Chapter 8

Fungi: Yeasts and Warm Fuzzies

Objectives: After reading Chapter Eight, you should understand…

- Why scientists put fungi into their own kingdom.
- How fungi benefit society through food production, industrial products and elemental cycling.
- The public health impacts of fungi.

Evolution: 250 million years ago, a great, catastrophic event wiped out much of the life on Earth.

This cleared the way for dinosaurs to dominate the planet.

Most land plants were destroyed as well.

The fungi became an important component of the Earth's ecosystem because all of the left-over plant biomass needed to be degraded (nothing around to eat it).

Fungi are **eukaryotic** and several times larger than bacteria (you can see them).

What is the advantage of having large cells?

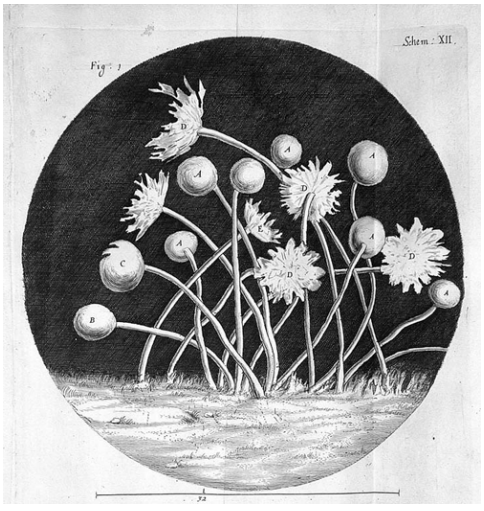
1. Information
2. Division of labor

What is the disadvantage?

1. Support larger biomass
2. Too much going on??

100,000 species of fungi are known (possibly 200,000 more to be discovered)

Who described the first fungi?



Structure and Growth of Fungi

Structure of fungi

Until the mid 1900s, fungi were considered as **simple plants**.

Now they have their own kingdom, **Fungi**.

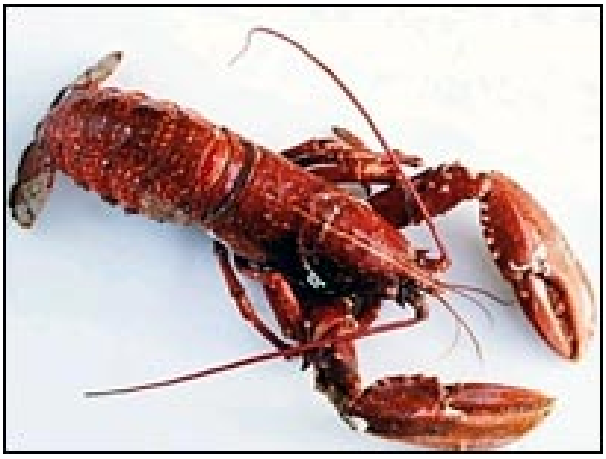
Most fungi are composed of strands of cells called **hyphae** (singular: **hypha**)

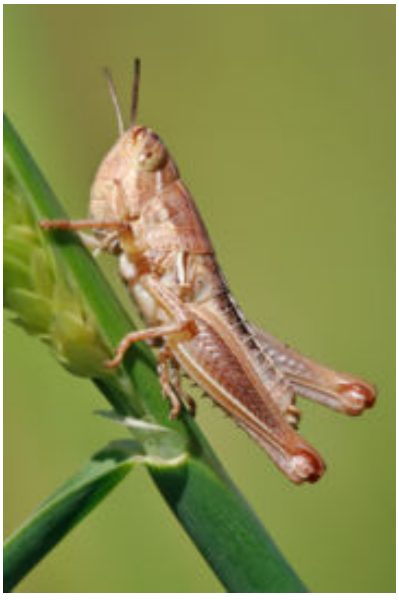
Hyphae cell walls are not composed of peptidoglycan, like bacteria cell walls, but rather of **chitin**.

Chitin is a polysaccharide **not found in bacteria or plants**.

