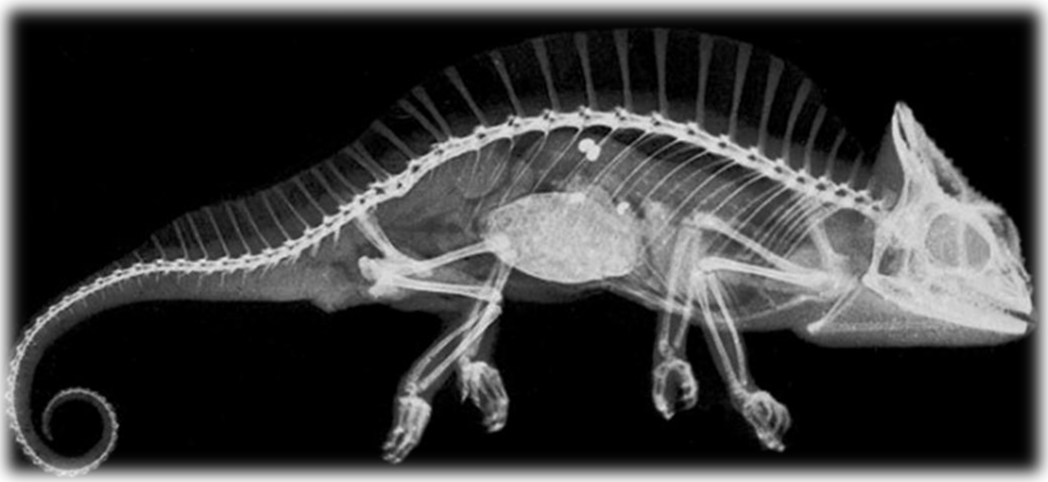
FOURTH FORM BIOLOGY



THE AUTUMN TERM PART II

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Classification

The Linnaean System

The Linnaean system was first devised by the Swedish biologist Carl Linnaeus (1707 – 1778) who used it to catalogue every species known at the time and published a book of his work called *Systema Naturae* in 1735. The system has been modified many times over the years (we no longer use it for rocks!), but remains true to the original idea.

The system organises organisms into smaller and smaller groups. The largest group is the **Kingdom**, then **Phylum** (plural: **Phyla**), **Class**, **Order**, **Family**, **Genus** (plural: **Genera**) and **Species**.

As well as being the smallest grouping in the Linnaean system a species can be defined as **a group of organisms with many characteristics in common which can interbreed and produce fertile offspring**. This definition was first used by the English botanist John Ray (1627 – 1705).

The Binomial System

Linnaeus was also the first person to routinely use the **binomial system** for referring to species. In the binomial system an organism is referred to by its genus and species name together (e.g. *Homo sapiens*). Binomials provide a universal language for biologists all over the world even though "common" names may vary from place to place. Binomials often have Latin or Greek roots, though biologists tend to play fairly fast and loose when inventing new names. Discovery of large numbers of fossil dinosaurs in China has led to a profusion of odd sounding Latinised Chinese names like *Guanlong wucaii* (shown left).

Note the correct convention for writing binomials: the genus is capitalised but the species is not. They should also be **either** *italicised* OR <u>underlined</u> (if handwritten). This helps them to stand out from other Latinised names in a piece of text.

Identification Keys

An identification key is a series of questions (more properly written as a statement rather than an actual question) that are used to put a name to an unknown organism. Usually keys are constructed to identify particular species, although it is possible to construct a key to larger groups such as genera or families. Keys may be written to distinguish between the species that are found in a particular region (e.g. a key to the flowering plants of Warwickshire), or just to all of the species of a particular group (e.g. a key to the species of earthworm).

Identification keys are often referred to as **dichotomous keys** because the questions are grouped into pairs, e.g. *organism is radially symmetrical* versus *organism is bilaterally symmetrical.* Although constructing a key is in theory simple enough, when working with real groups of organisms keys can be quite difficult to produce. The characters that you use to distinguish between the organisms need to be unambiguous and easy to apply – they cannot be subjective or refer to other organisms (the user of the key may only have one species to key out, and so won't know what other species look like).

