CHAPTER

8

Fungi The Kingdom Of Recyclers

Animation 8.1: Kingdom Fungi
Source & Credit: unifyingprinciplesofbiology

Approximately 100,000 species of organisms called "**fungi**" are known and many more are estimated to be present. This group includes notorious pathogens such as disastrous rusts, smuts of wheat and com, and molds found growing on important crops and foodstuff. Delicacies such as mushrooms, truffles and morels, and other organisms of commercial use such as *Penicillium* - the source of antibiotic penicillin, and the **yeasts** - used in bakeries and breweries are also members of this group. Ecological role of fungi as decomposers is paralleled only by bacteria.

Taxonomic status of fungi has changed from that of 'a group of Plant kingdom' to a separate kingdom "Fungi". They resemble plants in some respects - have cell wall, lack centrioles and are non-motile. But fungi resemble more animals than plants. Unlike plants and like animals, fungi are heterotrophs, lack cellulose in their cell wall and contain **chitin** - the chemical found in external skeleton of **arthropods**. For this reason, some **mycologists** (scientists who study fungi) think that fungi and animals probably arose from a common ancestor. But fungi are different from animals in having cell wall, being absorptive heterotrophs and non-motile. So fungi are neither plants nor animals. Their DNA studies also confirm that they are different from all other organisms. They show a characteristic type of mitosis, called '**nuclear mitosis**'. During nuclear mitosis, nuclear envelope does not break; instead the mitotic spindle forms within the nucleus and the nuclear membrane constricts between the two clusters of daughter chromosomes. (In some fungi nuclear envelope dismantles late). Because fungi are distinct from plants, animals and protists in many ways, they are assigned to a separate kingdom **'Fungi'.**

THE BODY OF FUNGUS

The body of a fungus, called **mycelium**, consists of long, slender, branched tubular thread like filaments called the **hyphae** (singular **hypha**). Hyphae spread extensively over the surface of substratum. Chitin in their wall is more resistant to decay than are cellulose and **lignin** which make up plant cell wall. Hyphae may be septate or non-septate. **Septate** hyphae are divided by cross-walls called **septa** (singular septum) into individual cells containing one or more nuclei. Non-septate hyphae lack septa and are not divided into individual cells; instead these are in the form of an elongated multinucleated large cell. Such hyphae are called **coenocytic** hyphae, in which cytoplasm moves effectively, distributing the materials throughout. Septa of many septate fungi have a pore through which cytoplasm flows from cell to cell, carrying the materials to growing tips and enabling the hyphae to grow rapidly when food and water are abundant and temperature is favourable. All parts of fungus growing through the substrate are metabolically active. Extensive spreading system of hypae provides enormous surface area for absorption.

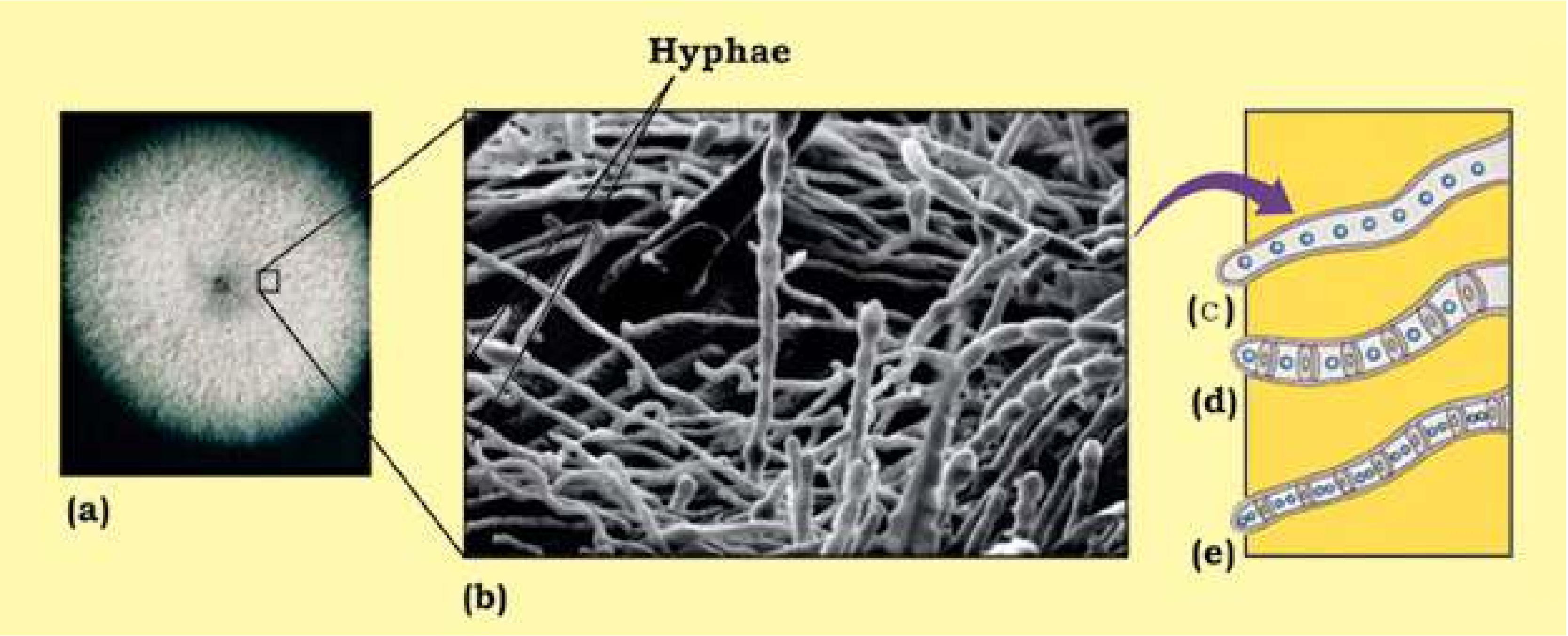

Fig 8.1 The fungus body plan : (a) Fungus mycelium growing on agar plate (b) Hyphae of mycelium (c) A coenocytic hypha (d) A septate hypha with porous septa and monokaryotic cells (e) A septate hypha with dikaryotic cell.

Hyphae may be packed together and organized to form complex reproductive structures such as mushrooms, puff balls, morels etc. which can expand rapidly. Yeast are non-hyphal unicellular fungi.

All fungal nuclei are **haploid** except for transient **diploid zygote** that forms during sexual reproduction.

A single mycelium may produce upto a kilometer of new hyphae in only one day. A circular clone of Armillaria, a pathogenic fungus afflicting conifers, growing out from a central focus, has been measured upto 15 hectares (1 hectare = 10000 m^2). Could it be the world's largest organism?

NUTRITION IN FUNGI

All fungi lack chlorophyll and are heterotrophs (obtaining carbon and energy from organic matter). They obtain their food by direct absorption from the immediate environment and are thus **absorptive heterotrophs**. Most fungi are **saprotrophs** (or **saprobes**), **decomposers** that obtain their food (energy, carbon and nitrogen) directly from dead organic matter. They secrete out digestive **enzymes** which digest dead organic matter, and the organic molecules thus produced are absorbed back into the fungus. Saprobic fungi anchor to the substrate by modified hyphae, the **rhizoids**. Fungi are the principal decomposers of cellulose and lignin, the main components of plant cell walls (most bacteria cannot break them). Extensive system of fast growing hyphae provides enormous surface for absorptive mode of nutrition. Saprobic fungi, alongwith bacteria, are the major decomposers of the biosphere, contributing to the recycling of the elements (C, N, P, 0, H etc) used by living things.

Some fungi are **parasites**, some are even **predators**, and still others are **mutualists**. **Parasitic** fungi absorb nutrients directly from the living host cytoplasm with the help of special hyphal tips called **haustoria**. They may be obligate or facultative. Obligate parasites can grow only on their living host and cannot be grown on available defined growth culture medium. Various **mildews** and most rust species are obligate parasites. **Facultative parasites** can grow parasitically on their host as well as by themselves on artificial growth media.

Some fungi are active **predators**. The oyster mushroom (*Pleurotus ostreatus*) is an omnivorous (predatory) fungus. It paralyses the nematodes (that feed on this fungus), penetrate them, and absorb their nutritional contents, primarily to fulfil its nitrogen requirements. It fulfills its glucose requirements by breaking the wood. Some species of *Arthrobotrys* trap soil nematodes by forming **constricting ring,** their hyphae invad and digest the unlucky victim. Other predators have other adaptations, such as secretion of sticky substances.

