WJEC (England) Biology A-level

Option 3A: Immunology and disease

Notes

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

Their differences are as following:

- **Bacteria are prokaryotic cells** meaning that they do not have a nucleus – their genetic information is stored in the form of a **circular strand of DNA** whereas **viruses consist of just nucleic acid enclosed in a protein coat** and their genetic material can take the form of **DNA or RNA**

- **Bacteria do not require a host to survive whereas viruses are entirely dependent on their hosts** and cannot survive without them

- 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 whereas **viruses possess no such structures.**

An example of a bacterial disease is **tuberculosis** also known as **TB.** TB is caused by a bacterium called ***Mycobacterium tuberculosis*** which infects **phagocytes** in the lungs. The first infection is symptomless as the infected phagocytes are sealed in **tubercles** as a result of **inflammatory response in** the lungs. However, the bacteria lie **dormant** inside the tubercles as 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, weight loss as well as fever.** TB can potentially lead to death.

Other examples of bacterial diseases include **cholera** caused by ***Vibrio cholera*** which is particularly prevalent in areas with poor sanitation. Cholera is transmitted in contaminated food and water. Severe diarrhea which is the main symptom of the disease is caused by a toxin which binds to a receptor in the **small intestine** and causes water to move from the lining of the small intestine into the lumen by **osmosis**, thus leading to excessive water loss from the body. The disease can be treated by **oral rehydration therapy**.

An example of a viral infection is **HIV i.e. Human Immunodeficiency Virus** which causes **AIDS.** The first symptoms of HIV include **fevers, tiredness and headaches**. After several weeks **HIV antibodies** appear in the blood thus making a person HIV positive. After this period, the symptoms disappear until the **immune system becomes weakened** again thus leading to **AIDS.**

Other viral infections include **smallpox** caused by ***Variola major* and *Variola minor*** which causes maculopapular rash which eventually turn into blisters and **influenza** caused by **influenza virus.**

Other examples include **Athlete's foot** in humans which is caused by a fungus and is spread by direct contact with the spores on the skin surface or other surface. **Malaria** is an example of indirect transmission via vector in the form of a female mosquito.

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
- **Bacteriostatic antibiotics** which inhibit the growth of bacteria by stopping protein synthesis and production of nucleic acids so the bacteria can't grow and divide

Examples of antibiotics include penicillin which prevents cell wall formation by blocking the synthesis of peptidoglycan polymer cross links.

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 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**

Physical barriers to infection include:

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

Non-specific responses of the body to infection 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 of that antibodies, white blood cells and plasma leak out into the infected tissue and destroy the pathogen
- **Lysozyme action –** lysozyme is an enzyme found in secretions such as tears and mucus which kills bacterial cells by damaging their cell wall
- **Interferon –** interferons prevent viruses spreading to uninfected cells by stopping protein synthesis in viruses
- **Phagocytosis** is a process in which white blood cells engulf pathogens thus destroying them by fusing a pathogen such as bacteria enclosed in a phagocytic vacuole with a lysosome.