Below is an example of a section of a key:

1a Organism longer than it is wide; bilaterally symmetrical 2

1b Organism approximately as long as it is wide; radially symmetrical 3

2a Organism with 6 pairs of jointed legs; wings present .... *House fly*

2b Organism with 8 pairs of jointed legs; wings absent .... *Spider*

3a Organism with 5 well-defined arms; spines short or absent; flattened .... *Sea star*

3b Organism lacking well-defined arms; spines elongated; cushion-forming .... *Sea urchin*

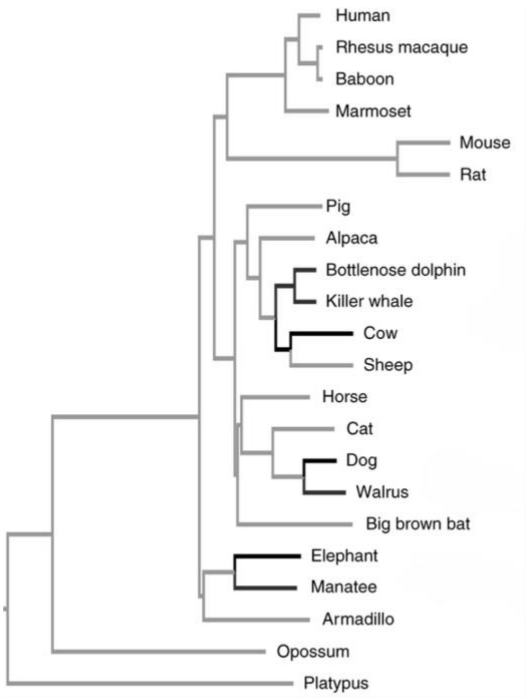
Note that the characters used in each pair of questions are the same and the alternative state is provided in the opposing question e.g. 6 legs versus 8 legs; wings present versus wings absent.

Identification keys are artificial – in other words they do not aim to represent any evolutionary groups. Their sole purpose is to identify an unknown specimen as easily as possible.

Evolutionary Trees

In 1859 Charles Darwin (1809 – 1882) published his book *On the Origin of Species*. Darwin put forward the evidence that all organisms on earth are related to each other, and that the species alive today are descended from ancestral species that are now extinct. Darwin included just one illustration in the book, a branching diagram that we would now recognise as an **evolutionary tree** or **phylogeny**.

A phylogeny is a pictorial representation of how species are related to each other – the more closely related they are then the more recently they shared a common ancestor. You will cover the ideas behind the mechanism through which species evolve and originate in the Sixth form. However, we make use of evolutionary trees in the Fourth form when looking at the evolutionary relationships between the 5 kingdoms and groups within those kingdoms.



On the right is an evolutionary tree of the mammals, containing some representative species from each of the main groups of mammals. This tree was made using data from DNA. At the tips of the tree are the names of the organisms. As you go back from the tips to the deeper branches of the tree (working from right to left), the branches join. The intersection between those two branches (the ***node***) represents the **common ancestor** of those two species. For example, the branches leading to the rat and mouse and rat join, and that node represents an **ancestral species**, now extinct, from which the mouse and the rat are descended.

Note that the branches could rotate – in other words you could spin round the two branches that lead to mouse and rat without changing the meaning of the tree – either way the rat and the mouse are more closely related to each other than they are to any other species in this phylogeny. The tree depicts *how closely related species are*, so a human is more closely related to a baboon or a macaque monkey than we are to a marmoset. This is because we share a more recent common ancestor with macaques and baboons than we do with a marmoset (you have to go further back along the tree to reach the common ancestor of humans and marmosets).

It is possible to annotate the tree with short bars on the branches leading to particular groups or species, and label these as characters. On page 7 is a phylogeny of the land plants on which some characters (flowers, seeds, vascular tissue) have been added along certain branches. This is to indicate that along the branch that particular character first evolved, and all species that evolved after that point would possess that character (unless it has subsequently been lost through evolution, which could also be indicated on the tree).

The Five Kingdoms

All living organisms have been classified into one of 5 major groups called kingdoms. Viruses, because they are not considered living organisms, are not placed in any of the 5 kingdoms (see the separate section on viruses).

