

HSC Biology

Module 1 - Maintaining A Balance

Focus 1:

 Most organisms are active in a limited temperature range.

Identify the role of enzymes in metabolism, Describe their chemical composition and use a simple model to describe their specificity on substrates.

Enzymes:

- **Biological catalysts.**
 - Provide a site for the reaction to take place.
 - Reduce the amount of energy required to initiate a reaction.
 - Influence the rate at which forward & reverse reactions reach equilibrium.
 - Not consumed in the reaction.
 - Required in minute amounts only.
- **Structure & composition.**
 - 3D protein structure.
 - Constructed of AAs.
 - 20 different AAs make up proteins & enzymes in organisms.
 - Have an active site.
 - Specific to substrate.
 - Site where reaction takes place.
 - May be:
 - Elongated (straight chained polypeptide).
 - Spherical (coiled polypeptide).
 - Many enzymes require the assistance of other chemicals.
 - Not made of proteins.
 - **Coenzymes.**
 - Organic molecules (vitamins).
 - **Cofactors.**
 - Metallic ions (Fe^{2+} , Ca^{2+} , Mg^{2+} , Zn^{2+} , Cu^{2+} , K^+).

- **Location.**
 - Intracellular (used within the cells that produce them.
 - *eg. photosynthesis enzymes.*
 - Extracellular (act outside cells that produce them.
 - *eg. digestive enzymes.*
- **Enzymes & Their Substrates.**
 - **Substrate:**
 - The compound on which an enzyme acts.
 - Anabolic reaction = bond molecules / substances.
 - Catabolic reaction = split molecules / substances.
 - Enzymes are highly specific the substrate they catalyse.
 - Shape of active site is designed to fit only 1 molecule.
 - Models for enzyme-substrate complexes:
 - Lock & key model:
 - Substrate fits exactly into active site, no modifications.
 - Induced fit model:
 - Enzyme makes slight adjustments to fit substrate.
 - Poisons (cyanide, arsenic) block the active site, preventing the substrate from joining. Inhibit a reaction.

Identify the pH as a way of describing the acidity of a substance.

pH:

- A measure of the $[H^+]$ in 1 litre of a solution.
 - A scale used to describe the acidity or basicity of a substance.
 - Ranges from 0 (highly acidic) to 14 (highly basic).

Explain why the maintenance of a constant internal environment is important for optimal metabolic efficiency.

A Constant Environment:

- Enzymes work most efficiently under optimal conditions.
 - For optimal conditions to occur, organisms control:
 - Body temperature.
 - Concentration of dissolved substances (nutrients & wastes).
 - Concentration of foods (BGL).
 - Absorption & removal of water.
 - Quantities of nitrogenous waste.
 - Removal of malfunctioning cells / foreign bodies.

- Mammals have the highest degree of maintenance.
 - Living process controlled by:
 - Nervous system.
 - Endocrine system.
 - Metabolic processes controlled by enzymes:
 - Enzymes work optimally in an environment where optimum conditions are met.
 - Temperature.
 - pH.
 - Enzyme concentration.
 - Substrate concentration.
 - Presence of cofactors & coenzymes.

- Enzymes coordinate all processes in organisms.
 - Therefore it is important that they function at their optimal level.
 - If the conditions are not met they may be;
 - Denatured.
 - Active site destroyed.
 - Reduced activity.
 - Reaction not initiated.

Describe homeostasis as the process by which organisms maintain a relatively stable internal environment.

Homeostasis:

- The process by which an organism maintains a constant internal environment, despite changes to the external environment.
- Homeostasis allows for the optimum conditions of enzymes to be met.
 - Internal conditions are maintained through negative feedback systems.
 - Monitor environment, counteract changes.
 - Feedback systems are a self regulating mechanism that maintains homeostasis (a balance).

Explain the homeostasis consists of two stages:

- Detecting changes from the stable state.
- Counteracting changes from the stable states.

- If homeostasis is to be maintained; the body must be able to detect stimuli that indicate a change in internal / external environment.

Stage 1:

- Receptors in body tissues detect changes in the environment (internal & external).
 - Mechanoreceptors.
 - Photoreceptors.
 - Chemoreceptors.
 - Thermoreceptors.
- Messages sent along neurones (nerve cells) as an electrochemical impulse.
 - Brain receives & interprets message.
- Receptors detect a change in the variable.

