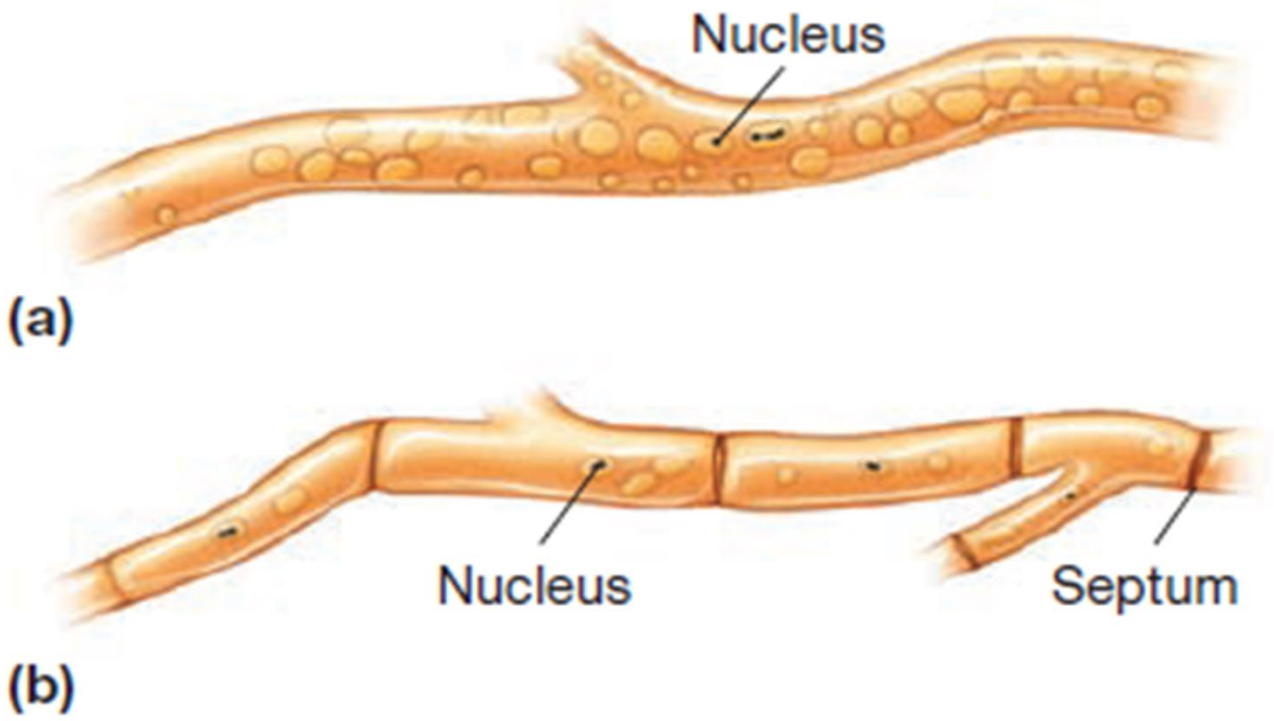
MCB 202

Classification of Fungi
Classification of viruses

FUNGI

- Fungi are large, diverse and widespread group of organism found wherever moisture is present.
- Their habitat are diverse. Some are aquatic, living in fresh water and a few in marine water however, most of them are terrestrial.
- Most fungi are **saprophytes,** securing their nutrients from dead organic material with the aid of hydrolytic exoenzymes that digest external substrates
- They are chemoorganoheterotrophs and use organic compounds as a source of carbon, electrons, and energy
- Most fungi are aerobes however, some especially yeast are facultatively anaerobic and can obtain energy by fermentation
- The fungal cell usually is encased in a cell wall of **chitin,** which is a nitrogen containing polysaccharide consisting of *N*-acetylglucosamine residues.

- The body or vegetative structure of a fungus is called a **thallus** [pl., thalli] that varies in complexity and size.
- Most fungi are multicellular while some are unicellular.
- **Yeast** is the unicellular form of fungus that has a single nucleus and reproduces either asexually by budding and transverse division or sexually through spore formation.
- The multicellular form of fungus is the **mold**. They form a network of long, branched, threadlike filaments called **hyphae.**
- Hyphae grow together across a surface and form compact tufts collectively called **mycelium** which can be seen easily without a microscope.
- The hyphae of some fungi have cross walls called **septa** with either a single pore or multiple pores that enable cytoplasmic streaming. These hyphae are termed **septate**
- In some other fungi, protoplasm streams through hyphae, uninterrupted by cross walls. These hyphae are called **coenocytic** or aseptate
- Reproduction in fungi can be either asexual or sexual
- Asexual reproduction in fungi is achieved in three ways; by simple cell division as in budding, by asexual production of spores or by the growth and spread of hyphal filament.