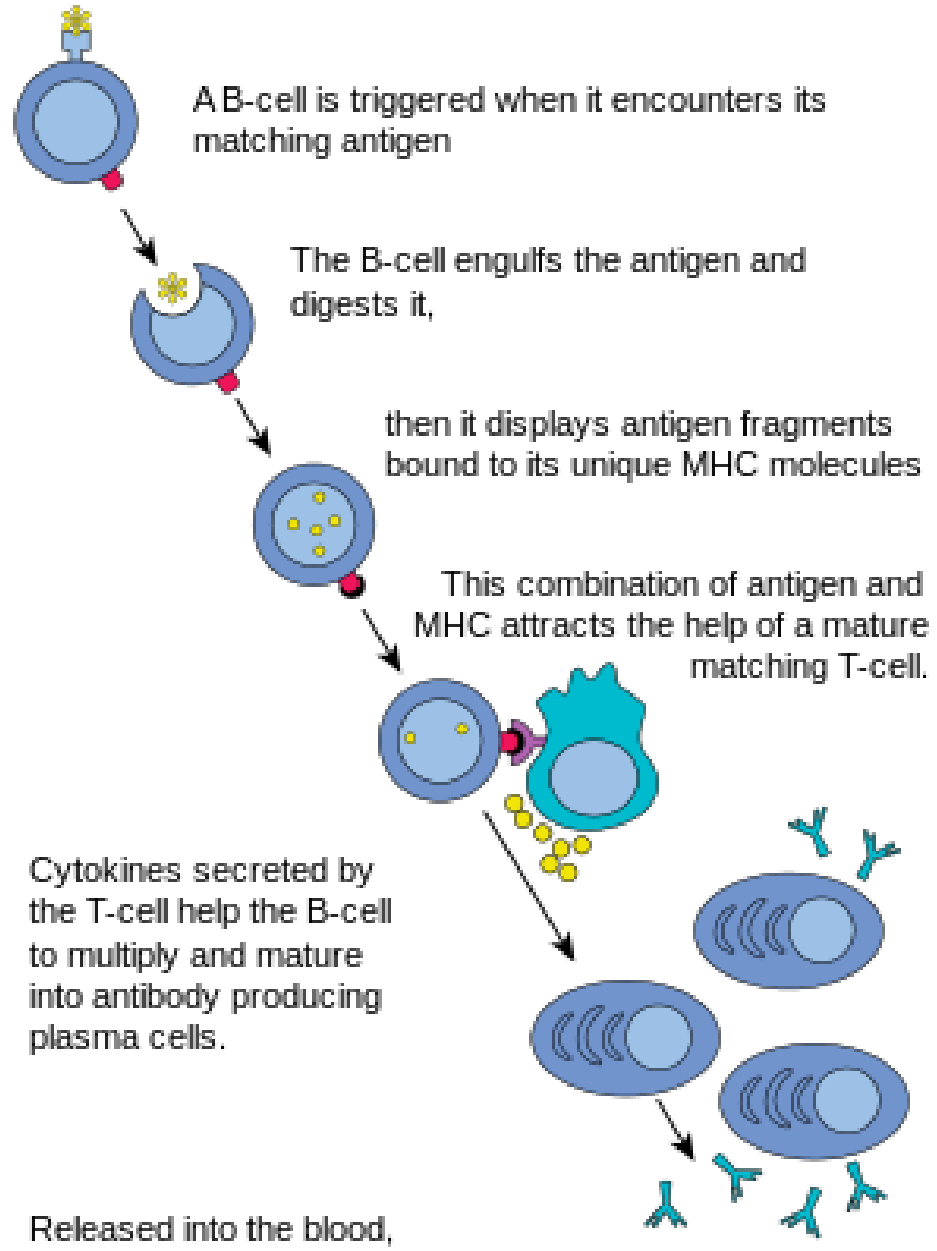
After the pathogen is engulfed and destroyed, its chemical markers called **antigens** are then **presented on the surface of the phagocyte**. The phagocyte then becomes an **antigen presenting cell** which actives other types of immune system, immune response will be stimulated if the antigen is recognised as foreign.
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 **cell mediated response**

Specific immune response glossary:

- **Memory cells** are cells which replicate themselves when exposed to an invading pathogen and remain in the lymph nodes searching for the same antigen thus resulting in a much **faster immune response**
- **B effector** cells are **antibody producing** cells
- **T helper** cells **stimulate B cells and T killer cells to divide**
- **T killer** cells **destroy pathogen infected cells**