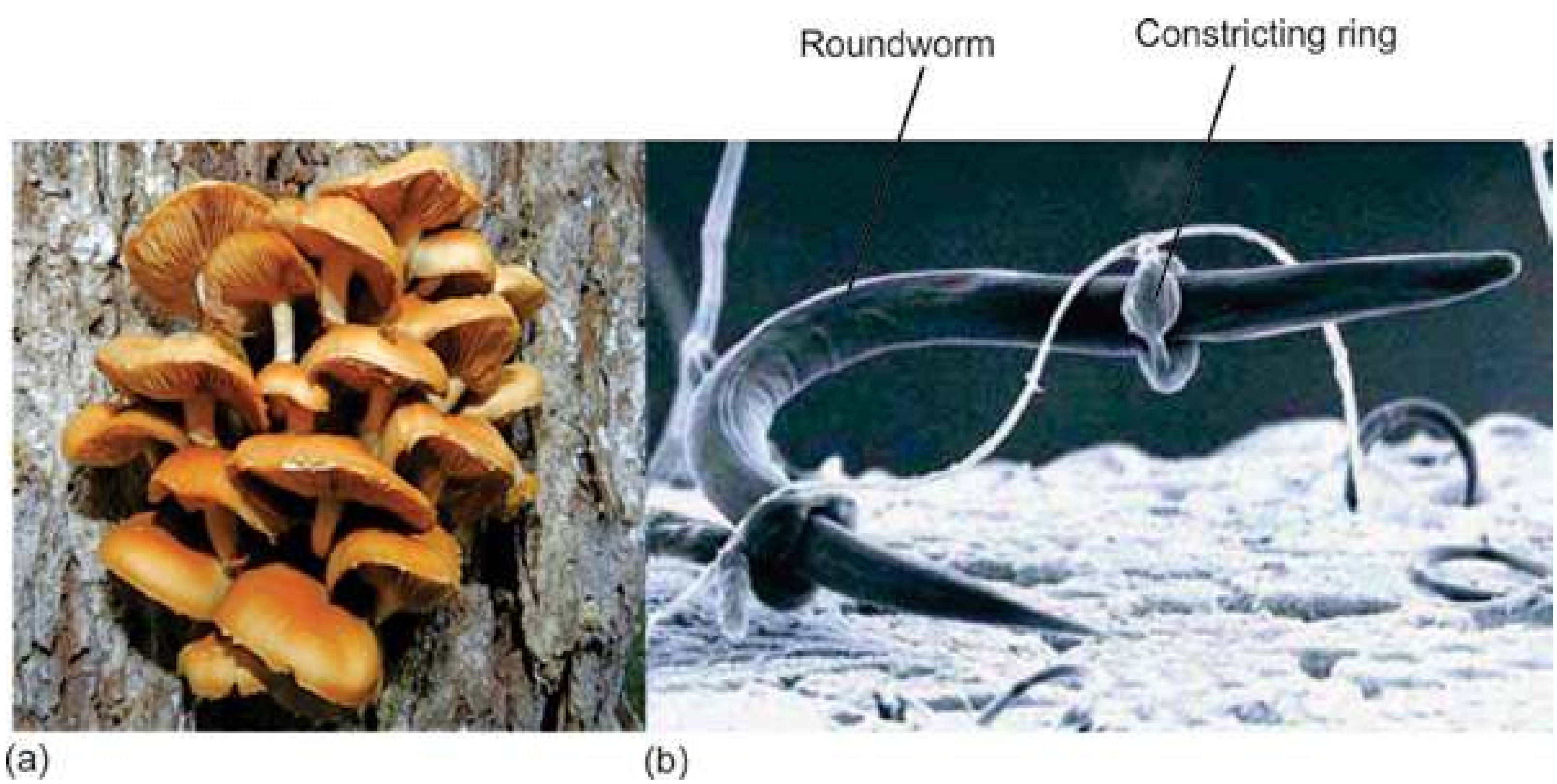

Fig 8.2 Carnivorous fungi (a) The osyter mushroom decomposes wood, and also uses nematodes as a source of nitrogen (b) A nematode is trapped in constricting ring of a soil - dwelling carnivorous fungus ***(Arthrobotrys sp.)****.*

Fungi form two key mutualistic symbiotic associations (associations of benefit to both partners). These are **lichens** and **mycorrhizae**.

Lichens are mutualistic symbiotic associations between certain fungi (mostly Ascomycetes and imperfect fungi, and few Basidiomycetes - about 20 out of 15000 species of lichens) and certain photoautotrophs-either green algae or a cyanobacterium, or some times both. Most of the visible part of lichen consists of fungus, and algal components are present within the hyphae (Fig 8.3). Fungus protects the algal partner from strong light and desiccation and itself gets food through the courtesy of alga.

Lichens can grow at such places where neither of the components alone can, even at harsh places such as bare rocks etc. Lichens vary in colour, shape, overall appearance, growth form (Fig 8.3). They are ecologically very important as bioindicators of air pollution.

Video 8.2: Fungal network
Source and Credit: pmb.ox.ac

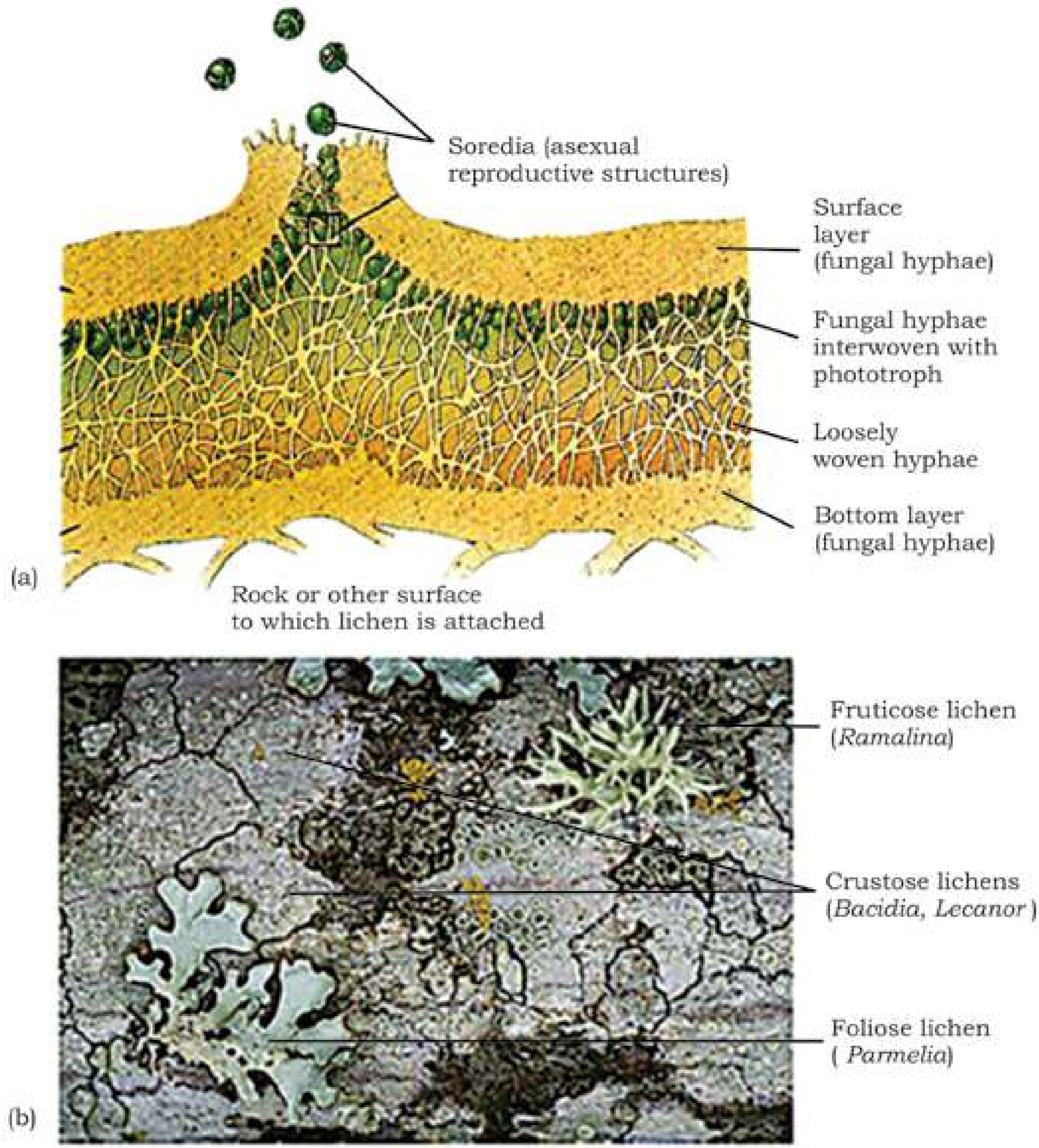

Fig 8.3 Lichens (a) Cross section of a typical lichen showing different layers, (b) Different types of lichens varying in size, colour and appearance. Three growth forms - crustose grow tightly attached to rocks, tree trunks etc; foliose are leaf - like, fruticose are branching.