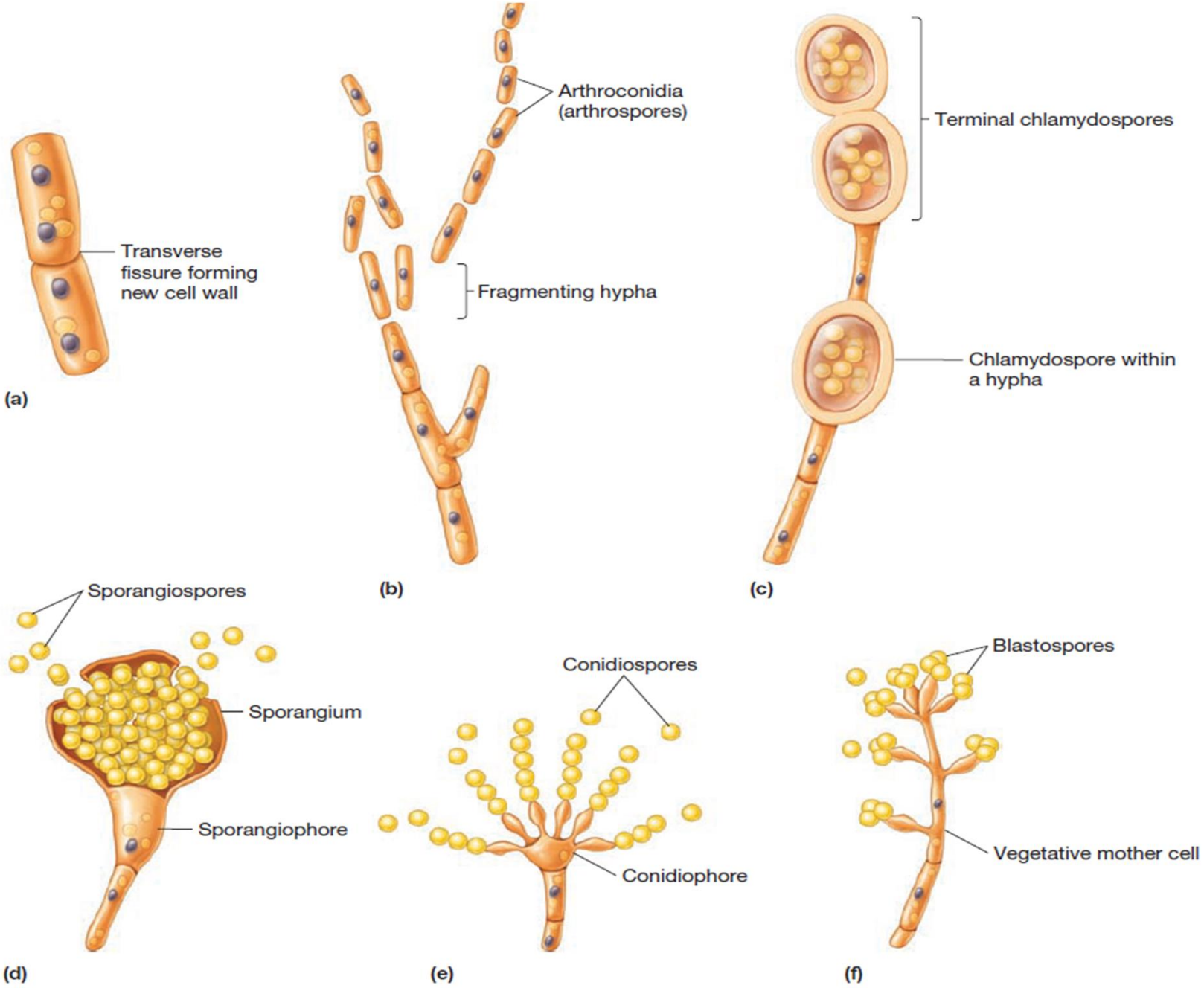


(a) Coenocytic hyphae (aseptate) and
(b) Septate hyphae divided into cells by septa

