OCR (B) Biology A-level

3.2 Pathogens, immunity and disease control

Notes

3.2.1 Pathogenic microorganisms

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

- **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.**

Disease transmission

Diseases can be **infectious** or **non-infectious**. Infectious diseases are caused by **pathogens** and can spread between organisms by physical contact, through the air, or through **vectors** such as mosquitoes. Non-infectious diseases, such as sickle cell anaemia and lung cancer, are not caused by pathogens and are not spread between organisms.

Infectious disease examples:

Name of disease	Pathogen name	How is it transmitted?	How to prevent transmission
Cholera	Vibrio cholerae	Water and food sources	Improve sanitation and hygiene
Malaria	Plasmodium falciparum, Plasmodium vivax, Plasmodium ovale and Plasmodium malariae	Infected female mosquitos	Reduce the number of mosquitos (e.g. by destroying their habitats) and prevent biting by using mosquito nets and insect repellent
Smallpox	Variola	Contact with an infected person or contaminated objects	Use smallpox vaccine; dispose of all contaminated objects

Measles	Morbillivirus	Airborne water droplets from coughing or sneezing	Use measles vaccine; cover mouth and nose when coughing or sneezing
Tuberculosis	Mycobacterium tuberculosis	Airborne water droplets from coughing or sneezing	Use TB vaccine; cover mouth and nose when coughing or sneezing; don't come into contact with others
HIV/AIDS	Human Immunodeficiency Virus	Sexually transmitted and in bodily fluids such as blood	Take HIV medication; use condoms; use clean needles; screen blood donations to make sure they are not HIV positive

Tuberculosis, also known as **TB,** is an example of an infectious bacterial disease. 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.

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.**

Location of diseases:

- **Malaria**- found in hot, humid countries near the equator as these areas have high numbers of mosquitoes to spread the disease.
- **HIV/AIDS**- 95% of infections are in less economically developed countries, mostly situated in sub-Saharan Africa.
- **TB**-occurs in all countries, predominantly in developing and densely populated countries.

To prevent disease, social, economic and biological factors must be considered. Diseases generally spread faster in **densely populated** and **poorly sanitized** areas. Countries with **healthcare systems** and good **education** often have less disease as people are educated on how to prevent the spread of pathogens and can access treatments and vaccines.

Bacterial identification

The simplest classification system of bacteria is based on their **shape** and **arrangement**. Bacteria come in **sphere**, **rod**, **spiral**, **comma** and **filament** shapes.

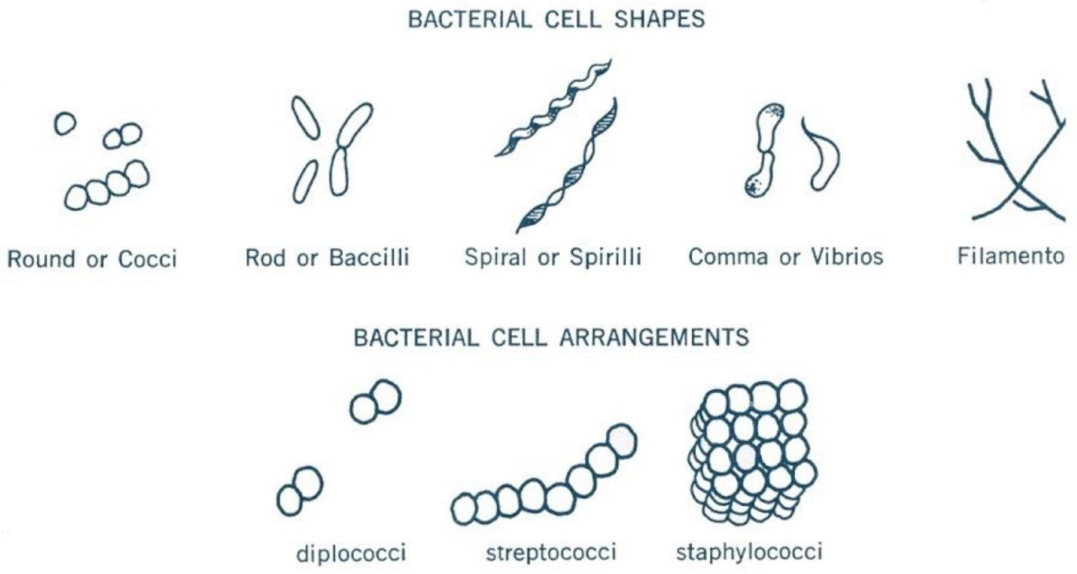


Image source: emilybiologyinteractivenotebook.wordpress.com

Incidence and prevalence of disease

Epidemiology is the study of breakouts and spread of infectious diseases.

