Chapter VI

Concepts of Mycology and Virology

1. Mycology

1.1. Definition

Mycology (from the Greek *"mukes"* = mushroom and *"logos"* = study, science) is the branch of biology that studies fungi.

Fungi are eukaryotic organisms, either unicellular or multicellular. They include both macroscopic species (*macromycetes*) and microscopic species (*micromycetes*), with either a filamentous or yeast-like appearance.

They are generally strict aerobes (facultative aerobes for some yeasts), mesophilic (optimal growth temperature between 25°C and 35°C), tolerant of a wider range of pH values than bacteria. They are chemo-heterotrophic and non-photosynthetic (non-chlorophyllous).

Microscopic fungi are divided into two main groups: **yeasts** and **molds**.

1.2. Morphology and cellular structure of microscopic fungi

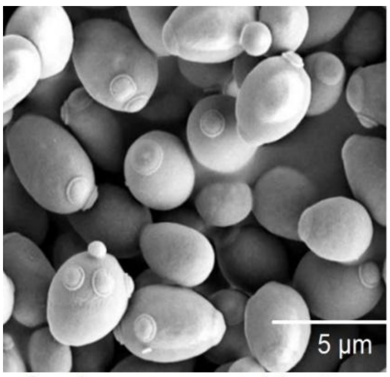
The cellular organization of fungi is referred to as the *thallus*. In microscopic fungi, the thallus can be either unicellular (yeasts) or filamentous (molds).

The plasma membrane, rich in ergosterol, is protected by a rigid and thick cell wall composed mainly of polysaccharides, typically chitin.

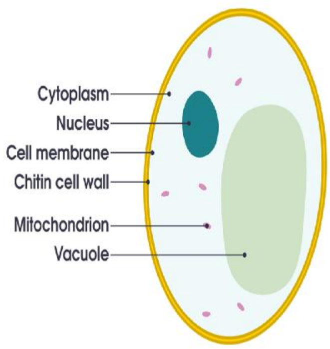
1.2.1. Yeasts

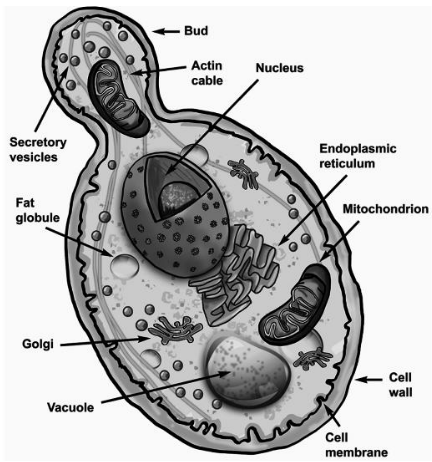
Yeasts are unicellular fungi, generally measuring between 10 and 50 µm. Their shape can be spherical, ovoid or elongated. Their thallus is referred to as *yeast-like*.

The cytoplasm contains organelles (endoplasmic reticulum, Golgi apparatus, mitochondria, vacuoles, and ribosomes) as well as a true nucleus containing chromosomes.