- The most common method of asexual reproduction is spore production.
- There are several types of asexual spores, each with its own name:

a. A hypha can fragment (by the separation of hyphae through splitting of the cell wall or septum) to form cells that behave as spores. These cells are called **arthroconidia** or **arthrospores** .
b. If the cells are surrounded by a thick wall before separation, they are called **chlamydospores**.
c. The spores can develop within a sac (**sporangium;** pl., sporangia) at a hyphal tip, they are called **sporangiospores**.
d. when the spores are not enclosed in a sac but produced at the tips or sides of the hypha, they are termed **conidiospores**.
e. Spores produced from a vegetative mother cell by budding are called **blastospores.**

- Sexual reproduction in fungi involves the fusion of compatible nuclei.
- Homothallic fungal species are self-fertilizing and produce sexually compatible gametes on the same mycelium while heterothallic species require outcrossing between different but sexually compatible mycelia.
- Depending on the species, sexual fusion may occur between haploid gametes, gamete-producing bodies called **gametangia,** or hyphae


Transverse fissure forming new cell wall
(a)
Arthroconidia (arthrospores)
Fragmenting hypha
(b)
Terminal chlamydospores
Chlamydospore within a hypha
(c)
Sporangiospores
Sporangium
Sporangiophore
(d)
Conidiospores
Conidiophore
(e)
Blastospores
Vegetative mother cell
(f)

- The importance of Fungal spores are;

1. The spores enable fungi to survive environmental stresses such as desiccation, nutrient limitation, and extreme temperatures
2. They frequently aid in fungal dissemination
3. The size, shape, color, and number of spores are useful in the identification of fungal species.

- Fungi, especially the yeasts, are essential to many industrial processes involving fermentation
- They also play a major role in the preparation and synthesis of some important metabolites including antibiotics
- They also play crucial role in the mineralization of organic carbon
- Fungi are important research tools in the study of fundamental biological processes
- On the other hand, fungi are a major cause of diseases in plants, animals and humans
- Many fungi, especially those that cause diseases in humans and animals, are dimorphic that is, they have two forms. Dimorphic fungi can change from the yeast (Y) form in the animal to the mold or mycelial form (M) in the external environment in response to changes in various environmental factors (nutrients, CO2 tension, oxidation-reduction potentials, temperature)

CLASSIFICATION OF FUNGI

- Before the application of molecular techniques, fungi was grouped into five different divisions namely; *Chytridiomycestes, Zygomycota, Ascomycota, Basidiomycota* and *Deuteromycetes* (fungi imperfecti).
- However, advances in molecular techniques, has shown that the *Fungi* comprise a monophyletic group with eight subdivisions.
- Four of these—the *Chytridiomycetes, Zygomycota, Ascomycota,* and *Basidiomytota*—have been recognized as separate groups for some time.
- The other four—the *Urediniomycetes, Ustilaginomycetes, Glomeromycota,* and *Microsporidia* have only recently been proposed as separate groups.

