Edexcel (B) Biology A-level

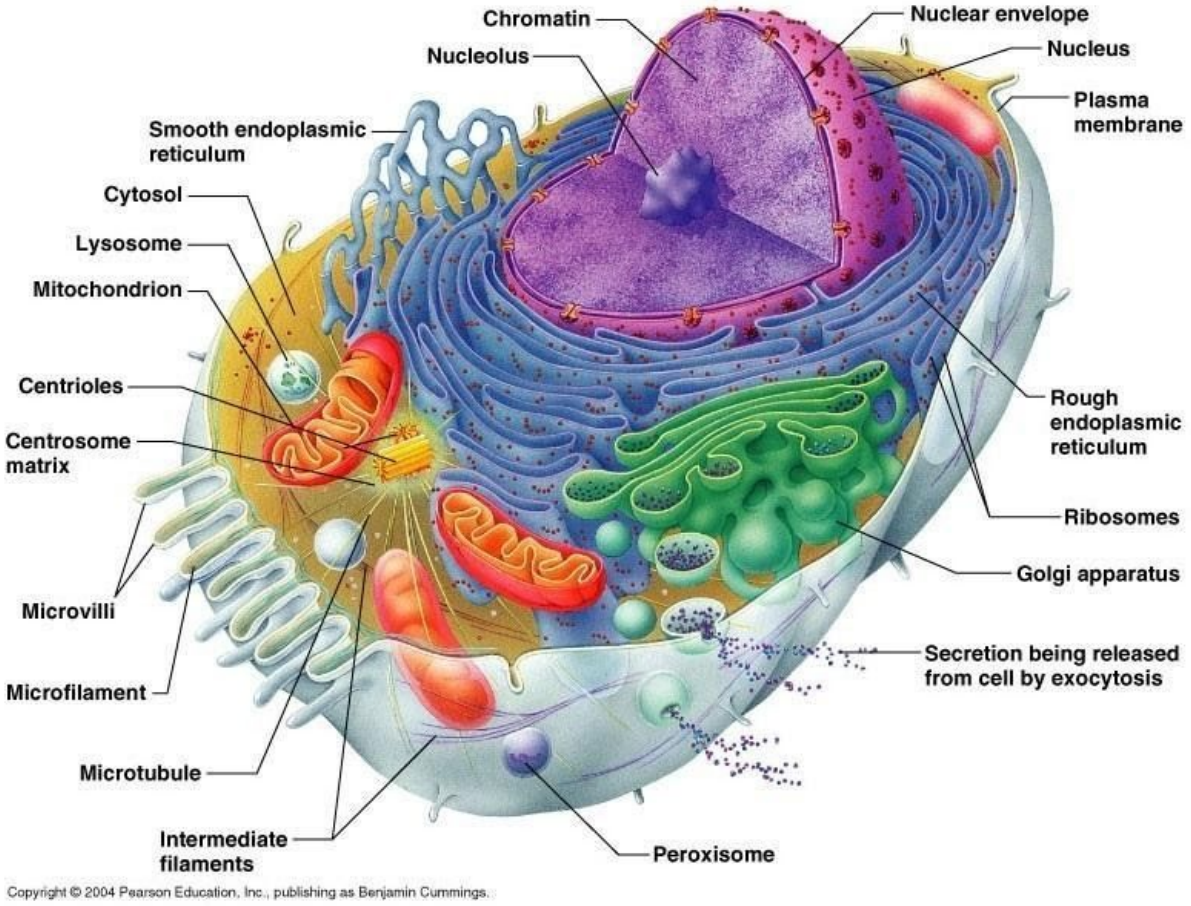
Topic 2: Cells, Viruses and Reproduction of Living Things

Notes

Cell Structure

All living organisms are made of cells. In multicellular organisms, cells are organised into **tissues**, tissues into **organs** and organs into **organ systems**. There are several different types of cells; some of them share common features. Humans are made up of **eukaryotic cells**, which contain a **nucleus** and **membrane-bound organelles**. A more detailed structure of a cell, called the **ultrastructure**, can be observed using a microscope.