Organisms may also be divided into two larger groups – the prokaryotes and the eukaryotes, as described above under cell structure. Prokaryotes include all the bacteria. The eukaryotes (defined by the possession of a membrane-bound nucleus) includes all the other 4 kingdoms – plants, fungi, Protoctists and animals).

Plants

The plant kingdom contains the land plants. They are all multicellular, terrestrial organisms that:

- have **chloroplasts** and are able to carry out **photosynthesis**
- have **cellulose cell walls**
- store carbohydrate in the form of **starch.**

There are four major groups of land plants:

- Bryophytes (mosses, liverworts and hornworts) – about 20,000 species
- Pteridophytes (ferns and their relatives) – about 13,000 species
- Gymnosperms (such as the conifers) – about 1,000 species
- Angiosperms (the flowering plants) – about 300,000 species.

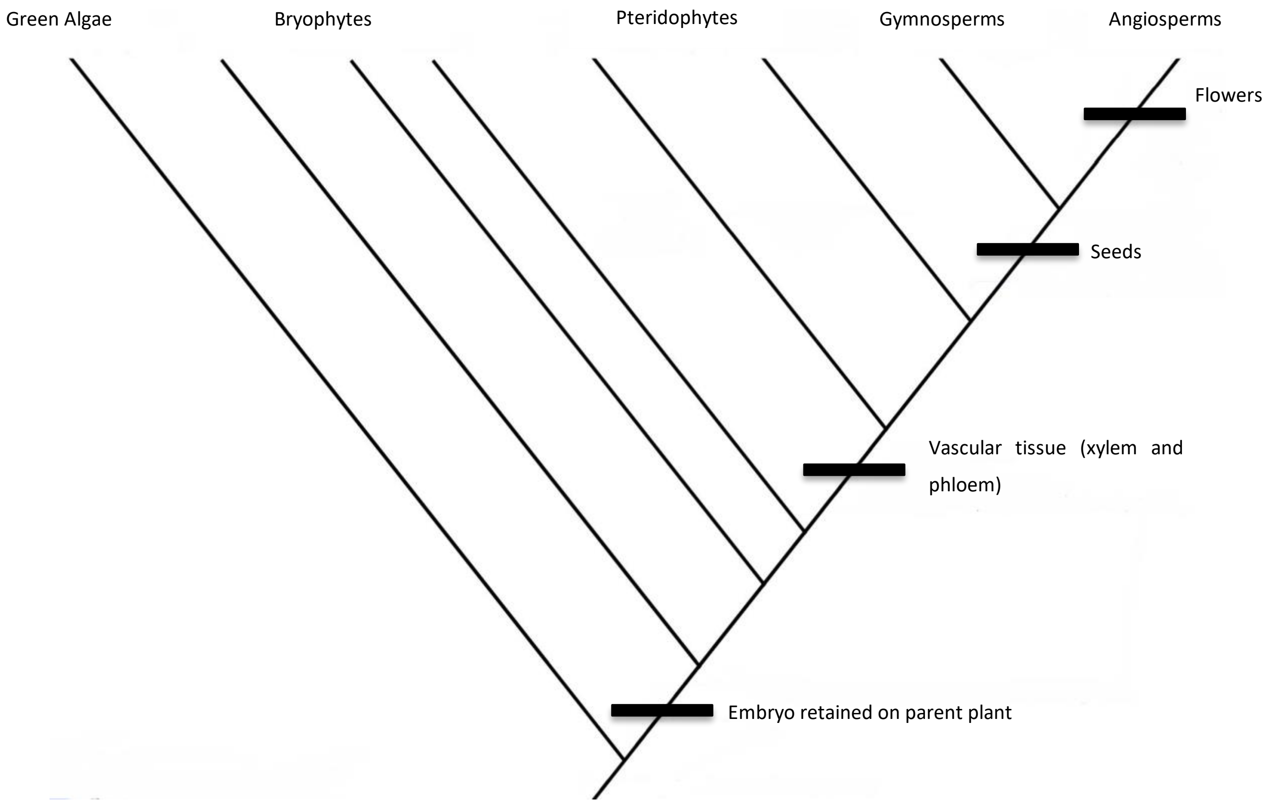
The major characters that define the various groups of land plants are:

- Possession of **vascular tissue** – specialised **xylem** and **phloem** which conducts water, mineral ions or sugars and amino acids throughout the plant (these are covered in more detail in the Spring term).
- Possession of seeds – seed plants reproduce using pollen rather than dispersing spores, and the embryo that forms is contained within a seed.
- Possession of flowers and fruits – the majority of plant species are **flowering plants** in which the seeds are held in an enclosed structure (the **ovary**, which becomes the **fruit**). Plant reproduction is covered in more detail in the Summer term.

You may wonder what character distinguishes the land plants from algae, given that they are very closely related. The defining character is that the young embryo plant is retained on one of the parent plants, whereas in algae both the male and female gametes are dispersed from the parent organism. The proper name for the land plants is *Embryophytes* which reflects this important character.

The Bryophytes lack specialised tissue to transport water or sugars around the plant. However, the other three groups have specialised xylem and phloem (vascular tissue). Bryophytes and Pteridophytes reproduces using spores, rather than pollen grains; they do not produce seeds. When the spores germinate, they produce motile male gametes (like very simple sperm) and so they are restricted to wet habitats. Gymnosperms and Angiosperms reproduce using seeds (collectively, they are known as the seed plants). Only the Angiosperms produce flowers and fruits, however; in Gymnosperms the seeds are held in the open on cones.

An evolutionary tree showing the relationships between these groups and some of the characters that they possess is shown below. The closest relatives of the land plants are the green algae, but these have traditionally been classified in the Protoctista kingdom (see below).



Animals

Some of the general characteristics of animals are:

(i) Multicellularity. In contrast to the Bacteria and most Protoctista, all animals are multicellular.

(ii) Heterotrophic nutrition. In contrast to most plants, all animals are **heterotrophs**. Animals must synthesise organic molecules from pre-existing organic molecules obtained from their diet.

(iii) Internal digestion. Although the fungi are also heterotrophs, they digest their food outside of their bodies. Most animals, however, take in food (**ingest food**) into an internal **gut** in which digestion takes place.

(iv) Movement and nervous system. In contrast to plants and fungi, most animals can move their bodies. This movement is often coordinated through a well-developed nervous system. Muscle and nervous systems are unique to animals.

(v) Storage carbohydrate. Animals (and fungi) store carbohydrate in the form of **glycogen**.