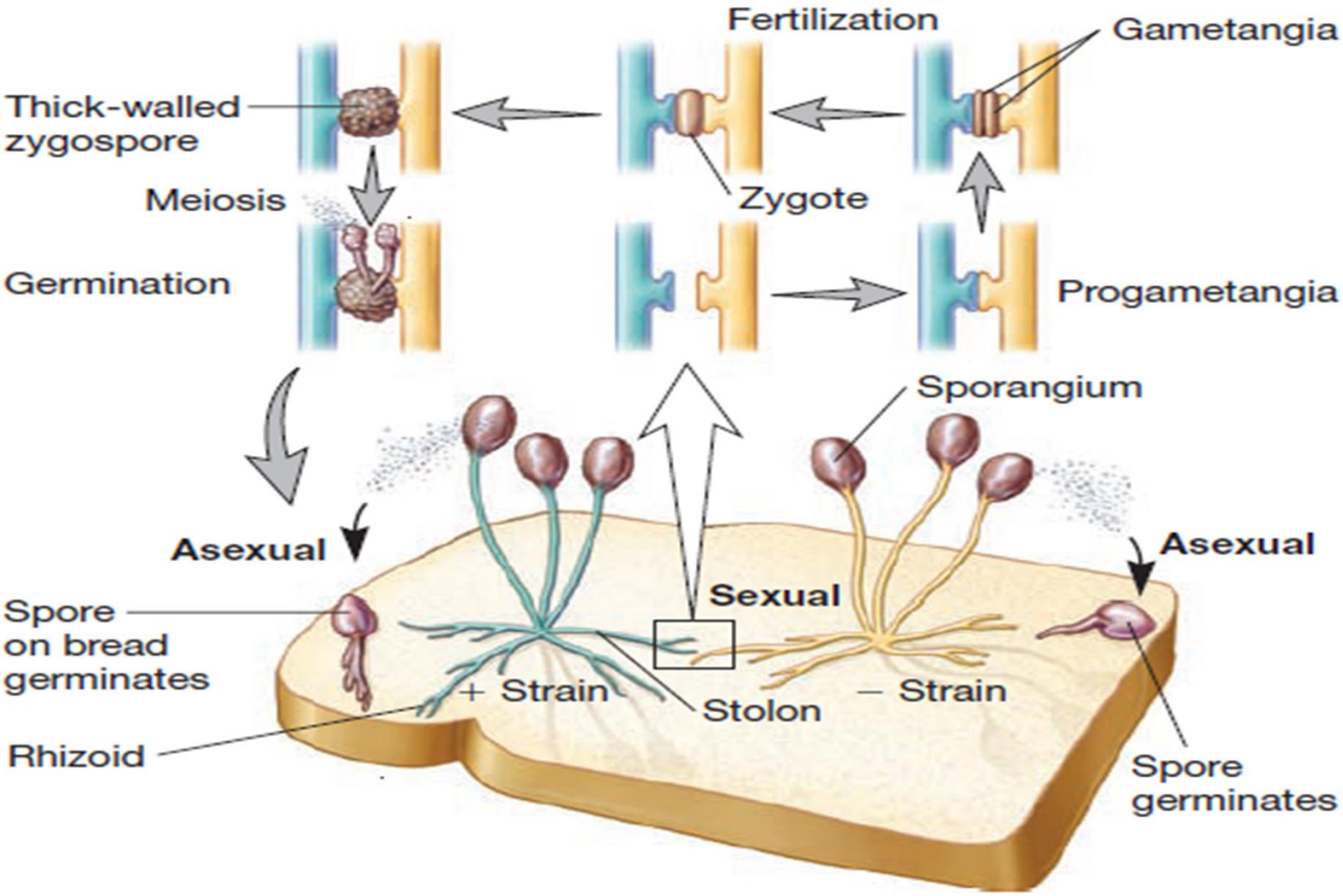
Chytridiomycota (Chytrids)

- They are the simplest fungi and the earliest diverging lineage of fungi.
- Their cell wall is made up of chitin, however, they differ from many other fungi in the production of a zoospore with a single, posterior, whiplash flagellum.
- Free-living members of this taxon are saprotrophic; living on plant or animal matter in freshwater, mud, or soil.
- Parasitic forms infect aquatic plants and animals including insects.
- A few are also found in the anoxic rumen of herbivores
- Based on zoospore morphology, the subdivisions within the Chytridiomycetes include the *Blastocladiales, Monoblepharidales, Neocallimastigaceae, Spizellomycetales,* and the *Chytridiales*

- *Chytridiomycota* display a variety of life cycles involving both asexual and sexual reproduction.
- Sexual reproduction results in the release of sporangiospores from sporangia at the surface Members of this group are microscopic in size and may consist of a single cell, a small multinucleate mass, or a true mycelium with hyphae capable of penetrating porous substrates.
- Many are capable of degrading cellulose and even keratin, which enables the degradation of crustacean exoskeletons

Zygomycota

- The *Zygomycota* contains fungi called zygomycetes. They are primarily known for their role in food spoilage.
- Most live on decaying plant and animal matter in the soil; a few are parasites of plants, insects, other animals, and humans.
- All members of this group are coenocytic (multinuleate).
- Asexual spores, develop in sporangia at the tips of aerial hyphae and are usually dispersed by wind.
- Sexual reproduction produces tough, thick-walled zygotes called zygospores that can remain dormant when the environment is too harsh for growth of the fungus.
- The bread mold, *Rhizopus stolonifer,* is a very common member of this division.
- *Rhizopus* usually reproduces asexually, but if food becomes scarce or environmental conditions unfavorable, it begins sexual reproduction.



The *Zygomycota*. Diagrammatic representation of the life cycle of *Rhizopus stolonifer.* Both the sexual and asexual phases are illustrated.