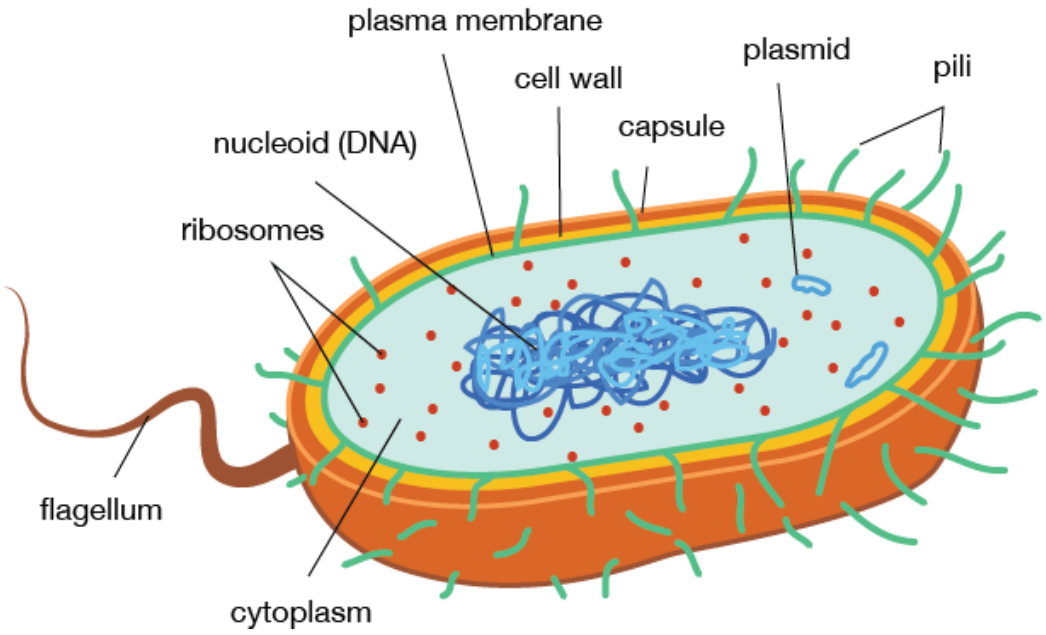
Ultrastructure of eukaryotic cells:



- Nucleus – surrounded by a **double membrane** called the **nuclear envelope,** which contains pores enabling molecules to enter and leave the nucleus. The nucleus also contains **chromatin**, and a **nucleolus**, which is the site of **ribosome production**.
- Rough Endoplasmic Reticulum – a series of **flattened sacs enclosed by a membrane** with ribosomes on the surface. The RER **folds and processes proteins** made on the ribosomes.
- Smooth Endoplasmic Reticulum – a system of **membrane-bound sacs**. The SER **synthesises and processes lipids** and **steroids.**

- Golgi Apparatus – a series of fluid-filled, flattened and curved sacs called **cisternae,** with **vesicles** surrounding the edges. The Golgi apparatus **sorts, processes and packages proteins** and lipids. It also produces lysosomes.
- Mitochondria – usually oval-shaped and bound by a **double membrane** called the envelope. The inner membrane is folded to form projections called **cristae**, with **matrix** on the inside containing the enzymes needed for **cellular respiration.**
- Centrioles – **hollow cylinders** containing a ring of microtubules arranged at right angles to each other. Centrioles are involved in **cell division**.
- 80S Ribosomes – composed of a large (60S) subunit and a small (40S) subunit; the site of **protein synthesis**.
- Lysosomes – vesicles, containing **digestive enzymes**, bound by a single membrane.