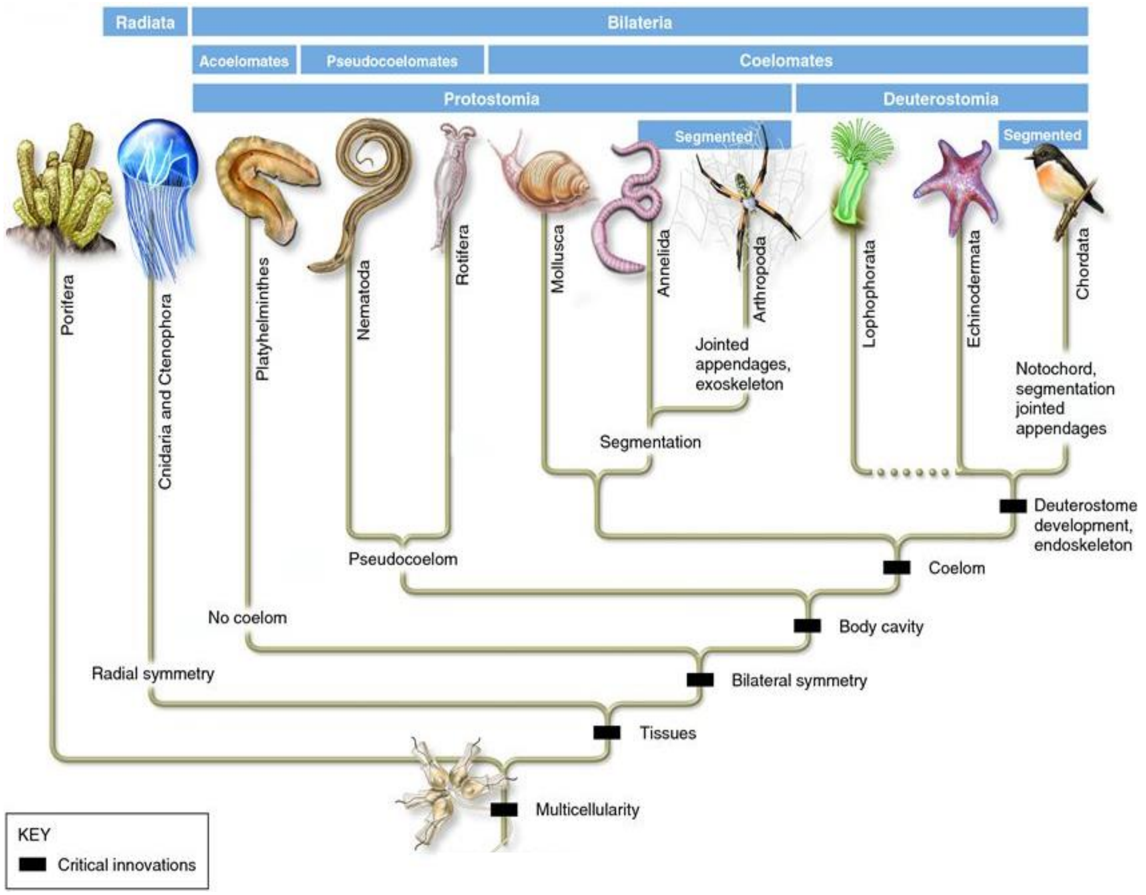
Major Groups of Animals

The features that are used to define the major groups of animals are often ones that form early in the development of the organism in the embryo. Some examples are:

- The number of cell layers in the embryo (two or three distinct layers form very early on which develop into specific organs and organ systems). Sponges do not have well-defined tissue types, however.
- Symmetry, e.g. bilateral symmetry as in humans, radial symmetry as in star fish, no symmetry as in sponges.
- Body cavity formation – in many groups a body cavity (*coelom*) forms very on in the embryo as an indentation forms in the ball of cells, forming an opening. In some groups, this initial opening forms the mouth and the anus forms later (*protostomes – "mouth first"*), whereas in others it forms the anus and the mouth forms later (*deuterostomes – "mouth second"*).
- Structure of the body cavity.

The very first branch of animals are the **sponges**, which although they have some specialised cells, do not have distinct cell layers in the embryo or true organs. At one time sponges were classified as plants since they do not move (are **sessile**) and lack any body symmetry.

The evolutionary tree below summarises some of the major groups of animals, and includes some of the characters listed above. (Note that this is for reference only - we do not expect you to know the details of animal groups or their characters.)



An evolutionary tree of the major groups of animals. The first split is between the sponges (Porifera) which have no symmetry and all other animals which are either radially symmetrical (Radiata) or bilaterally symmetrical (Bilateria). The next major divisions are based on the form of the body cavity (Acoelomates / Pseudocoelomates / Coelomates), and then the development of the mouth or anus first (Protostomia / Deuterostomia).

Fungi

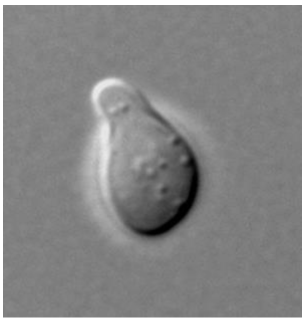
Linnaeus classified fungi as plants, and you can probably understand why, but the similarity is only superficial. In fact, fungi are more closely related to animals than plants.

Fungi are eukaryotic and heterotrophic. They have no chloroplasts and cannot photosynthesis. They have cell walls made of **chitin**, not cellulose. Although animals don't have cell walls many make chitin (the chemical in arthropods exoskeletons) and all animals store glycogen rather than starch.

Fungi feed by **extracellular digestion**. They **secrete** digestive enzymes onto their food and absorb the smaller molecules that are released such as glucose and amino acids. They are usually **saprotrophic** (digesting dead organisms or material, thus helping the process of decomposition) but some are **parasitic** and will live in or on living plants or animals.