Where disease is present constantly over time, it is said to be **endemic**, for example as tuberculosis is endemic to parts of India. When an otherwise absent or infrequent disease surges in cases in a population, it creates an **epidemic**. If an epidemic spreads internationally, then it becomes a **pandemic**.

For example, chickenpox is endemic to the UK, SARS (severe acute respiratory syndrome) caused an epidemic in China in 2002, and H1N1 influenza caused a pandemic in 2009.

Tracking these events requires calculating **incidence rates**, **prevalence rates** and **mortality rates**.

The **incidence rate** of a disease refers to the new cases of infected individuals per population, over a specific time period.

The **prevalence rate** of a disease represents the number of affected individuals per population, over a given time frame. Unlike the incidence rate, the prevalence rate refers to **all** individuals affected by that disease, not just those that have newly acquired it.

The **mortality rate** is the number of affected individuals in the population that have died in a specific time period.

Gram test

Amongst bacteria, the **cell wall composition** is a key determinant of what type they belong to. This is important in terms of predicting their response to various antibiotics. Based on different bacteria species' response to crystal violet stain, Gram positive bacteria are able to take up the stain and appear violet under a microscope, while Gram negative bacteria do not take the stain up

Notifiable disease

Part of controlling and preventing communicable disease in the UK is the legal duty to report **notifiable diseases**. For example, a GP has to inform the local authority whenever a case of a notifiable disease (that must be monitored to prevent spread and contain an emerging epidemic) occurs.

There are around 30 notifiable diseases including leprosy, plague, tuberculosis, food poisoning, anthrax, cholera, malaria, whooping cough and dysentery.

