1.1 – Living with a limited temperature range

1.1.1 Enzymes

- Enzymes:
  - Are:
    - Found in all living things (they are biological chemicals)
    - Catalysts (changes the rate of a chemical reaction)
    - Proteins
    - Active within a limited range of physical and chemical conditions
    - Very specific (each enzyme is involved with only kind of chemical reaction)
  - Usually end with “ase”
  - Named for the substrate (reactant), eg Sucrase acts on sucrose
  - Co-Factor/Co-Enzymes = Some enzymes can only function when another factor is present, usually vitamins or minerals

- Enzymes and Metabolism
  - Enzymes control the hundreds of chemical reactions that make up the metabolism of each cell
  - These chemical reactions are needed to:
    - Obtain energy
    - Build new chemicals for growth and repair of the cell
    - Make substances needed by other cells
  - Each process requires numerous reactions to occur
  - Enzymes are essential because they make slow reactions occur quickly

- Chemical Composition of Enzymes
  - Enzymes are proteins
  - Proteins are built from amino acids
  - The number and order of amino acids gives an enzyme is primary chemical structure

- How Enzymes Work
  - An enzyme fits into its substrate at a small part of the enzyme called the active site
  - The enzyme and substrate form a complex
  - This is followed quickly by separation, where the products are released along with the unaltered enzyme
  - The shape of the enzyme at the active site is important for enzyme specificity
  - The lock and key model best demonstrates this:

  ![Diagram of enzyme action](image)

  - Any changes to the active site will result in the enzyme being unable to catalyse the reaction.
  - Factors that affect enzyme activity include: pH, temp. and substrate concentration
1.1.2 pH
- Is a way of describing acidity
- It is a scale from 0 to 14:
  - pH of 7 = Neutral, it is not acidic or alkaline
  - pH of less than 7 = Acidic
  - pH more than 7 = Alkaline

1.1.3 Some factors affecting enzymes
- Changes in pH
  - Enzymes have a specific range in which they function
  - Most enzymes function in a pH that's slightly alkaline
  - As the pH moves away from the optimum value for the enzyme, the activity of the enzyme falls
  - If the change is too great, the enzyme can become denatured
  - Denatured = permanent change in the structure of an enzyme so it can no longer function
- Changes in Temperature
  - Each enzyme has an optimal temperature
  - Decreasing temperature = decreasing activity
  - Increasing temperature = increasing activity, until structure changes then a sharp decrease in activity occurs
- Concentration of the Substrate
  - The concentration of the substrate affects the activity of the enzyme
  - Decreasing concentration = decrease in activity
  - Increase in concentration = increase in activity, until optimum activity is reached

1.1.4 Homeostasis and Metabolic efficiency
- Homeostasis
  - “the process by which organisms maintain a relatively stable internal environment”
- Why is Homeostasis important?
  - Each organism has its own range of conditions in with its cells continue to operate
  - The conditions for normal functioning of cells is very restricted
  - Role of Homeostasis: to maintain conditions and reactions needed for life
  - Homeostasis keeps the conditions as close to optimum as possible so that the organism’s metabolism can operate as efficiently as possible

1.1.5 Homeostasis as a two stage process
- Detecting changes – when conditions differ from optimum
- Causing changes – to return conditions to optimum
- Negative feedback mechanism = when the body causes changes to correct another change

1.1.6 Role of the Nervous system in homeostasis
- Receptors: collect information about environment, information is called “stimulus”
- Sensory Nerves: message from receptors travels along nerves to spinal cord
- Spinal Cord: passes electrical impulse message up to the brain
- Brain: processes information, different parts process different kinds of information
- Spinal Cord: if response is needed, message back down spinal cord
- Effector Nerves: receive brain message from spinal cord, pass onto effectors
- Effectors: act to change internal environment (eg sweat glands)
1.1.7 Temperature ranges
- Life is found over a broad range of temperatures
  - Life can exist between -40°C and 120°C
  - Extremes are mostly inhabited by bacteria
- Individual species can exist in more limited temperature ranges
  - Humans = 27°C – 43°C
  - Platypus = -8°C – 34°C
  - Aust. Alpine = -10°C – 5°C
  - Species may be able to survive in these temperatures, but can only function optimally in an even smaller range

1.1.8 Endotherms and Ectotherms
- Endotherms
  - “Organisms that use their internal metabolism to generate heat”
  - They are able to regulate their body temperature
  - They are able to maintain a constant internal temp under most circumstances
  - E.g. Emu
    - Can increase temp by: increasing activity, absorbing sunlight heat
    - Can decrease temp by: decreasing activity, staying in shade, evaporation (wings)
- Ectotherms
  - “Organisms that rely on behavioural adaptations to obtain heat from their environment”
  - They are able to regulate their body temperature
  - They are unable to maintain a constant internal temp under most circumstances

1.1.9 Plants and temperature change
- Plants have adaptations to help them to survive environmental temperature changes
- Adaptations include:
  - Thick, silvery cuticle – reflects and insulates against heat – reduces water loss
  - Hairy stems – insulation - reduce water loss
  - Shape of tree – water runs down the stem to the base to be absorbed by the roots
Additional Information – The Effect of pH on an Enzyme

- Enzyme = Catalase
- Catalase breaks hydrogen peroxide into harmless water & oxygen gas
- Method:
  - Test tubes contain the same amount of hydrogen peroxide & liver tissue
  - pH differs between test tubes – using Sulfuric Acid
  - Activity of Enzyme is measured by the height & intensity of the oxygen bubbles
- Result:
  - Catalase is most effective at a neutral pH (7)
  - It becomes less effective as the pH becomes higher or lower than neutral

Additional Information – The Effect of Temperature on an Enzyme

- Enzyme = Catalase
- Method:
  - Each test tube contains the same amount of hydrogen peroxide & liver tissue
  - Temperature differs between test tubes
- Result:
  - Catalase is most effective at around 35°C
  - It is less effective either higher or lower than the temperature where it has optimal activity
  - Heating liver can denature enzyme

Additional Information – The Effect of Substrate Concentration on an Enzyme

- Enzyme = Catalase
- Method:
  - Each test tube has the same pH, temperature and liver tissue size
  - Water has been mixed with the hydrogen peroxide to produce different concentrations
- Result:
  - As the concentration of the hydrogen peroxide increases, the reaction increases
  - Above a certain concentration, no further increase in reaction would occur
  - This is because all the available catalyse is taking part in the reactions
  - This is called the “saturation point”
Additional Information – Model of a Feedback Mechanism

Additional Information – Adaptations & Responses in Australian Organisms that assist Temperature Regulation

- **Red Kangaroo**
  - Australian mammal that maintains its internal temperature at 36°C
  - When the kangaroo needs to lose heat it:
    - Is less active - during hot periods of the day
    - Stays in shade - out of direct sunlight
    - Pants - heat is lost out of nasal passages
    - Licks its forearms – evaporation
    - Sweats

- **Brown Snake**
  - Australian reptile
  - Makes enough heat from metabolism to be active for periods in cold weather
  - It gains heat by basking in the sun
  - When the temperature drops – it hibernates
  - When the temperature rises – shelters in shade under logs & is active only in the cooler parts of the day (eg evening)
1.2 – Transporting essential substances

1.2.1 Water as a solvent
- The universal solvent
  - Called this because so many substances will dissolve in it
  - Some substances form ions (charged particles), eg Salt
  - Other substances are polar (partially charged) dissolve into water, eg Sugar
- In Multicellular organisms
  - Cells are usually surrounded by watery solutions called intercellular/interstitial fluids
  - This allows dissolved substances to move into and out of cells
- Substances that dissolve in water & are importance to cells
  - Oxygen ($O_2$) - released during photosynthesis and is required for respiration
  - Carbon Dioxide ($CO_2$) - used by plants, waste product of respiration
  - Salts/Minerals - needed as part of the buffering system in body fluids
  - Sugars - needed as energy sources
  - Amino Acids - building blocks of proteins
  - Vitamins – needed to regulate processes throughout the body
  - Nitrogenous Wastes – formed during the breakdown of amino or nucleic acids
  - Antibodies, hormones, enzymes and other chemicals – help the body function

1.2.2 Transport in mammals, including haemoglobin
- Circulatory system - transport system for mammals
  - Blood – watery liquid in which many substances dissolve and carries along blood cells
  - Blood vessels – tubes that blood passes through
  - Heart – pump that pushes blood around the circulatory system
- Blood
  - Mostly made up of a watery solution called plasma
  - Plasma transports numerous substances, such as
    - Carbon Dioxide
    - Some Oxygen
    - Nitrogenous Wastes
    - Food substances – sugars, amino acids, vitamins
    - Water
- Red Blood Cells
  - Make up 44% of blood
  - Filled with a complex iron-containing protein called Haemoglobin
- Haemoglobin
  - Carries oxygen
  - Bonds with oxygen to form Oxyhaemoglobin (turns blood red)
  - During respiration, the oxygen separates (turns blood bluish-purple)
- Haemoglobin as an adaptive advantage
  - Transports oxygen from where it is available (lungs) to cells throughout the body
  - Carries millions of molecules of oxygen in each red blood cell
  - Body cells could not receive enough oxygen from oxygen dissolved in plasma
  - All vertebrates have haemoglobin
- Other components:
  - White blood cells – fighting disease as a part of the immune system
  - Platelets
1.2.3 Blood vessels