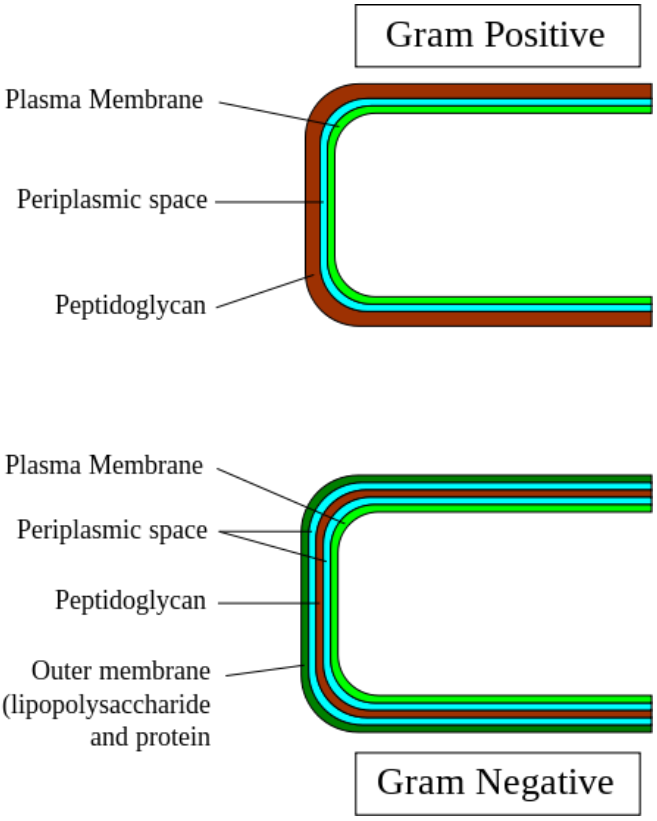
Ultrastructure of prokaryotic cells, such as bacteria:



- Cell Wall – the cell's rigid outer covering made of **peptidoglycan**. Provides the cell with **strength and support**.
- Slime Capsule – protective slimy layer which helps the cell to **retain moisture** and **adhere** to surfaces.
- Plasmid – circular piece of DNA.
- Flagellum – a tail-like structure which **rotates to move** the cell.
- Pili – hair-like structures which attach to other bacterial cells and allow plasmids to move from cell to cell
- 70S Ribosomes – composed of a large (50S) subunit and a small (30S) subunit. The site of **protein synthesis**.

- Mesosomes – **infoldings** of the inner membrane which contain **enzymes required for respiration**.

Bacterial Cell Wall



Bacteria can be classified according to their **shape** and their reaction to **Gram stain.**

There are two types of bacteria - **Gram positive bacteria** and **Gram negative bacteria**.

Gram Positive bacteria have a cell wall comprised of a thick layer of **peptidoglycan**, and an inner plasma membrane.
Gram Negative bacteria have a thin layer of peptidoglycan with an **outer lipopolysaccharide membrane**.

Gram staining occurs as follows: firstly, **crystal violet** is used to stain over a fixed culture, which binds to the peptidoglycan cell wall. After a minute, the stain is poured off and the slide is rinsed with water. Subsequently, **iodine solution** is added and removed after a minute. Alcohol is then added, and because lipopolysaccharides are soluble in alcohol, gram negative bacteria are **decolourised** as the outer lipopolysaccharide membrane dissolves. The final step of the procedure is **counterstaining with red safranin** for another minute. The sample is then dried and examined. Gram positive bacteria appears **violet/purple** under the microscope whereas Gram negative bacteria appears **red/pink.**

Microscopy

Magnification - how much bigger the image is compared to the original object
Resolution - how far apart two points can be before they are seen as one

Types of microscopes:

- **Optical:** A beam of light through the object, objective lens and eyepiece lens magnifies the sample. Magnification = 1500X. Resolution = 200nm.
- **Scanning electron:** A beam of electrons scans back and forth over the surface of the sample, producing a 3D image. Magnification = 50,000X. Resolution = 0.1nm.

- **Transmission electron:** A beam of electrons is transmitted through the object, producing a 2D image. A very thin sample must be used. Magnification = 100,000x-500,000x. Resolution = 0.1nm.
  Ultrastructure = structures only visible through a TEM. Electron microscopes show more due to their shorter wavelength giving them a higher resolution.

  Either type of microscope can give **artefacts** (things that are observed due to preparative or investigative techniques e.g. bits of stain).
  Staining of the samples is required for both light and electron microscopes.
  Electron microscopes = stained by heavy metals (reflect electrons).
  Light microscopes = methylene blue, acetocarmine, haematoxylin.
  Staining provides **contrast** between the **organelles and the cytoplasm**, allowing structures to be observed.