Mycorrhizae are mutualistic association between certain fungi and roots of vascular plants (about 95% of all kinds of vascular plants). The fungal hyphae dramatically increase the amount of soil contact and total surface area for absorption and help in the direct absorption of phosphorus, zinc, copper and other nutrients from the soil into the roots. Such plants show better growth than those without this association. The plant, on the other hand, supplies organic carbon to fungal hyphae.

There are two main types of mycorrhizae (Fig 8.4): **endomycorrhizae**, in which the fungal hyphae penetrate the outer cells of the plant root, forming coils, swellings, and minute branches, and also extend out into surrounding soil; and **ectomycorrhizae**, in which the hyphae surround and extend between the cells but do not penetrate the cell walls of the roots. These are mostly formed with pines, firs etc. However, the mycelium extends far out into the soil in both kinds of mycorrhizae.

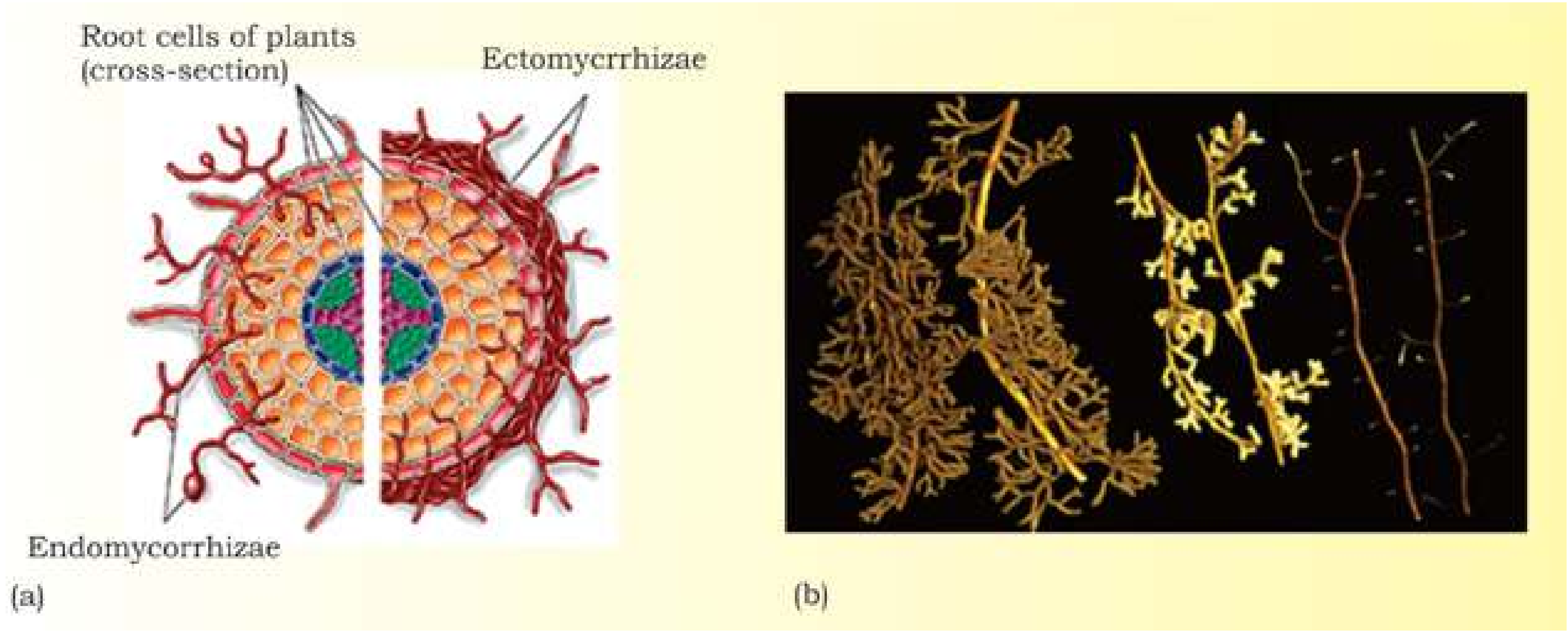

Fig 8.4 Endomycorrhizae and ectomycorrhizae. (a) In endomycorrhiza (left side of figure), fungal hyphae penetrate and branch out in a root cells. In ectomycorrhiza (right side of figure), fungal hyphae simply grow around but do not penetrate the root cell (b) Ectomycorrhizae on roots of pines.

Fungi grow best in moist habitats, but are found wherever organic matter is present. They survive dry conditions in some resting stage or by producting resistant spores. They can also tolerate a wide range of pH from 2 - 9, a wide temperature range, and high osmotic pressure such as in concentrated salt/sugar solutions as in jelly, jam etc. These features also help them in their survival on land. Fungi store surplus food usually as lipid droplets or glycogen in the mycelium.

REPRODUCTION

Most fungi can reproduce asexually as well as sexually (except imperfect fungi in which sexual reproduction has not been observed).

Asexual reproduction

Asexual reproduction takes place by spores, conidia, fragmentation, and budding. **Spores** are produced inside the reproductive structures called **sporangia**, which are cut off from the hyphae by complete septa. Spores may be produced by sexual or asexual process, are haploid, non-motile and not needing water for their dispersal, are small, produced in very large number and dispersed by wind to great distances and cause wide distribution of many kinds of fungi, including many plant pathogens. When spores land in a suitable place, they germinate, giving rise to new fungal hyphae. Spores may also be dispersed by insects and other small animals and by rain splashes. Spores are a common means of reproduction in fungi.

Conidia (singular conidium) are non- motile, asexual spores which are cut off at the end of modified hyphae called **conidiophores**, and not inside the sporangia, usually in chains or clusters. These may be produced in a very large number, can survive for weeks and cause rapid colonization of new food.

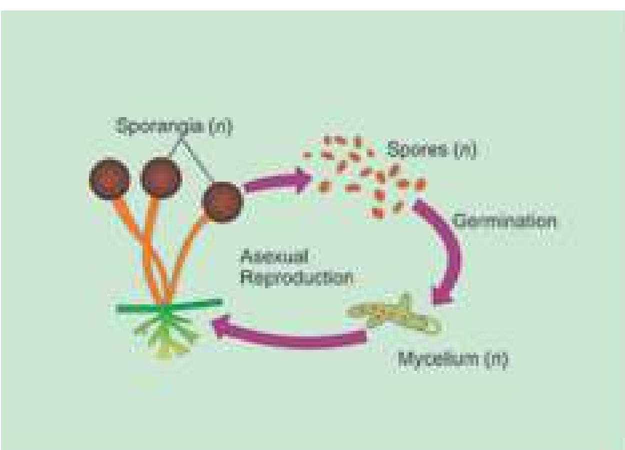

Fig. 8.5 Spores are released from sporangia and germinate to produce new hyphae.