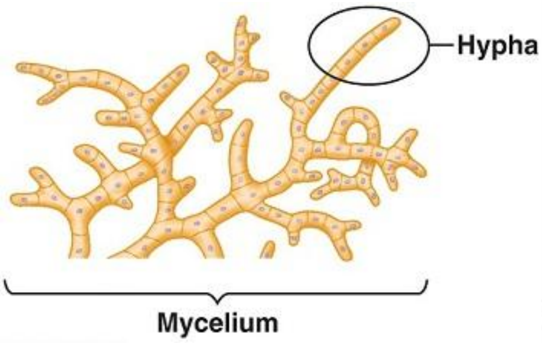
Saccharomyces cerevisiae

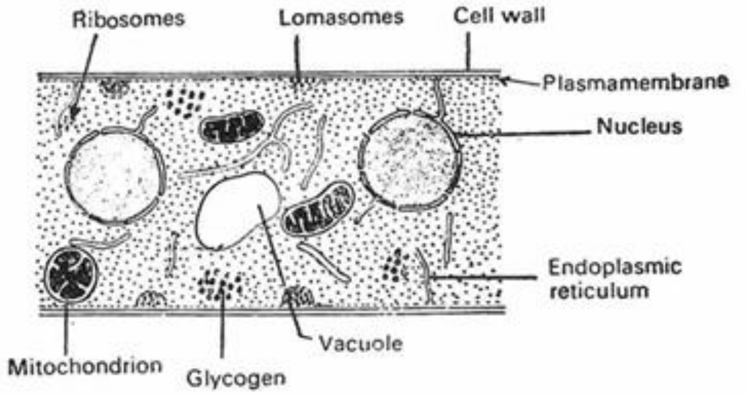




1.2.2. Molds

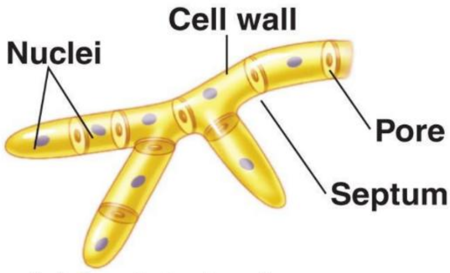
Molds are multicellular fungi whose thallus consists of filaments, more or less branched, called *hyphae*. The network of hyphae forms the ***mycelium***, which constitutes the vegetative part of the fungus.





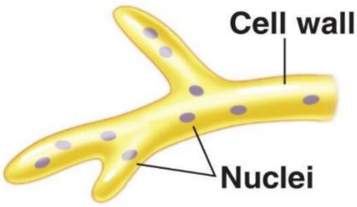
Depending on the organization of their thalli, molds can be classified as:

a. **Fungi with septate hyphae**, whose thallus is divided by cross-walls (septa). Perforations (pores) allow communication between cells;



(a) Septate hypha

b. **Fungi with coenocytic hyphae**, whose thallus is not divided by transverse walls, forming a continuous multinucleate structure.



(b) Coenocytic hypha

1.3. Nutrition and modes of life

Fungi exhibit an osmotrophic mode of nutrition: they absorb nutrients by first releasing hydrolytic enzymes into the external environment, thereby digesting food outside the cell. Nutrients are then absorbed in a soluble form.

These organisms lack chlorophyll and are strictly heterotrophic. They interact with other organisms in various ways:

a) **Saprophytic** lifestyle: Most fungi obtain their nutrients by degrading dead organic matter.

b) **Commensalism**: Some fungi live in a commensal relationship, benefiting from their host without causing harm or providing any advantage in return.

c) **Parasitism**: others feed on living organisms. They can cause diseases (mycoses) in animals and plants.

d) **Symbiosis**: some fungi establish symbiotic relationships with plants, forming mutualistic associations where both partners benefit (e.g., lichens, mycorrhizae).

1.4. Reproduction

Fungal reproduction is a complex process that involves the formation of specialized cells known collectively as *spores*. A spore is a unicellular reproductive structure that can develop into a new individual. Spores are very light and can be dispersed through the air, facilitating the spread of fungi in nature.

Reproduction can occur through two mechanisms: sexual or asexual. Some fungi can even alternate between these two types of reproduction.

1.4.1. Asexual reproduction (Anamorph)

In asexual reproduction, spores are diploid and result from successive mitotic divisions. They are classified into three types:

A. Thallospores: Exospores formed from the thallus by the transformation of pre-existing elements.

B. Sporangiospores: Spores formed inside a sporangium (a sac-like structure) located at the tip of a hypha.

C. Conidiospores: Spores formed without an enclosing sac, typically produced in specialized structures called conidia.

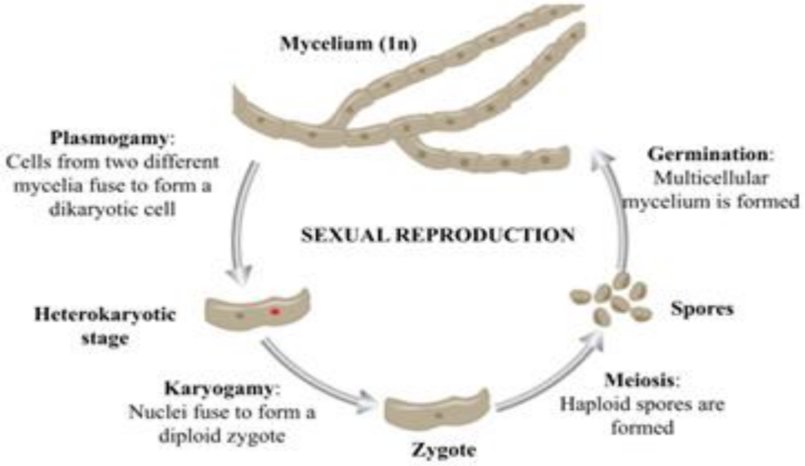
1.4.2. Sexual reproduction (Teleomorph)

Sexual reproduction involves the fusion of two haploid cells (cells with *n* chromosomes) acting as gametes, leading to the formation of a diploid zygote (cell with *2n* chromosomes). A (+) structure carrying *n* chromosomes encounters a (–) structure, and the fusion of their cytoplasms gives rise to a new mycelium with *2n* chromosomes.

- Some species are self-fertile (*homothallic*), producing sexually compatible gametes on the same mycelium.
- In other species, mating between different individuals (*heterothallic*) is necessary.

The process of sexual reproduction includes the following stages:

- **Plasmogamy**: the fusion of the cytoplasm of two specialized filaments, either from the same thallus (*homothallic*) or different thalli (*heterothallic*), without immediate nuclear fusion.
- **Karyogamy**: the fusion of the two haploid nuclei, resulting in diploid (2n) cells.
- **Meiosis**: a reduction division that restores the haploid (n) state, producing haploid spores of both (+) and (–) types : sexual spores



2. Virology

2.1. Definitions

- **Virology** is the branch of microbiology that studies viruses, including their structure, function, and interactions with host organisms.
- The word virus is Latin for "poison". This acaryotic infectious agent is a biological entity incapable of reproducing on its own, requiring a host cell, whose components it uses to replicate—hence the term obligate intracellular parasite.
- The virion is the free viral particle found in the external environment. It has no metabolism, no capacity for replication, and no autonomous activity.

2.2. Morphology

Viruses are generally small in size (ranging from 18 to 400 nm). They are acellular and lack most components found in cells, such as organelles, ribosomes, and the plasma membrane.

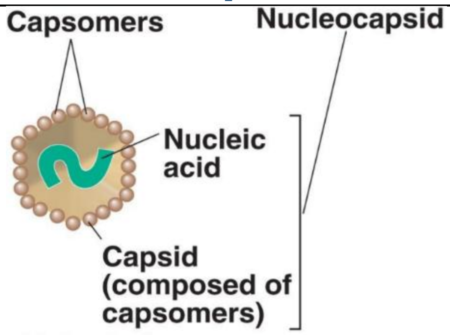
A virion consists of a nucleic acid core, an outer protein coat called a *capsid*, and sometimes an outer envelope derived from the host cell. Viruses may also contain additional proteins, such as enzymes.

2.2.1. **The *genome*** (which carries the genetic material) consists of a single type of nucleic acid, either DNA or RNA. This genome can be single-stranded or double-stranded, segmented or non-segmented, and linear or circular. The viral genome typically contains anywhere from a few genes to about 1200 genes.

2.2.2. **The *capsid*** (from the Latin *capsa* = box) is a structured protein shell made up of many copies of protein subunits called ***capsomeres***, which are themselves composed of one or more smaller protein subunits called ***protomers***. The capsid serves two main functions:

- It encloses and protects the genome
- It allows naked viruses to attach to the host cell

The combination of the capsid and the nucleic acid forms the **nucleocapsid**.