  - Advantages of electron microscopes:
    - Higher resolution and magnification
  - Disadvantages of electron microscopes:
    - Sample must be placed in a vacuum, so you can't magnify living things.
    - Very expensive and not portable.
    - Produces only black and white images

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**. As viruses are non-living, antivirals must work by inhibiting virus replication. Viruses can be **difficult to treat** once an infection has occurred, therefore the focus of disease control should be on **preventing the spread**. This idea is exemplified by the **2014 Ebola outbreak in West Africa.**

In the 2014 Ebola outbreak, new drugs were needed quickly. Some vaccines were fast-tracked - many doses were made so if one passed Phase I, it could be given to many people, and an experimental drug, **ZMapp,** was given to seven people. It had never been given to humans before. Some of the seven recovered but some died.

There are **ethical implications** to using, or not using, untested drugs:

- Difficult to obtain informed consent
- Unknown side effects
- May not be as effective as the currently accepted treatment

There are two cycles of viral reproduction, the **lytic cycle** and the **lysogenic cycle:**

- **Lysogenic viruses** insert DNA in the form of a **provirus** into the DNA of the host cell which enables the viral DNA to be replicated via cell division of the host cell. The provirus can stay dormant if the virus produces **repressor proteins** which inhibit the transcription of the provirus.
- **Lytic viruses** insert DNA/RNA into the cytoplasm of the host cell, therefore the viral genome is replicated independently of the host cell genome. Eventually, this leads to **lysis of the host cell** when a large number of viruses are assembled and ready to infect more cells.
- In a case where the lysogenic host cells become **damaged or the immune system becomes weak**, the dormant viruses can **enter the lytic pathway** which leads to lysis of the cell and the spread of viral infection.

Eukaryotic Cell Cycle and Division

The cell cycle is a **regulated process** in which cells divide to produce two **genetically identical daughter cells** for growth, repair and asexual reproduction. As all the cells produced by mitosis are genetically identical, mitosis does not give rise to genetic variation.

There are three stages of the cell cycle:

