Area of Study 2: Detecting and Responding

1. Homeostasis

2. The Nervous System

3. The Endocrine System

4. Pathogens & The Immune System
**Homeostasis**

**Homeostasis** is the active regulation of physical and chemical conditions to provide optimal conditions for biochemical reactions. Such conditions may include pH level, temperature, ion concentrations, dissolved gases etc.

*Homeostasis is a feature of large multicellular organisms* who maintain a constant internal environment for their cells and tissues. These internal conditions are a buffer against the changes of the external environment.

By contrast, the internal environment of small organisms typically matches that of the external environment because all cell layers are exposed.
Homeostatic regulation can be broadly defined by the **stimulus-response model**

- **Stimulus (Input)**: Chemical or Physical, Internal or External
- **Receptor**: Membrane Receptor or Cytoplasmic Receptor
- **Processing**: Chemical or Electrical
- **Effector**: Cells that initiate a response
- **Feedback**: Negative or Positive
- **Response (Output)**: Action or Inaction

The messages (arrows) may be relayed by either **electrical** or **chemical signals**.
Stimulus-Response Example: Climate Control

This model can be applied to non-biological examples. Let’s suppose we have a climate controlled room with a thermostat set for 25°C.

Temperature drops → Stimulus (Input) Physical & External

- **Negative Feedback**
  - Heater switches off at 25°C

OR

- **Positive Feedback**
  - Heater continues to heat the room above 25°C

Response (Output) Heater switches on

Positive feedback tends to magnify a stimulus and tends to be less useful to biological systems.
An important biological example of homeostasis is thermoregulation in mammals. Temperature decreases, leading to the stimulation of thermoreceptors (sensory neurons), which send electrical signals to the hypothalamus. The hypothalamus processes this information and initiates electrical signals to effectors such as blood vessels and muscles. The response includes vasoconstriction and shivering, which help to maintain body temperature. Once the core temperature is re-established, negative feedback mechanisms cause vasoconstriction and shivering to cease. Mammals have many mechanisms of thermoregulation.
Homeostatic regulation is entirely dependent upon cellular communication. Animals are supported by two systems of **signal transduction**.

**Nervous System**
The **Central (CNS)** and **Peripheral (PNS)** nervous systems are responsible for high speed electrical signals.

**Endocrine System**
The **Endocrine glands** are responsible for "broadcasting" slower, more global, effects that can also be sustained for long periods.
Describing the nervous system as a stimulus-response model gives us:

- 3 functions
- 3 types of neurons
- 2 distinct networks

You may also come across the words “afferent” and “efferent” just to make things confusing!

<table>
<thead>
<tr>
<th>Function</th>
<th>Neuron</th>
<th>Network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensory Input</td>
<td>Sensory Neuron</td>
<td>PNS</td>
</tr>
<tr>
<td>Integration</td>
<td>Interneuron</td>
<td>CNS</td>
</tr>
<tr>
<td>Motor Output</td>
<td>Motor Neuron</td>
<td>PNS</td>
</tr>
</tbody>
</table>

*Stimulus-Response Example: Voluntary Response*
A reflex arc is a “hard-wired” response to a stimulus that requires no conscious effort.

You should be able to draw a reflex arc in terms of the stimulus-response model.

Many stimulus-response pathways are involuntary.
Neurons have a very distinct shape and are characterised by lengthy extensions from the **cell body** (or **soma**).

**Dendrites** receive signals from other neurons.

**Axons** carry signals to the **axon terminal** to be passed on to other neurons. Axons are surrounded by a **myelin sheath** composed of **Schwann cells**. The sheath acts as an insulator for electrical impulses.
Types of Neurons

Be aware that neurons can have different shapes according to their purpose. Despite this, they all still exhibit the dendritic and axon extensions.
Electric current travels through a circuit because a potential difference is set up at either end. Electrons flow from the negative to the positive terminals of a battery.

Neurons transmit electrical messages in the same way; they generate potential difference across their membranes (called membrane potential).

Axons create this potential difference by regulating the concentrations of Na\(^+\) and K\(^+\) ions in the intracellular and extracellular space.

Because ions have a charge channel proteins and Sodium-Potassium pumps allow neurons to control the flow of ions; both passive and active transport is involved.
Axon Signal Relay: Membrane Potential

• An axon at rest is negatively charged inside and positively charged outside. This polarised state called the resting potential.

• To transmit an electrical signal an axon will transport more Na\(^+\) inside. The membrane is depolarised.

• More positive ions are transported inside- The membrane is now positive inside and negative outside; this is the action potential.