This is a major reason why the fungi were put into a separate kingdom from plants.

Where else is **chitin** found?



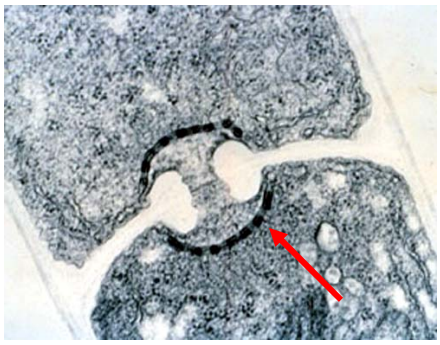


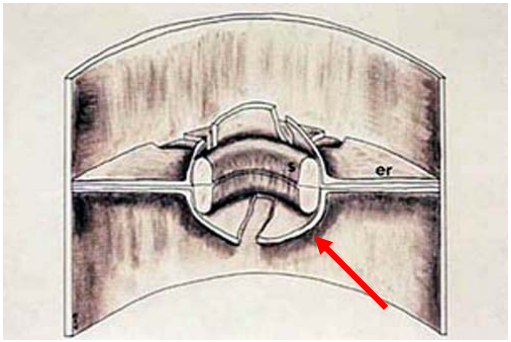
Interwoven hyphae make a mat called mycelium.

Mycelia on a leaf

Mycelia covering nutrient agar

Hyphae are essentially one long tube with cross-walls called **septa** (singular: **septum**).





Creates **partitions** between cells

Pores (arrow) in the septa permit the flow of cytoplasm from cell to cell. (these are **not** cell walls).

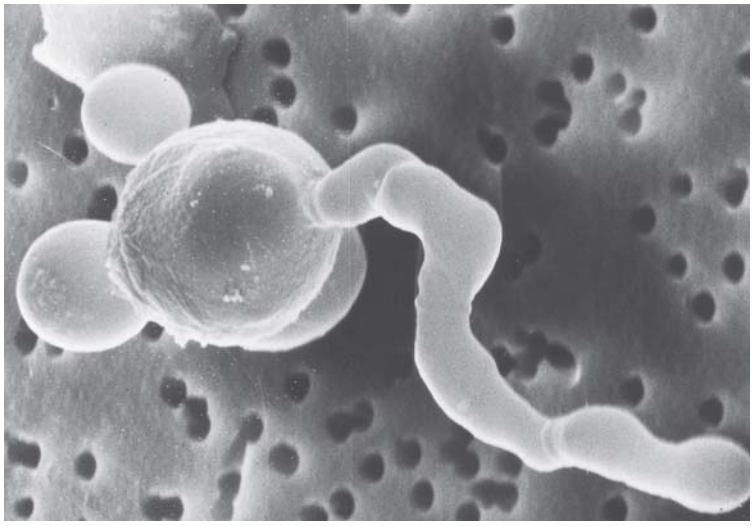
What might need to flow within the cytoplasm?

The septa also provide structural support to the hyphae.

Hyphae arise by growth from a **single spore** (where else have we seen spores?)

As the hypha elongates, new cell formation takes place at the tip, where proteins are concentrated (called **apical extension**).

Rapid growth - one hypha can produce enough cells in a 24 h period to stretch **one-half mile** if placed end-to-end.



An SEM of a spore of *Cephalosporium* germinating to form a hypha (X6000)

Hyphal growth gives the fungi many advantages over forms of growth common to other organisms…

1. **Open ended** as long as resources are not limited.
2. Ideal for **penetration and exploration of the environment**.
3. Forms **networks** and an interconnected physical continuum.
4. Spans **nutrient deficient zones**.
5. **Navigate** around physical barriers and gas pockets.

These characteristics result in **variable sizes** of the fungi depending on environmental conditions.

From a **pinpoint** mass to coverage of **several square hectares**

Example - **fairy rings**

Most noticeable in turfgrass.

Appear as a dark-green ring with or without an inner ring of dead grass

Lush rings of turf are formed by the **release of nutrients**, in particular nitrogen, from the activity of the fungus living on organic matter in the soil.