- Arteries
  - Size: Large
  - Walls: Muscular
  - Special features:
    - Blood is under high pressure
    - Arteries pulse (expand/contract) with each heartbeat
- Capillaries
  - Size: Small
  - Walls: Very thin
  - Special features:
    - Substances readily diffuse from blood into cells (vice versa)
    - Only one cell thick
    - Run throughout entire body
- Veins
  - Size: Large
  - Walls: Non-muscular
  - Special features:
    - Blood is under lower pressure
    - Contain Valves to keep blood flowing towards the heart (the right direction)
    - Surrounding muscles help to move blood in veins

1.2.4 Movement of substances into and out of blood

- Heart – Structure
  - 4 chambered muscular pump that keeps blood moving through the blood vessels
  - Moving blood is essential for transporting substances to cells and collecting wastes
- Heart – Function
  - Sends blood to the lungs (capillaries in Alveoli)
  - Oxygen is absorbed and Carbon Dioxide removed
  - Blood is then pumped through arteries to tissues throughout the body
  - Blood inside capillaries passes through tissues, oxygen diffuses into cells
  - Substances move through the capillary walls into surrounding cells as needed
  - Waste substances are removed (carbon dioxide & urea)
- Organs that pick up and release substances
  - Kidneys – the capillaries in the nephron – Urea, excess salts & water removed
  - Intestine – the capillaries in the villi – nutrients (sugars & lipids) added
  - Liver – protein fragments are removed from blood, broken down into Urea and then added back into the blood from removal

1.2.5 Exchanging oxygen and carbon dioxide

- Oxygen
  - Lungs of a mammal to tissues where oxygen is exchanged to body cells
  - Living cells need oxygen for respiration
  - Most organisms use respiration to provide energy needed for metabolic processes
  - Products of respiration are carbon dioxide and water
- Carbon Dioxide
  - Required for plants, waste in many cells that needs to be removed
  - Carbon dioxide becomes poisonous in high concentrations
  - Dissolved carbon dioxide can change the pH of body fluids – reduce the activity of enzymes
  - Removing excess
1.2.6 Vascular bundles in a flowering plant

- Transport system in Plants
  - Needed to supply cells with substances needed and remove wastes
  - Flowering plants, gymnosperms and ferns contain vascular bundles
  - Vascular bundles move water, dissolved minerals, glucose and other products
  - There are 3 types of vascular tissue:
    - Cambium – produces new xylem/phloem tissue
    - Xylem – carry water with dissolved minerals, not living tissues
    - Phloem – carry water & sugars, living tissues
Additional Information – Relative Sizes of Red and White Blood Cells

- **Method:**
  1. Set up your microscope
     - Mount a piece of millimetre grid paper
     - View paper using the x10 objective (magnification of x100)
  2. Estimate the field of view
     - Use the grid paper to estimate the diameter of the field of view
     - Approx. 1.6mm
  3. Magnify the field of view
     - Use the x40 objective (magnification x400)
     - Field of view is now approx 0.4mm
  4. View a prepared slide of blood
     - Using x400 magnification
     - Estimate how many cells would fit across the diameter of the field of view
     - Approx. 50 red blood cells,

- **Results:**
  1. Red blood cell = 8 microns
  2. White blood cell is x1.5 a red blood cell, = 12 microns

Additional Information – Products Extracted from Donated Blood

- **Transfusion**
  - Where blood from one person is transferred to another person
  - Performed when a patient has lost a lot of blood

- **Whole blood**
  - Blood straight from donors
  - Used for some transfusions

- **Stable Protein Plasma**
  - Treated plasma
  - Used in an emergency situation before whole blood is available
  - Also used for burn patients, who lose fluid rather than blood

- **Packed red blood cells**
  - Boost the patients ability to transport oxygen

- **Platelets**
  - Used to promote clotting in people with leukaemia

- **Clotting factors**
  - Used by patients who have excessive bleeding problems (eg Haemophilia)

- **Serum Albumin**
  - Patients with low plasma levels
  - People with liver disease

- **Immunoglobulins**
  - Contracted antibodies used by patients with damaged immune systems
  - People with AIDS

Additional Information – Artificial Blood

- Real blood is limited by need to match donor and recipient
- Real blood has the risk of spreading diseases
- Restrictions on the number of people willing/able to donate blood
- Restrictions on shelf-life of real blood
Additional Information – The Effect of Dissolved Carbon Dioxide on the pH of Water

- Observed that the pH of the water decreases as carbon dioxide levels increase
- Carbon Dioxide forms a weak acid called carbonic acid \( \rightarrow \) water becomes more acidic
- Increase of acidity = decrease in pH in water

Additional Information – Current Technologies for measuring the Concentrations of Gases in Blood

- Arterial Blood Gas Analysis Machine
  - Measures the concentrations of oxygen and carbon dioxide in a freshly-take sample of blood
  - Measurements of the pH change = carbon dioxide levels
  - Measurements of electricity current = oxygen levels
- Pulse Oximeter
  - Detects changes in the colour of blood
  - Oximeter clips onto finger and shines red/infra-red light through the tissue
  - A detector collects information about the colour of the blood in the capillaries
  - Oximeter displays information as a percentage of oxygen in the blood
  - This is referred to as “oxygen saturation”
  - Normal oxygen saturation is about 96%
  - Used to constantly monitor patients with severe problems, unconscious or recovering from surgery
Diagram 1.17 Transverse (TS) and longitudinal sections (LS) of phloem tissue

Diagram 1.18 Transverse (TS) and longitudinal sections (LS) of xylem tissue
1.3 – Regulating essential substances and wastes

1.3.1 Water in cells
- The concentration of water in cells is critical
- It must remain constant
- Water is so important because:
  - Water maintains the shape of the cell membrane – too much = cells burst
  - Changes in water concentration = changes in concentrations of dissolved substances
  - Dissolved substances – eg Carbon Dioxide, becomes toxic in high concentrations

1.3.2 The need for excretion
- Wastes from the metabolic processes of cells can be toxic to cells
- Such wastes include:
  - Carbon Dioxide - Must be excreted or pH in tissues will fall = fall in enzyme activity
  - Nitrogenous Wastes – (ammonia & urea) they poison cells & change pH
- Even excess non-toxic wastes can be a problem, increased concentrations of product can affect reaction rates
- Water-soluble wastes can be washed out with water
  - Eg Freshwater fish, who have plenty of water to spare
  - Most other organisms cannot use this form of excretion
- Most organisms cannot waste water in this fashion, so they excrete concentrated waste
- Most organisms need to balance their need to conserve water and to excrete wastes

1.3.3 The role of the kidney
- Role of the Kidney
  - Most animals can control the amount of water lost when nitrogenous wastes are excreted
  - Kidney is an organ that can alter the water loss during excretion
- The Nephron
  - The functional unit of the Kidney
  - There are thousands of nephrons in a kidney

1.3.4 Difficulties in removing nitrogenous wastes
- Excreting nitrogenous wastes in concentrated forms requires special adaptations
- Nitrogenous wastes diffuse into bodily fluid with lower concentration → urine
- When an organism created concentrated urine, diffusion cannot occur
- With concentrated urine osmosis is an issue (water moving to a higher concentration)
- Organisms require adaptations to prevent osmosis into concentrated urine

1.3.5 Active and passive transport
- Active transport
  - Energy is expended – to move substances against a concentration gradient
  - Eg Kidney overcoming the inadequacies of diffusion & osmosis
- Passive transport
  - Energy is not required
  - Eg Diffusion & Osmosis
1.3.6 Filtration and reabsorption in a nephron
- Processes that perform the complex balancing of retaining essential substances & removing wastes from blood
- Filtration – substances are removed from blood physically due to size (in the Bowman’s Capsule)
- Reabsorption, occurs in 2 ways:
  - Diffusion
    - Glucose
      - Reabsorbed from urine until levels are equal
      - Active transport needed to move all glucose into blood
    - Salts
      - Would diffuse back into blood
      - Urine lower salt concentration
      - Active transport needed
      - Body will excrete excess salts
    - Amino acids, vitamins, hormones and other substances
      - Actively transported to be recovered from excretion
  - Osmosis
    - Most of the movement of water is by osmosis
    - Shape and function of nephron (loop of Henle) aid reabsorption of water
    - Active transport is needed when urine is very concentrated
- Urea
  - Is not reabsorbed
  - Normally it would diffuse
  - Active transport is used to ensure Urea does not return to the blood

