

Supplemental Lecture (97/05/01 update) by [Stephen T. Abedon \(abedon.1@osu.edu\)](mailto:abedon.1@osu.edu)

1. Chapter title: Fungi

- a. A list of [vocabulary words](#) is found toward the end of this document
- b. Fungi are chemoheterotrophic, mostly aerobic or facultatively anaerobic organisms. They live in soil or in water and employ exoenzymes to decompose mostly dead plant material, which they then absorb (i.e., they are saprophytes, they live off of dead organisms). In general, they are adapted to niches similar to those occupied by bacteria though in environments which are hostile to bacteria (drier, more acidic, unusual carbohydrates, etc.). All fungi develop from spores and no fungi display flagella, cilia, or chloroplasts.
- c. The Kingdom Myceteae (the fungi) includes the fleshy fungi, the molds (or hyphae), and the yeasts. There are about 100,000 known species of fungi of which about 100 are pathogenic to animals (fungal infections are called mycoses.). Not surprisingly, given how the majority of fungi make their living, thousands are pathogenic to plants, many more than there are bacteria serving as plant pathogens.
- d. Advice: Although mushrooms are certainly fungi, don't let a vague understanding of mushroom biology serve as a stand in for actually learning this material. I've seen this happen sufficiently often that I will be bold enough to predict that a large fraction of you would do this if not so warned (and, indeed, might do so even having been warned).

2. Some human diseases caused by fungi

- a. aspergillosis
- b. candidiasis
- c. coccidioidomycosis
- d. histoplasmosis
- e. mucormycosis
- f. opportunistic pneumonia.
- g. thrush

3. Overview (of fungi)

- a. The following is quoted from Prescott et al., 1996 (p. 503):
 - i. Fungi are widely distributed and are found wherever moisture is present.
 - ii. Fungi exist primarily as filamentous hyphae. A mass of hyphae is called a mycelium.
 - iii. Like some bacteria, fungi digest insoluble organic matter by secreting exoenzymes, then absorbing the soluble nutrients.
 - iv. Two reproductive structures occur in the fungi: (a) sporangia form asexual spores, and (b) gametangia form sexual gametes.
 - v. The zygomycetes are characterized by resting structures called zygospores---cells in which zygotes are formed.
 - vi. The ascomycetes form zygotes within a characteristic club-shaped structure, the ascus.
 - vii. Yeasts are unicellular fungi---mainly ascomycetes.
 - viii. Basidiomycetes possess dikaryotic hyphae with two nuclei, one of each mating type. The hyphae divide uniquely, forming basidiocarps within which basidia can be found.
 - ix. The deuteromycetes (Fungi Imperfecti) have either lost the capacity for sexual reproduction, or it has never been observed.
 - x. The slime and water molds resemble fungi only in appearance and lifestyle. The three divisions (*Myxomycota*, *Acrasiomycoata*, and *Oomycoto*) are now widely regarded as protists.

4. Kingdom Myceteae

- a. *Kingdom Myceteae*, found in the domain Eucaryota, consists of the various fungi.
- b. The fungi arose approximately 900 million years ago.

5. Mycology

- a. *mycology* is the study of fungi.

6. Fungi

- a. Chemoheterotrophic nutrient absorbers:
 - i. Equivalent to kingdom Myceteae, the *fungi* particularly are chemoheterotrophic nutrient absorbers (absorptive heterotrophs).
 - ii. They employ exoenzymes to extracellularly digest substrate prior to its absorption.
 - iii. "Fungi are hetertrophs and must obtain preformed organic molecules from the environment and modify them. Fungi secrete powerful enzymes that enable the cells to digest organic matter in their environment, breaking down large molecules into smaller ones. The cells then absorb the nutrient molecules through their cell membranes. Because the actual digestive process takes place outside the organism's body, it is called extracellular digestion. A similar type of food breakdown takes place in an animal's hollow gut." (p. 470, Postlethwait and Hopson, 1995)
- b. All *fungi*:
 - i. are eucaryotes
 - ii. develop from spores
 - iii. display neither flagella, cilia, nor chloroplasts
 - iv. have cell walls (though not necessarily ones composed of cellulose as are plant cell walls, but instead of chitin and other polysaccharides)
 - v. to at least some extent are filamentous (that is, their cells remain attached following a division)

