Multicellular Eucaryotes

large size is usually achieved only by being multicellular
→ cells can't get too large without breaking better to make lots of small cells than a few very large cells

multicellularity evolved many separate times among eucaryotes:
seaweeds
slime molds
fungi
plants
animals
→must have been a clear advantage

advantages of small size:

1. simplest of life forms
   don't need lots of instructions (DNA)
   much easier to do things: jack of all trades

2. requires much less food for survival and reproduction

3. don't need elaborate organ systems for coordination and control or collection and dispersal of food and wastes
   → simple physical and chemical processes take in food & oxygen and get rid of wastes

4. don't really need to deal with gravity
   → in water are fairly buoyant:
   tend to float and
   can drift with currents instead of under own power
   → in air cells can blow for miles for dispersal
   → on land don't need elaborate support system

5. can reproduce much more quickly
   → minutes to hours vs days to months to years

6. dispersal is much easier
   → caught in water or wind currents
   → carried by animals

   eg. most bacteria and protists species have world wide distributions

disadvantages of small size:

1. are greatly affected by viscosity
   if air were same viscosity as water, humans would “fall” through it at 1mm/hr

   they don’t really swim; they ‘crawl’ through water

2. must expend energy to move at all under your own power, can’t coast
   →low mass and buoyancy is not affected by gravity or inertia

   if swimming bacteria stopped propelling itself it would “coast” <width of an atom [ie. ~0 inertia]

3. surface-to-volume ratio becomes a limiting problem

   small cells work because diffusion works as long as diameter of cell is less than about .1 mm

   diffusion suffices only as long as its surface area can provide enough diffusion to accommodate the volume of an organism

   as size increase:
   surface area increases more slowly than volume

   area = length x width (or side^{2})

   volume = side^{3}

   eg. 10x increase in length
   = 100 fold increase in surface
   =1000 fold increase in volume

advantages of large size:

1. complex multicellular structures allow much more variation in size shape and form

   there are many more possible solutions to solve various problems
   eg. food: herbivores, carnivores, fluid feeders, insectivores, etc

   eg. oxygen: gills, book gills, lungs, tracheae, etc

   →evolution of multicellularity is correlated with an explosion of diversity in the fossil record

2. allows individual cells to become specialized for

specific functions:

all cells don't have to do everything
eg. epithelial cells: cover, protect, support, etc
eg. muscle cells: movements
eg. vascular tissues: transport of nutrients and wastes and hormones

but:
individual cells become completely dependent on each other
→ can no longer survive on their own

3. organism becomes more resilient
damage doesn't kill you; it can often be repaired

disadvantages of larger size:

1. as size increases need more elaborate ways to supply each cell with nutrients and remove wastes

    eg. vascular systems, etc

2. need method of coordination and control to get all parts on the "same page"

    eg. hormones, nervous systems

3. need support, especially on land, to counteract gravity

4. Need MUCH MORE food and oxygen
→ lots more cells to feed

5. Dispersal becomes more of an issue

    eg. relatively few large animals and plants have worldwide distributions

intermediate forms may have been **colonial** form

organisms consist of groups of cells
→ but individual cells can survive on their own as well

allows increased specialization and division of labor
flagellated vs nonflagellated cells
vegetative vs reproductive cells
groups of cells of same organism specialized

for attachment, support, flotation, photosynthesis
paved way for later evolution of true tissues and organs

Fungi

simplest of three complex **multicellular eucaryotic** kingdoms in terms of structure

include: mushrooms, puffballs, morrels, bracket fungi, and molds

many are familiar with fungi only due to the diseases and economic damage to crops and materials they cause:

(some even take it personally):

→ French Botanist=S Veillardi said fungi "are a cursed tribe, an invention of the devil, devised by him to disturb the rest of nature created by God."

over 100,000 species described →est to 1.5M

extremely abundant in some ecosystems but not commonly seen:

top 20 cm (8") of soil contains over 2 tons of microorganisms (mainly fungi)/acre

(or 5 metric tons of fungi and bacteria per hectare (=2.47 acres))

eg. thimblefull of soil contains several miles of fungal filaments

not all are **multicellular**;

some are unicellular = **yeasts**

multicellular fungi = **molds**

fungi are mainly **terrestrial**

earliest fossils are associated with land plants

but some are aquatic

fungi are the most **resilient** of land eucaryotes

-thrive on a great variety of compounds

-a few inhabit seemingly inhospitable habitats

eg. inside glaciers

eg. acidic waters

fungi are **absorptive heterotrophs**:

