Edexcel (A) Biology A-level

Topic 6: Immunity, Infection and Forensics

Notes

Forensics and Time of Death

Time of death of a mammal can be determined by looking at the following:

1. **Extent of decomposition** – bodies usually follow the same **pattern of decay and decomposition,** starting with the enzymes from the digestive system breaking down the surrounding tissues while cells begin to release enzymes as they are broken down. Therefore a stage of decomposition can be used to determine how long a body has been dead for.

2. **Forensic entomology** – is the study of insects to determine the time of death. Each species of insects has a **specific life cycle.** Determining the age of insects present enables the time of death to be determined.

   The Stage of succession - as the body decays, **the species colonising the body change.** Therefore, analysis of the community of species present can be used to determine time of death.

3. **Body temperature** – temperature of the body begins to decrease after death as **heat-producing metabolic reactions stop.** However, temperature can only be used to determine time of death in the first 24 hours, until the body reaches the temperature of its surroundings. This will also depend upon surrounding conditions such as the size of the body, covering and weather conditions.

4. **Degree of muscle contraction –** after death muscles begin to stiffen as ATP is used up, calcium ions build up in the muscle cells and they become fixed in a state of contraction. This is called **rigor mortis,** and the extent of rigor mortis can be used to determine time of death. Beginning at around 2-4 hours after death, the stiffness only lasts around 36 hours, so limited in use in determining time of death.

Microorganisms such as **bacteria and fungi** play an important role in the decomposition of organic matter and the recycling of carbon (releasing nutrients that were locked up in organic material). Bacteria and fungi **secrete enzymes** that **decompose dead organic matter** into small molecules which they then use as **respiratory substrates** – **carbon dioxide and methane** are released in this process, thus recycling carbon.

DNA Profiling

Not all of the DNA in a genome codes for proteins in the organism. Non-coding regions are known as **introns**, while coding regions are known as **exons**. This gives rise to great genetic variability between organisms both within and between species. The introns consist of many repeating base sequences known as **short-tandem repeats** in sections known as **satellites**.

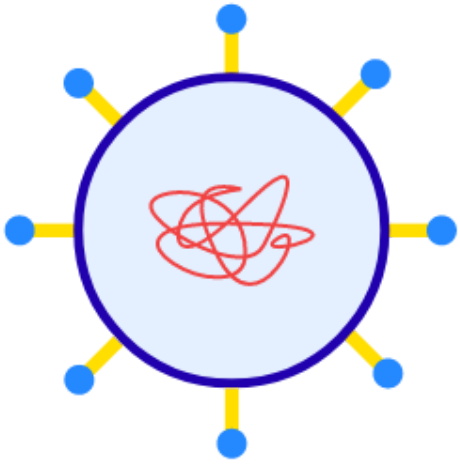
Before the sample can be analysed via DNA profiling, the sample needs to be **amplified** using **Polymerase Chain Reaction**:

1. A reaction mixture is set up by mixing the **DNA sample, primers, free nucleotides and DNA polymerase** which is the enzyme involved in creating new DNA strands.
2. The mixture is then **heated to 95 degrees** to break the hydrogen bonds and to separate the two strands for around **30 seconds.**
3. The mixture is then **cooled to a temperature between 50-65 degrees** depending on the type of primers used, so that they can bind to the strands, this takes around **20 seconds**.
4. Temperature is increased to about **70 degrees** as this is the temperature DNA polymerase works at. **DNA polymerase** creates a copy of the sample by **complementary base pairing using the free nucleotides.** The mixture is left for at least **one minute** for the sample to be amplified. The cycle can then be repeated many times and gives rise to an amount of DNA sufficient to create a DNA profile.

DNA profiling is a forensic technique used for **identification and determining genetic relationships** between organisms. **Gel electrophoresis** is used to separate and visualise the amplified sample:

1. Fragments of DNA are cut with **restriction endonuclease enzymes** (either side of **satellites**).
2. These fragments are placed in wells in agarose gels and dyed with **ethidium bromide** so they fluoresce under UV light. A current is then applied to the gel. DNA is negative hence moves towards the **anode.** Fragments of different sizes move at different speeds, according to mass so 'bands' appear.
3. A nylon or nitrocellulose filter is placed on top of the plate - the dry, absorbent material draws solution containing DNA fragments to the filter. The fragments appear as 'blots'.
4. **Gene probes** (complementary sequences labeled with fluorescent or radioactive markers) are added and bind with the DNA in a process known as **hybridisation**.
5. 'Blots' compared and number of satellites visualised.
   Repeated sequences of DNA in introns are referred to as mini/microsatellites depending on their size. The more closely related two people/species are, the more similar the repeats are.

Bacteria and Viruses



Viruses are **non-living structures** which consist of a **nucleic acid** (either DNA or RNA) enclosed in a protective protein coat called the **capsid**, sometimes covered with a lipid layer called the **envelope**.