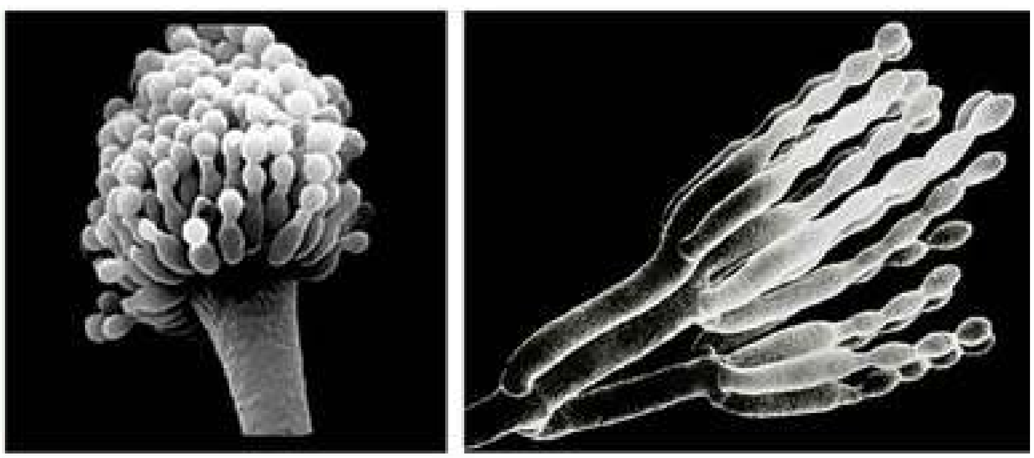

Fig. 8.6 Conidia cut off at the tip of conidiophores in clusters chains

Fragmentation is simple breaking of mycelium of some hyphal fungi, each broken fragment giving rise to a new mycelium.

Unicellular yeasts reproduce by **budding** (an asymmetric division in which tiny outgrowth or bud is produced which may separate and grow (Fig 8.7), or by simple, relatively equal cell division.

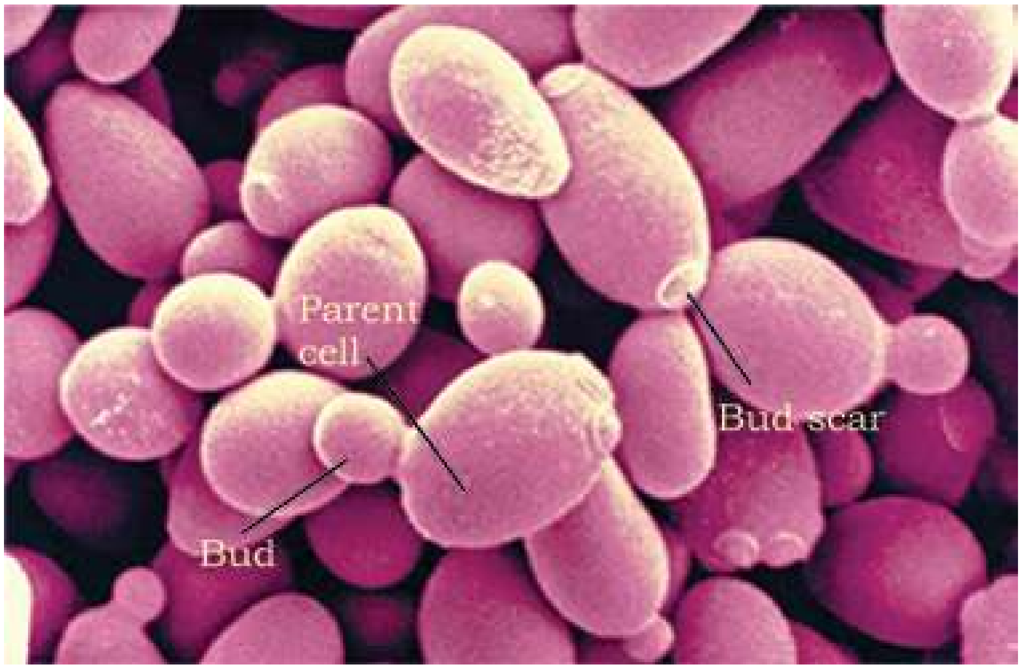

Fig. 8.7 Micrograph shows yeast (Saccharomyces cerevisiae) in various stages of budding.

Sexual Reproduction

Details of sexual reproduction vary in different groups of fungi but fusion of haploid nuclei and meiosis are common to all. When fungi reproduce sexually, hyphae of two genetically different but compatible mating types come together, their cytoplasm fuse followed by nuclear fusion. In two of the three main groups of fungi (Basidiomycetes, Ascomycetes), fusion of nuclei (**karyogamy**) does not take place immediately after the fusion of cytoplasm (**plasmogamy**); instead the two genetic types of **haploid** nuclei from two individuals may coexist and divide in the same hyphae for most of the life of the fungus. Such a fungal hypha/cell having 2 nuclei of different genetic types is called **dikaryotic** (also **heterokaryotic**) hypha/cell (Fig. 8.1).

Different groups of fungi produce different types of haploid sexual spores, such as **basidiospores** and **ascospores**, subsequent upon meiosis in zygote. These spores may be produced by their characteristic structure/fruiting bodies such as **basidia/basidiocarps** and **asci/ascocarps**.

CLASSIFICATION OF FUNGI

Classification of fungi into four main groups is based primarily on the type of their sexual reproductive structures and methods of reproduction. However, these groups also differ in the type of hyphae and some other characters (Table 8.1).

Table 8.1 Classification of Fungi

Phylum (group)	Typical examples	Sexual reproduction	Asexual reproduction	Hyphae
Zygomycota (Zygomycetes)	*Rhizopus*, (Black bread mold) *Pilobolus* (spitting fungus)	Zygospores	Non-motile spores form in sporangia	Nonseptate, multi nucleate
Ascomycota (Ascomycetes or sac - fungi)	Yeasts, morels, truffles, powdery mildews,molds	Ascospores inside sac-like asci	Conidia cut off from tips of conidiophores	Septate, lengthy dikaryotic phase.
Basidiomycota (Basidiomycetes or club-fungi)	Mushrooms, rusts, smuts, puffballs, bracket fungi	Basidiospores borne on club shaped basidia	Uncommon	Septate, lengthy dikaryotic phase
Deuteromycota (Deuteromycetes/ Imperfect fungi)	*Aspergillus, Penicillium, Altemaria*	Sexual phase has not been observed	Conidia	Varied

Zygomycota (Zygomycetes or Conjugating Fungi)

During their sexual reproduction, zygote formed directly by the fusion of hyphae forms temporary, dormant, thick walled resistant structure called zygospore, hence the name Zygomycetes. Meiosis takes place when zygospore germinates and haploid spores are produced. Spores on germination produce new mycelium. Asexual reproduction by spores is common. Hyphae are coenocytic.

Example: Rhizopus, found growing on spoiling moist bread, fruit etc.