→they must eat organic foods for nutrients and energy but

→they reverse the animal technique of taking in food and then digesting it

fungi digest *outside* their bodies

they secrete enzymes to digest food outside their bodies, then absorb it

mostly **terrestrial**

→were among the first terrestrial organisms >400 MY history

→ fungi appear in fossil record at the same time and associated with the first land plants

→ strong symbiosis between them

→Fungi and Plants are the only kingdoms that are mainly terrestrial

many form important **symbioses**

eg. lichens, mycorrhizae

Structure

cells of fungi have cell walls like plant cells but are heterotrophs like animals

the cells of most fungi have flexible cell walls of **chitin**

(a N containing polysaccharide; similar to exoskeleton of arthropods)

while multicellular, fungi remained much simpler in structure than higher plants and animals

→ instead they retained a high surface/volume ratio

most multicellular forms have **vegetative** portion and **reproductive** portion.

except for yeasts, bodies consists of filaments called **hyphae**

in most the hyphae consist of chains of individual cells

the filamentous structure provides an extensive surface area for absorption of nutrients:

10 cm^3 (**.61 in^3**) **of soil can have**

→1 km (**.6 mi**) **of hyphae**

→**providing about** 314 cm^2 (**50 in^2**)**of surface area** ~7″x7″

grow rapidly, up to 1 km of hyphae/day

fungi make up for lack of mobility by **growing rapidly** into their food source

and having an **extensive surface area** for absorption

don't have to move, they grow into new food source by growing hyphae

→continuous exploratory growth

virtually all growth is in the form of elongation of the **tips** of hyphae

the hyphae form an interwoven mat = **mycelium** (mushroom growers call it "spawn") of individual feeding filaments (=**hyphae**) extending into their preferred food supply

mycelium represents the *individual organism*

vegetative portion of most fungi are often hidden in the food they are eating

fungi are organisms with no clear shape:

always growing and changing

when growing space is limited, the fungus infuses the food with hyphae and assumes the shape of its food.

the hyphae grow rapidly

nutrients move quickly through hyphae to growing tips
the fungus concentrates its energy and resources
by constantly adding more area for absorption in new areas

many fungi have direct passages in their cell walls that allow even organelles such as mitochondria, nuclei to move between cells

some of the more primitive fungi lack cross walls altogether and are more a growing mass of continuous tubes than multicellular individuals

mycelium can get quite large:

ex. fungus growing beneath coniferous forest in Michigan
37 acres
11 tons of hyphae
1500 years old

ex. *Armillaria ostoyae* (Washington State)
2.5 square miles – covers three counties
probably 1000's of years old
probably 100's of tons

→ fungi may be Earth's oldest and largest organisms

such large "individuals" are often broken into separate "pieces" but maintain their genetic integrity

→ are they separate individuals? clones?

fungi **lack true tissues** but in some hyphae have become **specialized** into:

1. **haustoria**
   –hyphal tips of parasitc fungi that invade cells of host

2. **rings** and **traps**
   – that predatory soil fungi use to capture prey

3. **fruiting bodies**
   – usually the most visible part of the fungus body that produces spores

Physiology:

fungi grow best in dark, moist habitats

but are found wherever organic matter is available

fungi are **absorptive heterotrophs**:
→they must eat organic foods for nutrients and energy
→fungi digest *outside* their bodies

they secrete enzymes to digest food outside their bodies, then absorb it

fungi secrete a wide variety of **enzymes** to digest **organic molecules**:

-break down complex organic molecules
contain a wide array of enzymes that can decompose almost any organic molecule
eg. **cutinases** → digest leaf surface waxes
eg. **cellulases** → destroy plant cell walls

fungi show a variety of feeding strategies:

1. some **saprobes**
   – eat dead organic matter; especially wood

   some suggest that the earliest fungi were not yet able to digest **lignin** (a plant compound) that appeared only when woody plants 1st evolved

   This lag of several million years in fungi ability to digest lignin was primary reason why early forests of woody plants were not decomposed and become massive **coal deposits**