1.3.7 Aldosterone and ADH
- Aldosterone
  - Produced by Cortex
  - Increases the amount of sodium ions reabsorbed in kidney’s tubules
  - INCREASES SALT IN BLOOD
  - Makes urine dilute
- ADH
  - Antidiuretic Hormone
  - Produced in the Hypothalamus
  - INCREASES WATER IN BLOOD
  - Makes urine concentrated

1.3.8 Adaptations for harsh environments
- Some organisms need special adaptations to survive in harsh environments
- Enantiostasis = “the ability to maintain metabolic & physiological functions in response to variations in the environment”
- Adaptations include:
  - Mangroves – have a layer of cells that restrict the movement of salt into xylem
  - Saltbush – can tolerate extremely high levels of salinity

1.3.9 Minimising water loss
- Australian plants:
  - Eucalypts – hard/thick waxy cuticles on leaves
  - Spinifex – leaves that move to reduce exposure of stomates
  - Saltbush – small leaves – small surface area
### Additional Information – Differences in Urine Concentration of Terrestrial mammals, Marine fish and Freshwater Fish

<table>
<thead>
<tr>
<th>Type of Animal</th>
<th>Urine Component &amp; Concentration</th>
<th>Explanation</th>
</tr>
</thead>
</table>
| Terrestrial Mammal (eg Bilby) | • Concentrated Urine  
• Composed of: Urea, Salts, Water and other wastes                                               | Excess salts and wastes are excreted in water. Water needs to be conserved, hence concentrated urine. Urea is used because it is less toxic than ammonia and can be present in higher concentrations. |
| Freshwater Fish (eg Native Bass) | • Large amounts of dilute urine  
• Composed of: ammonia and large amounts of water                                                    | Freshwater fish absorb large volumes of water through osmosis. Ammonia is used because there is sufficient water to make it dilute.                                                                        |
| Marine Fish (eg Whiting) | • Small amounts of concentrated urine  
• Composed of: trimethylamine oxide                                                                | Marine fish constantly lose water through osmosis. Excrete little water in concentrated urine.                                                                                                             |

### Additional Information – Structures of a Sheep’s Kidney

![Image of a sheep's kidney](image_url)

### Additional Information – Renal Dialysis vs. Excretion of the Kidney

<table>
<thead>
<tr>
<th>Kidney Function</th>
<th>Renal Dialysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Natural body process</td>
<td>An artificial process to replace damaged kidneys</td>
</tr>
<tr>
<td>Performed by two organs</td>
<td>Performed by a large machine</td>
</tr>
<tr>
<td>Removes wastes continuously</td>
<td>Performed intermittently</td>
</tr>
<tr>
<td>Varies output automatically depending on concentrations of wastes in the blood</td>
<td>Concentrations of substances in blood and dialysis fluid monitored by computers so the most wastes are removed during treatment</td>
</tr>
<tr>
<td>Wastes may be removed by both diffusion and active transport</td>
<td>Waste removed by diffusion</td>
</tr>
</tbody>
</table>
Additional Information – Hormone Replacement

- For people who cannot secrete aldosterone
- Main artificial substitute for aldosterone is: fludrocortisone
- Hormone replacement for kidney function usually involves numerous artificial hormones
- Addison’s Disease = Cortex does not produce sufficient amounts of aldosterone
- Appropriate hormone replacement therapy can enable patients to live normal lives

Additional Information – Processes used by different Plants for Salt Regulation in Saline Environments

- Mangrove
  - Roots are permanently in salt-laden water/mud
  - Developed a layer of cells to restrict the movement of salt into the xylem
- Saltbush
  - Lives in soil with high salinity
  - Developed a method of surviving salt environment
  - Absorbs and excretes large amounts of salt
  - So effected, used to desalinate land

Additional Information – Structures in Plants that assist in Conserving Water

- Hard/waxy cuticle in leaves
- “hairy” plants
- Leave sizes
- Movement of leaves to avoid sunlight

Additional Information – Relationship between conservation of Water and the production and excretion of concentrated nitrogenous wastes

- Australian Insects
  - Lose very little water because they excrete non-toxic uric acid as a paste
  - Examples:
    - Desert Grasshopper
    - Desert Cicada
    - Desert Ant
- Australian Mammals
  - Are able to produce & tolerate high concentrations of salts & urea in their urine
  - Examples:
    - Bilby
    - Wallaroo
    - Mala
HSC TOPIC 2: Blueprint of Life

2.1 – Evolution

2.1.1 Changes in the environment

• Changes in physical conditions in the environment
  o Conditions that change:
    ▪ Temperature
    ▪ Wind
    ▪ Amount of rainfall
    ▪ Moisture available
  o These can change daily or over long periods of time
  o Drying of Australia = vegetation from rainforest to grasslands and dry sclerophyll forests

• Changes in chemical conditions in the environment
  o Chemical conditions can change
  o Australia, increase in salinity of soil
  o Some plants can tolerate high salt levels, most however can’t and die
  o In high salt environments, selection favours these high tolerance species, eg saltbush.

• Changes in competition for resources
  o Resources are not unlimited in an environment
  o The number of offspring produce is greater than the available resources = competition
  o New species have to compete with the already established species
  o Australia, most introduced species have out competed the local species
  o This has resulted in numerous extinctions of native species
  o Eg, the European rabbit has out competed the Bilby in many areas.

2.1.2 Support for the theory of evolution

• Palaeontology
  o “The study of fossils”
  o Fossils show that some species have changed gradually over time, become extinct or haven’t changed much (eg sharks and crocodiles)
  o Fossil record is incomplete, due to the rareness of an organism becoming fossilised
  o Horses have numerous fossils and demonstrate vast change over the ages
  o Transitional forms:
    ▪ “Fossils that show characteristics that place them between major classification groups”
  o Archaeopteryx
    ▪ Bird-like reptile
    ▪ Has reptile features: teeth & long tail
    ▪ Has bird features: feathers & breastbone
    ▪ Supports the theory that reptiles were the ancestors of birds
  o Punctuated equilibrium
    ▪ “Theory of evolution which suggests that changes in species occur suddenly followed by long periods of no change”
• Biogeography
  o “Study of the geographical distribution of organisms”
  o Six major biogeographical zones:
    ▪ Oriental
    ▪ Australian
    ▪ Ethiopian
    ▪ Palaearctic
    ▪ Neotropical
    ▪ Neartic
  o Zones are separated by physical barriers (eg Seas)
  o Barriers restrict movement and prevent interbreeding
  o New species if populations evolve independently
  o Wallace
    ▪ Noted Australia and Asia had different species
    ▪ Differences exist because Australia separated from Asia
    ▪ Australia’s marsupials thrived due to isolation
    ▪ Asia’s marsupials were out competed by placental mammals
  o The changes in isolated populations give support to the theory of evolution

• Comparative embryology
  o “Study of embryos and the comparison of embryos between different species”
  o Embryos of vertebrates
    ▪ Fish, amphibians, reptiles, birds and mammals
    ▪ Have similar structures (gill slits and prehensile tails)
  o Similarities in the structure of the embryos point to a common ancestry

• Comparative anatomy
  o “Study of anatomy and comparison of anatomy between different species”
  o Some organisms have similar anatomy/structures
  o This can be evidence of evolution from a common ancestor
  o Homologous structures:
    ▪ “Similar structures, with different functions, that have been derived from a common ancestor”
  o Pentadactyl Limbs
    ▪ “Five Fingered” limbs
    ▪ Vertebrates: frogs, whales, dogs, bats and humans
    ▪ Each limb has: one upper bone, two lower bones and 5 digits
  o Vestigial Organs
    ▪ “Organs that no longer have any function or little use”
    ▪ Whale, have parts of pelvis/leg bones
    ▪ Humans, appendix no longer used in digestion
    ▪ Presence of vestigial organs provides evidence of descent from a common ancestor

• Biochemistry
  o Organisms share the same basic chemical makeup
  o The common genetic material in all organisms is DNA
  o Organisms also share common:
    ▪ Proteins
    ▪ Amino acid sequences
    ▪ Haemoglobins
  o Humans & Bacteria share proteins (eg cytochrome c)
  o Advances in technology reveal more detailed information about biochemistry
  o Biochemistry provides evidence for the evolutionary relationship between organisms
2.1.3 Darwin/Wallace’s theory by natural selection and isolation

- Theory of evolution
  - Proposed jointly by Darwin & Wallace in 1858
  - Theory points:
    - In any population there is variety
    - Some variety is inherited and passed onto the next generation
    - More offspring are produced than can survive because of the environment
    - Not all individuals in a population reproduce → pass on characteristics
    - Individuals with characteristics best suited to the environment will survive and reproduce
    - Over many generations, these characteristics will increase in the population
    - New species may form as a result of changing environmental conditions
    - If a population becomes isolated, new species may arise because of different selective pressures
    - Isolated species become different species when they are unable to interbreed and produce offspring