- which occurs in only a single plane, one perpendicular to the filament)
 - vi. undergo mitotic division in which the nuclear membrane remains intact and in which centrioles are not employed
 - c. Though displaying great variety and complexity, the *fungi* are routinely divided into two major groups:
 - i. the macroscopic (fleshy) *fungi*
 - ii. the microscopic *fungi* (molds and yeasts)
7. **Extracellular digestion**
- a. **External digestion:**
 - i. *Extracellular digestion* is the digestion of complex nutrient material into simple, absorbable nutrients.
 - ii. This is accomplished through the secretion of enzymes (called *exoenzymes*) into the extracellular environment.
 - b. **Not ingestion:**
 - i. Fungi are typically thought of as the definitive employers of *extracellular digestion* though note that animals, too, employ *extracellular digestion*.
 - ii. The difference in strategies between the fungi and animals is one between intra-organismal, extracellular digestion (i.e., ingestion) in animals and extra-organismal, extracellular digestion in fungi.
 - iii. In other words, fungi live in their food and digest that food that surrounds their "bodies" while animals engulf their food usually prior to digesting and typically prior to absorbing it.
8. **Saprobe [saprophyte]**
- a. *Saprobies* (a.k.a., *saprophytes*) are organisms which consume dead organic matter.
 - b. **Eaters of dead plants:**
 - i. Most fungi are *saprobies*.
 - ii. In fact, most fungi are *saprobies* which subsist off of dead plant material.
9. **Fungal growth requirements**
- a. In contrast to bacteria, fungi tend grow in places that are:
 - i. more acidic
 - ii. have higher osmotic pressures
 - iii. are lower in moisture
 - iv. are low in nitrogen
 - v. contain complex carbohydrates that even bacteria generally can't catabolize (bacteria may be kings of divergent biochemistries, but fungi are pretty good, too, and for the similar reasons).
 - b. **Contrast to protozoa:**
 - i. The ideal fungal growth environment also differs fundamentally from that of the typical protozoa.
 - ii. Particularly, the use of exoenzymes makes fungal growth more suited to environments which are not well mixed (i.e., which contain structure).
 - iii. Protozoa, in contrast, employ engulfment which is a way of limiting the application of enzymes to small spaces (membrane-bound vesicles). Thus, protozoa are well suited to (and in fact are to a large extent limited to) growth in wet, well mixed environments such as pond water.
 - iv. Fungi in contrast are well suited to growth in dry, well defined environments such as on the surfaces of dead plants or within well-drained soil.
10. **Hyphae [pl., hypha, sing.]**
- a. **Linear cell arrangements:**
 - i. *Hyphae* are the defining fungal motif.
 - ii. *Hyphae* are one dimensional (i.e., linear) arrangements of cells.
 - iii. *Hyphae* are essentially the "staphylo" form-equivalent (well, sort of) found among fungi. That is, the hyphae form as a consequence of cell division along a single plane and a lack of subsequent separation of fully divided cells.
 - b. **Nutrient conduits:**
 - i. *Hyphae* differ structurally and functionally from their procaryotic equivalents.
 - ii. Particularly, *hyphae* grow at their tips and are supplied nutrients for this growth via streaming through cells and perforated septa toward these tips.
 - iii. As a consequence, *hyphae* are capable of extremely rapid growth under appropriate conditions (i.e., when nutrients and water are available).
 - c. **Hyphae in mushrooms:**
 - i. The filaments which form the underground portion of a mushroom are *hyphae*.
 - ii. The potential for rapid elongation seen with *hyphae* explains the rapid growth of mushrooms.
 - iii. Mushrooms are essentially bundles of *hyphae tips* otherwise associated with underground (or substrate) mycelium.
11. **Septa [pl., septum, sing.; perforated septa]**
- a. *septa* are the cross walls which separate individual cells in hyphae.
 - b. **Perforated septum:**
 - i. *Septa* containing holes (pores) through which cytoplasm can flow are known as *perforated septa*.
 - ii. Note that it is through *perforated septa* that rapid nutrient transport is achieved.
 - c. **No septa:**
 - i. For one division of fungi, Zygomycota, *septa* are lacking in hyphae except when reproductive bodies are formed.
 - ii. Such fungi are considered *coenocytic*.
 - iii. That is, their hyphae consist of one continuous cytoplasm having multiple nuclei: They are *aseptate*, i.e., lacking septa.
12. **Mycelium**