No major coal deposits have formed since the Carboniferous even though there were many more woody plants since then

play important role in recycling nutrients in many ecosystems

→convert complex organic matter into simple chemicals (=**decomposers**)

they make no distinction between a rotting tree, a railroad tie, cloth, paint, leather, insulation, etc

also grow on foods, grains, bread, fruits, vegetables
→ cause **food spoilage**

2. some are **parasites**
– eat living organic matter

some are parasitic in plants and animals, including humans

→ about 300 known animal pathogens
→ most important cause of agricultural plant diseases

3. a few are even **predators**

at same time that they are secreting enzymes they are also secreting **mycotoxins**

which inhibit growth of other microbes
→ possibly to discourage competition for food

some of these we use as antibiotics
many of the chemicals that fungi routinely produce cannot be synthesized in the laboratory

many fungi are less sensitive to acidic pH's, higher salt (solute) concentrations, and to colder temperatures than are bacteria

eg. pH→ range 2-9; optimum = 5.6
eg. thrive in a wide range of temperatures:
→common in refrigerator
eg. thrive in high osmotic pressures
→high sugar or salt concentrations, jellies, jams

once original food supply is depleted,

the hyphae explore areas further distant leaving an area exhausted of food surrounded by a growing ring of hyphae

→ "**fairy rings**" on lawns

→ **ringworms** on skin

When environmental conditions are unfavorable or

food supply runs out, hyphae may aggregate into a roughly spherical body

= **scerotium**

outside cells – thick pigmented walls form protective shell

pigments protect agains UV

when favorable conditions return the **sclerotium**

may germinate into hyphae again or produce a fruiting body

Bioluminescence

>40 fungal species glow in the dark

don't know why

in some cases may improve reproductive success

eg. bioluminescent fruiting bodies

of *Omphalotus olearius, Panus stypticus, Mycena illuminens*

unsure of function

perhaps: attracts insects that help to disperse spores

may attract animals such as nematodes

which eat fungus and excrete undigestible spores

eg. bioluminescent mycelia

unsure of function; apparently not always reproductive

=**foxfire** of lore

have been used to mark trails at night

used by troops to identify friend from foe

to brighten hair of young maidens on tropical isles

Motility

almost all fungi lack flagellae and are nonmotile

Reproduction:

most fungi reproduce both **asexually** and **sexually** by producing **spores**

reproduce asexually most of the time
reproduce sexually when conditions change and become less favorable

some fungi reproduce asexually only

Asexual:

most fungal reproduction involves the production of **asexual spores**

-spores can be single or multicelled
-spores vary greatly in shape and ornamentation
-rarely exceed 100 µm; most < 20 µm dia

whenever conditions are favorable
fungi clone themselves by producing millions of asexual spores from specialized fruiting bodies

many fungi produce specialized spore-bearing hyphae
(=fruiting bodies) on which clusters or chains of spores grow.

Such spores are usually dry and powdery at maturity
and are easily whisked away by **wind**

yeasts reproduce asexually by **budding**

Sexual Reproduction:

~1/3rd of all fungi reproduce in more than one way
eg. sexual and asexual

in multicellular fungi the "parents" first fuse (their hyphae join)

only later do some of the nuclei combine to eventually
produce single cells (zygote)

also fungi are apparently not tied to the male/female dichotomy

→ there are numerous different mating types
(complementary genders) in fungi (not called male and female)

[some fungi can have up to 78,000 different mating types or "sexes" in a single species]

unlike plants and animals they **do not form embryos**

sexual spores are generally much less commonly produced than asexual spores

often involve much more elaborate (macroscopic) spore bearing structures = **fruiting bodies**

eg. such as mushrooms and bracket fungi

in some species the sexual spores are the product of self fertilization (evolution depends primarily on mutation only)

	Type of fruiting body	**Type of spore**
Asexual Spores		
	sporangia	**sporangiospores**
	conidiophore	**conidiospores**
Sexual Spores		
	none	**zygospores**
	asci	**ascospores**
	basidia	**basidiospores**

number of spores produced is often enormous:

eg. corn smut → 25 billion / ear of corn
eg. wheat rust → 10 billion / acre (moderate infection)
eg. wood decay fungus, Ganoderma applanatum, produces 350,000 spores/sec up to 6 months/yr for up to 10 years
eg. some club fungi: → 80 Million spores/hour for several days

spores are dispersed by:

a. **wind**, most common method
b. **projectile dispersal**
c. **rain**
d. **insects**
e. **mammals**
f. **flowing water** (a few primitive forms)