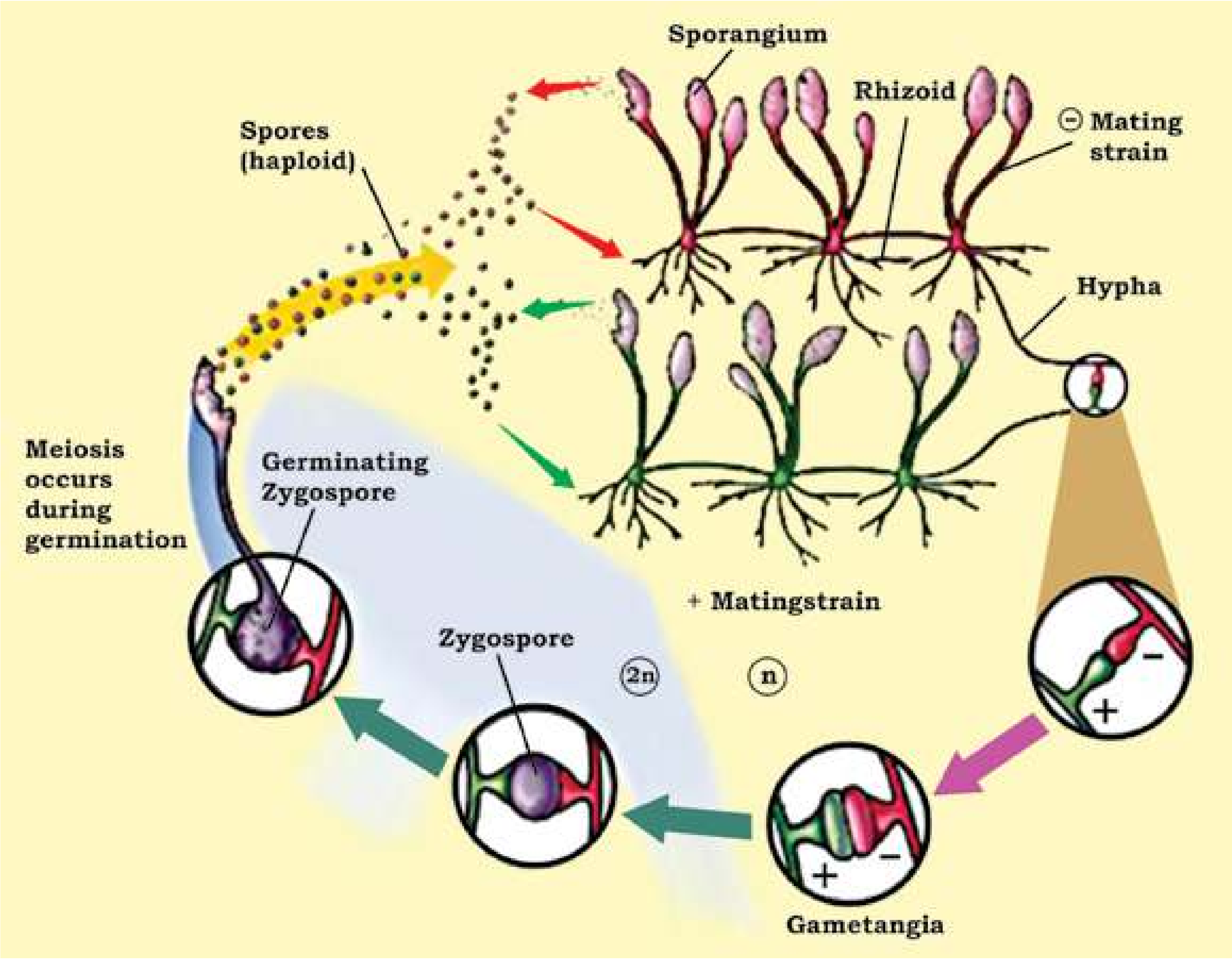

Fig. 8.8 Life cycle, of Rhizopus (black bread mold), a Zygomycete. Zygote formed by fusion, of gametangia directly develops into a resting zygospore.

Ascomycota (Ascomycetes or Sac - Fungi)

It is the largest group of fungi, including over 60,000 species, 50% or so occurring in lichens and some, such as morels, are mycorrhizal. Most are terrestrial, though some are marine or fresh water. The group shows diversity from unicellular yeasts to large cup fungi and morels. They produce haploid sexual spores called **ascospores** by meiosis inside their characteristic sac like structures called **asci** (sing.ascus). Meiosis follows nuclear fusion inside the ascus, commonly 8 ascospores are produced inside each ascus. Most sac-fungi have asci inside macroscopic fruiting bodies called **ascocarps**-the visible morels etc. Their hyphae are septate. They have lengthy dikaryotic phase that forms ascocarps. They reproduce asexually by conidia that are often dispersed by wind.

Yeasts are unicellular microscopic fungi, derived from all the three different groups of fungi but mostly Ascomycetes, and reproducing mostly asexually by budding (Fig. 8.7).

However yeasts reproduce sexually by forming asci/ascospores or basidia/basidiospores. They ferment carbohydrate (glucose) to ethanol and carbondioxide. Because of this feature and many other reasons, these are of great economic importance (see economic importance of fungi). *Saccharomyces cerevisiae* is the most commonly exploited yeast.

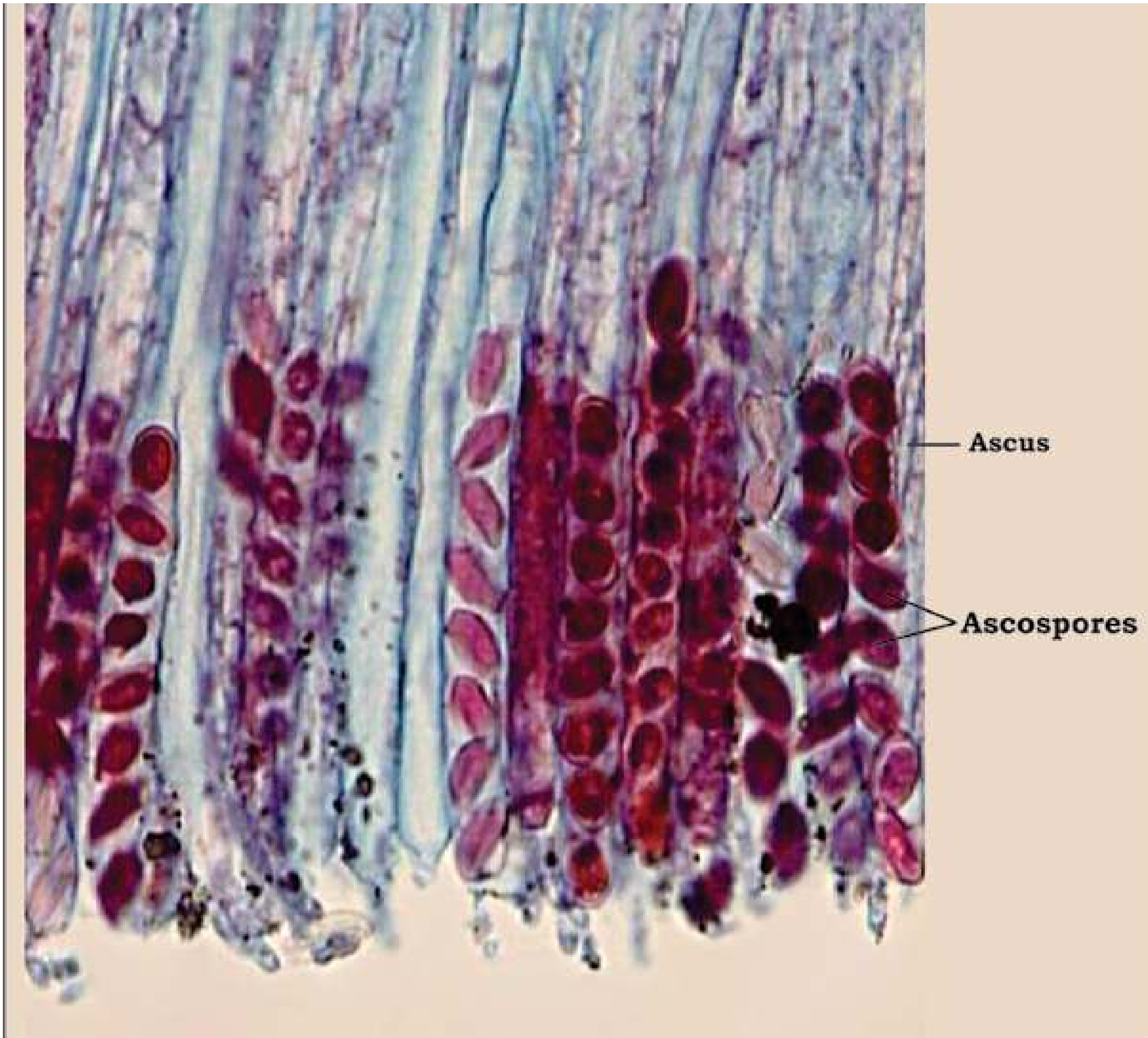

Fig. 8.9 Asci and Ascospores. Each ascus contains eight haploid ascospores

Basidiomycota (Basidiomycetes or Club - Fungi)

These are among the most familiar fungi; edible mushrooms, devastating plant pathogens rusts and smuts, puffballs, and bracket/shelf fungi are all club fungi. Basidiomycetes are named so for their characteristics, club-shaped (hence also called club fungi) sexual reproductive structure, the **basidium** (plural **basidia**). Nuclear fusion in the basidium is followed by meiosis.