- a. **Tangle of hyphae:**
 - i. *Mycelium* are a tangled mass of hyphae.
 - ii. *Mycelium* can extensively permeate the substrate within which the fungi grows whether it be soil, water, or even living tissue.
13. **Microscopic fungi**
- a. The *Microscopic fungi* are a group of fungi which includes the obviously smaller, not fleshy fungi: The yeasts and the molds.
14. **Macroscopic fungi [fleshy fungi] >**
- a. The *macroscopic fungi* (a.k.a, the *fleshy fungi*) are macroscopic, multicellular, filamentous fungi with often large reproductive bodies.
 - b. This group includes the:
 - i. mushrooms
 - ii. puffballs
 - iii. gill fungi
 - iv. coral fungi
15. **Molds**
- a. *Molds* are aerobic, filamentous fungi including
 - i. mildews
 - ii. rusts
 - iii. smuts
 - b. *Molds* tend to grow on surfaces rather than throughout substrates.
16. **Yeasts**
- a. **unicellular/nonfilamentous:**
 - i. *Yeasts* are fungi which are:
 - ii. nonfilamentous
 - iii. unicellular
 - iv. typically spherical or oval
 - v. facultatively anaerobic
 - b. They are often observed as powdery coatings on plant material.
 - c. **Polyphyletic:**
 - i. It is highly likely that yeasts do not constitute a monophyletic clade but instead arose repeatedly from filamentous ancestral fungi.
 - ii. Most known *yeasts* are members of the fungal division Ascomycota. However, even here it is likely that Ascomycota *yeasts* do not constitute a monophyletic clade.
 - iii. About 350 species (and 40 genera) of *yeasts* have been identified.
 - d. **Bacteriological techniques:**
 - i. *Yeasts* generally are treated similarly to bacteria in the laboratory.
 - ii. This treatment includes culturing methods and methods of identification (details, however, differ).
 - e. Yeasts may be divided into two types based on how they divide: Those that bud and those that undergo fission.
17. **Dimorphic fungi**
- a. *Dimorphic fungi* are fungi that behave like molds (i.e., are multicellular---consist of hyphae) under some conditions, and like yeasts (i.e., are unicellular---lack hyphae) under others.
18. **Pseudohyphae**
- a. **Yeast hyphae:**
 - i. Hyphae found among yeasts are not considered to be true hyphae.
 - ii. They are consequently referred to as *pseudohyphae*.
19. **Mushrooms**
- a. **Filamentous and fleshy:**
 - i. *Mushrooms* may be classified as both macroscopic fungi and filamentous fungi.
 - ii. In particular, *mushrooms* are the fruiting bodies of large, underground, colonial fungi.
 - iii. The underground portion of mushrooms is filamentous and may spread multi-square meters or more around the fruiting body.
20. **Lichens**
- a. **Algae symbionts:**
 - i. *Lichens* are fungi (usually division Ascomycetes) which are symbiotically associated with either eucaryotic algae or cyanobacteria (blue-green algae).
 - ii. The fungi protect their algal partners from many harsh aspects of the environment (including excessive sun light).
 - iii. The algae, in turn, are the photoautotrophs supplying both energy and carbon to the symbiotic pair.
 - b. **Organics-poor substrate niche:**
 - i. *Lichens* are often found growing on otherwise bare rock and, in fact, their niche is one of exploitation of substrates so bare, in environments often so harsh that these environments are otherwise unavailable to other organisms.
 - ii. The *lichen* fungi serve as the substrate within which the algae grow, i.e., the fungi attach the algae to the rock.
21. **Fungal reproduction**
- a. All fungi replicate by mitosis rather than the binary fission employed by bacteria.
 - b. Types of fungal reproduction, both mitotic and non-mitotic, include:
 - i. budding
 - ii. fission
 - iii. hyphae fragmentation

iv. sporulation

c. Reproductive structures:

- i. Often fungal division involves the formation of reproductive structures.
- ii. These reproductive structures are connected to hyphae by non-perforated septa.
- iii. Three types of reproductive structures exist corresponding to the products released from them:
 1. spores (produced by structures known as sporangia)
 2. haploid spores (called conidia)
 3. gametes (produced by structures known as gametangia)

22. Budding

- a. *Budding* is an uneven cytoplasmic division practiced by *Saccharomyces* spp. yeasts as well as some bacteria.
- b. *Budding* follows mitosis in yeasts.
- c. See illustration below.