- Divergent Evolution
  - “Evolution of one species into a number of different species”
  - New species developed as a result of different environmental conditions
  - Speciation:
    - “Development of one or more new species from an existing species”
  - Eg Darwin’s Finch’s, Their beaks have changed depending on their diet

- Convergent Evolution
  - “Evolution of different species into similar species”
  - Different species that live in similar environments
  - This means they have similar survival pressures and adapt similarly
  - Eg Marsupial mammals & Eutherian (placental) mammals
    - Not closely related, but have developed similar features
    - Eutherian mole vs. Marsupial mole
    - Mouse vs. Marsupial mouse
    - Flying squirrel vs. Flying fox
    - Wolf vs. Tasmanian Tiger (thylacine)
2.2 Inheritance and the work of Gregor Mendel

2.2.1 Gregor Mendel’s experiments

- Background
  - 1822-1884
  - Augustinian Monk

- His work
  - Demonstrated that inheritance occurred in a definite pattern

- Experiments
  - Used the garden pea plant, *Pisum sativum*
  - Identified 7 easily distinguishable characteristics (traits) that had alternate forms
    - Seed shape (round/wrinkled)
    - Flower colour (purple/white)
    - Seed colour (yellow/green)
    - Pod shape (inflated/constricted)
    - Pod colour (green/yellow)
    - Flower position (terminal/axillary)
  - Mendel believed these characteristics were controlled by factors (genes)
  - Bred the plants for 2 years, ensuring that his experiments were all homozygous
  - Crossed pure-breeding plants with alternative forms of each trait (alleles)
  - Made sure that the pea plants did not self-pollinate by removing immature stamens
  - Monohybrid cross (one characteristic studied)
  - At the time, offspring characteristics were assumed to be a blend of the parents
  - Mendel noticed that some characteristics occurred more often (dominant genes)
  - Mendel also noticed that some characteristics occurred less often (recessive genes)
  - Monohybrid Ratio = 3:1

- Conclusions
  - Characteristics were not blended but were discrete units
  - Each characteristic was controlled by a pair of factors
  - The factors separated from one another when the sex cells were formed (Mendel’s Law of Segregation)
  - At Fertilisation the offspring received one factor from each parent randomly (Mendel’s Law of Independent Assortment)
  - One factor was dominant while the other was recessive

2.2.2 Reasons for Mendel’s success

- Experiments were successful and reliable because he:
  - Kept accurate records
  - Looked at individual characteristics (traits) that were easy to distinguish
  - Controlled the pollination process carefully
  - Chose peas, which were easy to grow & produced offspring rapidly
  - Analysed his results mathematically
  - Used large numbers of plants and repeated his experiments numerous times
2.2.3 Monohybrid crosses involving simple dominance
- You can predict the features of offspring of monohybrid crosses
- Terms:
  - Genotype – “All the genes present”
  - Phenotype – “Outward appearance”
  - Dominant – “Expressed in the phenotype whenever present”
  - Recessive – “Expressed in the phenotype whenever a dominant gene isn’t present”
  - Homozygous – “Alleles are the same and are true breeding” (eg TT)
  - Heterozygous – “Alleles are not the same, known as a hybrid” (eg Tt)
  - Gene – “Parts of chromosomes, units of inheritance passed from parent to offspring”
  - Alleles – “Alternative forms of the same gene”
  - Hybrid – “Having one dominant and one recessive gene”

2.2.4 Genes and alleles
- Genes:
  - “Units of inheritance”
  - Mendel called them “factors”
  - They are segments along chromosomes
  - Are passed from parents to offspring
  - Genes consist of a DNA sequence that codes for a specific polypeptide
- Alleles
  - “Alternative forms of a gene”
  - They are located on the chromosomes in corresponding positions

2.2.5 Dominant and recessive alleles and phenotype
- Dominant alleles
  - Expressed in the phenotype whether they are heterozygous or homozygous
- Recessive alleles
  - Expressed in the phenotype if no dominant allele is present
- Pedigree Trees
  - A way of showing inheritance of characteristics
  - Like a family tree
  - Males = Squares
  - Females = Circles
  - Unshaded shapes = Individual without the characteristic
  - Shaded shapes = Individual with the characteristic
  - Can be used to find homozygous and heterozygous individuals

2.2.6 Mendel’s work was unrecognised
- Mendel published his work in 1866
- Was not recognised for 34 years
- Reasons:
  - His ideas of dominant/recessive inheritance went against the accepted concept of blending of characteristics in inheritance
  - There was no knowledge of chromosomes or genes at the time
  - He was an unknown monk, rather than a leading scientist
  - He was a shy man, who may not have pushed his ideas
  - Lack of communication at the time
2.3 Chromosomal Structure

2.3.1 The work of Sutton & Boveri

- Boveri
  - Background: German scientist
  - Investigated: Sea Urchins
  - Proposed:
    - Chromosomes were not all the same
    - A full set of chromosomes was necessary for development of an organism

- Sutton
  - Background: American graduate student
  - Investigated: Grasshopper cells
  - Proposed:
    - Each chromosome was unique
    - During meiosis the number of chromosomes is halved
    - Each chromosome was a distinct structure that kept its character throughout division and fertilisation of sex cells
    - That fertilisation restored the full chromosome number
    - Chromosomes were the carriers of the hereditary units (genes)

2.3.2 The chemical nature of chromosomes and genes

- Chromosomes are thread-like structures
- Found in the nucleus of cells
- The consist of DNA (40%) and a protein called Histone (60%)
- Genes are small lengths of DNA, linked together to make up chromosomes

2.3.3 Structure of DNA

- DNA is a nucleic acid that has double-stranded molecules in the shape of a helix
- Side of the helix are composed of deoxyribose (a sugar) and phosphoric acid
- “Rungs of the ladder” are made up of 4 nitrogenous bases:
  - Adenine (A)
  - Thymine (T)
  - Guanine (G)
  - Cytosine (C)
- Bases are complementary:
  - A-T (Adenine pairs with Thymine)
  - G-C (Guanine pairs with Cytosine)
- The sugar, phosphate and base make up a sub unit called a nucleotide
- Nucleotide:
  - “A molecule formed from a nitrogenous base, a sugar and a phosphate unit”
  - Model:
2.3.4 The structure and behaviour of chromosomes during meiosis

- **Meiosis**
  - Meiosis only occurs during the production of sex cells (gametes)
  - Produces cells with half the normal chromosome number (haploid)
  - Normal chromosome number is called Diploid
  - Meiosis there are 2 nuclear division, but only 1 DNA replication

- **Behaviour**
  - Before a cell undergoes Meiosis, the chromosomes are copied
  - Copies are called “Chromatids”, linked by a “Centromere”

- **Process of Meiosis**
  - 1\textsuperscript{st} Stage:
    - Homologous chromosomes line up
    - Crossing over (two chromosomes swap chromatid parts) may occur
  - Crossing over
    - The greater the distance between genes on the chromosome = the greater chance of crossing over occurring
    - New chromosomes are called “recombinants”
    - Genes located on the same chromosome are called “linked genes”
    - Crossing over can break these linked genes and therefore increase variability
    - Crossing over increases genetic variation
  - 2\textsuperscript{nd} Stage:
    - Chromatids separate
    - Four cells are formed with a haploid (half) number of chromosomes

2.3.5 Sexual reproduction and variability of offspring

- Leads to greater variability than asexual reproduction because:
  - It combines genetic information of two different organisms
  - Resulting in offspring was completely different set of genes from its parents

- Variability arises because:
  - Crossing over during meiosis produces new combinations of genes
  - The chromosomes move randomly into one of the four gametes created during meiosis, which results in random segregation of genes
  - The sex cells come together randomly at fertilisation
2.3.6 **Sex Linkage and co-dominance**
- **Co-dominance**
  - Both alleles are fully expressed in the phenotype
  - Neither is more dominant than the other
  - Eg Human Blood type: AB
- **Sex Linkage**
  - Sex is genetically determined
  - Sex-linked genes are those located on the sex chromosomes
  - This gives a unique pattern of inheritance
- **Colour Blindness**
  - “Inability to distinguish between certain colours”
  - A Sex-linked trait
  - Due to a recessive allele on the X chromosome
  - Females need to have 2 recessive genes to be affected (due to 2 X chromosomes)
  - Males need to only have 1 recessive gene to be affected (due to 1 X chromosome)
  - This is why colour blindness is more common in males than females
- **Haemophilia**
  - Sex Linked disease
  - People suffering from Haemophilia do not have the protein responsible for clotting blood
  - Due to a recessive allele on the X chromosome
  - Note its presence in the royal families of Europe

2.3.7 **Understanding sex linkage**
- **Morgan**
  - American geneticist
- **Experiment**
  - Used the Vinegar fly, *Drosophila Melanogaster*, to reproduce Mendel’s monohybrid crosses
  - Vinegar flies usually have red eyes (wild)
  - Morgan found a white-eyed male
  - Tried to explain this by using Mendel’s monohybrid ratio (3:1)
- **Results**
  - Instead found that 100% of females had red eyes, and 50% of males had red eyes
  - Morgan explained these results by saying that the gene for eye colour is located on the X chromosome and there in no corresponding gene on the Y chromosome.

