with the presynaptic membrane releases the neurotransmitter

Functions of synapses

- A single impulse from neuron can be transmitted to several other neurons at a synapse. This means that one impulse can create a number of simultaneous responses
- A number of different impulses can be combined at a synapse. This means that several responses can be combined to give on single response

Neurotransmitters are made in the presynaptic cleft only
When an action potential reaches the presynaptic knob, it causes vesicles containing the neurotransmitter to fuse with the presynaptic membrane
The neurotransmitter will the diffuse across the synaptic cleft
The neurotransmitter then bind with receptors on the postsynaptic membrane, in doing so generating a new action potential in the postsynaptic neuron

Features of synapses

Unidirectionality

Impulses can only be sent from the presynaptic membrane to the postsynaptic membrane

Summation

- **Spatial summation -** Different presynaptic neurons together will release enough neurotransmitter to exceed the threshold value to form an action potential
- **Temporal summation –** One neuron releasing neurotransmitter many times over a short period. Eventually the neurotransmitter will accumulate so as to overcome the threshold value of the postsynaptic membrane. Therefore generating a new action potential

Inhibition

Some postsynaptic membranes have protein channels that can allow chloride ions to diffuse into the axon making it more negative than usual at resting potential.
This type of hyperpolarisation inhibits the postsynaptic neuron from generating a new action potential.
The importance of these inhibitory synapses is that it allows for nervous impulses to be controlled and stopped if necessary

<u>Transmission across a synapse</u>

When the neurotransmitter across a synapse is the chemical **acetylcholine** it is called a **cholinergic** synapse
Acetylcholine is made up of acetyl (ethanoic acid) and choline
Cholinergic synapses are more common in vertebrates
Cholinergic synapses occur in the central nervous system and at neuromuscular junctions

1. When an action potential reaches the presynaptic knob, calcium channels open allow calcium to diffuse into the presynaptic knob
2. The influx of calcium ions causes presynaptic vescicles containing acetylcholine to fuse with the presynaptic membrane, releasing the neurotransmitter into the synaptic cleft
3. Acetylcholine diffuses across the cleft and fuses with receptor sites on sodium channels found on the presynaptic membrane. When they do so, the sodium channels open, allowing sodium ions to diffuse along their concentration gradient into the postsynaptic knob.
4. The influx of sodium ions, generates a new action potential in the postsynaptic neuron
5. Acetylcholinesterase hydrolyses acetylcholine back into the acetyl and choline which will the diffuse back across the synaptic cleft into the presynaptic neuron. In this way acetylcholine can be recycles and reused and also is prevented from continuously generating new action potentials on the postsynaptic neuron.
6. ATP is released by mitochondria, providing energy to recombine acetyl and choline. Sodium channels on the postsynaptic membrane are now closed due to the absence of acetylcholine attached to receptor sites.