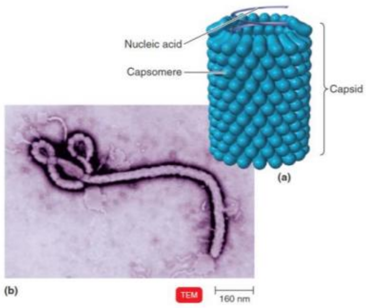


The nucleocapsid can be organized according to the following symmetry types:

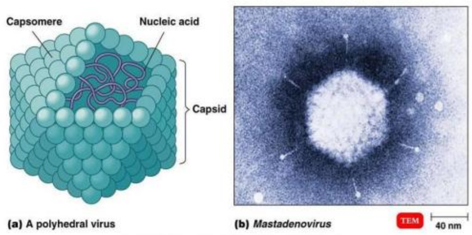
✓ **Icosahedral (polyhedral) symmetry**: These capsids have the geometric shape of an icosahedron (a regular polyhedron with 12 vertices and 20 equilateral triangular faces).

✓ **Helical symmetry**: The nucleocapsid has a helical shape. The capsomeres are attached to the RNA strand, which is coiled into a helix (this capsid shape does not occur in DNA viruses).

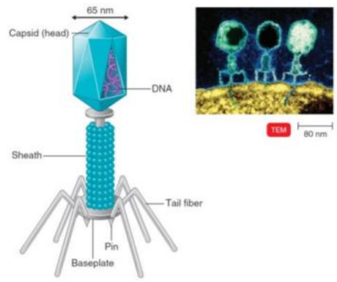
✓ **Other forms**: A limited number of viruses have **complex** capsid symmetry. Some bacteriophages, for example, have a polyhedral "head" and a helical "tail," sometimes with additional structures like tail fibers and spikes.



▷ Helical Viruses



▷ Polyhedral Viruses



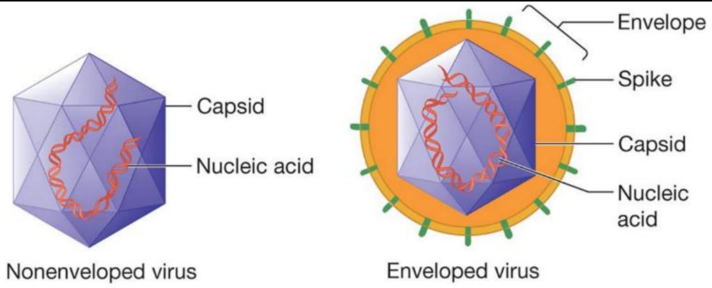
▷ Complex Viruses

2.2.3. **The envelope**: In some viral families, the nucleocapsid is surrounded by an optional outer structure called the *envelope* or *peplos* (coat), in which case the virus is referred to as an *enveloped virus*. Conversely, viruses that lack this envelope are called *naked viruses*.

The envelope is a phospholipid bilayer derived from the host cell, within which proteins and glycoproteins encoded by the viral genome are embedded. It plays a role in host cell recognition during attachment and in the release of virions.

This envelope, which is not present in all viruses, has important antigenic properties due to glycoproteins called *spikes*.

Note: The envelope does not provide protection for the virus. On the contrary, because of its lipid content, it represents a point of vulnerability, making the virus more sensitive to environmental conditions and to treatment with organic solvents.



2.3. Classification of viruses

Biologists have used several classification systems based on different criteria:

2.3.1. Classification by host type

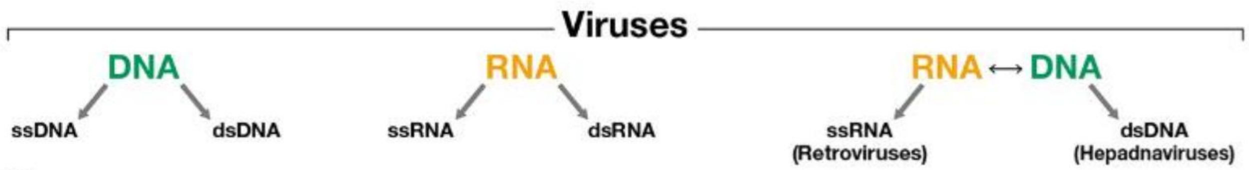
- Plant viruses: These viruses infect plants and can cause diseases in agricultural crops. Animal viruses: These infect animals, including humans, and can cause a range of diseases from the common cold to more serious infections such as HIV, influenza, or Ebola fever.
- Bacterial viruses (bacteriophages): These viruses infect bacteria and use them as hosts to replicate.