a. Wind

Most sexual and asexual spores are dispersed by wind

smaller spores will remain aloft longer

eg. dish opened on 1st floor in office bldg
in 5 minutes some spores were on 4th floor
in 10 minutes they were on 4th floor at densities of 1000's/yd^2

also spores are usually resistant to adverse conditions
→ can survive long periods in transit

most spores must have clear access and use gravity to fall out of fruiting body

fruiting bodies have gills, long tubes or teeth from which the spores are released

if fruiting body is tilted or falls over, spores are not dispersed

most have the ability to right themselves if tipped or tilted over

eg. *Ganoderma*
a shelf fungus
if tree or log falls it will grow new shelves to realign tubes for dispersal

some spores get help getting into the wind:

eg. many ascomycetes have cup like fruiting bodies
→ spore must get out of cup into wind for dispersal
spores are inside sac
the exposed end of sac has hole in it or is hinged
water pressure within causes tip to give way
spores are shot out through the end
sacs at the bottom of the cup shoot their spores straight up
those on the edges bend toward light
thick clouds of spores can shoot several inches into the air
then are caught by wind and dispersed

eg. shaggy mane (*Coprinus*)
produces its spores on long deep gills
as gills on outer rim of mushroom release their spores, the fungus secretes enzymes to digest this area and expose the next area for spore release

b. projectile dispersal

eg. *Pilobolus* (Ascomycete)
grows on horse dung (rich in undigested cellulose, nitrogen, etc.)
spores were eated with plants and are released in dung
as soon as dung is released, Pilobolus absorbs water and sends up a
 small fruiting body (2-4 cm)
sporeheads on fruiting body aim toward light
fruiting body slowly dries
when internal pressure exceeds 700 kg/cm^2
 sporeheads pop out of manure and land several meters away in
 grazeable grass

eg. *Sphaerobolus*
 grows on decaying wood
 common in wood chips used for mulch, esp NE US
 spores produced inside cup
 cup is covered with slimy substance
 on a rainy day when spores are ready
 slime absorbs water and swells
 pressure builds
 slime lining "explodes" and hurtles spore packets and slime
 out of cup
 → 27 ft/sec
 → to 18 ft away
 you can hear them "go off"

c. Rainfall

eg. some wood disease causing fungi
 produces fruiting bodies that look like small flasks under
 bark of tree
 when bark is moistened by rain spores ooze out of flask in
 sticky gooey mixture
 like toothpaste out of tube

eg. birds nest fungus (Basidiomycete)
 produces packets of spores inside cuplike "nest"
 up to 1/3rd " diameter
 each cup contains 4-10 packets
 water dropping on nest during rain causes packets to
 splash up the sides of "nest"
 some have teather like filaments with sticky ends that help
 to fasten packet to nearby objects
 packets weather and dry to release spores

d. insect dispersal

to work must have some way to attract insect to fungus for dispersal

eg. stinkhorns (Basidiomycete)
produce spores in a slimy, stinky mass
resembles rotting meat
stench attracts carrion flies and insects to disperse spores
100's of flies descend and can remove all spores in a few hours

eg. Ergot and Rusts
plant parasites
need to get from host to host
deposit spores in sweet nectar
insects are attracted to the nectar and disperse spores

eg. yellow rust fungus
mimics a flower
infects rock cress (mustard) in Colorado Mtns
once infected the fungus makes a nectar rich rosette resembling a flower
it attracts "would be" pollinators to spread spores

eg. some fungi apparently use bioluminescence to attract insects to spores

e. **mammals**

eg. **Morels & Truffles**
which superficially resemble mushrooms and truffles are considered gormet fiar
many of the fruiting bodies have a strong smell and flavor
→ excavated and eaten by animals (squirrels & rabbits) (including humans)
→ dispersal

eg. *Tuber melanosporum* (Black Truffle)
contains alpha-androsterol a steroid also found in breath of male pigs, (and male and female humans)
ingested by mammals who spread their spores in feces

natural truffles are collected using trained pigs or dogs or following "truffle flies" to source

f. **flowing water** (a few primitive forms)
Ponds, rivers, streams

a few fungi reproduce **parthogenetically**

Classification of Fungi

fungi are classified according to:
 the type of sexual spores they produce
 characteristics of the hyphae