23. Fission

- a. *Fission* is the even cytoplasmic division practiced following mitosis as practiced by *Schizosaccharomyces* spp. yeasts.
- b. *Fission* is analogous though not identical to bacterial binary fission.
- c. See illustration below.

24. Illustration, budding vs. fission in yeasts



25. Hyphae fragmentation

- a. *Hyphae fragmentation* is an asexual method of fungi reproduction.
- b. Fragments of hyphae can reinitiate multicellular growth.

26. Fungal spores

- a. *Fungal spores* are not the same as bacterial endospores. In contrast to bacterial endospores they:
 - i. are not as durable
 - ii. serve as a mechanisms of reproduction

b. Fungal seeds:

- i. Think of *fungal spores* as seeds.
- ii. Particularly, *fungal spores* play very important roles in the dispersion fungi.

c. Sexual and asexual:

- i. Fungal spores come in two varieties:
 1. asexual spores
 2. sexual spores
- ii. Spores are used extensively to identify fungi.

27. Asexual spores

- a. *asexual spores* are formed by a single parental fungi and therefore genetically identical to the parental fungi.
- b. *Asexual spores* come in a variety of types formed by a variety of mechanisms including:
 - i. arthrospores
 - ii. blastospores
 - iii. chlamydo spores
 - iv. conidiospores
 - v. sporangiospores

28. Sexual spores

a. Product of fertilization:

- i. Less frequent than asexual spores, *sexual spores* are formed upon the mating of two fungi and therefore are genetically intermediate to the parental fungi.
- ii. Sexual spores are fungal zygotes.

- b. Typically in fungi true diploidy is found only in zygotes.

29. Karyotic permutations

a. Haploid hyphae nuclei:

- i. The nuclei found within hyphae are generally haploid.
- ii. Sexual reproduction can bring nuclei descended from different parents into the same hyphae or hyphae segment (i.e., cell).

b. Delayed nuclear fusion:

- i. Fusion of unlike haploid nuclei to form diploid nuclei eventually occurs.
- ii. However, this fusion usually follows a long period (i.e., much growth/cell division/nuclear divisions) in haploid nuclei sourced from different parents are found in the same cytoplasm.

- c. The following is terminology used to describe these various *karyotic permutations* that fungi can support:

- i. Hyphae contain haploid rather diploid nuclei and individual cells found in hyphae can contain more than one nuclei. If those nuclei are genetically identical (i.e., share ancestors) then the hypha in which they exist are termed *homokaryotic*.
- ii. Hypha containing haploid nuclei descended from more than one parent are termed *heterokaryotic*. Heterokaryotes are products of gamete fertilization.
- iii. If a single compartment (cell) within a hypha contains more than one type of haploid nuclei then the term *dikaryotic* is employed. Note that because all nuclei may transcribe, a dikaryote can display diploid-like gene expression.
- iv. Individual compartments (cells) which contain only a single nucleus type are termed *monokaryotic*.