Rings grow outward at the rate of 6 to 24 inches annually depending on grass, soil and weather conditions.

Fruiting bodies (mushrooms) might be visible in the dark areas (active fungi)

Nutrition in fungi

Most fungal species are **heterotrophic**.

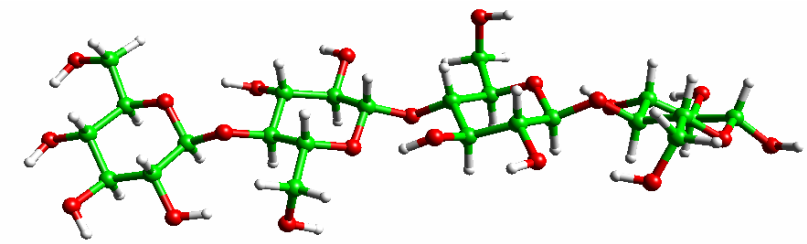
Fungi digest organic matter by releasing enzymes into the environment, and then absorbing the simple digestion products.

Why do fungi need to rely on extracellular enzymes?

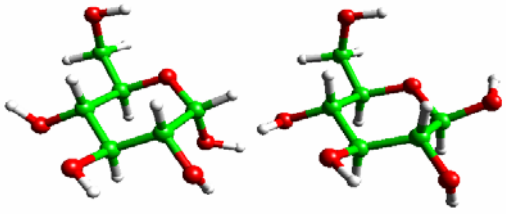
Some products of the enzymatic digestion remain outside of the cell and are used by other organisms.

Fungi can break down two complex carbohydrates that are very difficult to break down:

1. **Cellulose** (where might we find cellulose?)



cellulose fragment



α-D-glucose β-D-glucose

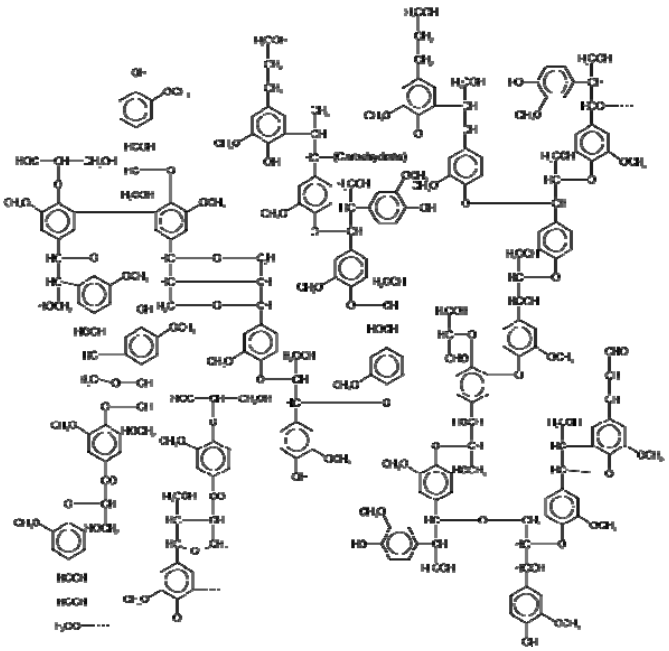
Fungi can produce the enzyme **cellulase** to degrade **cellulose**

Humans cannot break down cellulose.

Digestion of cellulose results in **glucose molecules** (who can use glucose?)

2. Lignin

Some fungi can also produce **ligninase**, an enzyme that breaks down **lignin** fibers in plants.



Lignin is usually an efficient physical barrier against pathogens that invade plant tissues.

Three main modes of fungal nutrition:

1. **Saprophytic –** feeds on dead, organic material (example?)

This promotes several key processes:

1. Prevent organic matter buildup
2. Liberates nutrients
3. Facilitates further degradation (remember, cellulose cannot be broken down easily by bacteria)
4. Creates strata for plants to colonize
5. Enhances soil physical properties

These activities allow saprophytic fungi to impact the integrity of **roofs**.