- Sexual reproduction requires compatible strains of opposite mating types.
- When the two mating strains labeled + and – strains are close, hormones are produced that cause their hyphae to form projections called **progametangia** and then mature gametangia.
- After fusion of the gametangia, the nuclei of the two gametes fuse, forming a zygote. The zygote develops a thick, rough, black coat and becomes a dormant zygospore.
- Meiosis often occurs at the time of germination; the zygospore then splits open and produces a hypha that bears an asexual sporangium and the cycle begins anew.
- The key genera in this group are *Rhizopus* and *Mucor*

Ascomycota

- The *Ascomycota* contain fungi called **ascomycetes,** commonly known as sac fungi
- Ascomycetes range from primarily single-celled species such as yeast *Saccharomyces* to filamentous species such as *Neurospora crassa*.
- Ascomycetes are ecologically important in freshwater, marine, and terrestrial habitats because they degrade many chemically stable organic compounds including lignin, cellulose, and collagen. Many species are quite familiar and economically important.
- The ascomycetes are named for their characteristic reproductive structure, the saclike **ascus**

- The term yeast is used to refer to unicellular fungi that reproduce asexually by either budding or binary fission
- The unicellular ascomycete *Saccharomyces cerevisiae* alternates between haploid and diploid states.
- As long as nutrients remain plentiful, haploid and diploid cells undergo mitosis to produce haploid and diploid daughter cells, respectively.
- Each daughter cell leaves a scar on the mother cell as it separates, and daughter cells bud only from unscarred regions of the cell wall.
- When a mother cell has no more unscarred cell wall remaining, it can no longer reproduce and will senesce (die).
- When nutrients are limited, diploid S. cerevisiae cells undergo meiosis to produce four haploid cells that remain bound within a common cell wall, the acsus.
- Upon the addition of nutrients, if two haploid cells of opposite mating types (*a* and α) come into contact, they will fuse to create a diploid. Typically only cells of opposite mating types can fuse; this process is tightly regulated by the action of pheromones.
- Filamentous ascomycetes form septate hyphae.
- Asexual reproduction is common in these ascomycetes and takes place by means of conidiospores.
- Sexual reproduction also involves ascus formation, with each ascus usually bearing eight haploid ascospores, although some species can produce over 1,000.

- In the more complex ascomycetes, ascus formation is preceded by the development of special **ascogenous hyphae** into which pairs of nuclei migrate.
- Thousands of asci may be packed together in a cup- or flask-shaped fruiting body called an **ascocarp**
- The key genera in this group are *Saccharomyces, Candida, Neurospora* and *Aspergillus*

Basidiomycota

- The *Basidiomycota* includes the **basidiomycetes,** commonly known as club fungi.
- They are a large group of fungi. Many are the commonly recognized mushrooms and toadstools, some are edible such as commercially grown mushroom *Agaricus* and others such as *Amanita* which are highly poisonous.
- During most of its existence, a mushroom fungus lives as a simple haploid mycelium, growing vegetatively in soil, leaf litter or decaying logs.
- It is the sexual reproductive phase of basidiomycetes that produces the familiar mushroom
- Basidiomycetes are named for their characteristic structure or cell, the **basidium,** which is involved in sexual reproduction.
- A basidium is produced at the tip of hyphae and normally is club shaped. Two or more basidiospores are produced by the basidium, and basidia may be held within fruiting bodies called **basidiocarps.**
- The basidiomycetes affect humans in many ways. Most are saprophytes that decompose plant debris, especially cellulose and lignin

- Many mushrooms (e.g. *Agaricus campestris)* are used as food throughout the world and their cultivation is a multimillion-dollar business.
- Many mushrooms (e.g. *Amanita phalloides.*) produce specific alkaloids that act as either poisons or hallucinogens
- The key genera in this group are *Agaricus* and *Amanita*

Glomeromycota

- The glomeromycetes are a relatively small group of fungi that is of major ecological importance because most are endomycorrhizal symbionts of vascular plants*.*
- All known species of this group from endomycorrhizae called arbuscular mycorrhizas typically with the root of herbaceous plants but in some cases also with woody plants.
- This mycorrhizal fungi association with the roots of plants is considered a mutualistic relationship because both the host plant and the fungus benefit: the fungus helps protect its host from stress and delivers soil nutrients to the plant, which in turn provides carbohydrate to the fungus.
- Only asexual reproduction is known to occur in the *Glomeromycota*.
- Spores are produced and germinate when in contact with the roots of a suitable host plant.
- An appressoria is formed and the outgrowth of hyphae forms a new mycelial symbiosis.
- Propagation can also occur by fragmentation and colonization of hyphae from the soil or a nearby plant.