Bacteria and viruses are the main disease-causing pathogens in humans. Even though they both cause disease, they vary in many ways:

- Bacteria are **prokaryotes**, meaning that they have no membrane-bound organelles – their genetic material is found in the form of a circular strand of DNA. Viruses consist of just nucleic acid (DNA or RNA) enclosed in the protein coat.
- Bacteria **do not require a host** to survive, whereas viruses do not carry out the processes that define a living organism, they are entirely dependent on their hosts and cannot survive without them; consequently they are not classified as living organisms.
- Viruses are **significantly smaller** than bacteria.
- Bacteria have a **cell membrane, cell wall and cytoplasm**, as well as other organelles such as **ribosomes, plasmids, flagellum and pili**. Viruses possess no such structures.

An example of a bacterial disease is **tuberculosis** (TB). TB is caused by a bacteria called ***Mycobacterium tuberculosis*** which infects phagocytes in the lungs:

- First infection may be symptomless. Infected phagocytes are sealed in **tubercles** in the lungs as a result of an **inflammatory response**.
- Bacteria lie **dormant** inside the tubercles. They are not destroyed by the immune system, as tubercles are covered with a thick **waxy coat**.
- When the immune system becomes weakened, the bacteria become active again, and slowly destroy the lung tissue, thus leading to breathing problems, coughing, and weight loss, as well as fever.
- TB can then spread to other areas of the body, at which stage it can be **fatal**.

An example of a viral infection is **Human Immunodeficiency Virus** (HIV). HIV destroys T helper cells in the immune system leading to AIDS:

- The first symptoms of HIV are flu-like including fevers, tiredness and headaches.
- After several weeks **HIV antibodies** appear in blood, thus making a person HIV positive.
- After this period, the symptoms disappear until the **immune system becomes weakened** again, thus leading to AIDS.
- Symptoms of AIDS include weight loss, diarrhoea, dementia, cancers and opportunistic infections such as TB. These opportunistic infections can lead to death.

Response to Infection

Physical barriers to infection include:

- **Skin** - a tough physical barrier consisting of **keratin**.
- **Stomach Acid** (hydrochloric acid) and enzymes - which **kills bacteria.**
- **Gut and skin flora –** natural bacterial flora **competes with pathogens** for food and space.

The body can respond to pathogens without recognition of their **antigens**. This is known as **non-specific response** and can include:

- **Inflammation –** histamines released by damaged white vessels cause vasodilation, which increases the flow of blood to the infected area and increases permeability of blood vessels. As a result, antibodies, white blood cells and plasma leak out into the infected tissue which can help to destroy the pathogen.
- **Fever –** the hypothalamus sets body temperature higher, increasing the rate of enzyme-controlled reactions. This decreases speed of pathogen reproduction and increases rate of specific immune response. A careful balance must be struck between harming the pathogen and denaturing enzymes in the body.
- **Lysozyme action –** lysozyme is an enzyme found in secretions such as tears and mucus which kills bacterial cells by damaging their cell wall (causing lysis).
- **Phagocytosis -** is a process in which white blood cells engulf pathogens; destroying them by enclosing a pathogen in a phagocytic vacuole with a lysosome.

The **specific immune response** is antigen-specific and produces responses specific to one type of pathogen only. This type of immune response relies on **lymphocytes** produced in the bone marrow:

- **B cells** mature in the bone marrow and are involved in the **humoral response.**
- **T cells** move from the bone marrow to the thymus gland where they mature, they are involved in both the humoral and **cell-mediated response.**

Humoral Response

T Helper Activation:

1. Bacterium is engulfed by a **macrophage**. **Antigens** are displayed on the surface of the macrophage on MHCs (**major histocompatibility complexes**). The macrophage acts as an **antigen-presenting cell** (APC).
2. Macrophage APC binds to T Helper cell with **complementary receptor proteins**.
3. The T Helper cell is 'activated' and divides by mitosis to form **T memory cells** and **active T helper cells.**

Effector Stage:

1. **B cells** with a complementary receptor bind to the antigens upon a bacterium, itself becoming an APC.
2. An activated T helper cell (from the previous stage) with a complementary receptor protein to the antigens binds to the B cell APC. It produces **cytokines**.
3. Cytokines stimulate the B cell to divide by mitosis and form **B memory cells** and **B effector cells**.
4. B effector cells differentiate into **plasma cells**.
5. Plasma cells synthesise antibodies.
6. Antibodies destroy the pathogen by:
    a. **Agglutination** (microbes clump together – makes phagocytosis easier)
    b. **Lysis** (bursting of bacterial cells)
    c. **Opsonisation** (antibodies coat microbes and mark them for phagocytes)
    d. **Precipitation** (soluble toxins are made insoluble)
    e. **Neutralisation** (neutralising harmful toxins)
7. **T Suppressor cells** stop the immune response.