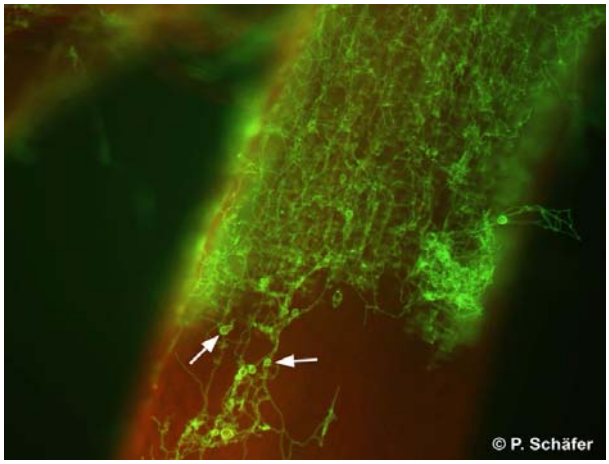
The tar used in the manufacture of asphalt is really **dead organic matter**.

To digest this material, the fungus secretes enzymes into the shingles, which causes the breakdown of the tar holding everything together.

This eventually leads to the breakdown of the shingle.

2. **Parasitic** - nutrition at the expense of another living organism.

Plant pathogens (brown patch of turfgrass)



Rhizoctonia hyphae (green) invading plant tissue (red).

3. **Symbiotic** - fungus forms a relationship with a host and both benefit.

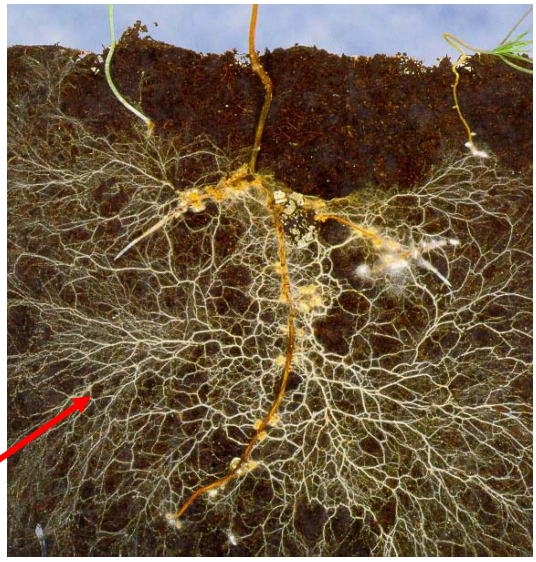
It has been shown that in forests, **mycorrhizal fungi** might allow large trees to support smaller, more vulnerable ones.

Mycorrhizae - mycelia attach to plant roots and mediate the exchange of nutrients.

The fungi increase the exploratory area of the roots, while the plant provides sugars for the fungi.

An example of a symbiotic relationship

These are not roots!



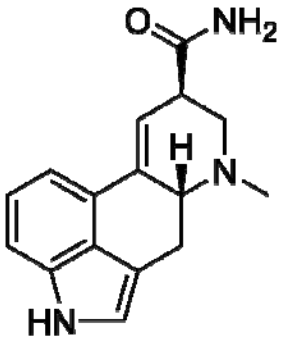
Beneficial and Harmful Fungi

Many fungi live in a beneficial relationship with other species in nature – **mutualism**.

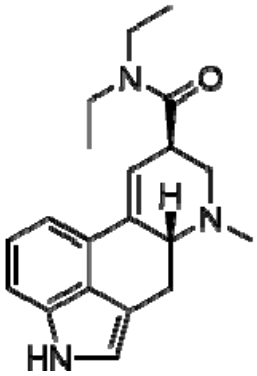
In the Rocky Mountains, the fungus *Acremonium spp*. lives on the blades of a grass called "robust grass".

The fungus produces a powerful alkaloid toxins that can put large animals to sleep for up to a week (when infected, the grass is called "sleepy grass").