Microsporidia

- The *Microsporidia* have had the most confused taxonomic history amongst all the fungi. They have been considered protists and are sometimes still cited as such.
- Unlike other fungi, they lack mitochonidria, peroxisomes, and centrioles.
- Importantly, they are obligate intracellular parasites that infect insects, fish, and humans.
- They also infect immunocompromised individuals, especially those with HIV/AIDS.
- *Microsporidia* morphology is unique among eucaryotes. Small spores of 1 to 40μm are viable outside the host. Depending on the species, spores may be spherical, rod, egg- or crescent shaped.
- Spore germination is triggered by a signal from the host cells and results in the expulsion of a tightly packed organelle called the polar tube or filament .
- The polar tube is ejected with enough force to pierce the host cell membrane, which permits the parasite's entry.
- Once inside the host cell, the microsporidian undergoes a developmental cycle that differs among the various microsporidian species.
- However, in all cases more spores are produced and eventually take over the host cell.
- Examples of species in this group are *Enterocystozoon bieneusi* and *Encephaolitozoon cuniculi*

Urediniomycetes* and *Ustilaginomycetes

- They are often considered *Basidiomycota but unlike the* basidiomycetes the *Urediniomycetes* and *Ustilaginomycetes* do not form large basidiocarps. Instead small basidia arise from hyphae at the surface of the host plant. The hyphae grow either intra- or extracellularly in plant tissue.
- *They are* important plant pathogens causing “rusts” and “smuts.” In addition, some *Urediniomycetes* are human pathogens. These fungi are virulent plant pathogens that cause extensive damage to cereal crops
- The ustilaginomycete *Ustilago maydis* is a common corn pathogen that has become a model organism for plant smuts and is dimorphic.
- In nature, the yeast form must mate to produce infectious, filamentous dikaryons that depend on the host plant for continued development.
- Once a plant is infected, *U. maydis* forms specialized flat hyphae called **appressoria** that enable penetration and subsequent reproduction within the host.
- This triggers the plant to form tumors, in which the fungus proliferates and eventually produces diploid spores called teliospores.
- Upon germination, cells undergo meiosis and haploid sporidia are released, causing the infection to spread from plant to plant

- NB

Scientists who study fungi are **mycologists** and the scientific discipline devoted to fungi is called **mycology.** The study of fungal toxins and their effects is called **mycotoxicology,** and the diseases caused by fungi in animals are known as **mycoses**

CLASSIFICATION OF VIRUSES

- Viruses are infectious agents with fairly simple, acellular organization
- They are genetic elements that cannot replicate independently of a living cell called host cell.
- Thus, viruses are obligate intracellular parasites that rely on entering a suitable living cell to carry out their replication cycle. However, they have their own genetic information and are independent of the host cell's genome but they exploit the metabolic machinery of the host cell.
- Viruses can exist in the intracellular or extracellular forms
- The extracellular form enables them to exist outside the host cell for long periods and facilitates transmission from one host cell to another.
- In this extracellular form, the virus is microscopic, contains nucleic acid surrounded by protein and other macromolecules.
- The extracellular form of virus particle called virion is metabolically inert and does not carry out respiration or biosynthesis
- Viruses enter their host cell through a process called infection
- Viral replication in a host cell can be either beneficial or destructive
- Most viruses possess only one type of nucleic acid, either DNA or RNA
- Viruses differ from living cells in at least three ways: (1) their simple, acellular organization; (2) the presence of either DNA or RNA, but not both, in almost all virions; and (3) their inability to reproduce independent of cells and carry out cell division as procaryotes and eucaryotes do.

- All virions, are constructed around a **nucleocapsid** core which is composed of a nucleic acid, usually either DNA or RNA, held within a protein coat called the **capsid,** which protects viral genetic material and aids in its transfer between host cells.
- The various morphological types of viruses primarily result from the combination of a particular type of capsid symmetry with the presence or absence of an envelope, which is a lipid layer external to the nucleocapsid
- There are three types of capsid symmetry: helical, icosahedral, and complex.
- Those virions having an envelope are called **enveloped viruses;** whereas those lacking an envelope are called **naked virus**
- viral reproduction/ replication is divided into five major;

1. The first step in the life cycle of a virus is attachment to a host.
2. This is followed by penetration or injection of either the viron or the viral nucleic acid into the host.
3. The third step is synthesis of virus nucleic acid and protein by cell metabolism as directed by the virus.
4. This is followed by assembly of the capsids (and membrane component in enveloped viruses) and packaging of viral genomes into new virions (a process called maturation).
5. The final step is the release of the mature virions

- Animal viruses are cultivated by inoculating them into suitable host animals, tissue (cell) culture on monolayers of animal or embryonated eggs—fertilized chicken eggs incubated about 6 to 8 days after laying.