3.2.2 The immune system

Immune response

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

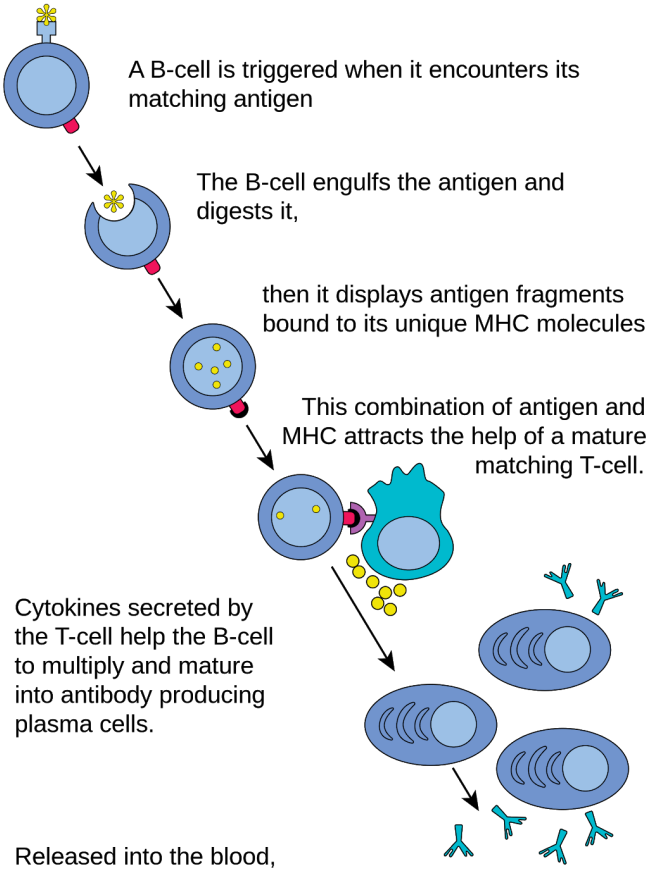


Image source: en.wikipedia.org

Cell mediated response immunity

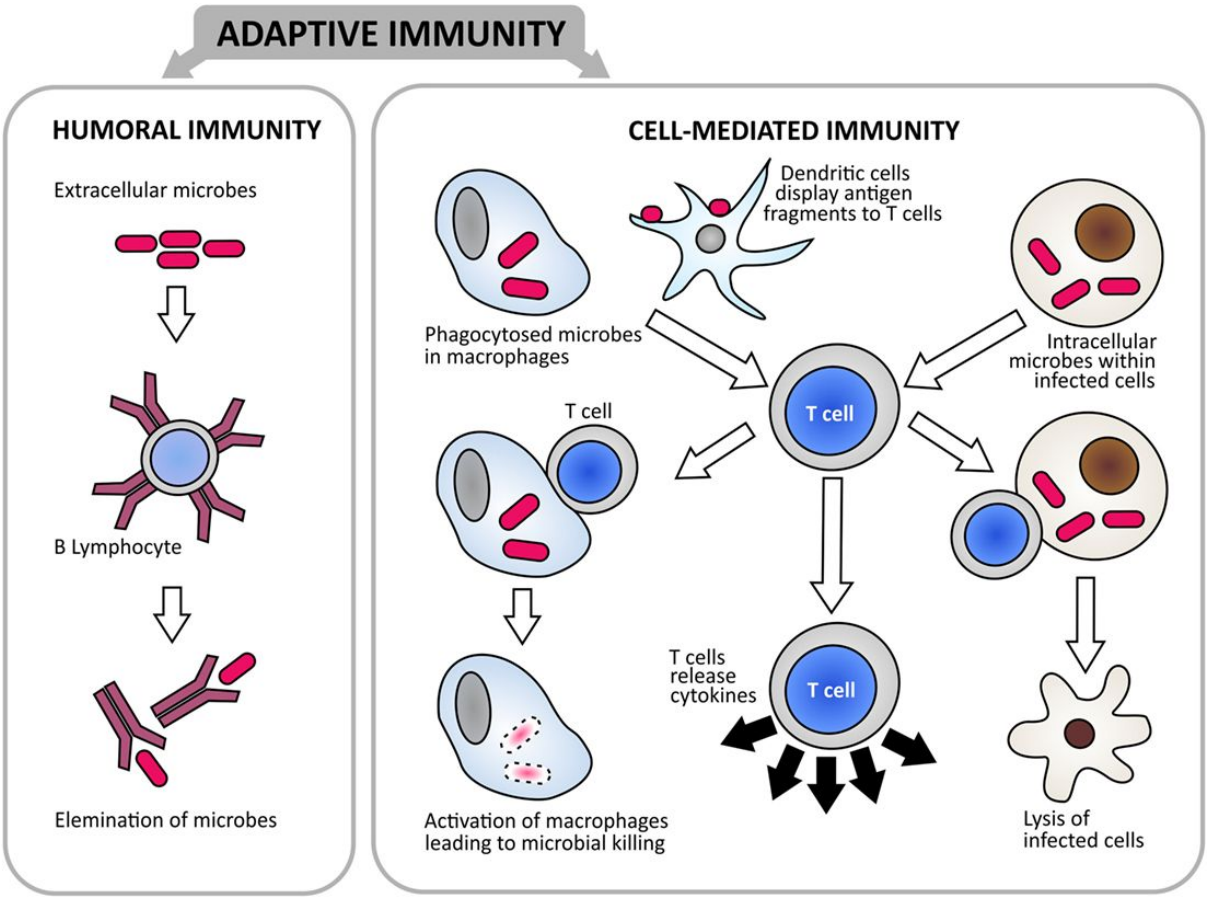
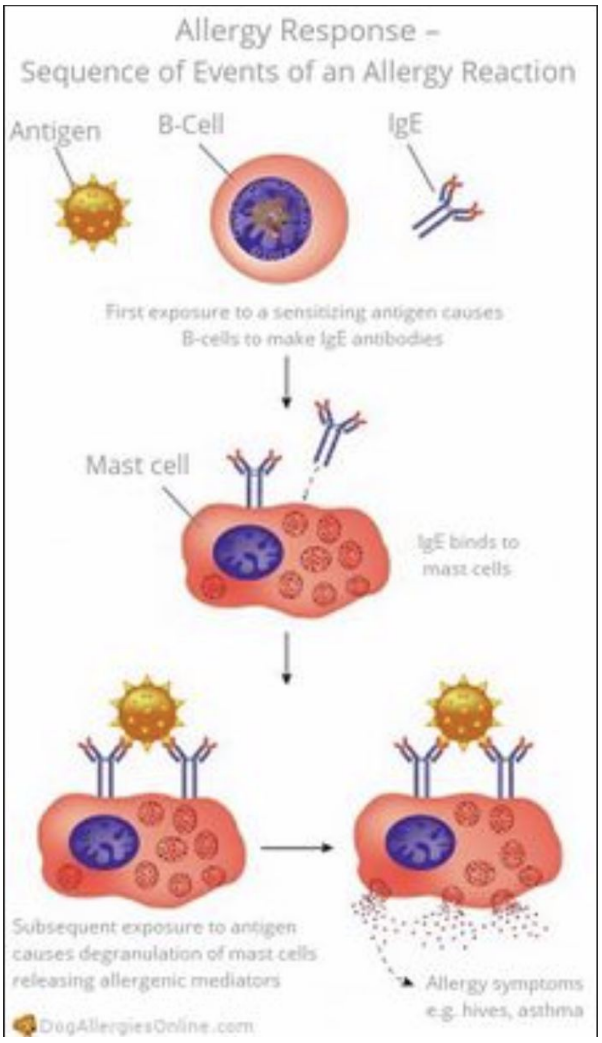


Image source: frontiersin.org

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.