2.3.2. Classification by mode of transmission

- Respiratory transmission : Influenza, SARS-CoV-2
- Oral/Fecal transmission: Norovirus, rotavirus, hepatitis A
- Vector-borne transmission: Dengue, Zika, Rift Valley fever
- Blood/body fluid transmission: HIV, hepatitis B and C, Ebola
- Vertical (mother-to-child) transmission: Cytomegalovirus, Zika, rubella
- Cutaneous/direct contact transmission: Herpes, human papillomavirus
- Sexual transmission : HIV, human papillomavirus
- Zoonotic transmission: Rabies, SARS-CoV-2, Ebola

2.3.3. Classification based on the genome structure

This classification groups viruses based on the **type of nucleic acid**



2.4. Virus replication

Viruses reproduce by using living cells to replicate their nucleic acids. The life cycle of viruses can differ greatly between species and category of virus, but they follow the same basic stages for viral replication.

Viral infection and replication can be summarized in six steps:

- **Attachment**: The virus binds to the surface of the host cell using capsid proteins or envelope glycoproteins.
- **Penetration**: Naked viruses may enter via pinocytosis, while enveloped viruses may fuse with the cell membrane or be internalized by endocytosis.

There are several mechanisms depending on the nature of the virus:

a) Membrane fusion ***(enveloped viruses)***

The virus fuses its lipid membrane with that of the host cell. Then, the viral content (capsid or genome) is released into the cytoplasm.

Examples: HIV, influenza virus (after endosomal acidification).

b) Endocytosis ***(enveloped and non-enveloped viruses)***

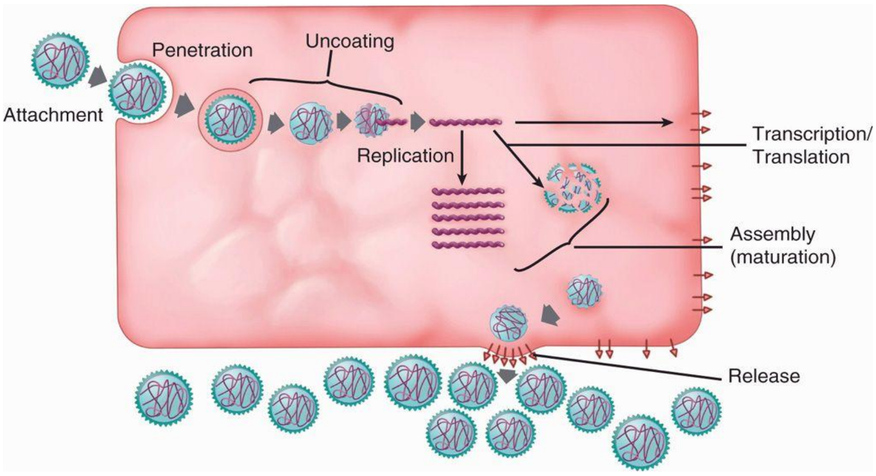
The virus is internalized by the host cell via endocytic vesicles.

Then, the virus is released from the endosome (often due to a pH change) to reach the cytoplasm.

c) Direct injection ***(non-enveloped viruses or bacteriophages)***

The virus directly injects its genome through the plasma membrane. This mechanism is typical of bacteriophages (viruses that infect bacteria): the capsid remains outside the cell.

- **Uncoating**: Once inside the cell, viral structures are degraded, releasing the viral genome.
- **Replication** or Viral Multiplication: The released viral genome takes control of the host's cellular machinery and uses viral mRNA to synthesize new copies of the genome and viral proteins.
- **Assembly**: Newly synthesized viral components are assembled into complete virions within the infected cell. Enveloped viruses acquire their lipid envelope by budding through the host cell membrane, incorporating viral glycoproteins.
- **Release**: Newly assembled virions leave the host cell either through lysis—commonly observed with non-enveloped viruses—or through budding from the plasma membrane, a process typical of enveloped viruses.



The viral life cycle (virus replication)