2.3.8 **Homozygous and heterozygous genotypes in co-dominance**
- When alleles are co-dominant, both alleles are fully expressed in the phenotype
- **Shorthorn Cattle:**
  - Both Red and White coat colour alleles are dominant
  - When co-dominance occurs, Roan coloured cattle are produced

2.3.9 **Environment affects gene expression**
- **Hydrangeas**
  - Will have pink or blue flowers depending on the pH of the soil
  - Pink – pH of greater than 7 (alkali)
  - Blue – pH of less than 5 (acidic)
2.4 Changes in DNA

2.4.1 The process & significance of DNA replication

- **Process**
  - An exact copy of DNA is made
  - DNA double helix unzips
  - Nucleus contains many free nucleotides
  - Those join and form a bond between nitrogenous bases
  - Making 2 identical strands of DNA

- **Significance**
  - DNA has the ability to replicate identically
  - Occurs during Mitosis and Meiosis

2.4.2 DNA controls polypeptide production

- **Theory**
  - Proteins are the building materials for organisms
  - Amino Acids are the building blocks of proteins
  - There are 20 different amino acids in the human body
  - Polypeptides contain two or more amino acids
  - Sequence of bases along a DNA molecule determines which amino acid is produced
  - Different base sequences produce different amino acids

- **Polypeptide Synthesis**
  - DNA controls the synthesis of polypeptides
  - Majority of synthesis occurs outside the nucleus in the ribosomes
  - Genetic information is transferred to the ribosomes by RNA (ribonucleic acid)
  - RNA is differs from DNA:
    - RNA is a single strand of nucleotide bases
    - RNA contains ribose sugar
    - Only contains exon (amino acid coding part of DNA)
    - Nitrogenous base Thymine (T) is replaced by Uracil (U)
    - Adenine (A) bonds to Uracil (U) instead of Thymine (T)
  - Two types of RNA involved in polypeptide synthesis:
    - Messenger RNA (mRNA)
    - Transfer RNA (tRNA)

- **Transcription**
  - "The process by which the information on the DNA is transferred to mRNA"
  - **Process**
    - DNA unzips
    - mRNA molecule is created using DNA as a template
    - mRNA molecule exits nucleus, goes into the cytoplasm and attaches to a ribosome and forms a template for production of a polypeptide
  - Only exon is copied – the part that codes for amino acids
  - The non-coding Intron information is not copied

- **Translation**
  - Small tRNA pick up amino acids and transport them to the mRNA on the ribosome
  - tRNA has an anticodon (3 unpaired bases) and 1 amino acid
  - There are different types of tRNA for the different amino acids
  - Anticodon attaches to the matching codon on mRNA
  - Amino acid attached to the other end of the tRNA forms a polypeptide bond with the new amino acid and forms a polypeptide chain
  - When the sequence reaches a STOP codon, the polypeptide is released to be used by the cell
2.4.3 Relating proteins and polypeptides
- Polypeptides join to make up proteins
- Proteins contain many polypeptides

2.4.4 Mutations as a source of new alleles
- Mutations
  - “Changes in the DNA information on a chromosome”
  - Are a source of new alleles
  - Are random and most are lethal
  - Some are beneficial and could give an organism a selective advantage
  - Small changes in DNA = large-scale alterations
  - Mutations are caused by:
    - Deletion – DNA is lost
    - Duplication – a section of DNA is copied twice
    - Substitution – a different base is included
    - Inversion – DNA breaks and rejoins the wrong way
- Sickle-cell anaemia
  - A single mutation on the haemoglobin molecule
  - Results in the production of a different amino acid (valine instead of glutamic acid)
  - This produces a genetic change = different shape of red blood cells

2.4.5 Mutagenic nature of radiation
- Mutagens
  - “Factors that cause mutations”
  - They interact with DNA and cause changes to the DNA sequence
  - A mutagen that causes cancer is called a “carcinogen”
  - A mutagen that causes a birth defect is called a “teratogen”
  - Only mutations in sex cells are passed on to the next generation
- Examples of Mutagens – High energy electromagnetic radiation:
  - X-Rays
  - Alpha/Beta/Gamma rays
  - Ultraviolet radiation

2.4.6 Understanding of variation supports Darwin’s theory
- Sources of variation in organisms:
  - Random (independent) assortment of chromosomes during meiosis
  - Random pairing of gametes at fertilisation
  - Crossing-over during meiosis
  - Mutation
- Variety in a population
  - Evolution occurs due to the variation of individuals
  - Sexual reproduction ensures that individuals differ from each other
  - Selective pressures determine the individuals that survive and reproduce
  - Sources of new genes (eg mutations) increase variation in a population and support Darwin’s theory of evolution

2.4.7 Punctuated Equilibrium
- “Theory of evolution which suggests that long periods of equilibrium are punctuated by sudden environmental changes which lead to rapid evolutionary changes”
- Support for theory is the lack of fossil records which is claimed to the “state of equilibrium”.
2.5 The Impact of Reproductive Technologies and Genetic Engineering

2.5.1 Current reproductive technologies

- **Artificial Insemination**
  - “The fusion of sperm and ova with the normal mating process”
  - **Livestock breeding**
    - Artificial insemination is used to quickly produce desirable characteristics
    - Eg Sperm from a good meat producing bull is used to inseminate thousands of female cattle
    - The process results in a reduction in genetic diversity in the population
  - **In Vitro Fertilisation (IVF)**
    - Humans
    - Fertilisation occurs outside of the body
    - Embryo is then implanted into the uterus
    - Enables normally sterile parents to produce offspring

- **Artificial Pollination**
  - Pollen from the stamens of one plant is dusted onto the stigmas of another
  - Removing immature stamens eliminates self-pollination
  - Genetic composition of a population can be rapidly changed to suit the breeder’s requirements

- **Cloning**
  - “Producing individuals that are genetically identical”
  - **Cuttings of plants**
    - Simple method of cloning
    - Identical plants are produced
  - **Tissue culture**
    - More complex cloning technique
    - Used with plants
    - A few cells of an organism are grown in culture into a mature organism
  - A particularly desirable characteristic can be rapidly spread through a population
  - Now being used on animals (eg Dolly)
2.5.2 Processes used to produce transgenic species

- Transgenic Species
  - “When a gene from one species is placed into another”
  - Done through:
    - Recombinant DNA technology
    - Genetic Engineering

- Reasons for creating a transgenic species:
  - Increasing crop yields
  - Increasing resistance to pests/disease
  - Increasing the ability to survive harsh conditions

- The 3 steps in producing a transgenic species:
  - Restriction enzymes – cut the DNA
  - Ligases – strengthen the bonds in the recombinant DNA
  - Polymerase Chain Reaction – creates billions of copies

- Main methods used to create transgenic species
  - Microinjection
    - DNA from one species is inserted into a cell
    - Using a fine glass needle or micro-pipette
    - This is the most common method used
  - T\textsubscript{i} plasmid
    - Bacterium \textit{Agrobacterium Tumefaciens} inserts its DNA into plants
    - The infection causes a tumour, called a “crown gall”
    - T\textsubscript{i} plasmid = Tumour Inducing plasmid
    - Desirable gene is inserted into the bacterium’s plasmid
  - Biolistics
    - Gene gun fires small metal particles coated with DNA into another cell nucleus
  - Electroporation
    - Cells are exposed to short electrical impulses
    - Small pores (holes) form in the membrane
    - Allows new genes to be inserted

2.5.3 Potential impact of reproductive technologies on genetic diversity

- Potential impact:
  - Individuals vary within natural populations
  - This gives the population the ability to adjust to environmental change
  - Use of reproductive technologies reduces natural variation by deliberately producing large numbers of identical organism quickly
  - Genetic uniformity in agriculture has produces monoculture.
  - This reduces the ability of farmers to react to changes in the environment (eg new pests)
  - Transgenes can move into the surrounding population
  - Knowledge of the potential impact is incomplete

- Genetically modified plants
  - Bt Cotton
    - Insect resistant cotton
    - Insects could develop immunity to Bt Cotton