Allergies and hypersensitivity


Allergy Response –
Sequence of Events of an Allergy Reaction
Antigen
B-Cell
IgE
First exposure to a sensitizing antigen causes
B-cells to make IgE antibodies
Mast cell
IgE binds to
mast cells
Subsequent exposure to antigen
causes degranulation of mast cells
releasing allergenic mediators
Allergy symptoms
e.g. hives, asthma
DogAllergiesOnline.com

3.2.3 Controlling communicable diseases

Vaccination

Vaccination provides immunity to specific diseases. A person who had been vaccinated has artificial immunity. This is created by deliberate exposure to **antigenic** material that has been rendered harmless. The immune system treats the antigenic material, as a real disease. As a result, the immune system manufactures **antibodies** and **memory cells**. The memory cells go on to provide the long-term immunity.

The antigenic material used in vaccinations can take a variety of forms:

· Whole, live microorganisms – not as harmful as those that cause the real disease. Possess similar antigens so that the antibodies produced will be effective against the real pathogen (e.g. the smallpox vaccine).

· A harmless or attenuated version of the **pathogenic** organism (e.g. measles and TB vaccines)

· A dead pathogen (e.g. typhoid and cholera vaccines)

· A preparation of the antigens from a pathogen (e.g. hepatitis B vaccine)

· Some harmless toxin (called a toxoid) (e.g. tetanus vaccine)

Vaccination can be achieved by injection, or the vaccine can be taken orally (i.e. polio).

Herd Immunity: is using a vaccine to provide immunity to all or almost all of the population at risk. Once enough people are immune, the disease can no longer spread. In order to be effective, it is essential to vaccinate almost all the population.

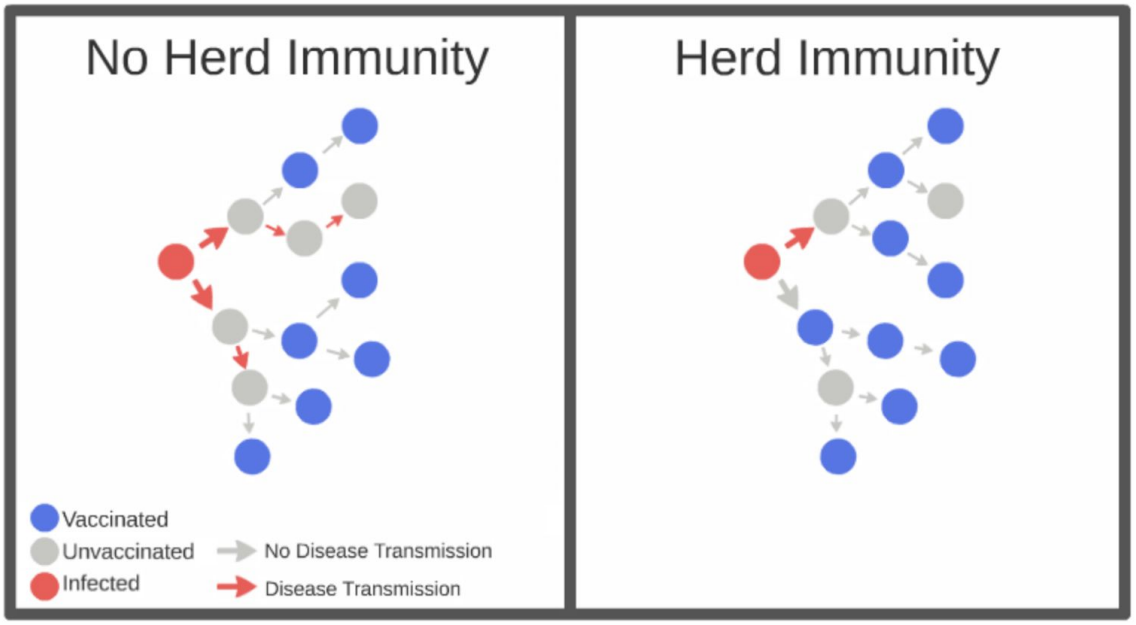


Image source: collegian.com

In the UK there is a vaccination programme to immunize young children against the following diseases: TB, diphtheria, tetanus, whooping cough, polio, meningitis, measles, mumps and rubella.

Human Papillomavirus (HPV)

- A virus with different strains
  - HPV 16 & 18 – linked to cervical cancer [neck of the womb/uterus]
  - HPV 6 & 11 – linked to genital warts
- All girls aged 12-13 are offered a HPV vaccination as part of the NHS vaccination programme.
- Some have stated that early vaccination against a sexually transmitted infection would increase sexual activity due to a false sense of being protected, although this has been shown to not be the case.
- Concerns regarding a failure to continue getting cervical smears have been expressed. - Cervical screening is essential because the vaccine does not provide 100% protection.

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

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**