Stage 2:

- Brain responds to message by sending a nervous message to an effector to counteract the changes in the environment.
 - Effectors counteract the change (muscle / gland).

Outline the role of the nervous system in detecting & responding to environmental changes.

The Role of The Nervous System:

- Detect changes in the internal / external environment & counteract them.
- Rapid coordination of the internal organ system.

Structure of The Nervous System:

- The nervous control system consists of the brain, spine & all other nerve cells throughout the body.
- The central nervous system:
 - Brain & spinal chord.
 - **Thalamus** receives impulses from sensory neurones, directs them to parts of the brain.
 - **Hypothalamus** regulates release of hormones responsible for controlling many variables (major role in maintaining homeostasis).
- The Peripheral nervous system:
 - All nerve cells that lie outside of the brain & spine.
 - **Consists of the afferent** (sensory) & **efferent** (motor) **divisions.**
 - **The afferent (sensory) division:**
 - Monitors & informs the CNS of changes to the internal & external environment.
 - 2 types of neurones carry information.
 - **Somatic sensory neurones** (external environment).
 - **Visceral sensory neurones** (internal environment).
 - **The efferent (motor) division:**
 - Transmits information away from the CNS to muscles & glands (effector organs).
 - 2 systems of the efferent division.
 - **Somatic nervous system**; signals to the **voluntary nervous system** (skeletal muscle).
 - **Autonomic nervous system**: signals to the **involuntary nervous system** (smooth muscle, heart muscle & glands).
 - Consists of sympathetic & parasympathetic nervous systems.

- Nerve cells (neurones):
 - Basic units of the nervous system.
 - Consist of:
 - **Cell body** (contains nucleus).
 - **Axon** (carries info away from the cell body to another neurone).
 - Group of bound axons = a nerve.
 - Connecting & effector neurones have **dendrites** (finger-like projections which receive info).
 - 3 kinds of neurones.
 - **Affector neurones**; receptors detect change. Impulse transmitted to CNS.
 - **Effector neurones**; impulses transmitted away from CNS (to effectors, causing a response).
 - **Connecting neurones**; located in CNS, connect affector neurones to effector neurones.
- Hormones (chemical regulators).
 - The **endocrine system** (hormonal system).
 - Works with the nervous system as a major controlling system.
 - Hormones; chemicals produced in endocrine glands.
 - Transported in bloodstream.

Identify the broad range of temperatures over which life is found compared with the narrow limits for individual species.

Temperature Range:

- Organisms on Earth faced with a large range of ambient temperatures.
 - From -70°C to 120°C .
 - Most forms of life can exist between 40°C & 120°C .
 - Individual organisms can't withstand temperatures across the whole range.
 - Most live in a narrow range.
- They must be equipped to withstand daily & seasonal changes.
 - Especially land organisms.
 - Temperatures on the land vary much more than those in the sea.
- Some species of Archaea can live outside the range.
 - Live in glaciers, volcanoes, hot springs & mid-ocean ridges.
- Most mammals live in environments between 0°C & 45°C
 - With normal levels of activity between 30°C & 45°C .
 - Human technology allows us to build structures which broaden the range of temperature we can tolerate.
 - *eg.* Air conditioning, thermal suits, blankets, etc...

Reasons:

- Enzyme activity:
 - Above 45°C enzymes may become denatured.
 - Below 0°C enzyme activity reduced.
- Cell structure:
 - Ice crystals may form in cells, causing tissue damage.

Compare responses of named Australian ectothermic & endothermic organisms to changes in the ambient temperature & explain how these responses assist in temperature regulation.

Ectotherms:

- **Ectothermic:**
 - Animals that **can't** maintain a constant core body temperature.
 - Metabolism & level of activity affected by the temperature of the environment.
 - Low temperature = low metabolic rate = low activity.
 - Most animals are ectothermic.
 - *eg.* Reptiles.
- *Eg. Magnetic termites.*
 - Pack walls of their mounds with insulating wood pulp.
 - Align mounds north-south to maximise sun exposure in mornings & evenings, minimise heat during the day.
- *Eg. Bogong moths.*
 - Avoid cells freezing by supercooling tissues.
 - Reduce temperature of body fluids below usual freezing point to avoid ice crystals forming & destroying cells.