- Genetically modified animals
  - Salmon
    - Genetically modified to grow bigger than normal salmon
Additional Information – Model of Natural Selection
- Used a computer based program where you affected the population by clicking (killing) coloured dots
- Results
  - Brightly coloured dots were easy to see and were clicked more often
  - The dots more resembling the background were harder to see, and were clicked less often
  - The dots which were harder to see thrived

Additional Information – Environmental change can lead to changes in a species
- Environmental change & Bent grass
  - Bent grass occurs in a copper contaminated area and a non-contaminated area
  - Grass from the contaminated area
    - Thrive in the contaminated soil
    - Are out competed in non-contaminated soil
  - Grass from non-contaminated area
    - Thrive in the non-contaminated soil
    - Cannot survive in the contaminated soil

Additional Information – Pentadactyl Limb
- Range of vertebrate forelimbs are compared and analysed
- Bones carefully observed and labelled
- This indicates the homozygous structures and the relationship between the different organisms

Additional Information – Advances in Technology have changed Scientific thinking about evolutionary relationships
- DNA Hybridisation
  - Recent advance
  - Allowed comparisons of chemicals in organisms
  - Species that share a common recent ancestor are closer chemically
  - Evidence to support previous classification schemes
  - New links discovered
- Method
  - DNA of two species is extracted
  - Restriction enzymes are used to split the DNA into smaller pieces
  - DNA is heated so that DNA molecules separate
  - Strands of DNA are allowed to mix and cool
  - DNA strands collide, and reform double strands of DNA
  - The more in common the 2 species are, the more areas of DNA join properly
- Changed thinking
  - Before this technology, Gorillas were thought to be most related to Humans
  - Now, Chimpanzees are more closely related to Humans
  - Before this technology, Giant panda & panda both in bear family
  - Now, Giant panda in Bear family, lesser panda in racoon family

<table>
<thead>
<tr>
<th>Primate</th>
<th>% DNA Similarity to Humans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chimpanzee</td>
<td>97.6</td>
</tr>
<tr>
<td>Gorilla</td>
<td>96.5</td>
</tr>
<tr>
<td>Rhesus Monkey</td>
<td>91.1</td>
</tr>
</tbody>
</table>
**Additional Information – Historical Development of Theories of Evolution**

- **Theories of Evolution**
  - Leonardo da Vinci (1452-1519)
    - Found fossil shells high up on mountains
    - Concluded that the shells had been buried in a long gone sea
  - George-Louis Buffon (1707-1778)
    - Suggested life was older than 6,000 years
    - Organisms changed over time
  - Carolus Linnaeus (1707-1778)
    - Suggested that organisms could change through hybridisation
    - He grouped organisms together to show their similarities
  - Erasmus Darwin (1731-1802)
    - Suggested that the strongest & most active individuals would survive
  - Jean-Baptist Lamarck (1744-1829)
    - Suggested that features acquired during the lifetime of an organism would be passed onto its offspring
    - E.g., Giraffe’s neck would stretch to reach leaves, offspring would have long neck of their parents
  - James Hutton (1726-1797)
    - Suggests that geological changes happen gradually (gradualism)
  - Cuvier (1769-1832)
    - Documented fossils changed the deeper he dug
    - Fossils in deeper layers more different from modern species
    - Also noted extinctions were common
  - Charles Lyell (1797-1875)
    - Suggested that geological processes occurred at the same rate in the present as they did in the past (uniformitarianism)
  - Alfred Wallace (1823-1913)
    - Independently came up with the theory of natural selection
  - Charles Darwin (1809-1882)
    - Developed modern theory of evolution

- **Social and political influences**
  - Darwin’s ideas caused a revolution in scientific thought
  - At the time it was believed the Earth was 6000 years old
  - And each species was created in its present form by god
  - Threatened the power of religious institutions
  - Power from religion to science

**Additional Information – Describe an example of Hybridisation**

- Santa Gertrudis Cattle in 1910
  - Crosses a Brahman Bull with a Shorthorn cow
- **Characteristics**
  - Brahman Cattle – High degree of heat and tick resistance
  - Shorthorn Cattle – High meat quality and little/no hump

**Additional Information – Effect of Environment on Phenotype**

- Wheat
  - Two sets of Wheat plants grown in controlled conditions
  - Amount of light varied
  - High (phenotype) as affected
Additional Information – Watson, Crick, Franklin and Wilkins

- Discovering the structure of DNA
  - Watson
    - Worked with Crick to model the structure of the DNA molecule
    - Suggested that pairing of bases made it possible to copy & pass on genetic information
  - Crick
    - Worked with Watson to model the structure of the DNA molecule
    - Studied the genetic code
  - Franklin
    - Used X-ray crystallography to discover the shape of DNA – The double helix
  - Wilkins
    - Studied the structure of large molecules
    - Informed Watson and Crick of Franklin’s discoveries

Additional Information – Simple Model for Polypeptide Synthesis

\[ \text{DNA} \rightarrow \text{mRNA} \rightarrow \text{tRNA} \rightarrow \text{Amino Acids} \rightarrow \text{Polypeptide} \rightarrow \text{Protein} \]

Additional Information – Beadle & Tatum’s “One Gene – One Polypeptide” Theory

- Beadle & Tatum
  - 1941, published results of experiments
  - Showed that genes control biochemical processes
  - Experiment
    - Subjected spores of mould to X-Rays to cause mutations
    - Found that some mutated spores could not grow unless they added a specific amino acid/vitamin
  - Discovered that the amino acid required was arginine, which was produced in a 3-step path
  - They hypothesised that the X-rays had destroyed the gene that coded for the enzyme to make arginine
  - Without the correct gene there would not be any enzyme created
  - “One Gene = One Enzyme” theory
- Change to “One Gene = One Enzyme” Theory
  - Not all proteins are enzymes
  - Changed to “One Gene = One Protein”
  - Enzymes studied were made up of only 1 polypeptide
  - There is one gene for each polypeptide in the chain of polypeptides that make up an enzyme

Additional Information – Modern Example of Natural Selection

- Antibiotics & “Natural” selection
  - When antibiotics first introduced they were very effective in killing bacteria
  - Bacteria developed resistance to antibiotics
  - The effectiveness of treatments decreased
  - Eventually the treatment will become ineffective as the bacteria adapts
- The rise of “Superbugs”
  - Bacteria that have developed resistance to all known antibiotics
  - Golden Staph – Most notable superbug
  - Manuka Honey – works against Golden Staph
  - Bacteria cannot develop resistance
Additional Information – Method of Cloning

- Nuclear Transfer
  - Transferring a nucleus from one cell to another
  - The Sheep “Dolly” in 1996
  - Method
    - Nucleus of the donor ewe is made dormant by putting it into a nutrient poor environment
    - Nucleus added to a cell with its nucleus destroyed
    - Electric pulse fuses the egg cell
    - Egg cell develops into a cluster of cells
    - Cluster is implanted into surrogate mother
    - Lamb produced is identical to donor

Additional Information – Examples of Transgenic Species

- Bt Cotton
  - Bacteria added to genome
  - Bacteria naturally produces a chemical that kills insects
  - Cotton produces its own pesticide
- Roundup Ready Soy Beans
  - Roundup is a widely used pesticide
  - Soy beans have been GM to tolerate Roundup
  - Farmers can spray entire crops, without damaging plants
- OncoMouse
  - Mouse with Human cancer gene
  - Mouse only lives for 8 weeks before dying
  - Used in the search for the cure of cancer
- Tomatoes
  - GM to block the production of the ripening enzyme
  - Results in tomatoes that ripen slowly, extending shelf-life
3.1 – What is a healthy organism?