- **Mitosis – prophase, metaphase, anaphase and telophase.**

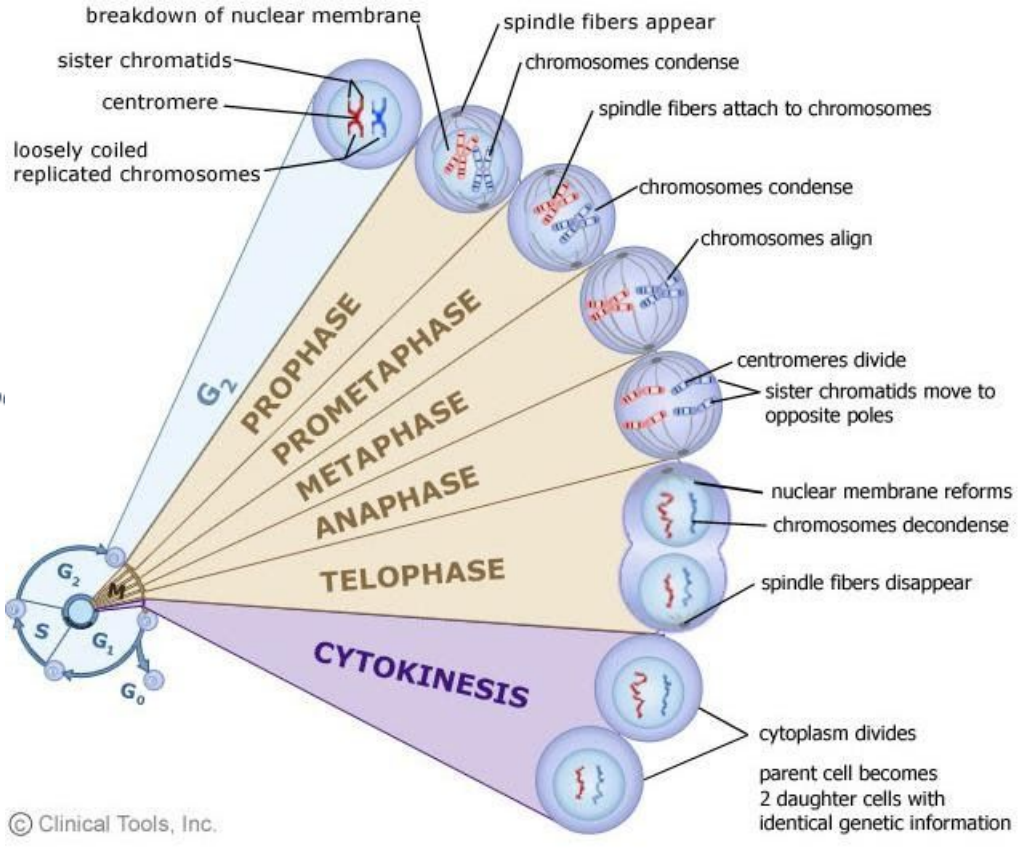
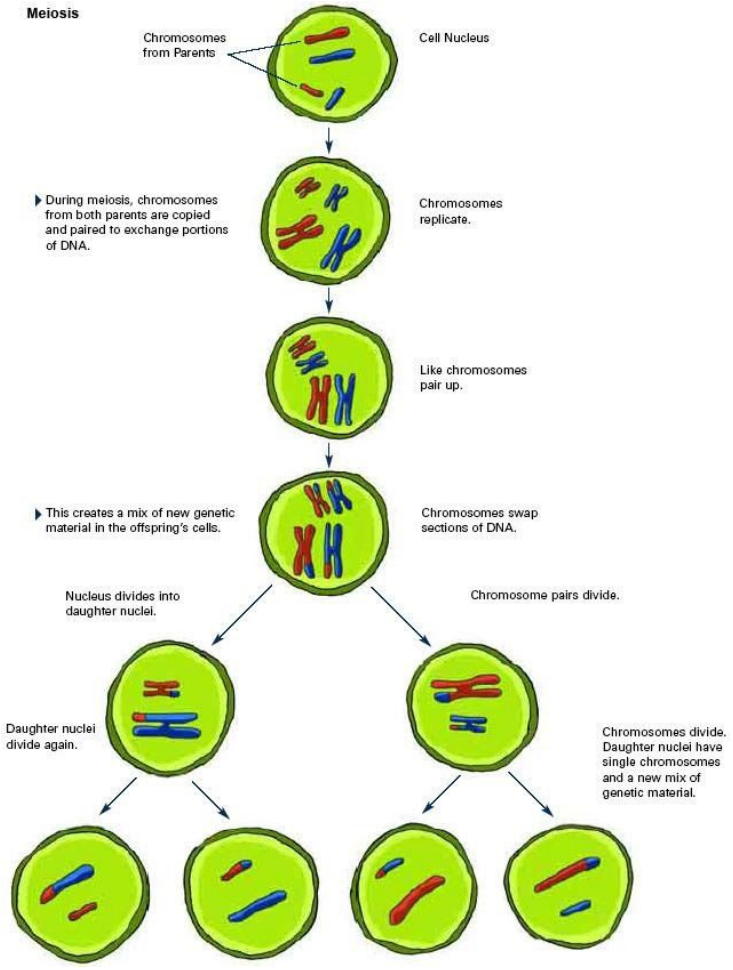


Figure: Wikip

- **Cytokinesis** – during cytokinesis the **cytoplasm divides,** thus producing two daughter cells.
- **Interphase** – G1, S and G2; **growth, DNA replication and preparation for division –** chromosomes and some organelles are replicated; chromosomes also begin to condense to form chromatin.



Meiosis is a form of cell division that gives rise to **genetic variation.** The main role of meiosis is the **production of haploid gametes and maintenance of chromosome number** as cells produced by meiosis have half the number of chromosomes. Meiosis produces genetically different daughter cells. Genetic variation is achieved through:

- **Crossing over** - the exchange of sections of DNA between homologous chromosomes.
- **Independent assortment** – there are various combinations of maternal and paternal chromosome arrangement.