The dominant alkaloid in sleepy grass is **lysergic acid amide**, a first cousin of **LSD**.



Lysergic acid



LSD

The animals learn to avoid the grass and the grass survives (doesn't get eaten).

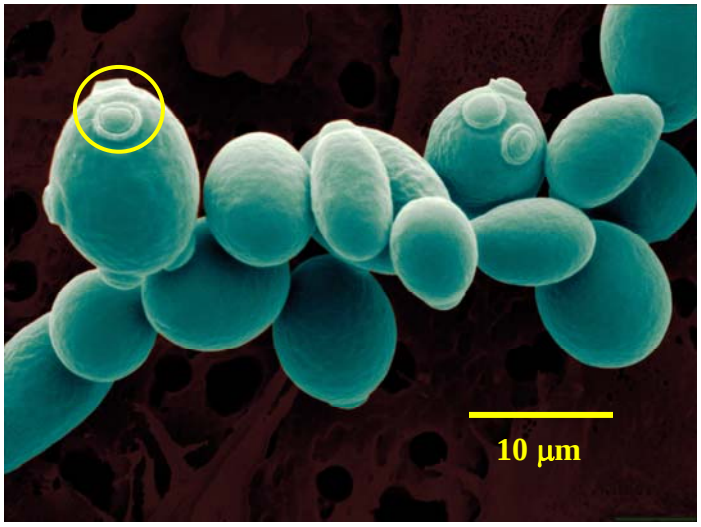
Who is benefiting from this relationship?

Yeasts – beneficial uses

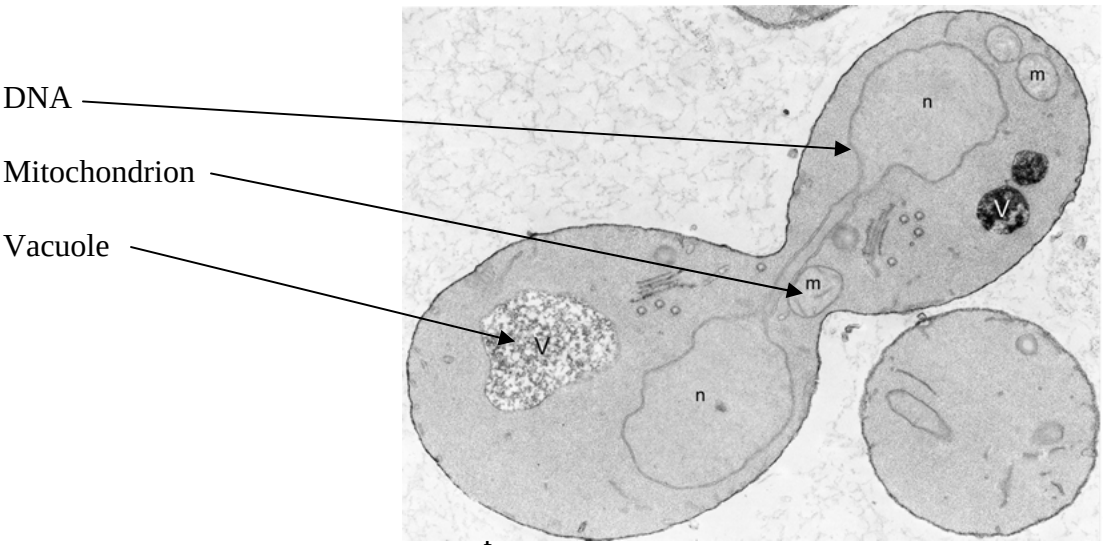
Yeasts are found within the genus *Saccharomyces*.

Single-celled (**but not bacteria**) and are oval in shape (8 μm x 5 μm)

Yeasts can reproduce by asexual budding (they can also sexually reproduce).



Some structures in a yeast cell:



From: http://www.jhu.edu/iic/yeast-1.htm

The chemistry performed by *Saccharomyces* spp. is of particular importance to humans.

One end-product of **aerobic** carbohydrate (sugar) metabolism by ***S. cerevisiae*** is abundant carbon dioxide, which causes dough to rise.