• This migration of positive ions passes down the axon like a wave.

• Behind this wave the membrane repolarises and returns to its resting potential.
Axon Signal Relay: Action Potential

Resting potential

Action potential

Resting potential

Na⁺ Na⁺ Na⁺ Na⁺ Na⁺ Na⁺ Na⁺ Na⁺ Na⁺ Na⁺ Na⁺ Na⁺

K⁺ K⁺ K⁺ K⁺ K⁺ K⁺ K⁺ K⁺ K⁺ K⁺ K⁺ K⁺

membrane polarised: outside positive, inside negative

membrane depolarised: inside becomes positive, outside negative

membrane polarised: outside positive, inside negative

direction in which the impulse travels

Millivolts

+70

0

-70

Milliseconds

Neuron Structure: Action Potential

Sunday, April 25, 2010
Action Potential: Link here

The Schwann Cell and Action Potential
At the furthest tip of the axon is a specialised region called the **synaptic terminal**, which typically connects with another neuron; either directly on the cell body or on the dendrites.

There are two types:

**Electrical synapses** and **Chemical synapses**.
Electrical synapses are uncommon in vertebrates- but also the simplest to describe.

Electrical synapses have intercellular channels, called gap junctions, that form a continuous cytoplasmic connection between two cell. The action potential can pass directly from the presynaptic neuron to the postsynaptic neuron.
Chemical Synapses

Chemical synapses are more common; and also more complicated.

The presynaptic axon has vesicles containing chemicals known as neurotransmitters.

When depolarisation reaches end of the presynaptic axon these chemicals are released.

The neurotransmitters bind to receptors on the postsynaptic membrane.

This triggers the intake of positive ions and the generation of an action potential.
The synapse - structure and function

The central nervous system of the human body is composed of billions of neurons which control almost every aspect of bodily movement and function.
After triggering the next action potential, neurotransmitters are either reabsorbed by the presynaptic terminal or quickly degraded by enzymes.

**Acetylcholine** is a common neurotransmitter.
Amelia has asked just how actin and myosin work in muscle contraction. The details are outside the VCE Biology course but the topic represents an important link between the actions of fibrous proteins and nerve impulses.

[Diagram of a neuron interacting with a skeletal muscle cell and myofibril]
# Disorders of the Nervous System

<table>
<thead>
<tr>
<th>Disorder</th>
<th>Action</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple Sclerosis</td>
<td>Autoimmune disorder involving the destruction of myelin sheaths.</td>
<td>Changes in sensation, muscle spasm, loss of coordination, speech &amp; visual problems</td>
</tr>
<tr>
<td>Parkinson’s</td>
<td>Disruption of dopamine (a neurotransmitter) release</td>
<td>Impaired motor skills</td>
</tr>
<tr>
<td>Carpal Tunnel Syndrome</td>
<td>Compression of a nerve in the wrist</td>
<td>Tingling, prickling, muscle weakness</td>
</tr>
<tr>
<td>Nerve Gases</td>
<td>Blocks the action of acetyl-cholinerase (the enzyme that breaks down acetylcholine)</td>
<td>Convulsions, muscle contraction, long term neurological damage, death</td>
</tr>
<tr>
<td>Some Venoms</td>
<td>Block acetylcholine</td>
<td>Paralysis</td>
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Rational Drug Design

Traditionally drugs have been discovered and improved through trial and error experimentation.

Rational drug design, is the inventive process of finding new medications based on the knowledge of the biological target. The drug is most commonly an organic small molecule which activates or inhibits the function of a biomolecule such as a protein which in turn results in a therapeutic benefit to the patient. In the most basic sense, drug design involves design of small molecules that are complementary in shape and charge to the biomolecular target to which they interact and therefore will bind to it. Drug design frequently but not necessarily relies on computer modeling techniques.

Rational drug design is part of the Unit 3 course. You are expected to appreciate how studies of molecular biology allow scientists to

- fully describe how biochemical reactions affect organisms
- pinpoint targets for new drugs
- synthesize molecular compounds for new therapies

The actual examples that I give you, however, are NOT ones that you need to memorise.
In humans the abundance or deficiency of serotonin affects the elevation or depression of our moods.

Serotonin is also a neurotransmitter that is reabsorbed by the presynaptic terminal after an action potential is passed to another neuron.

Selective Serotonin Reuptake Inhibitors (SSRIs) were the first psychoactive drugs to be rationally designed. The drug is essentially a ligand that binds to the uptake receptor of the presynaptic neuron.

With their “retreat” blocked off, more serotonin persists in the synaptic cleft to be taken up by the postsynaptic neuron.