Endotherms:

- **Endothermic:**
 - Animals that **can** maintain a constant core body temperature.
 - Core temperature controlled by metabolic processes, adaptive physiology & behavioural mechanisms.
 - Control the rate of heat exchange with surroundings.
 - More energy required; far more food consumed. (5x more than reptiles).
 - The release of Thyroxine from the thyroid increases metabolic rate.
 - Can remain active & keep constant body temperature under a wide variety of environment temperatures.
 - Allows for a broader distribution.
 - *eg.* Mammals & birds.
- *Eg. Red kangaroo.*
 - Licks inside of paws where skin is thinner & blood is closer to the surface. Heat easily evaporated off.
- *Eg. Rabbit eared bandicoot.*
 - Large ears provide a large surface area to pass excess heat when burrowing.

Identify some responses of plants to temperature change.

Plant Enzymes:

- Enzymes in plants have same characteristics to those in animals.
 - Have optimum temperature at which maximal efficiency occurs.
- Plants tend to maintain temperature in optimal range for optimal metabolic activity to occur & to minimise damage.
- Optimal temperature is also required for germination of seeds & growth.

Responses To Change:

Hot	Cold
<p><u>Radiation:</u></p> <ul style="list-style-type: none"> - Plant radiates heat to surrounding objects. <p><u>Transpiration:</u></p> <ul style="list-style-type: none"> - Heat within the plant is used to evaporate water off the surface of cells. - Water mainly exits through the stomata. <p><u>Convection:</u></p> <ul style="list-style-type: none"> - Air around plant becomes heated. - Heated air is less dense, rises away from plant. Takes heat with it. <p><u>Leaf shape:</u></p> <ul style="list-style-type: none"> - Thinnest where 2 surfaces come together, lose most heat from this section. <p><u>Heat shock proteins:</u></p> <ul style="list-style-type: none"> - Produce these @ 40⁰C. Protect enzymes & other proteins from denaturing. <p><u>Leaf orientation:</u></p> <ul style="list-style-type: none"> - Drooping leaves to minimise surface exposure to sun (parallel to light rays). <p><u>Structure:</u></p> <ul style="list-style-type: none"> - Trunks used to store water. - Deciduous (drop leaves in summer). <ul style="list-style-type: none"> - No stomata, less surface area to lose water / absorb heat. <p><u>Leaf fall:</u></p>	<ul style="list-style-type: none"> - Plants can't produce an 'anti freeze' like animals can. <ul style="list-style-type: none"> - Gradually become resistant to low temperatures. - Ions within plant cells prevent ice crystals from forming within them. <ul style="list-style-type: none"> - Cytosol (fluid inside cell, consists of water & ions) has lower freezing point than water. - Instead, crystals form outside cells. - Because ice has formed outside cell, concentration of water is higher inside than out. <ul style="list-style-type: none"> - Water moves from inside cell to outside cell. - Freezing point inside cell further reduced. - Ice crystals continue to grow outside cells. Pliable cell membrane prevents damage. - If the temperature drop is extreme, crystals will form within the cells, causing them damage.

<ul style="list-style-type: none">- Rate of leaf fall changes throughout seasons. <p><i>Plants may die:</i></p> <ul style="list-style-type: none">- Leave dormant seeds / roots under ground. <p><i>Alter growth rate:</i></p> <ul style="list-style-type: none">- Plants change growth rate to conserve water. <p><i>Leaf surface:</i></p> <ul style="list-style-type: none">- Shiny / waxy cuticles reflect light rays & prevent water escaping.	
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Identify data sources, plan, choose equipment or resources & perform a first-hand investigation to test the effect of:

- Increased temperature.
- Change in pH.
- Change in substrate concentration.

On the activity of named enzyme(s).

Increased Temperature:

Aim:

To investigate the effect of increased temperature on the activity of an enzyme.

Hypothesis:

The enzyme in the water that is closest to that of the range of the body's core temperature will act the fastest. Water that is above the optimal temperature of the enzyme will destroy its active site, causing it to be denatured. If the temperature is below the optimal temperature its activity will be reduced as there is not enough energy to activate the reaction.

Equipment:

- Distilled water.
- 3x junket tablets.
- 6x test tubes.
- 3x beakers.
- Milk.
- Bunsen burner.
- Beaker.
- Tripod.
- Ice.
- 10mL measuring cylinder.
- Celsius thermometer.
- Timer.

Method:

- Make a rennin solution by dissolving a junket tablet in distilled water.
- Add 5mL of milk to each test tube.
- Place 2 test tubes in a water bath at 35-40⁰C.
- Place 2 test tubes in a water bath below 4⁰C.
- Place 2 test tubes in a water bath at 75⁰C.
- Once milk temperatures have stabilised, add 3 drops of rennin solution to one of each pair of test tubes.
- Record time taken for enzymes to coagulate milk.