30. Mycorrhizae

- a. **Fungal plant symbionts:**
 - i. *Mycorrhizae* are fungi which live in association with plants, particularly plant roots.
 - ii. As with lichens, here the plants supply both energy and carbon.
 - iii. However, the plants in this case also supply the substrate upon which the fungi live.
 - b. **Root hair analogs:**
 - i. Similarly to their role in lichen, *mycorrhizae* make their unique biochemistry available to the plant.
 - ii. This makes soil-borne nutrients (such as phosphorus) which are otherwise not available to the plant, available.
 - iii. That is, *Mycorrhizae* essentially serve as absorptive root hairs.
 - c. Approximately 80% of all plants are thought to possess symbiotic fungi.
 - d. "The earliest fossil plants often have *endomycorrhizal* roots (the fungi actually penetrate the root). Such associations, which were common during the initial period of invasion of the land by plants, may have played an important role in allowing this invasion to take place. The soils that were available at such times would have been sterile and completely lacking in organic matter. Since plants that form mycorrhizal associations are particularly successful in infertile soil now, and considering fossil evidence, the suggestion that mycorrhizal associations were characteristic of the earliest plants seems reasonable. In addition, the most primitive vascular plants surviving today continue to depend strongly on mycorrhizae." (p. 652, Raven and Johnson, 1995)
31. **Mycosis [pl. mycoses]**
- a. **Fungi-caused disease:**
 - i. A *mycosis* is a disease/infection caused by a fungi.
 - ii. Because fungi are slow growing, *mycoses* are generally long-lasting.
 - b. *Mycoses* are divided into five types:
 - i. systemic
 - ii. subcutaneous
 - iii. cutaneous
 - iv. superficial
 - v. opportunistic
32. **Haustoria**
- a. Parasitic fungi often exhibit thin hyphae extensions, called *haustoria*, which penetrate the living tissue and are employed to extract nutrients.
33. **Division Ascomycota**
- a. Approximately 30,000 species including yeasts (such as *Saccharomyces cerevisiae*), some of the molds (e.g., *Aspergillus*), morels, and truffles. *Ascomycetes* have typical reproductive structures called asci. (see pp. 641-644,646 Raven and Johnson, 1995)
34. **Division Basidiomycetes**
- a. Approximately 25,000 species including many macroscopic fungi (mushrooms, puffballs, shelf fungi) as well as a number of plant pathogens (rusts, smuts). (see pp. 644-646 Raven and Johnson, 1995)
35. **Division Deuteromycota [fungi imperfecti]**
- a. Approximately 25,000 members. *Fungi imperfecti* is a grab bag of members who all have the common characteristic of not expressing a known sexual form (included are the *Penicilliums*). Note that *division Deuteromycota* aren't considered monophyletic. The division exists for the most part because it is the sexual structures which are used to differentiate the other divisions. (see pp. 647-648 Raven and Johnson, 1995)
36. **Division Zygomycota**
- a. Approximately 600 species including bread molds (such as *Rhizopus*). Zygomycetes tend to be saprophytic and to have hyphae lacking septa. (see pp. 640-641,646 Raven and Johnson, 1995)
37. **Cutaneous mycosis [dermatomycosis]**
- a. A mycosis of the epidermis, hair, or nails. These are caused by contagious fungi that secrete keratinase, an exoenzyme that digests the protein keratin.
38. **Subcutaneous mycosis**
- a. A mycosis that occurs beneath the surface of the skin which is caused by direct implantation of fungi into wounds.
39. **Superficial mycosis**
- a. Mycoses of surfaces including hair shafts and skin that are common in tropical climates.
40. **Systemic mycosis**
- a. A mycosis that occurs deep within the body. Typically *systemic mycoses* are not contagious and start in the lungs then spread to other parts of the body.
41. **Vocabulary**
- a. [Asexual spores](#)
 - b. [Budding](#)
 - c. [Budding vs. fission in yeasts, illustration](#)
 - d. [Candida albicans](#)
 - e. [Cutaneous mycosis](#)
 - f. [Dermatomycosis](#)
 - g. [Dimorphic fungi](#)
 - h. [Division Ascomycota](#)
 - i. [Division Basidiomycota](#)
 - j. [Division Deuteromycota](#)
 - k. [Division Zygomycota](#)
 - l. [Exoenzyme](#)
 - m. [Extracellular digestion](#)

- n. [Fission](#)
- o. [Fleshy fungi](#)
- p. [Fungal growth requirements](#)
- q. [Fungal reproduction](#)
- r. [Fungal spores](#)
- s. [Fungi](#)
- t. [Fungi imperfecti](#)
- u. [Haustoria](#)
- v. [Human diseases caused by fungi](#)
- w. [Hyphae](#)
- x. [Hyphae fragmentation](#)
- y. [Karyotic permutations](#)
- z. [Kingdom Myceteae](#)
- aa. [Lichens](#)
- ab. [Macroscopic fungi](#)
- ac. [Microscopic fungi](#)
- ad. [Molds](#)
- ae. [Mushrooms](#)
- af. [Mycelium](#)
- ag. [Mycology](#)
- ah. [Mycorrhizae](#)
- ai. [Mycosis](#)
- aj. [Perforated septum](#)
- ak. [Pneumocystis carinii](#)
- al. [Pseudohyphae](#)
- am. [Saccharomyces spp.](#)
- an. [Saccharomyces cerevisiae](#)
- ao. [Saprobe](#)
- ap. [Saprophyte](#)
- aq. [Septa](#)
- ar. [Schizosaccharomyces spp.](#)
- as. [Sexual spores](#)
- at. [Subcutaneous mycosis](#)
- au. [Superficial mycosis](#)
- av. [Systemic mycosis](#)
- aw. [Yeasts](#)