One end product of ***S. ellipsoideus*** anaerobic metabolism (fermentation) of sugar is **ethyl alcohol**.

When *S. ellipsoideus* is added to grape juice and fermentation is allowed to occur, **wine** is formed.

The degree to which the sugar gets used determines the sweetness of the wine.

Champagne is made by allowing a second round of fermentation by adding more sugar.

Produces extra **carbon dioxide**.

Why is the champagne cork often strapped to the bottle with wire?

Yeasts and human disease

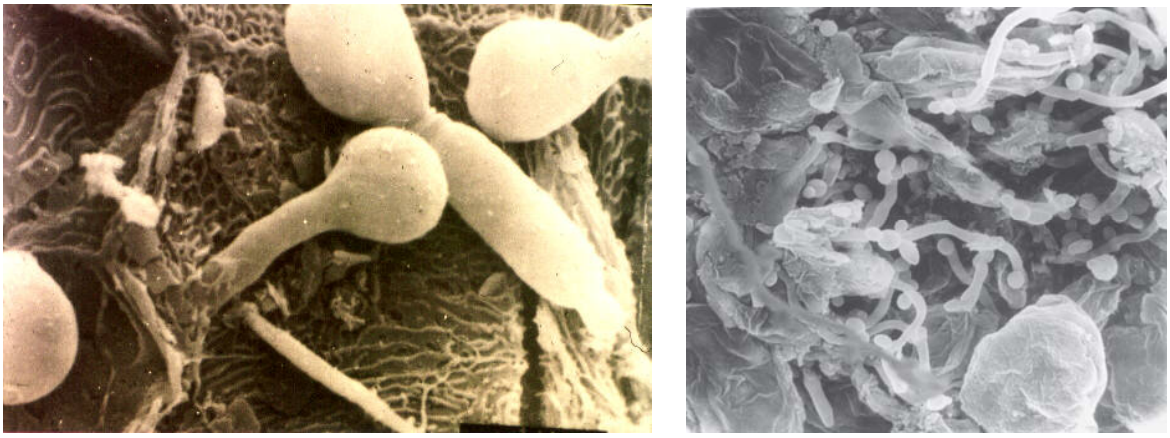
Yeast infections

Caused by *Candida albicans* (candidiasis) in the female vaginal tract and produces white discharge and painful urination.

While *C. albicans* lives primarily in the female vaginal tract, it is often kept in check by bacteria such as *Lactobacillus spp*.

The lactobacilli produce **lactic acid** as part of their normal metabolism.

The high acidity creates an inhospitable environment for *C. albicans*.



SEM of *Candida albicans.* From Balish et al., Appl. Environ. Microbiol, 1984 May; 47(4): 647-625

…then how does *C. albicans* get a foothold to cause problems?

1. Excessive antibiotic use.
2. Poor air circulation

In addition to antifungal compounds, women are often encouraged to eat **yogurt** to help treat the infection. Why?

Oral candidiasis - thrush.

Occurs when the **immune system is compromised** or when other controlling microbes disappear (who might this effect?)

Thick, white lacy patches of *Candida albicans* can form on the tongue, palate, or elsewhere inside the mouth.

Oral *Candida albicans* infection.

Sometimes the infection looks like milk curds, but cannot be wiped away.

Thrush can be painful and make it difficult to eat.

Thrush is often treated with oral antibiotics, but persistent infections are often an early sign of other, more significant problems, like AIDS.

Other fungal diseases

1. Cryptococcosis – dangerous disease of the human lungs and meninges.

Usually a problem in **immunocompromised** patients.

Therefore it might also be a warning sign for ????

Immunocompromised patients:	2-4 cases per 1,000 (0.2%)
General Population:	0.2-0.9 cases per 100,000 (0.0002%)

Caused by the **yeast** *Cryptococcus neoformans*.

Found in soil and in pigeon droppings.

Aerosolized *C. neoformans* enters the respiratory tract, progress deep into the lungs where they are passed to the bloodstream and eventually to the meninges.