Phylum: zygote fungi (Zygomycota)
Phylum: sac fungi (Ascomycota)
Phylum: club fungi (Basidiomycota)
Phylum: Fungi Imperfecti (Deuteromycota)

1. Zygote Fungi (Zygomycota)

1050 species (~175 genera)

most are molds

mainly terrestrial

most are saprobes: in soil or decaying plant or animal matter
 a few are parasitic
 some are symbionts

coenocytic hyphae

asexual spores: mainly sporangiospores

sexual spores: zygospores
 sexual reproduction occurs when hyphae of 2 mating types
  "+" and "-" come together
 attracted by hormones
 hyphae fuse to produce zygosporangium
  can resist freezing and drying
  metabolically inactive
 within zygosporangium are zygospores
 zygospores can lay dormant form months

2. Sac Fungi (Ascomycota)

32,000 - 60,000 species (3200 genera)

largest group of fungi

examples: cup fungi, morels, truffles, most yeasts, powdery mildew filamentous forms with septate hyphae

called sac fungi since sexual spores are produced from zygote resulting from fusion of compatible nuclei

asexual reproduction:
molds mainly by **conidiospores** (conidia="fine dust")
yeasts by budding
→rapid propagation under favorable conditions

sexual reproduction: **ascospores**
occurs when 2 hyphae grow together and their cytoplasm mingles
in most, they form a cuplike fruiting body (=ascocarp) in which **asci** develop
zygote yields 8 spores, =**ascospores**,
ascospores are released when tip of ascus breaks open

yeasts are unicellular ascomycetes
reproduce asexually by budding
also produce sexually by ascosopores
able to ferment carbohydrates

3. Club Fungi (Basidiomycota)

smaller group in # of species but the most familiar fungi to most people
→ larger, fleshy fungi

examples: include mushrooms, toadstools, bracket fungi, puffballs, stinkhorns, smuts, rusts, earthstars, birds nest fungi & jelly fungi

members of this phylum occupy a wide range of habitats
decay organic matter
cause plant and animal diseases
form symbioses with plants
obligate parasites in plants (eg. rusts)

most are saprophytes → decay litter, wood, dung, etc

about half form **mycorrhizal** symbiosis with plant roots

some are parasites and some cause disease (eg. dryrot of wood)

named for the clublike basidium which produces the sexual spores inside the fruiting body

sexual reproduction is by fusion of compatible nuclei and production of (usually) 4 basidiospores on the *outside* of a generative cell (= the basidium)

the "mushroom" of this group grows from the hidden mycelium

the mushroom is a fruiting body called a basidiocarp
the lower surface of the mushroom consists of vertical plates called gills
basidia develop on the surfaces of the gills
each basidium produce 4 – 9 basidiospores
on the gills the dikaryotic nuclei fuse to form zytote which

asexual reproduction is highly variable
→some produce conidia
→some rarely reproduce asexually

a few basidiomycetes produce lichens

4. Deuteromycota (Fungi Imperfecti)

15,000 species

reproduce only asexually, usually conidiospores

a large group of fungi whose sexual method of reproduction is unknown so they cannot be classified into one of the categories above.

Most are probably ascomycota since most produce asexual conidia

molds of unknown affinity → sometimes their sexual stage is discovered and they are placed in one of the other phyla

eg. predatory soil fungi
which trap, kill and feed on nematode worms
provide nitrogen

eg. *Rhodotorula* which is a pink yeast common in showers and baths

Economic Importance of Fungi

1. Used directly as food
2. Used to manufacture foods and beverages
3. Pharmaceuticals and Industrial Chemicals
4. Food Spoilage
5. Pests and diseases

6. Ecological impacts - symbioses

1. Used directly as food

eg. among the basidiomycetes are 200 species of edible mushrooms

some are cultivated commercially

eg. *Agaricus brunesscens* (supermarket fungus)
grown in large limestone caverns in Peru
has been thoroughly domesticated

Many other mushrooms and fungi are edible and commonly used in soups and stews as well as main dishes. Some

examples are:
Woodear Mushrooms (=tree ears, black fungus)
Shiitake Mushrooms (=oak mushroom): grows on oak logs or cultivated on oak chips
Oyster Mushrooms: grow on dead and decaying hardwoods or can be cultivated on sterilized straw

poisonous mushrooms
but about 70 species are poisonous (=toadstools)
edible and poisonous can look very similar;
may even be in same genus
no simple way to distinguish them
some of most poisonous:
Amanita (destroying angel, death cap)
one bite is fatal

eg. Ascomycetes: **Morels & Truffles**
which superficially resemble mushrooms and truffles are considered gormet fair

many of the fruiting bodies have a strong smell and flavor
→ excavated and eaten by animals (squirrels & rabbits) (including humans)→ dispersal