Humoral response



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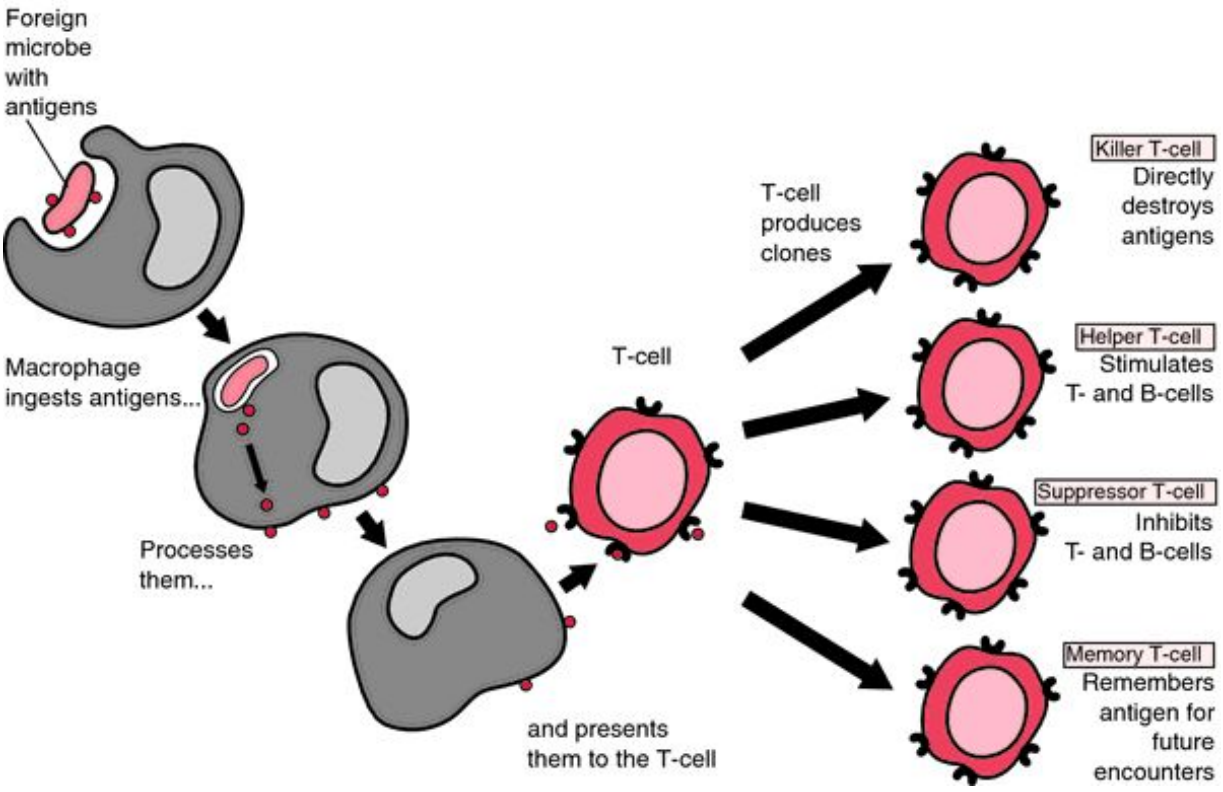
Cell mediated response



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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 e.g. rubella whereas **passive artificial immunity** is where antibodies are injected into the body. E.g. rabies

Antibodies

- Antibodies are **globular molecules** produced by **lymphocytes**. Antibodies are complementary in shape to a specific antigen, to which they attach and subsequently inhibit its action. This process is known as **neutralisation** and can occur in a number of ways, such as facilitating binding of phagocyte to pathogen, agglutination which is where several antibodies bind together as well as neutralisation of toxins released by the pathogen.

- Antibodies are composed **of four polypeptide chains**, which are linked together by **disulphide bridges**. All antibodies possess a region known as the constant region which is involved in phagocyte interaction to stimulate phagocytosis. Antibodies also possess a variable region which differs for each type of antibody, of varying amino acid sequence which is responsible for the specificity of antibody for one particular antigen. All antibodies also contain hinge regions responsible for flexibility of the branches, which is important for binding to multiple pathogens.