Immunity

- The immune system
- Vaccination

Learning Objective

Recognise phagocytes and lymphocytes under the light microscope;

The following micrographs show as to how different types of phagocytes and lymphocytes look under the microscope.

The cell with the lobed nucleus [in the centre] is a neutrophill; a type of a phagocyte.

The cell with a horseshoe-shaped nucleus is a monocyte; from the family of phagocytes.
The cell with a uniformly circular nucleus is a lymphocyte; it can either be a B-lymphocyte or T-lymphocyte. Notice its size; which roughly equals that of a RBC.

The comparatively huge cell in the centre is a plasma cell; it is formed upon differentiation [something close to specialization] of B-lymphocytes during an immune response.

**State the origin and describe the mode of action of phagocytes:**

Phagocytes are produces in the bone marrow by the mitotic division of precursor cell. This produces cells that develop into monocytes or neutrophils.

Monocytes are inactive cells which circulate in the blood. They eventually leave the blood, often as the result of encountering chemical signals indicating that bacteria or viruses are present. As monocytes mature, they develop more RER, Golgi apparatus and lysosomes. When they leave the blood they become macrophages. They engulf bacteria by endocytosis and digest them inside phagosomes. Monocytes and macrophages can live for several months.
Similar precursor cells in bone marrow produce neutrophils. These also can travel in blood. They leave the blood in large numbers at sites of infection and engulf and digest bacteria in a similar way to macrophages. A neutrophil lives for only a few days.

Phagocytes are able to act against any invading organism. Their response is non-specific.

**Describe the modes of action of B-lymphocytes and T-lymphocytes;**

**Action of B-lymphocytes**

A B-lymphocyte places some of its specific receptor molecules in its cell surface membrane. If it encounters an antigen that binds with this receptor, the B-lymphocytes is activated. It divides repeatedly by mitosis to produce a clone of genetically identical plasma cells. Some of these synthesis and secrete large quantities of proteins called immunoglobulins or antibodies. The antibodies have the same binding sites as the specific receptors in the B-lymphocyte’s membrane, so they can bind with the antigens. This may directly destroy or neutralise the antigens, or it may make it easier for phagocytes to destroy them.

Some of the clone of B-lymphocyte cells because memory cells. These remain in the blood for many years. They are able to divide rapidly to produce plasma cells if the same antigen invades the body again. More antibody is therefore secreted more rapidly than when the first invasion happened, and it is likely that the pathogens will be destroyed before they have a chance to reproduce. The person has become immune to this pathogens.

**Action of T-lymphocytes**

T-lymphocytes include T helper cells and T killer cells. Both of these types of cell place their specific receptors in their cell surface membranes. On encountering the relevant antigen, they are activated by mitosis to form a clone.

Activated T helper cells secrete chemicals called cytokines. These stimulate B-lymphocytes to produce plasma cells, and stimulate monocytes and macrophages to attack and destroy pathogens.

Activated T killer cells attach to body cells that display the antigen matching their receptor. This happens when a body cell has been invaded by a virus. The T killer cell destroys the infected body cell.
Some of the clones of T cells become memory cells, which remain in the body and can react swiftly if the same pathogen invades again.
Explain the meaning of the term immune response, making reference to the terms antigen, self and non-self;

Explain the role of memory cells in long-term immunity;
Lymphocytes, unlike phagocytes, act against specific pathogens. Each lymphocyte contains a set of genes that codes for the production of a particular type of receptor. We have many million different types, each producing just one type of receptor.

Both B-lymphocytes and T-lymphocytes are made in bone marrow. B-lymphocytes then spread through the body and settle in lymph nodes, although some continue to circulate in the blood. T-lymphocytes collect in the thymus gland, where they mature before spreading into the same areas as B-lymphocytes. The thymus gland disappears at round the time of puberty. Both types of lymphocyte have a large, rounded nucleus that takes up most of the cell. They can only be told apart by their different actions.

During the maturation process, any lymphocytes that produce receptors that would bind with those on the body’s own cells are destroyed. This means that the remaining lymphocytes will only act against non-self molecules that are not normally found in the body. Non-self molecules, such as those on the surfaces of invading bacteria, are called antigens.