Results:

Temp ^o C Range	Time For Milk To Set	
	Control	Enzyme
0-5 ^o C	N/A	N/A
35-40 ^o C	N/A	15 mins
75- 80 ^o C	N/A	N/A

Conclusion:

Enzymes will only function at their optimum temperature. High temperatures will denature the proteins in an enzyme, while cold temperatures will only reduce their activity.

Change in pH:**Aim:**

To investigate the effect of changing pH on the activity of an enzyme.

Hypothesis:

The enzyme in acidic conditions will function most efficiently as it simulates the environment in the body where the enzyme is active. The solutions that are neutral & acidic will denature the enzyme as its active site will be destroyed.

Equipment:

- 6x test tubes.
- 3x beakers.
- Distilled water.
- Acetic acid.
- Sodium bicarbonate.
- 3x junket tablets.
- Celsius thermometer.
- Timer.
- Water at 35-40⁰C.
- 10mL measuring cylinder.
- 60mL milk.

Method:

- Make rennin solution by dissolving a junket tablet in distilled water.
- Prepare a water bath at 35-40⁰C.
- Use measuring cylinder to add 10mL milk to each test tube.
- Place test tubes in water baths, allow temperature to stabilise.
- Add acetic acid to 2 test tubes.
- Add sodium bicarbonate to 2 test tubes.
- Add 3 drops of rennin solution to a test tube with acid, base & neutral pH.
- Record time taken for milk to coagulate.

Results:

pH	Time (Control) (sec)	Time (Enzyme) (sec)
3	-	40
7	-	420
9	-	-

Discussion:

The results yielded support the hypothesis. The acidic solution was the quickest to coagulate. This is because the acidic conditions simulated those found in the stomach where rennin metabolises milk. The rennin was active in the neutral solution, though its rate was greatly reduced.

Conclusion:

Rennin functions most efficiently in an acidic environment while its efficiency is greatly reduced in a neutral environment. Rennin is not active in a basic environment.

Changing Substrate Concentrations:

Aim:

To investigate the effect of changing substrate concentrations on the action of an enzyme.

Hypothesis:

The solution with the lowest concentration of milk will coagulate the fastest because there is a lesser amount of protein per volume to act on. Higher concentrations of protein will take longer to act on.

Equipment:

- 7x test tubes.
- 1x beaker.
- Distilled water.
- Powdered milk.
- Junket tablets.
- Celsius thermometer.
- Timer.
- Milk.

Method:

- Make different solutions of with different concentrations of substrate by diluting milk with distilled water or by using powdered milk.
 - 5mL milk.
 - 3mL milk, 2mL water.
 - 2mL milk, 3mL water.
 - 1mL milk, 4mL water.
 - ¼ tsp powder, 5mL milk.
 - ½ tsp powder, 5mL milk.
 - ¾ tsp powder, 5mL milk.
- Place each test tube in a water bath at 35-40°C, allow temperatures to stabilise.
- Add 3 drops of rennin to each test tube.
- Record amount of time taken for milk to coagulate.

Results:

Concentration	Time (minutes)
Control	12
3mL water	10
2mL water	15
1mL water	20
¼ tsp	15
½ tsp	25
¾ tsp	30

Discussion:

The milk that was most dilute coagulated the fastest. Higher concentrations of protein took longer to coagulate.