Fungi form some of the largest organisms in the world by mass, though they are usually invisible underground. They grow a network (a **mycelium**) of fine, branching hair like structures called **hyphae** which can extend over many square miles. They do not construct sophisticated root structures like a plant, however. Periodically they send up **fruiting bodies** which produce reproductive **spores**. The spores may have been produced sexually or asexually. Some of these fruiting bodies are very large and we know them as mushrooms and toadstools.

Not all fungi are multicellular, there are thousands of different kinds of single-celled fungi which are collectively called **yeasts**. Yeasts can reproduce asexually by budding, in which a new small cell grows out of the side of an existing one. They may also reproduce sexually using a special reproductive cell called a **shmoo**. The shmoo has only half the normal number of chromosomes and fuses with another shmoo of the opposite sex to form a zygote which may then bud many times.

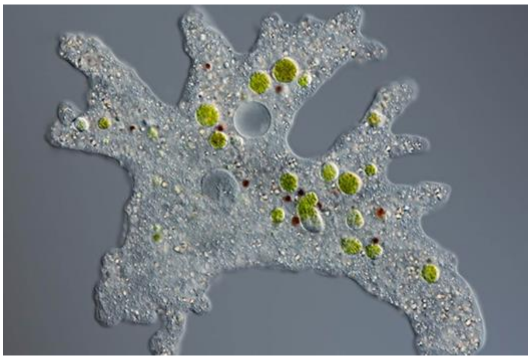

A shmoo, viewed using a light microscope.

Protoctista

These are a group of usually single celled misfits which are hard to classify into any other kingdom. Some seem plant-like (e.g. the algae), others more animal-like (e.g. *Paramecium*), and some seem to have characteristics of both. The plant, animal and fungal kingdoms have evolved from groups within the Protoctista. Thus, the Protoctista is really a group of convenience rather than a natural grouping – it's where organisms that didn't fit anywhere else were classified. (Note that the plant, animal and fungal kingdoms as defined above do represent natural groups of organisms that have each evolved from a single common ancestor.) As a consequence, there are few defining features of the Protoctista other than they are Eukaryotes that are not plants, animals or fungi. They exhibit much diversity – most are single-celled, a few (e.g. some algae such as seaweeds) are multicellular; some are photosynthetic (algae), most are heterotrophic; some are obligate parasites (e.g. *Plasmodium* that causes malaria). Below are a few examples that you might come across.

Amoeba

A single celled Protoctist, it feeds by engulfing small food particles and hunts actively, so is 'animal-like'. *Amoeba* used to be classified as a Protozoan ("first animal") and the Protozoa were considered the simplest animal phylum, but for various reasons are now considered Protoctists (you may still see the terms Protozoa in text books). This gives you an idea of how our understanding of the relationships between organisms has changed as we have obtained more data.



An Amoeba, viewed under a light microscope. This specimen has engulfed ome algal cells which can be seen in the cytoplasm as food vacuoles.

Plasmodium

Another single-celled Protoctist, this one has a complicated life cycle including several stages where the cells have a different appearance. *Plasmodium* causes malaria and is spread by mosquitoes.

Paramecium

A ciliated Protoctista, which means that on the surface of the cell are many hair-like projections called **cilia** which can beat and move the single-celled organism through water. *Paramecium* lives in fresh water,

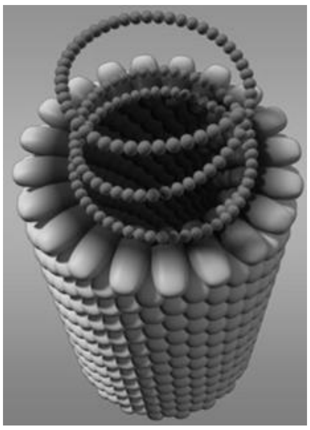
which would normally cause problems for a cell that lacks a cell wall as water may enter the cell and cause it to burst. *Paramecium* gets round this problem by having a **contractile vacuole** that excretes the excess water from the organism (this is the star-shaped structure in the photograph of the *Paramecium* on the left). *Paramecium* engulfs solid food, forming a **digestive vacuole** within which the food is digested.