Several different types of cell, including macrophages, place antigens of pathogens they have encountered in their cell surface membranes, where there is a good chance that a B-lymphocyte or T-lymphocytes may encounter them. These cells are called antigen-presenting cells.

Memory cells – lymphocytes which develop during an immune response and retain the ability to respond quickly when an antigen enters the body on a second or any subsequent occasion.

**Relate the molecular structure of antibodies to their functions;**

**Antibodies**

Antibodies are glycoproteins called immunoglobulins that are secreted by plasma cells in response to the presence of antigens.
The variable region of the immunoglobulin molecule is specific to the particular clone of B-lymphocytes that secreted it. It is able to bind with a particular type of antigen molecule. Immunoglobulins can:

- Stick bacteria together, making it impossible for them to divide or making it easier for phagocytes to destroy them;
- Neutralise toxins (poisonous chemicals) produced by pathogens;
- Prevents bacteria from sticking to body tissues;
- Bind to viruses and prevent them infecting cells.

**Distinguish between active and passive, natural and artificial immunity and explain how vaccination can control disease;**

In active immunity person makes their own antibodies. This happens when the lymphocytes are activated by antigens on the surface of pathogens that have invaded the body. As this activation occurs naturally during an infection is called naturally active immunity.

The immune response can also be activated artificially either by injecting antigens into the body or – for certain diseases such as polio – taking them by mouth. This is the because of artificial active immunity, more commonly known as vaccination. The immune response is similar to that following an infection, and the effect is the same – long term immunity.

Passive immunity occurs when antibodies from elsewhere are introduced into the body. In a young baby this can be natural, as the baby acquires antibodies from its mother in breast milk. It can also be artificial, as the result of an injection of antibodies obtained from another animal.

A vaccine is a preparation containing antigens which is used to stimulate an immune response artificially. It may contain a whole live microorganism, a dead one, a harmless version (known as an attenuated organism), a harmless form of a toxin (known as toxoid) or a preparation of surface antigens. Immunity derived from a natural infection is often extremely good at providing protection, because the immune system has met living organisms which persist inside the body for some time, so the immune system has time to develop an effective response. When possible, vaccination tried to mimic this. Sometimes this works very well, when vaccines contain live microorganisms. The microorganisms reproduce, albeit rather slowly, so that the immune system is continually presented with a large dose of antigens. Less effective are those vaccines that do not mimic an infection because they are made from dead bacteria or viruses that do not replicate inside the body.

**Discuss the reasons why vaccination has eradicated smallpox but not measles, TB, malaria, sickle cell anaemia or cholera;**

Smallpox has been successfully eradicated by vaccinating large numbers of children with weakened viruses similar to those that cause smallpox. This succeeded because that vaccine
is highly effective. The programme involved the vaccination of all relatives and contacts of anyone who had the disease, called a ring vaccination. The virus did not mutate, so the same vaccine could be used everywhere.

- **Measles.** This is partially because several successive doses of vaccine are required to produce immunity, especially in children who have weak immune systems because of poor diet or living conditions. The virus is very infective, so a very high percentage of people must be vaccinated to ensure a population is free of it. Booster vaccinations are also needed. This is difficult to achieve in places where infrastructure is poor.

- **TB.** The BCG vaccination gives only partial immunity, although new vaccines are now being developed which it is hoped will be more effective. Tb is difficult to treat because the bacteria live inside body cells. Many stains have developed resistance to the antibiotics.

- **Malaria.** No effective vaccine has yet been developed against Plasmodium. This is a eukaryotic organism, not a bacterium or virus, and is not affected by antibodies produced by B-lymphocytes or by T-lymphocytes.

- **Cholera.** This disease is caused by the bacterium Vibrio cholera. In the body, it lives and reproduces in the intestine, which is outside the body tissues and not easily reachable by lymphocytes or antibodies. Current cholera vaccines are ineffective, partly because injected vaccines do not readily reach the intestines. Oral vaccines are being developed, which are proving more effective.

Vaccines are, of course, completely ineffective against any diseases that are not caused by pathogens, such as sickle cell anaemia.