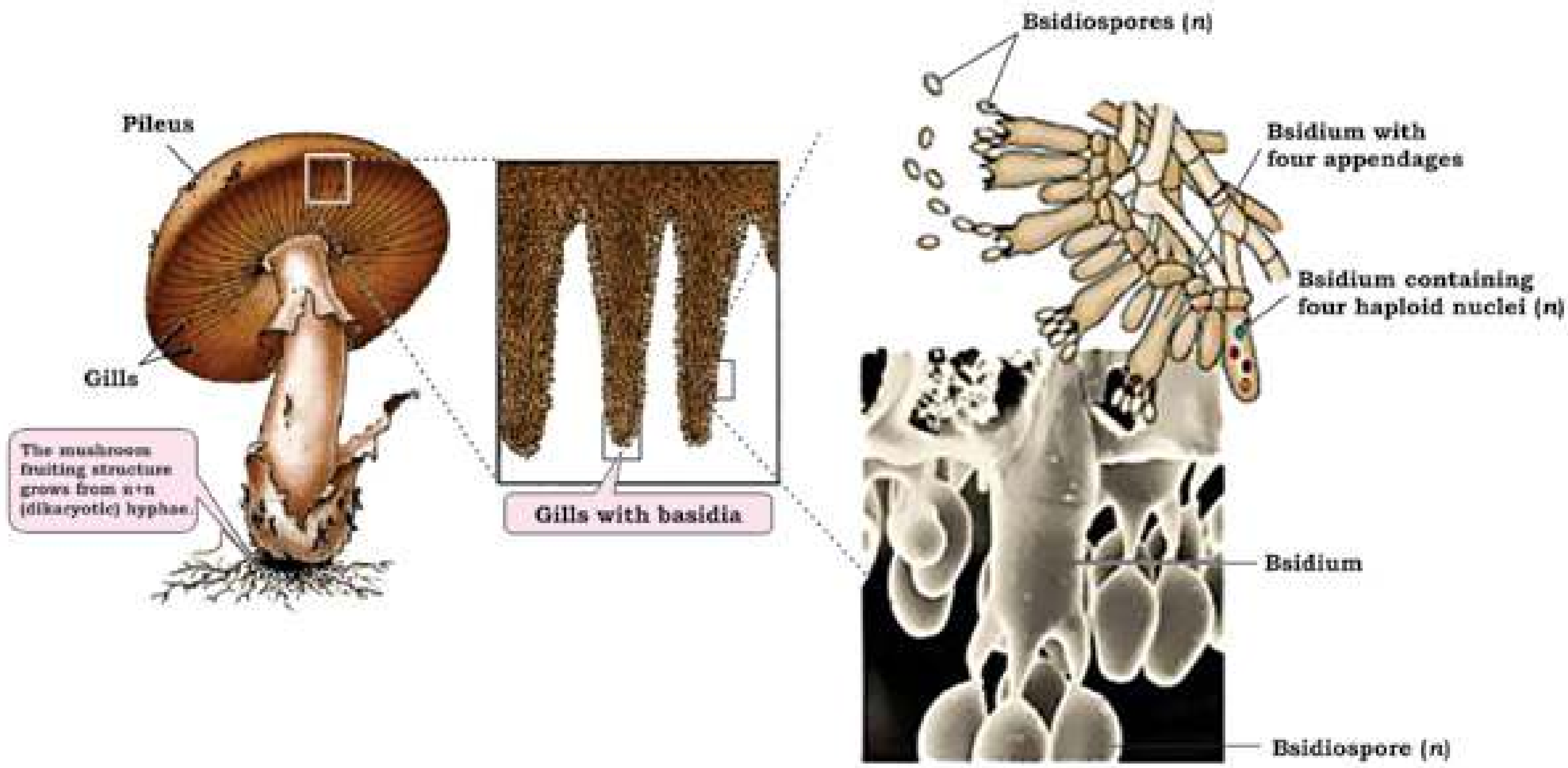

Fig. 8.10 Basidiomycetes. A mushroom's fruiting structures. The gills on underside of mushroom's cap are lined with basidia, on which basidiospores are produced.

Four haploid sexual spores, called the **basidiospores**, are born on, not inside, each basidium. During most part of their life cycle the hyphae are septate; the cells are uninucleate during one phase, and binucleate (dikaryotic) during the remaining, lengthy phase. Their characteristic fruiting bodies, or visible mushrooms, are formed entirely of dikaryotic mycelium. **Puccinia** species are most common rust fungi, and **Ustilago** species most common smut fungi.

Rusts are called so because of numerous rusty, orange-yellow coloured disease spots on their host surface (mostly stem, leaves), later revealing brick/rust-red spores of the fungus. **Smuts** are called so because of their black, dusty spore masses that resemble soot or smut; these spore masses replace the grain kernels such as those of wheat, corn etc. (Fig. 8.11, 8.15)

Spores (teliospores) of *Ustilago tritici* (loose smut of wheat) are carried by wind from infected wheat ears to healthy flowers, where they germinate. The resulting hyphae penetrate flower ovaries. Inside the ovary mycelium spreads and becomes dormant and remains so in the seed (grain). When such infected seeds are sown next season, the hyphae also grow within the growing plant and form smut spores inside the kernel, thus destroying them completely. The covering of the grain breaks exposing the black spores mass, that may be dispersed by wind (Fig. 8.11)

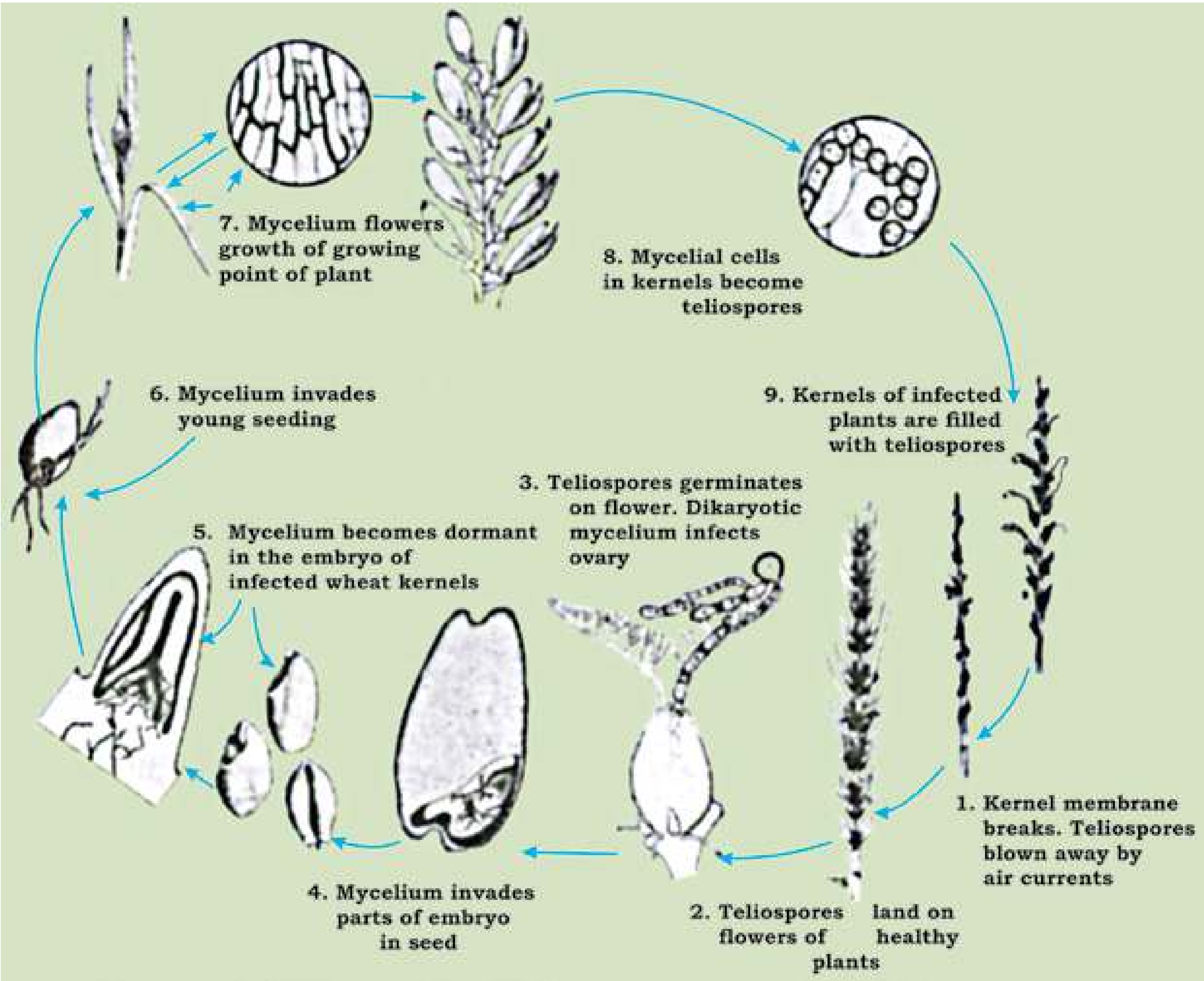

Fig. 8.11: Disease cycle of loose smut of wheat caused by a club - fungus (Ustilago tritici)

Deuteromycota (Deuteromycetes or Imperfect Fungi)

This heterogenous group includes all such fungi in which sexual phase has not been observed. Most of them are related to their sexually reproducing relatives of Ascomycetes; however some are related to other two phyla (Zygomycota, Basidiomycota) as well. If sexual structures are found on an imperfect fungus, it is then reassigned to the appropriate phylum. Biologists now can classify most imperfect fungi on the basis of DNA sequences, though sexual structures may not be found.