42. **Practice questions**

- a. The outstanding characteristic of kingdom Fungi is (circle only one correct answer) [\[PEEK\]](#)
 - i. all members are photosynthetic
 - ii. absorption of dissolved organic matter
 - iii. absorption of dissolved inorganic matter
 - iv. all members are macroscopic
 - v. all members are microscopic
 - vi. all of the above
 - vii. none of the above
- b. Which of the following is not a characteristic of yeasts (circle only one correct answer) [\[PEEK\]](#)
 - i. some form pseudohypha
 - ii. undergo fission or budding
 - iii. facultatively anaerobic
 - iv. form a slimy layer on vegetable matter
 - v. all of the above
 - vi. none of the above
- c. Describe the ideal fungal growth environment in terms of how it is different from the ideal bacterial growth environment: [\[PEEK\]](#)
- d. Which is the most durable (circle only one correct answer) [\[PEEK\]](#)
 - i. bacterial endospores
 - ii. yeast spores
 - iii. protozoal cysts
 - iv. stationary phase bacteria
 - v. all of the above
 - vi. none of the above
- e. While the means by which fungi and most protozoa acquire nutrients allows these two eucaryotic types to easily coexist, the nutrient acquisition distinction between fungi and many bacteria, which allows this second pair of organismal types to readily coexist, is more subtle. Give three ways in which the fungal niche differs from that associated with otherwise similar niche many bacteria occupy. [\[PEEK\]](#)
- f. Molds are aerobic, filamentous fungi. In terms of physical substrates, where do molds tend to prefer to grow? (hint, to answer this question you might want to sketch or picture a simple volume, such as a sphere representing the fruit of an apple tree, and indicate where in relation to that volume, such as in, on, or both, you would expect mold growth to occur---such a sketch, however, is by no means necessary to answer the question). [\[PEEK\]](#)
- g. Within lichens, name two things the fungi mutual contributes to its algae symbiont? [\[PEEK\]](#)
- h. Explain why the existence of mycorrhizae was likely crucial to the successful invasion of land by plants.

[PEEK]

- i. What is/are mycelia? [PEEK]
- j. Name three diseases which are caused by a fungal pathogen or name the pathogen which causes the disease (but not both for any one disease/pathogen). [PEEK]
- k. *Animals are organisms that secrete extracellular enzymes (exoenzymes) to digest food they have ingested. Animal cells then take up the digested food into their cytoplasm.* Using similar terms, describe the means by which fungi obtain nutrients. [PEEK]
- l. Another name for a parasitic flatworm which lives in the tissues of your body, other than the lumen of your digestive tract, is _____. [PEEK]
- m. In terms of their anatomy and physiology, which of the following is the more sophisticated, multicellular creature? [PEEK]
 - i. a protist
 - ii. a flatworm
 - iii. a capsid
 - iv. a bacterium
 - v. a roundworm
 - vi. a virus

43. **Practice question answers**

- a. ii, absorption of dissolved organic matter
- b. iv, yeasts do not form slimy layers on vegetable matter. It is bacteria that do that.
- c. fungi are competitive with bacteria when conditions are (i) drier, (ii) of higher osmotic pressure, (iii) more acidic, (iv) lower in nitrogen, and (v) when only weird carbohydrates are available. Note, some of you will be highly tempted to describe a perceived optimal mushroom growth environment to answer this question (i.e., dark, warm, moist). Resist the temptation!!!
- d. i, bacterial endospores
- e. Compared with bacteria, fungi prefer environments containing (i) more acid, (ii) higher salt concentrations (osmotic pressures), (iii) less moisture, (iv) less nitrogen, and (v) various unusual complex carbohydrates. In short, are highly evolved for growth on the surfaces of plants and decomposing plant material.
- f. on surfaces.
- g. (i) nutrients other than energy and carbon, (ii) resistance to desiccation, (iii) protection from light, (iv) attachment to a surface.
- h. They allowed plants, newly freed from their aquatic environment in which essential minerals were available in a soluble form, to colonize sterile soils in which those minerals probably were not nearly as readily available.
 - i. tangled masses of fungal hyphae
 - j. Candida (yeast infection), histoplasmosis, athlete's foot, ring worm, atypical pneumonia
- k. Fungi are organisms that secrete extracellular enzymes (exoenzymes) to digest food they *are either growing in or on*. Fungal cells then take up the digested food into their cytoplasm.
- l. Fluke
- m. v, a roundworm

44. **References**

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