- Bacterial and archaeal viruses are cultivated in either broth or agar cultures of young, actively growing cells
- Plant viruses are cultivated in a variety of ways. Plant tissue cultures, cultures of separated cells, or cultures of protoplasts (cells lacking cell walls) may be used. Viruses also can be grown in whole plants or leaves

Classification of viruses

- The classification of viruses is in a much less satisfactory state than that of cellular microorganisms
- Viruses can be classified on the basis of host they infect as well as by their genomes
- Based on their host we have;

1. Bacterial and archaeal viruses
2. Animal viruses
3. Plant viruses.

- The International Committee for Taxonomy of Viruses (ICTV) developed a uniform classification system. In their latest classification, the ICTV described almost 9110 virus species and placed them in 59 orders, 189 families, 136 subfamilies, and 2224 genera.
- ICTV classification of viruses is based on features such as molecular composition of the genome; the structure of the virus capsid and whether or not it is enveloped; the gene expression program used to produce virus proteins; host range; pathogenicity; and sequence similarity.

- However, sequence comparisons using both pairwise sequence similarity and phylogenetic relationship have become the basic set of character used to define and distinguish virus taxa
- Although the ICTV committee reports are the official authority on viral taxonomy, many virologists find it useful to use an alternative classification scheme devised by Nobel laureate David Baltimore.
- The Baltimore system complements the ICTV system but focuses on the genome of the virus and the process used to synthesize viral mRNA
- The Baltimore classification scheme for viruses is based on the relationship of the viral genome to its mRNA.
- In this classification scheme, **seven classes** of viruses are recognized;

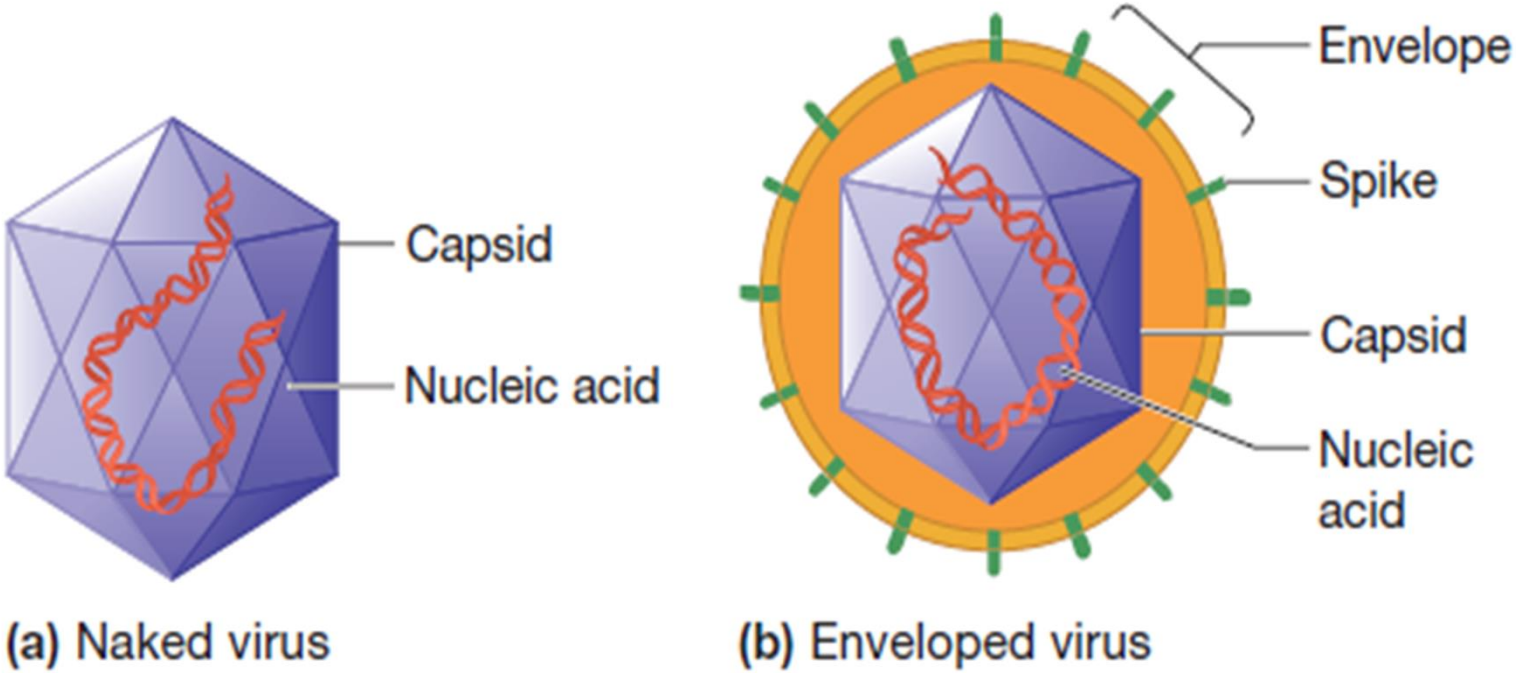
- **Class I** are the **Double-stranded (ds) DNA** viruses. The mechanism of mRNA production and genome replication of class I viruses is the same as that used by the host cell genome. However, different viruses use different strategies to ensure that viral mRNA is expressed in preference to host mRNA. Example is the Herpesvirus
- **Class II** viruses are the **Single-stranded (ss) DNA** viruses. This class of viruses form a double-stranded DNA intermediate during replication which is used for the synthesis of mRNA. Example is the Parvovirus
- **Class III** viruses are the **Double-stranded (ds) RNA** viruses. This class of viruses contain RNA polymerase which transcribe the dsRNA genome to produce plus-stranded mRNA upon entry into the host cell. Example is the Reovirus