Cell Mediated Response

When a pathogen invades a host cell...

1. The host cell displays the antigens on its **Major Histocompatibility Complexes** and becomes an **Antigen-Presenting Cell**.
2. **T Killer cell** with complementary receptor proteins binds to the APC.
3. **Cytokines** secreted by active T Helper cell stimulate the T Killer cell to divide by mitosis.
4. T Killer cell divides to form **active T Killer cells** and **T Memory cells** (which remain in the body to provide immunity - see below).
5. Active T Killer cells bind to APCs and secrete chemicals which cause pores to form in the cell membrane.
6. The infected cell lyses and dies.

Immunity

Immunity can either be **active or passive**; active **immunity results from the production of antibodies by the immune system** in response to the presence of an antigen whereas passive immunity results from the **introduction of antibodies from another person or animal.**

There are also two subtypes of immunity; natural or artificial:

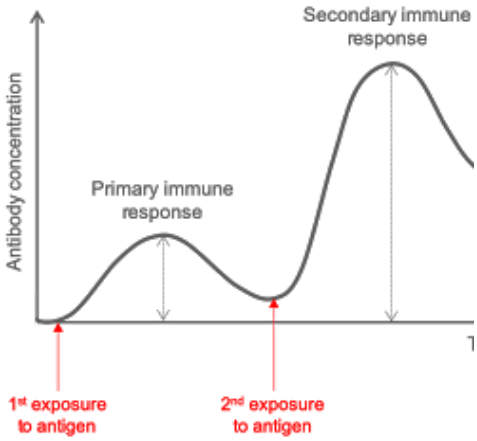
- **Natural active immunity** arises from being exposed to an antigen/getting the disease whereas **natural passive immunity** is the result of crossing of mother's antibodies through the placenta and their presence in breast milk.
- **Active artificial immunity** is acquired through vaccinations which stimulate the immune system and lead to production of antibodies whereas **passive artificial immunity** is where antibodies are injected into the body.

Herd Immunity = enough people have been vaccinated to make transmission of a disease very unlikely. Requires 80-90% vaccination.

Immunisation is the process of protecting people from infection with passive or active artificial immunity via vaccination.

Vaccination is the process by which immunisation is achieved. Vaccines may introduce live but weakened strains of a pathogen (attenuated antigens) or a pathogen/toxin that has been inactivated/killed.

Vaccination is a method of inducing immunity, by prompting a secondary immune response. The first infection results in the production of memory cells, this is the **primary response**. Memory cells can remain in the blood for a long time and provide protection upon re-infection, this is the **secondary immune response**. As a result, the production of antibodies occurs faster and in greater number, as the lag time to produce active lymphocytes is reduced.



Antibiotics

Antibiotics can also be used to fight infection by killing the bacteria and stopping their growth. There are two types of antibiotics:

- **Bactericidal antibiotics** kill bacteria by destroying their cell wall, thus causing them to burst (lysis).
- **Bacteriostatic antibiotics,** which inhibit the growth of bacteria by stopping protein synthesis and production of nucleic acids so the bacteria can't divide and grow.

However, some bacteria become **resistant** to antibiotics as a result of **natural selection**. The bacteria which are not killed by the antibiotic possess a **selective advantage** – resistance which enables them to survive and reproduce. Therefore the allele for **antibiotic resistance** is passed onto their offspring thus creating a **resistant strain.**

Moreover, there is an ongoing **evolutionary race** between organisms and pathogens as **pathogens evolve adaptations** which enable them to survive and reproduce. For instance, the constantly changing protein coat (antigen coat) of HIV means that the virus is not recognised and destroyed by the immune system.

Resistance to antibiotics results in **antibiotic resistant bacterial infections,** sometimes referred to as 'superbugs', **in hospitals,** such as **MRSA.** Hospitals have developed various ways of controlling the spread of antibiotic resistant infections, for example:

- New patients are **screened** at arrival, isolated and treated if they are infected to prevent the spread of bacteria between patients.
- Antibiotics are only used when needed and their course is completed to ensure that all the bacteria are destroyed, and to **minimise the selection pressure** on bacteria, to prevent resistant strains from forming.

- All staff must follow the code of practice which includes **strict hygiene regimes** such as **washing hands with alcohol based antibacterial gels** and wearing suitable clothing which **minimises the transmission of resistant bacteria.**

Post-Transcription Modification of RNA

RNA splicing is a post-transcription modification of mRNA which enables eukaryotes to produce more proteins than they have genes. RNA splicing enables more than one protein to be produced from one gene.

1. A gene is transcribed which results in **pre-MRNA** (the transcript of the whole gene).
2. **All introns** (non-coding regions) and **some exons** (coding regions) are **removed**.
3. The remaining genes are joined back up by enzyme complexes called **spliceosomes**. The same exons can be joined in a variety of ways to produce several different versions of **mature functional RNA**.