Results in meningoencephalitis (swelling of meninges and brain), headaches and neck stiffness, and can lead to paralysis.

Cryptococcosis is the most frequent CNS **fungal** infection.

Cryptococcus neoformans is most infective when it is **encapsulated**.

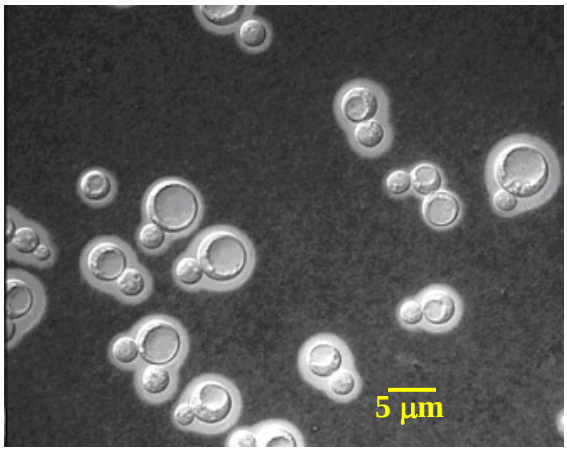


Image of encapsulated *Cryptococcus neoformans*.

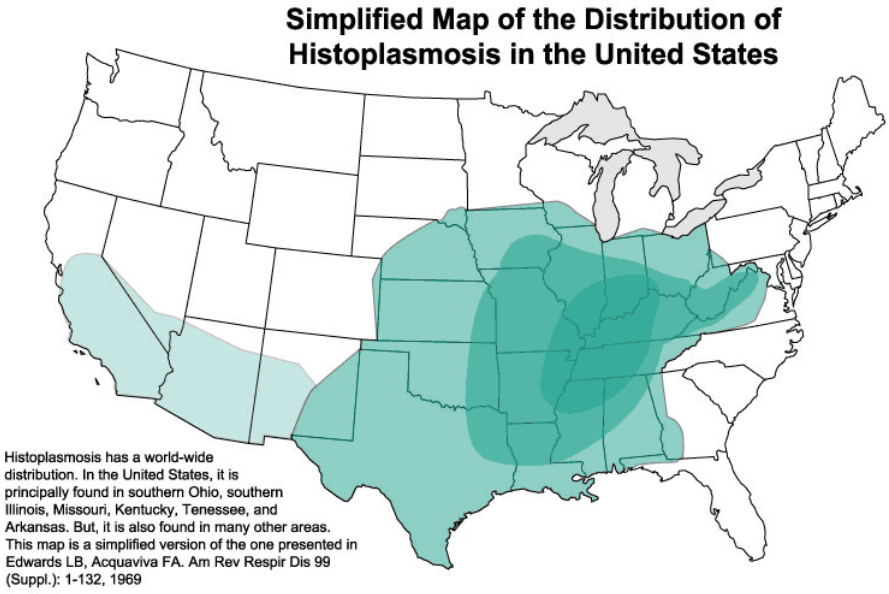
From what material do you think the capsule is made?

What is its purpose?

2. Histoplasmosis

Respiratory disease caused primarily by the fungus *Histoplamsa capsulatum*.

Also known as Ohio Valley disease, Central Mississippi Valley disease, Appalachian Mountain disease and Darling's disease.



The environmental reservoir for *H. capsulatum* is bird and bat droppings and soil with an acidic pH, some degree of moisture, and moderate temperature.

The fungi can be transmitted in **air** (no need for direct contact, animal – human or human – human transmission).

Most people with mild cases of histoplasmosis don't have any symptoms.

Serious or prolonged cases of histoplasmosis may lead to various complications. During the acute infection, for example, the lymph nodes in the chest may become enlarged and cause pressure on surrounding organs.

This can lead to:

- Heart valve damage
- Meningitis (inflammation of the membranes surrounding the brain or spinal cord)

Don’t confuse histoplasmosis with **toxoplasmosis!**