Viruses

Viruses are not generally considered living organisms by most biologists. They do not carry out many of the life processes discussed above. In particular, they are not made of cells and do not carry out respiration since viruses contain neither mitochondria or cytoplasm. Viruses are able to reproduce, but this can only occur by hijacking a host cell and using the virus genetic material to instruct the host cell to manufacture new viral proteins. All viruses, therefore, are **parasites**; the cell which the virus infects is called the **host cell**. Viruses can infect plant or animal cells, and some viruses known as **bacteriophages** infect bacterial cells.

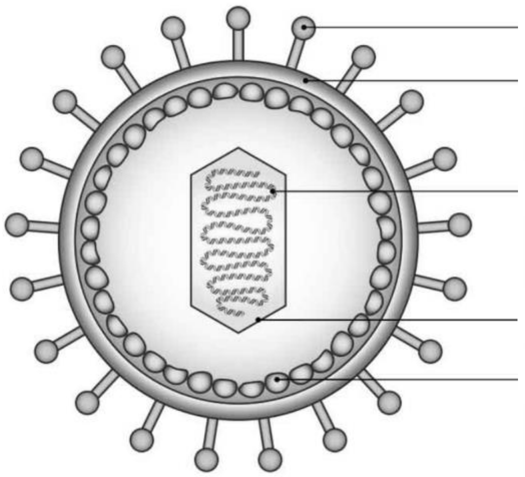
Viruses are much smaller than cells – most are between 0.01 and 0.1μm in diameter (recall that even bacterial cells are about 1 – 2 μm in diameter). They are consequently too small to be seen using light microscopes. Viruses are not made of cells but consist of some genetic material surrounded by a coat of protein. The tobacco mosaic virus, a plant virus, shown below, has this very simple structure. Note that we refer to **virus particles** rather than virus cells.

A computer generated image of tobacco mosaic virus, showing the nucleic acid in the centre surrounded by a protein coat.



The genetic material can be either RNA or DNA. This contains a few genes that code for the production of proteins that make up the virus particles and allow the virus to reproduce inside the host cell. Genetic material, whether DNA or RNA, can change over time through **mutations** that occur whenever a DNA or RNA molecule is replicated. This results in viruses changing over time – in the case of RNA viruses such as HIV (discussed below) this can happen very rapidly. Change in the genetic material over time means that viruses are able to **evolve**, even though they are not organisms.

The diagram below shows the influenza virus. This has a more complex structure because in addition to the protein coat surrounding the genetic material, it also has a membrane called the **envelope**. This is not made by the virus particle, but instead came from the membrane of the host cell when the virus particles emerged from the infected host cell. When new virus particles are released from a host cell, the cell is killed. This is the way in which viruses can damage the host organism. Viruses can be detected by the organism's immune system and an **immune response** will lead to the destruction of the virus particles. However, in some cases the immune response takes too long and the organism is killed by the virus. In the case of **HIV** (the **Human Immunodeficiency Virus**) which causes **AIDS** (**Acquired Immune Deficiency Syndrome**), the virus infects one type of white blood cell that is essential for the immune response.



The following illustrate the main stages in the lifecycle of a typical virus:

1. A virus particle gains entry to an organism, such as via infected semen or blood in the case of HIV or through droplets containing the 'flu virus when someone sneezes.
2. The virus particle binds to the cell surface membrane of a host cell. The proteins that stick out from surface of the virus particle often help the virus to make contact with the correct cell that it will infect. This is why one type of virus will often infect only one or a few specific species, or even specific cell types within that organism.
3. The virus penetrates the host cell and the genetic material is released into the host cell cytoplasm.
4. The genetic material is used by the host cell to manufacture new virus proteins – in effect the host cell's machinery has been hijacked by the virus. More copies of the virus genetic material are made by the host cell.

5. New virus particles are assembled in the cytoplasm – thousands of them which are often tightly packed within the cell.
6. The host cell bursts open, releasing the newly-made virus particles which can then go on to infect further cells. Some viruses bud off from the host cell, taking some of the host cell's surface membrane with them.