- **Class IV** viruses are the **Positive-strand (+ss) RNA** viruses**.** In this class, the viral genome is of plus configuration hence can function directly as mRNA. However, to make more viral genome, this mRNA codes a virus specific *RNA replicase* which makes a complementary minus strand RNA and uses them as templates to make more plus strands. Example is the Poliovirus
- **Class V** viruses are the **Negative-strand (-ss) RNA** viruses**.** The replication in this class of virus is complex because the incoming mRNA is in the wrong polarity. The virus carry the *RNA-dependent RNA polymerase* required to synthesize the plus strand RNA which serves as the mRNA and also as a template to make more negative-strand genome. Example is the Influenza virus
- **Class VI** viruses are the **Single-stranded (ss) RNA** viruses. They are also known as the **retrovirus**. This class of viruses have single-stranded RNA in their virions but replicate through a dsDNA intermediate through a process called **reverse transcription** with the help of an enzyme called *reverse transcriptase.* Example is the Retrovirus
- **Class VII** viruses are the **Double stranded (ds) gapped DNA** viruses. This class of viruses have double-stranded DNA in their virions but replicate through an RNA intermediate using *reverse transcriptase*. They produce their mRNA same way as class I viruses. However, they have unusual DNA replication process because their genome is only partially stranded. Example is the Hepatitis B virus

NB
Virus order names end in ***virales****;* virus family names in ***viridae****;* subfamily names, in ***virinae****;* and genus (and species) names, in ***virus***

The Baltimore System of Virus Classification

Class	Description
I	Double-stranded DNA genome; ***Replication****: dsDNA → dsDNA* ***mRNA synthesis****: dsDNA → mRNA*
II	Single-stranded DNA genome; ***Replication****: ssDNA → dsDNA →ssDNA* ***mRNA synthesis****: ssDNA → dsDNA → mRNA*
III	Double-stranded RNA genome; ***Replication****: dsRNA → ssRNA →dsRNA* ***mRNA synthesis****: dsRNA → mRNA*
IV	Plus-strand RNA genome; ***Replication****: RNA → RNA → RNA* ***mRNA synthesis****: RNA mRNA*
V	Negative-strand RNA genome; ***Replication****: RNA → RNA → RNA* ***mRNA synthesis****: RNA → mRNA*
VI	Single-stranded RNA genome; ***Replication****: ssRNA → dsDNA → ssRNA* ***mRNA synthesis****: ssRNA → dsDNA → mRNA*
VII	Double-stranded gapped DNA genome; ***Replication****: gapped dsDNA → dsDNA → RNA → DNA → gapped dsDNA* ***mRNA synthesis****: gapped dsDNA →dsDNA →mRNA*



Generalized Structure of Viruses.

(a) The simplest virus is a naked virus (nucleocapsid) consisting of a geometric capsid assembled around a nucleic acid strand.

(b) An enveloped virus is composed of a nucleocapsid surrounded by a flexible membrane called an envelope. The envelope usually has viral proteins called spikes inserted into it.