Penicillium (blue, green molds), *Aspergillus* (brown molds), *Alternaria, Fusarium, Helminthosporium* are some of the economically important genera of Deuteromycetes (see economic importance of fungi).

Penicillium sp. (blue, green molds) are wide spread saprotrophic species common on decaying fruit, bread etc. Its hyphae are septate. *Penicillium* reproduces asexually by means of naked spores called **conidia**. These are found in chains at the tips of special hyphae called **conidiophores**, which are branched. Brush-like arrangement of its conidia is characteristic of *Penicillium* (Fig. 8.12). These conidia give colour to the mycelial colony, which is circular. Mature conidia are easily and readily dispersed.

Despite absence of sexual reproduction, imperfect fungi show special kind of genetic recombination, called **parasexuality,** *in which portions of chromosomes of two nuclei lying in the same hypha are exchanged.*

Animation 8.3: Moldy Peach
Source and Credit: wikipedia

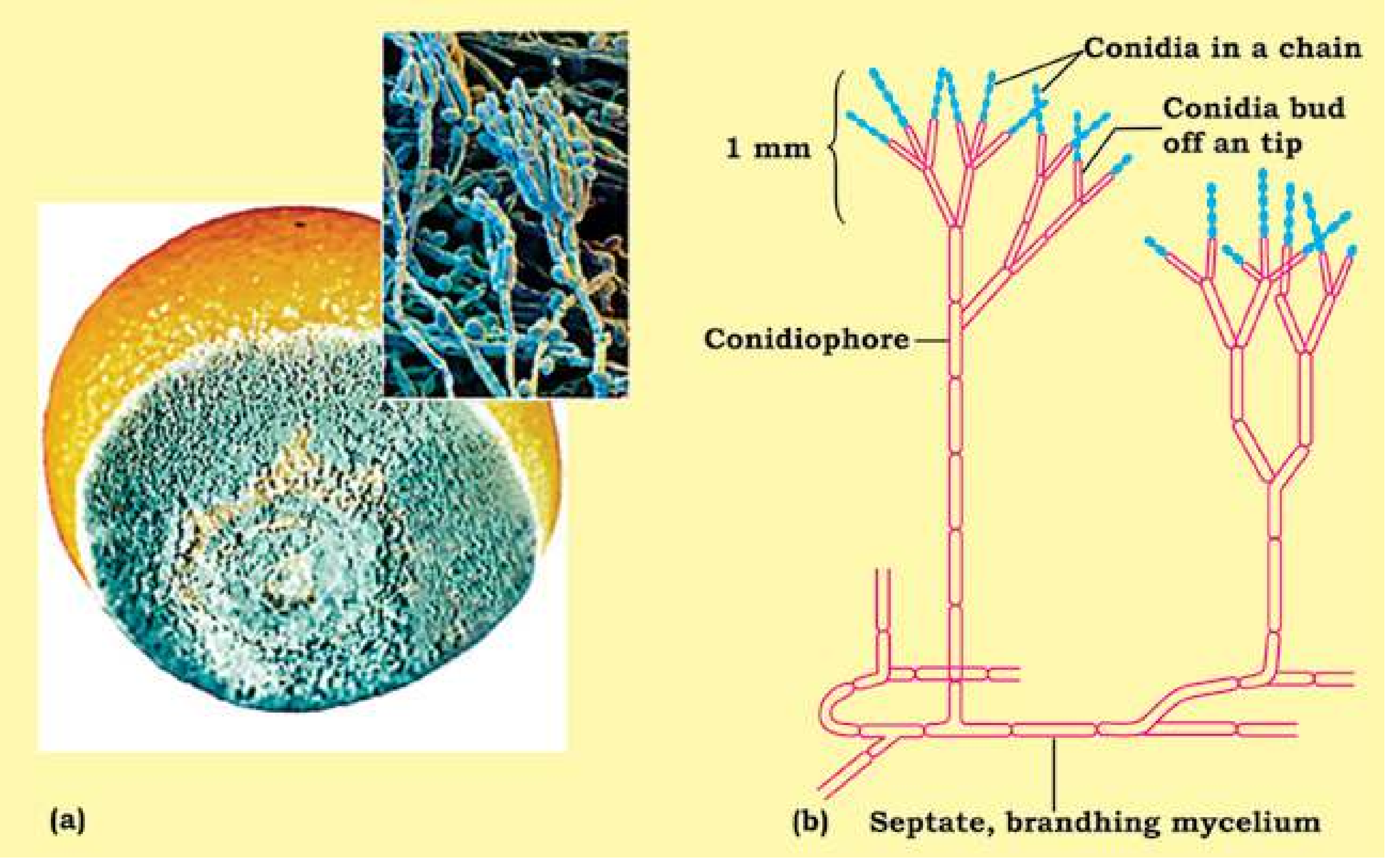

Fig. 8.12 Penicillium (a) A moldy orange; the blue mold is caused by saprobic species of Penicillium. (b) Penicillium showing asexual reproduction, characteristic brush-like arrangement of conidia.

LAND ADAPTATIONS OF FUNGI

Fungi; although grow best in moist habitats, are found wherever organic matter is present. They are a successful group of land organisms, and posses several features in their body and reproduction that adapt them to their habit and terrestrial mode of life.

Extensive system of fast-spreading hyphae penetrate the substrate and enormously increase the contact and surface area for absorption. Cytoplasmic flow throughout the hyphae is responsible for their rapid growth and spread. Chitin in their thickened hyphal wall is more resistant to decay than are cellulose and lignin found in plant cell wall. They can even break down the lignin (in addition to cellulose) to obtain their nutrients. In saprobes, certain modified hyphae called **rhizoids** anchor the fungus to the substrate and also digest and then absorb the food.

They are very well adapted to live on land due to lack of flagellated cells, nonmotile spores and conidia efficient dispersal by wind, thick-walled zygote and other resistant structures. Hyphae may be modified in such a way as to enable them to reproduce themselves without dependence on external water.

Many fungi are more tolerant than are bacteria to damage in hyperosmotic surroundings. Many can tolerate temperature extremes - 5°C below freezing and 50°C or more. Now you can tell why molds (e.g. *Penicillium*) can grow on oranges and jelly kept in a refrigerator, while generally bacteria cannot.

IMPORTANCE OF FUNGI

Ecological Importance

Fungi have great ecological impact. They are very important as decomposers and symbionts. Fungi, along with saprobic bacteria, play vital role in the recycling of inorganic nutrients in the ecosystem. Without their activity all the essential nutrients would soon become locked up in the mounds of dead animals, plants, would be unavailable for use by organisms, and life would cease. Mycorrhizal fungi improve the growth of plants with which they are associated. 95% of all kinds of vascular plants have this association.

Lichens growing on rocks break them, setting stage for other organisms during the course of ecological succession. Lichens are very good bioindicators of air quality as they are very sensitive to pollution. Some fungi are also used for bioremediation (degrading/removing environmental poisons/pollutants by organisms).

Commercial Importance

Fungi cause economic gains as well as losses.

Economic gains due to fungi

1. Certain fungi are edible. About 200 species of mushrooms (e.g. Agaricus sp), morels (e.g. Morchella esculenta), truffles (underground fruiting bodies of some

(a) (b)

Fig. 8.13 Edible fungi (a) A common morel (Morchella esculenta). (b) The truffles (Tuber species) are underground fruiting bodies that people find with the help of trained dogs or pigs.

Ascomycetes, e.g. *Tuber* sp) are common edible fungi. Beware of poisonous mushrooms called the **toadstools**, such as death cap/death angel (*Amanita*) and jack-O' latem mushroom (Fig. 8.14).

(a) (b)

Fig. 8.14 a: Poisonous mushroom Jack-O' lantern (Omphalotus olearius) whose gills glow in the dark, b: Amanita, another common poisonous mushroom.