France grows specific species of oak trees to act as hosts for truffles

each truffle crop takes 7 years to mature

eg. *Tuber melanosporum* (Black Truffle) so far has been impossible to grow commercially

contains alpha-androsterol a steroid also found in breath of male pigs, and male and female humans
→ sows used to hunt truffles

natural truffles are collected using trained pigs or dogs or following "truffle flies" to source

eg. elephant ear fungus
used in hot and sour soup
thought by some to prevent cancer and retard heart disease (not proven)

yeasts as food
high in B vitamins and proteins

1 acre → 70 lbs of meat or milk protein (cow)
→ 800 lbs of yeast protein

2. Used to manufacture foods and beverages

eg. **Cheeses**

The first step in making most cheeses is to prepare a **curd** by adding lactic acid bacteria and rennin or bacterial enzymes to milk.

The bacteria sour the milk and enzymes coagulate the milk protein, casein, to produce a soft 'curd' to make cheese and a liquid 'whey' which is a waste product.

The amount of **whey** removed determines the hardness of the cheese. eg. soft cheeses the whey is simply drained away. Harder cheeses are heated and pressurized to remove additional whey from the mixture.

After this separation, most cheeses are ripened with inoculations of various species of bacteria and/or fungi.

Soft Cheeses

Brie, Camembert: The curd is ripened by a variety of microorganisms including Streptococcus lactis, S. cremoris, Penecillium camemberti and P. candidum. In this case the ripening process is aerobic and the cultures are inoculated onto the surface of the cheese and extend hyphae throughout.

Roquefort: unique flavors and smells produced partly by *Penecillium roquefortii*

some of the finest French cheeses are distinguished by the smell of isobutyric acid produced by fungi
(also helps to produce the characteristic odor of vomit)

eg. **Soy Sauce**

Soy sauce is produced by the fermentation of roasted soy beans and wheat using a mixture of various bacteria and fungal species including:

bacteria: *Pectococcus halophilus*
Lactobacillus delbrueckii

fungi: *Aspergillus soyae*
A. oryzae
Saccharomyces rouxii
Candida versitilis

The starch degrading enzymes produced by the molds produces a sugar that is then fermented by the bacteria. The entire process takes about a year.

eg. Coffee

After coffee beans are picked they are soaked in water containing natural cultures of *Erwinia dissolvens* and *Saccharomyces* spp. to loosen the berry skins before roasting. Some fermentation occurs which is believed to produce some of the unique flavors of various varieties of coffee.

eg. Cocoa

Microbial fermentation by *Candida krusei* and *Geotrichum* spp. is used to help remove the cocoa beans from the pulp covering them in the pod. The products of this fermentation contribute to the flavor of the cocoa.

eg. Yeasts

yeasts are used commercially for producing bakery products and alcoholic beverages

=>fermentation produces
CO_2
alcohols

Yeasts are single celled fungi. Baker's yeast, *Saccharomyces cerevisiae*, ferments the sugars in a mixture of dough to produce carbon dioxide which causes the dough to "rise".

wine:	fruit sugars	=>	ethyl alcohol
beer:	barley	=>	CO_2 and ethyl alcohol

most of the flavors of wine arise from the direct activity of the yeast rather than the flavor of the grape

In US each American consumes on average:

~41 gallons of alcoholic beverages/yr

35 g beer

3.5 gal wine

2.5 gal spirits

Benefits of alcohol

L. Pasteur: "wine is the most healthful and most hygeinic of beverages"

moderate use

→ reduces heart disease

→reduces chances of clotting and blockages of vessels

[there are ~10g of alcohol/drink]

Costs of overconsumption

worldwide – alcohol abuse kills 1.2 Million/yr

US : alcohol related deaths claim 100,000 lives per year, 1/5th of these (20,000) in alcohol related auto accidents (mainly 19-24 yr olds)

alcohol causes neary 3x's the disability and illness that tobacco causes

regular overindulgence linked to:

high blood pressure

heart disease

obesity

liver damage & cancer

1.5 Million are currently in alcohol recovery programs

programs for treatment and prevention of alcohol abuse costs US ~ $125 Billion/year