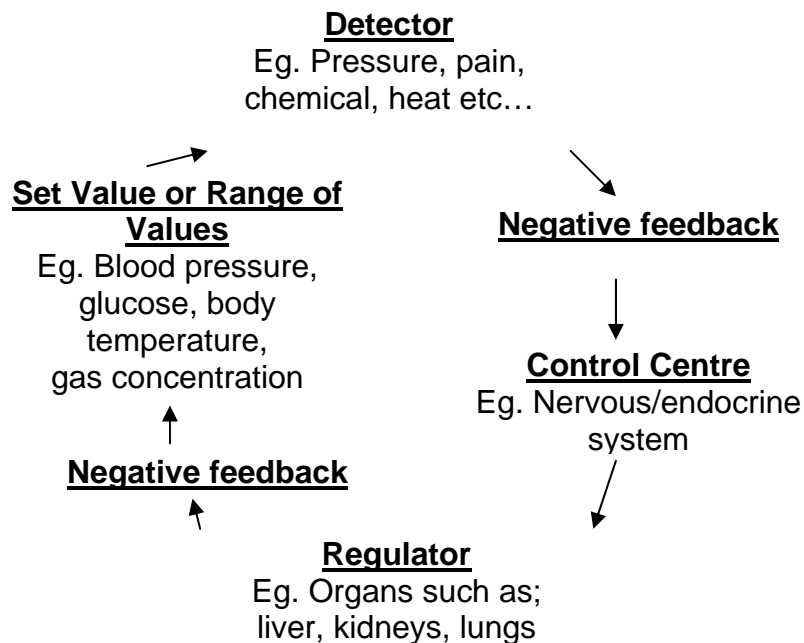
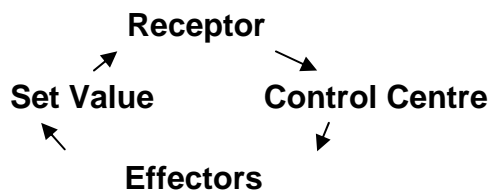
Conclusion:

Due to lesser concentration of protein per volume, milk & water solutions took the least time to coagulate. Solutions with a higher concentration of milk took longer to act on as there was more protein to act on by the same amount of enzyme.

Gather, Process & Analyse information from secondary sources & Use Available Evidence to develop a model of a feedback mechanism.

Feedback Mechanisms:

- The response alters the stimulus.
- Negative feedback system:
 - Feedback reduces the effect of the original stimulus.
 - Maintain stable conditions.
 - Achieve homeostasis.



Analyse information from secondary sources to describe adaptations & responses that have occurred in Australian organisms to assist temperature regulation.

Behavioural Adaptations:

- **Migration:**
 - Animal moves to avoid temperature extremes.
 - *eg.* Birds.
 - Birds spend spring & summer in Australia. Move before cold weather comes & food becomes scarce.

- **Hibernation:**
 - Animal remains sheltered.
 - Metabolism slows. Body temperature in endotherms drops.
 - **Aestivation** = hibernating in hot conditions.
 - *eg.* Bogong moths.
 - Spend the summer in caves in Aust. Alps.

- **Shelter:**
 - Burrows, caves or rocks to avoid extreme conditions.
 - Heat of day or cool of night.
 - *eg.* Central netted dragon.
 - Climbs trees when it is hot.

- **Nocturnal activity:**
 - Active during the night.
 - *eg.* Brown snake.
 - When it is hot become active in the night.
 - Shelters underground / under rocks during the day.

- **Controlling exposure:**
 - Control surface area exposed to sunlight.
 - *eg.* Endotherms.
 - Mammals curl up & tuck legs & tails around body in cold conditions.

- **Clothing:**
 - Clothing traps a warm layer of air against the skin.
 - *eg.* Humans.

Structural Adaptations:

- **Insulation:**
 - Fur in mammals & feathers in birds trap a layer of air that slows down heat exchange with the external environment.
 - Thickness of fur / feathers can be changed with changing seasons.
 - Subcutaneous fat traps heat beneath skin.
 - *eg.* Cockatoo.
 - Can contract muscles to lift feathers up in cold conditions.
 - *eg.* Whales.
 - Have layer of blubber to prevent transfer of heat to water.
- **Piloerection:**
 - 'Hair standing on end'
 - Important for most mammals.
 - Trapped air beneath hair/fur acts as insulation.
 - Sympathetic neurones carry impulses from hypothalamus to base of each hair, muscle contracts, hair stands on end.
- **Surface area : volume:**
 - Large volume with small surface area loses heat less efficiently than large surface area & small volume.

Physiological Adaptations:

- **Metabolic activity:**
 - Endotherms generate heat through metabolic activity.
 - Metabolic activity dependent on physical activity & other processes.

- **Control of blood flow:**
 - Blood flow to extremities controlled.
 - Heat exchange with environment increased / decreased.

- **Counter-current exchange:**
 - Blood vessels leading to & from extremities placed close together.
 - Chilled blood returning in veins picks up heat from arteries.
 - Prevents shock & preserves heat.
 - *eg.* Platypus.
 - Feet have vessels close to each other.

- **Evaporation:**
 - Heat from body used to evaporate water off surface of skin.
 - *eg.* Kangaroos.
 - Lick forearms, moisture evaporates off.