3.1.1 Defining health and disease
- Health
  - Absent of disease
  - Free of disease
- Disease
  - Any condition that adversely affects the normal functioning of the body

3.1.2 Health and disease at a cellular level
- Health and disease mainly affect cells and tissues of the body
- Some diseases however exist at the cellular level – genetic diseases
3.2 – Preventing Disease

3.2.1 Infectious and Non-infectious disease

- Infectious Disease
  - Caused by Pathogens – “disease causing organisms”
  - Transmitted from one organism to another
  - From the environment to an organism
  - Infectious diseases spread when:
    - Pathogens can be spread in large enough numbers
    - Pathogens are Virulent (instant infection, very severe)
    - Pathogens are able to survive outside a host – be readily transferred
    - Pathogens are able to enter a host’s body and reproduce without being destroyed by the Host’s defence systems

- Non-infectious Disease
  - Illnesses that are not caused by pathogens
  - Include:
    - Inherited diseases
    - Environmental diseases
    - Nutritional (“deficiency”) diseases

3.2.1 Cleanliness & Hygiene

- Aim: Prevention of disease
- History
  - Hebrews, separated ill people and washed foods/objects
  - Chinese, Taoists developed hygiene rules
- Principles helped to protect people from disease
- Similar techniques are still used today because they are effective in controlling disease:
  - Good personal hygiene
    - Washing your hands
    - Covering coughs and sneezes
    - Reduce the spread of pathogens
    - Washing body – removes bacteria that could cause disease
  - Good community hygiene practices
    - Sewage
    - Garbage disposal
    - Regulations on the preparation & handling of food
  - Cleanliness in food
    - Food processing & preparation reduce the risk of contaminated food
    - Requirements that food is fresh and properly stored
  - Cleanliness in water
    - Water is used for drinking and food preparation
    - Ensuring it is safe also reduces the risk of contamination

3.2.3 When are microbes Pathogenic?

- Wide range of organisms can be pathogenic
- Organisms that can cause disease:
  - Prions
  - Viruses
  - Bacteria
  - Protozoans
  - Fungi
  - Worms
3.3 – Micro-organisms and Disease

3.3.1 Louis Pasteur and Robert Koch
- Louis Pasteur
  - mid 1800s
  - Researched the contamination that occurred during the fermentation of wine/beer
  - Discovered that microbes (yeast) were responsible for alcohol
  - Other microbes (bacteria) resulted in acid being produced
  - Studied milk, and found again that bacteria caused milk to go sour
  - Germ theory of disease
    - Germs (microbes) cause disease when they invade and live inside the body
- Robert Koch
  - 1870s
  - Tested Pasteur’s findings
  - Injected healthy mice with anthrax bacteria, all mice became infected

3.3.2 Types of pathogens

<table>
<thead>
<tr>
<th>Type of Pathogen</th>
<th>Description of pathogen</th>
<th>Example of pathogen</th>
<th>Disease caused</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prion</td>
<td>Tiny particle made of protein. An abnormal form of a protein needed within the organism</td>
<td>Prions are named after the disease they cause</td>
<td>• Kuru (humans)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Mad Cow Disease (cattle)</td>
</tr>
<tr>
<td>Virus</td>
<td>Small particle containing RNA/DNA inside a protein coat. Only able to reproduce within a living cell</td>
<td>Named after the disease they cause:</td>
<td>• Influenza (flu)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Influenza virus</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Smallpox virus</td>
<td></td>
</tr>
<tr>
<td>Bacterium</td>
<td>Single-Living prokaryotic cell</td>
<td>• Staphylococcus aureus</td>
<td>• Golden Staph</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Clostridium tetani</td>
<td>• Tetanus</td>
</tr>
<tr>
<td>Protozoan</td>
<td>Single-Living eukaryotic animal-like cell</td>
<td>• Plasmodium</td>
<td>• Malaria</td>
</tr>
<tr>
<td>Fungus</td>
<td>Eukaryotic, non-photosynthetic cell with cell walls</td>
<td>• Candida albicans</td>
<td>• Thrush</td>
</tr>
<tr>
<td>Macro-parasite</td>
<td>Variety of animals that cause infection</td>
<td>• Tapeworm</td>
<td>• Tapeworm infestation</td>
</tr>
</tbody>
</table>

3.3.3 Using antibiotics
- Antibiotics
  - Kill or prevent many types of bacteria from growing
  - Different antibiotics affect bacterial processes in different ways
  - Different antibiotics therefore work better on different types bacteria
  - Misuse of antibiotics (penicillin) can lead to antibiotic resistance in bacteria
3.4 – Response to disease

3.4.1 Barriers for defence

- Body has numerous barriers
  - Skin
    - Is dry and dead
    - Flakes or washes off, removing bacteria
  - Mucous membranes
    - Line some organs of the body
    - Organs of the respiratory system
    - Mucous traps micro-organisms to remove them from the body
  - Cilia
    - Tiny hairs that trap debris
    - Move mucus
  - Chemical Barriers
    - Acids in stomach
    - Tears – contain chemicals to wash and clean eyes
    - Saliva – cleans and reduces bacterial growth in the mouth

- Surfaces that interact with the environment always have a coating of organisms
- Surfaces include:
  - Skin
  - Lining of respiratory system
  - Lining of alimentary canal (in digestive system)
  - Lining of the female reproductive system
- Organisms that live on these surfaces are called “microflora”

3.4.2 Triggering the immune response

- Antigens
  - Substances the body recognises as foreign
  - Trigger the immune response
- Antibodies
  - Proteins that are produced in response to antigens to inactivate or destroy the antigens

3.4.3 Organ transplants

- Patients who receive organ or tissue transplants must take drugs to suppress the immune response
- These drugs are called “immunosuppressants”
- This is because the transplant could be wrongly identified as an antigen and attacked/rejected by the immune response
3.4.4 Other defence responses

- White Blood Cells – important role in protecting the body from infection
- Defence adaptations of the human body:
  - Inflammation response
    - When the body detects an antigen in tissue
    - Blood vessels dilate do more blood reaches the affected area
    - Capillary walls begin to leak, letting more plasma & white blood cells move into the tissue
    - Purpose is to bring as many white blood cells as possible
  - Phagocytosis
    - White blood cells called “neutrophils”
    - Cells ingest a foreign object
    - Produce lysozymes, enzymes that destroy the engulfed object
    - Marcophages also perform phagocytosis
3.5 – Acquired immunity against disease

3.5.1 Components of the immune response

- Acquired immunity
  - Done through antibodies and lymphocytes
  - Antibody production is controlled by lymphocytes
  - Control is important, so that antibodies do not attack bodies chemicals

- B-Cells
  - B Lymphocytes made in the bone marrow ("b" = bone marrow)
  - Each B Cell has a antibody on its surface that can bind with a particular chemical shape
  - When a B Cell encounters an antigen
    - It moves into the lymph node where it is rapidly cloned
    - B Cell clones are plasma cells, which produce antibodies
    - Some B Cell clones become memory B cells
    - They remain in the body, ready to respond to another future infection

- T-Cells
  - Made in the bone marrow and lymph nodes
  - Effects of hormones produced in the Thymus gland (T Cells)
  - Live for longer than B Cells
  - Main role: destroying infected cells and cancer cells

3.5.2 Interactions between lymphocytes

- Interaction between lymphocytes
  - B cells can prevent T cells from replicating and acting
  - B cells can kill T cells and vice versa
  - A B cell can concentrate antigens by collecting them onto the cells surface
  - Antigens are then presented to the T cells to stimulate a T cell response
  - T cells are able to pass an antigen between cells so that many T cells can quickly become involved with B cells in response to an antigen

- Types of T Cells
  - Killer (Cytotoxic) T Cells
    - Develop & behave like B cells,
    - But instead of an antibody on the surface of each cell, T cells have a T cell receptor (TCR)
    - Each T cell searches for a matching antigen type
    - When found, the T cell cloning begins to destroy the cells
  - Memory T Cells
    - Produced during cloning
    - Behave like memory B cells
  - Helper T Cells
    - Not directly involved with the destroying of damaged/infected cells
    - Use TCRs to recognise antigens on B cells
    - Produce chemicals called “cytokines” which help Killer T cells locate and destroy it and also stimulate the production of more B & T cells
  - Suppressor T Cells
    - Produced during cloning
    - Role: “turn off” the production of other lymphocytes when the antigen has been removed
    - Protecting the body from immune attacks on itself
3.5.3 Vaccination to prevent infection

- Vaccination
  - “Inoculating organisms to cause them to develop immunity to a disease”
  - The Vaccine contains antigens that trigger the immune response
  - 3 main types of vaccines:
    - Live, attenuated (weakened) disease causing organisms (eg Polio)
    - Dead organisms, contain antigen that trigger antibodies (eg Typhoid fever)
    - Inactivated form of a toxin (“toxoid”) (eg Diphtheria)
  - To be effective, numerous vaccinations need to occur over a number of years

3.5.4 Acquired immunity and organ transplants

- Problems with organ transplants
  - Effectiveness of the immune response a problem
  - Organ transplant patients often have to take immunosuppressant drugs to stop the immune system from attacking the transplanted organs
  - Also Tissue Typing is used to try and get the closest possible match, this helps to minimise the risk of rejection
3.6 – Epidemiological Studies

3.6.1 Epidemiology
- “Study of the distribution and frequency of diseases”
- Scientists can find patterns in diseases
- This helps to locate the cause of the disease
- Smoking & Lung Cancer link found by epidemiology

3.6.2 Causes of non-infectious diseases
- See additional information on non-infectious diseases

3.7 – Modern disease control strategies

3.7.1 Quarantine
- Isolation of diseased organisms is a very old strategy of preventing the spread of disease
- Methods have become more sophisticated due to increased travel and transportation
- Regulations imposed by governments help to stop the spread of diseases