3. Pharmaceuticals and Industrial Chemicals

eg. Antibiotics:

Penicillium genus is source of first antibiotic penicillin

1928, Alexander Fleming discovered antibiotic properties

eg. some drugs are produced from ergot that induce labor, stop uterine bleeding, treat high blood pressue and relieve migrains

eg. *Tolypocladium* (?deutero?)
cyclosporin = one of least toxic, most effective immunisuppressives known

eg. **hallucinogens**
ingestion of some mushrooms causes intoxication and sometimes hallucinations:
=> used in religious ceremonies
eg *Psilocybes mexicana*

ergot also produces LSD

eg. *Aspergillus niger*
can produce aflatoxin and other mycotoxins
also produces an enzyme: alpha-d-galactosidase
suppresses methane production in human digestive tract
→ Beano©

4. Food Spoilage

most of the blue-green pink and brown molds that cause food to spoil are ascomycetes

eg: *Rhizopus* (=black bread mold)(zygomycete)
occasional household pest

5. Pathogens and disease

sac fungi include some of the most devastating plant pathogens:
dutch elm disease,
chestnut blight,
powdery mildew
apple scab
brown rot

bracket fungi cause enormous loss by decaying wood including stored lumber and living trees

plant diseases include smuts and rusts
attack corn, wheat, oats, other grains

Mycotoxins

eg. poisonous mushrooms
eg. aflatoxin
produced by species of *Aspergillus* which grows on peanuts, rice, grains, beans, milk
one of main sources of aflatoxin in US is peanut butter
causes liver damage
half of all cancers in Africa south of Sahara are liver tumors
same area also has high incidence of childhood liver cirrosis
correlated with report that 40% of foods screened there contained measurable amounts of aflatoxin including breast milk
other mycotoxins may cause liver degeneration, paralysis, blindness or death
most prevalent in areas of poverty and starvation
one such mycotoxin destroyed whole villages in Russia and Siberia when famine forced villagers to eat moldy grain

eg. *Claviceps* infects the flowers of rye and other cereal grains and produces a structure called ergot.

Eating ergot can cause nervous spasms, convulsions and psychotic delusions,

eg. *Candida* a common human pathogenic (deuteromycete) yeast that produces:
ringworm,
athelete's foot and
"yeast infections"

others cause internal infections called mycoses:
eg. Histoplasmosis

eg. some that parasitize arthropods are being investigated as potential "biopesticides"

4. Ecological impacts - symbioses

Fungi are noted for their numerous symbioses with other organisms
→ they commonly form symbioses with

bacteria (b-g)
algae } **lichens**

plants **mycorrhizae**

animals domesticated by insects and humans

Lichens:

~>20,000 “species”

a symbiotic association between a photosynthetic single celled organism and a fungus.

the photosynthetic organism is either a blue green bacterium or an alga

most lichens are formed by the symbiosis of ascomycetes and an alga or cyanobacterium

in some tropical lichens the fungus is a basidiomycete

the algae (but not the fungus) can also be found free living.

vary greatly in size: microscopic to Km’s

grow very slowly

three different forms: crustose, foliose or fruticose

they can grow virtually anywhere

can tolerate extreme temperatures and lack of moisture

especially noticeable in the arctic

→lichens very abundant in tundra

over 350 sp lichens

only 2 sp flowering plants

are an important food source for caribou and reindeer:

reindeer moss is not a moss but a lichen

and in deserts or hot, dry areas

often first organisms to colonize an area; facilitate weathering process

absorb minerals mainly from the air and rainwater

lichens cannot excrete elements that they absorb

→ some are very sensitive to air pollution (esp SO4) and can be an indicator for the level of pollution in a city

reproduce mainly asexually by fragmentation

→ bits of lichen break off

some lichens release **soredia** = special dispersal units that contain both partners

in others the fungus reproduces by ascospores while alga reproduces by fission → partners then find each other by chance

some lichens are 1000's of years old, especially in drier climates

usually considered a case of **mutualism**

but:

some algae cells are actually penetrated and destroyed by fungal hyphae

without the alga, the fungus requires numerous organic compounds to grow

alga actually grows better alone than with fungus

→ therefore probably more of a **parasitic** relationship

Economic Importance of Lichens

some provide pigments for dyes

litmus is a lichen pigment used as a pH indicator

Pollution Indicators

Mycorrhizae

(means "fungus root")