Chromosome mutations are changes to the **number or structure** of chromosomes. Chromosome mutations include:

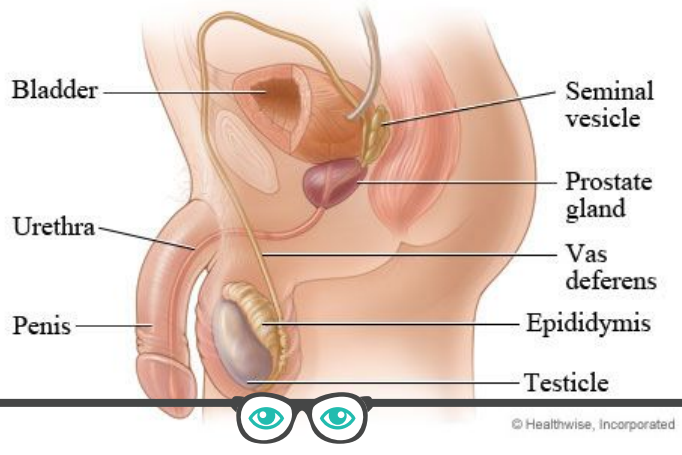
- **Translocations** - where a part of one chromosome breaks off and reattaches to another completely different chromosome. Can be balanced or unbalanced.
- **Duplication**
- **Deletion -** a section of a chromosome is removed, resulting in the loss of a large number of genes.
- **Inversion -** a part of a chromosome flips its orientation with respect to the rest of the chromosome.
- **Non-disjunction -** homologous chromosomes or sister chromatids fail to separate. This can result in:

- More than two chromosomes in a cell, called **polysomy**.
    - An example of polysomy is Down's Syndrome – three copies of chromosome 21 (trisomy).
- Less than two chromosomes in a cell, called **monosomy**.
    - An example is Turner's Syndrome, which is monosomy of the sex chromosomes where only one sex chromosome is present in a cell (X chromosome).

Gametogenesis in Mammals

Spermatogenesis:

1. **Primordial germ cells** (diploid cells which are the precursors to gametes) divide several times by mitosis to form **spermatogonia**.
2. Spermatogonia grow without further division to form **primary spermatocytes**.
3. Primary spermatocytes undergo the first meiotic division to form **secondary spermatocytes** (diploid).
4. Secondary spermatocytes undergo the second meiotic division to form **spermatids** (haploid, but without a flagellum, acrosome etc.).
5. Spermatids differentiate and grow to form mature **spermatozoa**.



Oogenesis:

1. **Primordial germ cells** divide several times by mitosis to form **oogonia**.
2. Only one oogonium continues to grow to form a **primary oocyte**.
3. The first meiotic division forms **one secondary oocyte and one polar body** (small cells that bud off the oocyte, stick to the oocyte and do not develop into gametes).
4. The second meiotic division of the secondary oocyte forms **one haploid ootid and one polar body**. The second meiotic division of the polar body forms two more polar bodies. They degenerate and die as the ootid develops. This meiotic division starts in utero but is halted at prophase and occurs only in response to fertilisation to form the **mature ovum**.

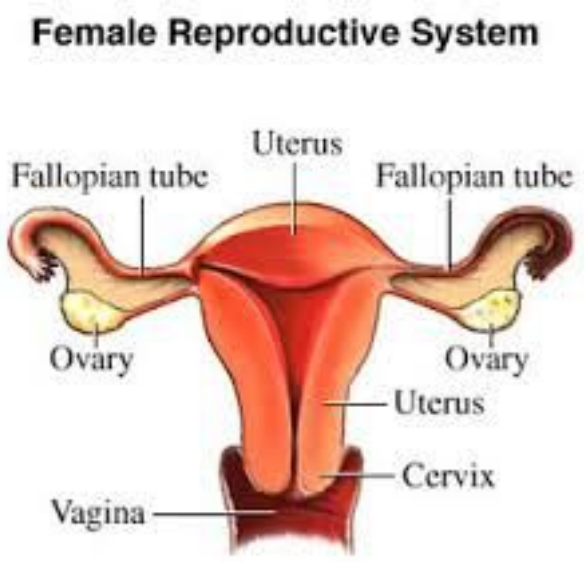


Figure: Shiksha

Mammalian Gametes and Fertilisation

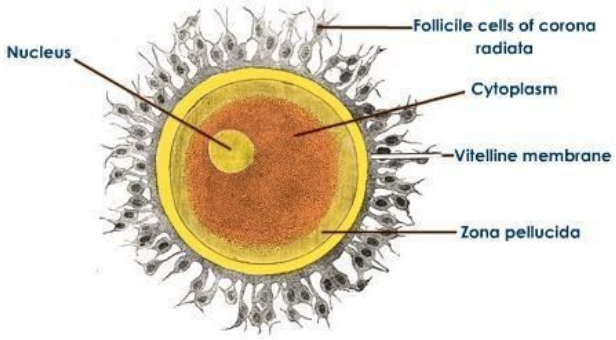


Figure: Tutorvista

Ovum:

- The ovum contains the **zona pellucida** which is a **protective coating** that the sperm have to penetrate in order for fertilisation to occur. The main purpose of zona pellucida is to prevent polyspermy (fertilisation by more than one sperm).
- The ovum contains a **haploid nucleus** that a full set of chromosomes is restored at fertilisation.

- **Cortical granules** release substances which cause the zona pellucida to harden, forming a **tough fertilisation membrane.**
- **Follicle cells** form a protective coating around the egg.

Spermatozoa:

- Sperm cells contain many **mitochondria** to provide energy for rotation of the flagellum which enables the cell to move.
- **Acrosomes** contain **digestive enzymes** which break down the zona pellucida and allow sperm to penetrate the egg.
- **Haploid nucleus** allows the restoration of the full set of chromosomes at fertilisation.

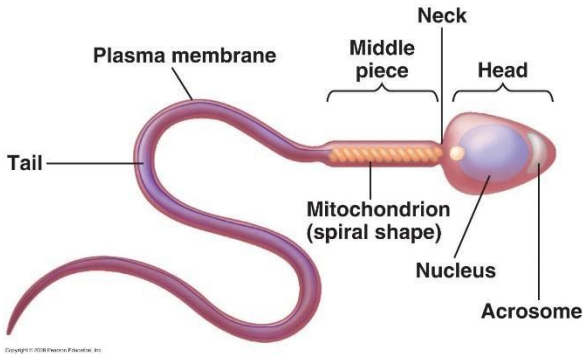


Figure 3 Lifeeasy Biology

Fertilisation:

1) The sperm head contacts the zona pellucida and the **acrosome reaction** occurs – enzymes digest the zona pellucida as the acrosome fuses with the cell membrane of the sperm and releases the digestive enzymes.
2) The **sperm head** fuses with the **cell membrane** of the egg cell, thus allowing the sperm nucleus to enter the egg cell.
3) The **cortical reaction** occurs which causes the zona pellucida to harden and prevents polyspermy.
4) The nuclei fuse and **a full set of chromosomes** is restored, thus forming a diploid zygote.

Gametogenesis in Plants

Pollen formation:

1. **Diploid microspore** mother cells in the anther undergo meiosis. They form **four haploid microspores**.
2. Haploid microspores undergo mitosis to mature into **pollen grains**. Pollen grains consist of two nuclei – the **generative nucleus** and the **pollen tube nucleus** – and a protective coating.

Ovum formation:

1. **Diploid megaspore** mother cells in the ovule undergo mitosis, forming an ootid and three polar bodies which degenerate and are reabsorbed.
2. The ootid undergoes three mitotic divisions to form an **embryo sac**. The embryo sac contains two polar nuclei (form the endosperm), an egg cell (forms the zygote), two synergids (help the generative nucleus reach the egg cell) and three antipodal cells (no established function) with a protective coating.

Fertilisation in Plants

- **Pollen grain** composed of the **pollen tube nucleus** and the **generative nucleus** adheres to the stigma, where it subsequently germinates.
- The pollen tube grows down the **style** via the secretion of **digestive enzymes** which digest the surrounding tissue and use it as a source of nutrients.
- The pollen tube grows through the **micropyle** into the **embryo sac.**
- The generative nucleus of the pollen divides by mitosis to produce **two sperm cells** which enter the embryo sac.
- Double fertilisation occurs: one of the male gametes fuses with the female nucleus to form a **diploid zygote** and the other male gamete fuses with **two polar nuclei** to form a **triploid endosperm nucleus** which serves as a source of nutrients for the embryo.