3.7.2 Other disease control strategies
- Public health programs
  - Exist to ensure clean water, sewage and garbage disposal
  - Goods are sprayed to kill organisms and insects
- Pesticides
  - Widely used to poison insects and other organisms
  - Malathion, used to kill malaria carrying mosquitoes
- Genetic Engineering to produce disease-resistant plants & animals
  - Genes can be introduced to make them resistance to disease (transgenic)
  - Bt Cotton = disease resistance crop – produces its own pesticide
  -
Additional Information – Gene expression and the maintenance & repair of body Tissue

- Genes contain coded information for proteins
  - Proteins made for repair & control of tissue function
  - If a gene is faulty, protein will not be produced
  - PKU (Phenylketonuria) is a disease that occurs in people with 2 non-expressed PKU genes
- Genes operate/are expressed as they are needed
  - Gene expression is controlled
  - This is so that the chemical produced are the required rate within cells
  - Increase/decrease in response to a disease to repair tissue
  - Eg Skin cells grow at an increased rate after being cut
- Mitosis
  - Response to a disease, damaged cells & tissue need to be replaced
  - Uncontrolled cell growth (cancer) is a disease
  - Genes control the rate of cell division
  - Faulty genes = cancer

Additional Information – Identifying Microbes

- Method:
  - 5 Petri dishes set up
  - Each had same amount of cheese
  - Differing qualities of water (pond, river, tap, distilled, sewage)
  - Control = distilled water
  - Incubated for 48 hours
- Results
  - Sewage = most growth, had the most microbes
  - Distilled = tiny growth
  - Tap = little growth
- Conclusions
  - “Sewage” cheese, had growths of 2 different types of fungus and bacteria

Additional Information – Ways in which drinking water is treated

- Screening
  - Large metal grates
  - Physical system
  - Removes objects that would rot & create microbes
- Flocculation
  - “Making organic matter to form clumps”
  - Clumps are then removed
- Filtering
  - Beds of stones and sand
  - Also used to remove clumps formed during flocculation
- Chlorination
  - Adding a small percentage of chlorine into the water kills any remaining microbes
- Ozone Treatment
  - Injected into water
  - Effective
- UV treatment
  - Ultra Violet light may be used to kill microbes
  - Radiation of light kills microbes
Additional Information – Pasteur’s Experiments

Initially

This flask of broth was untreated.

After three days in a warm place

Microbes present in the broth have grown, making the broth decay.

Open glass tube

This flask of broth was boiled to kill all microbes present in the flask and broth.

Microbes have entered to flask through the open tube. They have grown, making the broth decay.

Conical flask

Clear broth

Glass tube sealed by water in the U-bend

This flask of broth was boiled to kill all microbes present in the flask and broth.

Microbes are not present in the flask. They cannot enter through the water seal. No decay has occurred.
Additional Information – Historical development of our understanding of the cause and prevention of Malaria

- Symptoms:
  - Periodic fever
  - Anaemia
  - Enlargement of spleen
- Name “Malaria” comes from Roman times (2000 years ago)
- Quinine used in the 1600s to treat malaria
- 1880, Laveran discovered the pathogen that caused malaria, the protozoan Plasmodium
- 1897, Ross discovered that malaria was transmitted by Anopheles mosquitoes
- 1898, Grassi discovered that malaria was in the midgut of the mosquito
- Steps of life cycle:
  - Plasmodium infects mosquito
  - Plasmodium developed and spreads to salivary glands
  - Female mosquitoes need a meal of blood
  - Immature plasmodium (sporozoites) transmitted to animal
  - Sporozoites travel through the blood stream to the liver (now merozoites)
  - 12 days merozoites develop & reproduce
  - Reproduce asexually in red blood cells
  - Produce male & female gametes
  - Mosquito intakes male & female gametes when feeding
  - Male & female gametes sexually reproduce in mosquito midgut to form Plasmodium
- 1930s, Atebrin developed – used in WW2
- 1944, synthetic quinine developed from coal tar
- Late 1940s, Chloroquine developed, resistance problem
- 1948, life cycle of plasmodium & mosquito identified
- 1950s, World Health Organisation – coordinated effort to eradicate malaria
  - Used DDT to destroy larvae & extensive use of antimalarial drugs
- 1960s, increase in drug-resistance strains of malaria
- 1980s, Malaria genome project, find better methods

Additional Information – Named Infectious Disease

<table>
<thead>
<tr>
<th>Disease</th>
<th>Diphtheria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cause</td>
<td>Bacterium – Corynebacterium diptheriae</td>
</tr>
<tr>
<td>Transmission</td>
<td>Spread by touch of people, in air, on objects</td>
</tr>
<tr>
<td>Host Response</td>
<td>Acquired immunity can be developed, normal body defences overwhelmed by pathogen</td>
</tr>
<tr>
<td>Major Symptoms</td>
<td>Sore throat, runny nose, swollen neck glands, white/grey membrane</td>
</tr>
<tr>
<td>Treatment</td>
<td>Antibiotics to kill bacteria, antidote for toxin</td>
</tr>
<tr>
<td>Prevention</td>
<td>Highly contagious - People are isolated</td>
</tr>
<tr>
<td>Control</td>
<td>Immunisation</td>
</tr>
</tbody>
</table>
Additional Information – Antibiotic Resistance
- Natural variation in life, come bacteria naturally survive antibiotics
- Natural selection, those that survive, thrive
- Incorrect use of antibiotics
  - Main cause of resistance
  - Using them when they are not needed
  - Treating Viral infections
  - Wrong antibiotic for infection
  - Not completing the full course of antibiotics
- Superbugs developing, resistant to all antibiotics, Golden Staph

Additional Information – Thrush
- Microflora imbalance
- Natural balance normally
- Antibiotics can accidentally kill & lead to imbalance of microflora
- Thrush develops
- 3 main types;
  - Oral thrush
  - Vaginal thrush
  - Intestinal thrush
- Caused by yeast candida albicans

Additional Information – Effectiveness of Vaccination programs in preventing the spread and occurrence of disease
- Smallpox
  - Highly infectious disease
  - Eradicated through vaccination programs
- Polio
  - Disease that causes nerve damage
  - Since widespread immunisation in 1954, infection rate dramatically dropped
- Diphtheria
  - Serious disease
  - Death rate of 35%-90%
  - Immunisation has reduced infection numbers
  - Last reported case in Australia was 1992

Additional Information – Cause and Effect relationship of smoking and Lung Cancer
- 1966, comparisons in USA showed smokers were 10 times more likely to develop lung cancer than non-smokers
- 1970s, millions of people surveyed,
- Clear correlation between smoking and the incidence of lung cancer
- Data from other regions shows that other factors are not to blame
- 1900: most men smoked, no women smoked = high number of male lung cancer
- 1990: less men smoking, more women smoking = less male incidents, increasing female ones
**Additional Information – Non-Infectious Disease**

**Inherited Disease: Phenylketonuria (PKU)**

<table>
<thead>
<tr>
<th>Cause</th>
<th>Recessive genetic disease. When a person has 2 defective PKU genes. Suffers are unable to produce the enzyme needed to break down a common amino acid.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occurrence</td>
<td>1:15,000 - 1:50 people carry the PKU gene</td>
</tr>
<tr>
<td>Symptoms</td>
<td>Mental retardation, poor coordination, shaking, lack of control of muscles</td>
</tr>
<tr>
<td>Treatment/Management</td>
<td>Babies are tested at birth, affected babies placed on a special diet.</td>
</tr>
</tbody>
</table>

**Nutritional Deficiency: Scruvy**

<table>
<thead>
<tr>
<th>Cause</th>
<th>Lack of Vitamin C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occurrence</td>
<td>Rare</td>
</tr>
<tr>
<td>Symptoms</td>
<td>Black gums, Loss/discolouration of teeth</td>
</tr>
<tr>
<td>Treatment/Management</td>
<td>Balanced diet, containing adequate Vitamin C</td>
</tr>
</tbody>
</table>

**Environmental Disease: Skin Cancer**

<table>
<thead>
<tr>
<th>Cause</th>
<th>Ultra Violet Radiation Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occurrence</td>
<td>Common</td>
</tr>
<tr>
<td>Symptoms</td>
<td>Abnormal growth on skin, pain,</td>
</tr>
<tr>
<td>Treatment/Management</td>
<td>Cancer is removed completely, burnt off, sun protection program (slip,slop,slap)</td>
</tr>
</tbody>
</table>

**Additional Information – Effectiveness of Quarantine**

- Australia, AQIS oversee the movement of people & goods into the country
- Restrictions on substances that could potentially contain pathogens
- Quarantine has successful stopped the spread of numerous diseases into Australia
- Some spread before Quarantine was established in 1908
- AQIS destroys serious diseases, eg Newcastle disease in chickens

**Additional Information – Changing Methods of Dealing with Plant & Animal Diseases**

- 150 Years ago, limited understanding of the cause of diseases, reacted to the disease rather than prevent it
- Move to prevent diseases before they occur (vaccinations, quarantine)
- GM organisms that resist infection/pathogens (Bt cotton)