Reindeer moss (a lichen, not a moss) is used as food for reindeers and some other large animals in arctic/subarctic/boreal regions.

2. Certain fungi are used in food industry. Because of their fermenting ability, yeasts (*Saccharomyces cerevisiae*) are used in the production of bread and liquor. *Penicillium* species are used for giving flavour, aroma and characteristic colour to some cheese. Some species of Aspergillus are used for

fermenting/producing soya sauce and soya paste from soya bean. Citric acid is also obtained from some *Aspergillus* species.

3. Some fungi are source of antibiotics and some other drugs. *Penicillin*, first antibiotic to be ever discovered (by A. Fleming-1928) is obtained from *Penicillium notatum*. Lovastatin is used for lowering blood cholestrol; cyclosporine obtained from a soil fungus is used in organ transplantation forpreventing transplant rejection; and ergotine to relieve one kind of headache migraine. Griseofulvin is used to inhibit fungal growth.

4. Some natural dyes obtained from lichens are used in textile industry.

5. Yeasts are heavily used in genetic/molecular biological research because of their rapid generation and rapidly increasing pool of genetic and biochemical information. Yeast were the first eukaryotes to be used by genetic engineers. In 1983, a functional artificial chromosome was made in *Saccharomyces cervisiae.* The same yeast was the first eukaryote whose genomic sequence was completely studied in 1996. Yeasts are also being investigated for production of some hormones. Pink bread mold *Neurospora* has also been used for genetic research.

Economic losses due to Fungi

1. Fungi are responsible for many serious plant diseases because they produce several enzymes that can breakdown cellulose, lignin and even cutin. All plants are susceptible to them. Extensive damages due to rusts and smut diseases of wheat, com (Fig. 8.15) and rice prompted mass displacement, and starvation to death of many people.

Powdery mildews (on grapes, rose, wheat etc), **ergot of rye, red rot of sugar cane, Potato wilt, cotton root rot, apple scab**, and **brown rot** of peaches, plums, apricots and cherries are some other common plant diseases caused by fungi.

2. Fungi also cause certain animal diseases. **Ringworm** and **athlete's foot** are superficial fungal infections caused by certain imperfect fungi. *Candida albicans,* a yeast, causes oral and vaginal thrush (*Candidasis* or *candidosis*). **Histoplasmosis** is a serious infection of lungs caused by inhaling spores of a fungus which is common in soil contaminated with bird's feces. If infection spreads into blood stream and then to other organs (which is very occassional), it can be serious and even fatal. *Aspergillus fumigatus* causes **aspergillosis**, but only in persons with defective immune system such as AIDS, and may cause death. Some strains of *Aspergillus* produce one of the most carcinogenic

(cancer-causing) mycotoxins (toxins produced by fungi), called **aflatoxins**. *Aspergillus* contaminates improperlystored grains such as peanuts and com etc. Milk, eggs and meat may also have small traces of aflatoxins. Any moldy human food or animal forage product should be discarded. **Ergotism** is caused by eating bread made from purple ergot-contaminated rye flour. The poisonous material in the ergot causes nervous spasm, convulsion, Psychotic delusion and even gangrene.

3. Saprobic fungi are not only useful recyclers but also cause incalculable damage to food, wood, fiber, and leather by decomposing them. 15-50% of world's fruit is lost each year due to fungal attack. Wood-rotting fungi destroy not only living trees but also structural timber. Bracket/ shelf fungi (Fig. 8.16) cause lot of damage to stored cut lumber as well as stands of timber of living trees.

A pink yeast (*Rhodotorula)* on shower curtains and other moist surfaces.

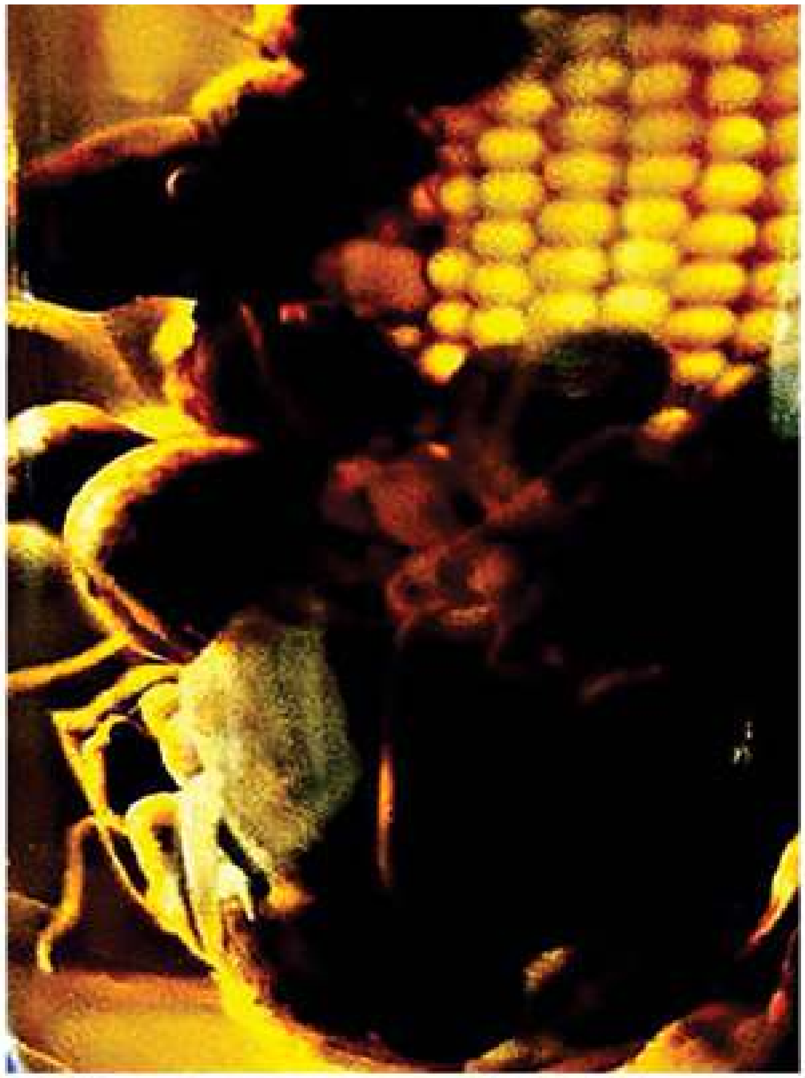

Fig. 8.15 Plant Pathogenic fungus. Corn smut on an ear of sweet corn is caused by *Ustilago maydis*

Video 8.4: Mushrooms Fungi
Source and Credit: rebloggy

Fig. 8.16 This shelf fungus is parasitizing a tree. These are important decomposers of wood

EXERCISE

Q .1. Short questions

(i) What is a hypha? What is the advantage of having incomplete septa?

(ii) What is the composition of fungal cell wall and how is this composition advantageous to fungi?

(iii) To which phyla do yeasts belong? How do they differ from other fungi?

(iv) Name sexual and asexual spores of Ascomycetes.

(v) What are mycorrhizae?

(vi) By what means can individuals in imperfect fungi be classified?

(vii) Give a single characteristic that differentiates Zygomycota from Basidiomycota.

(viii) Why is green mold more likely to contaminate an orange kept in a refrigerator than are bacteria?

(ix) What is a fungus?

(x) State two parallel characteristics of Ascomycetes and Basidiomycetes.

Q.2. Extensive questions

(i) Discuss taxonomic status of fungi.

(ii) Summarise differentiating/distinguishing characteristics of four main groups of Fungi, and give two common examples of each group.

(iii) State various features of fungi that adapt them to terrestrial mode of life.

(iv) What is ecological importance of saprotrophic fungi, of lichens and mycorrhizae?

(v) Same enzymes of fungi are useful on one hand and harmful on other. Discuss.

(vi) Name any four important fungal diseases of plants and four fungal diseases of humans, and briefly describe any one of the plant diseases and any one of the diseases of humans.

(vii) Describe, giving examples, different ways in which fungi are useful to humans.

(viii) Differentiate between the members of each of the following pairs.

(a) Spore/Conidium (b) Ascus/Basidium

(b) Dikaryotic/Diploid (c) Ascocarp/Ascus

(c) Obligate parasite/Facultative parasite

(d) Endomycorrhizae/Ectomycorrhizae

(e) Plasmogamy/Karyogamy