1st discovered in mid 1800's

symbiosis of fungus with plant **root hair** cells→ **mutualism**

most "mushrooms" found in the woods are the fruiting bodies of the fungi in these mycorrhizal relationships

members of all three major fungal phyla can form mycorrhizae

but mainly **basidiomycetes**

over 90% of all vascular plants (most perennial plants) have mycorrhizae

nearly all commercially important plants have micorrhizal associations

Benefits to Plant:

earliest fossil records of land plants contain evidence of mycorrhizae (>400MY)

→ played major role in evolutionary step that brought aquatic plants to land:

greater area allowed plants to leave marine environment and exploit relatively harsh soil environment

greatly extend the absorptive ability of roots

→ increase the absorptive area 10-1000 x's

→ mycorrhizae are able to absorb and transfer all 15 major and micro nutrients needed for plant growth.

mycorrhizae release "powerful chemicals" into soil to dissolve hard to capture (ie. tightly bound) nutrients (eg. P, Fe)

→ plants grown without mycorrhizae often require high levels of fertilizer to grow as well

mycorrhizae are also important in water uptake and storage

→ commerical plants need less irrigation

→ don't suffer as much under water stress as plants grown without mycorrhizae

may also provide disease and pathogen suppression:

they create a mantle of tightly interwoven 'socklike' covering of dense filaments around root hairs

acts as a physical barrier against invasion by root pathogens

also attack pathogens entering root zone

→ excrete specific antibiotics

Benefits to Fungus:

exchange water and inorganic minerals that they absorb for organic foods from the plant

Benefits to Plant	**Benefits to Fungus**
greatly increases absorptive surface area better able to withstand drought better able to absorb minerals better able to tolerate extremes in temperature and acidity protect from soil pathogens (fungi & nematodes)	refuge from hostile conditions withstand drought and cold plants may divert up to 80% of net energy fixed to "below ground" processes include mycorrhizae free organic food [up to 25% of food made by plant is "given" to fungus]

Economic Importance of Mycorrhizae

very important in natural ecosystems and in agriculture and in gardening industry

most plants usually grow poorly when deprived of their mycorrhizal symbiont

mycorrhizae have important effects on:
- nutrient cycling
  - extract nutrients from poor soil
- soil aeration & soil structure
  - mycorrhizae produce humic cmpds and organic "glues" (=glomalins) that promote aeration, root growth and water movement
- soil water uptake

many common practices can degrade mycorrhizal development:
- tilling
- fertilization
- removal of topsoil
- erosion
- road and home construction
- fumigation
- invasive plants
- bare soils

nursery grown plants are often deficient in mycorrhizae
- → get more watering and fertilizer and use sterile soils

→ plants poorly adapted for transplanting to more natural areas

but: can use inoculum when transplanting

in some cases plant diversity of inoculated & replanted plots is ~2x's that of uninoculated sites

the earlier the inoculation the better

Animal Associations

eg. *Atta* ants (leafcutter ants)

they eat fungi and cultivate them

have wheelbarrow-like depression on their backs for carrying spores

they cultivate fungi within their mounds

mounds up to 18 ft underground

they feed the fungi bits of leaves, bark and other plant material

they weed out debris that might spoil their garden

fungus is a basidiomycete:
Attamyces bromatificus

freeliving cultures of fungus have never been found

fungus is transferred from colony to colony by ants

larvae eat fungus

adults eat leaves and some fungi

fungus needs ants to provide them with food

in Central and South America leaf cutter ants are the dominant herbivores
→ consume 17% of total leaf production

eg. African termites (Microtermitinae)

don't have gut protozoans

eat plant material:
- bring it home and eat it before entering mound
- then go in and defecate

use their feces to grow fungi (*Termitomyces*)

a basidiomycete

build chimneys up to 30 ft tall of feces and mycelia

all stages of termite readily eat the fungus

fungus never forms mushrooms in mound

when rain is imminent
- termites carry bits of mycelia out of mound
- spread them around the ground
- several days after rain mushrooms appear and produce spores
- the termites reappear and collect the genetically mixed hyphae and take them back into the nest

abandoned mounds produce crops of mushrooms for several years after termites leave
- → African people consider them a rare delicacy