Multicellular Eucaryotes

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

like eucaryotic cells versus procaryotic cells: this allows much more diversity and complexity

evolution of multicellularity is correlated with a burst in diversity in fossil record

multicellularity evolved many separate times among eucaryotes:

- seaweeds
- slime molds
- fungi
- plants
- animals

[must have been a clear advantage]

intermediate may have been colonial form

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 - General

simplest of three complex multicellular eucaryotic kingdoms in terms of structure

over 100,000 species described

est to 1.5M

fungi are the most resilient of land eucaryotes
- -thrive on a great variety of compounds
- -break down complex organic molecules
- -inhabit seemingly inhospitable habitats
  - eg. inside glaciers
  - eg. acidic waters

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

→ 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."

include: mushrooms, puffballs, morrels, bracket fungi

not all are multicellular; some are unicellular
= yeasts

extremely abundant in some ecosystems:
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))

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

contain a wide array of enzymes that can decompose almost any organic molecule
cutinases → digest leaf surface waxes

cellulases → destroy plant cell walls

some **saprobes**

– eat dead organic matter

some **parasites** or **predators**

– eat living organic matter

play important role in recycling nutrients in many ecosystems

=>convet 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

some suggest that the earliest fungi were not yet able to digest lignin (a plant compound) that appeared only when woody plants 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 are many more woody plants

mostly terrestrial

→were among the first terrestrial organisms; >400 MY history

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

but some inhabit diverse environments

some aquatic

some mutualistic (lichens, mycorrhizae)

some parasitic in plants and animals, including humans

=> about 300 known animal pathogens

=> most important cause of agricultural plant diseases

a few are predators

Structure

most fungi have flexible cell walls of **chitin**
(a N containing polysaccharide; similar to exoskeleton of arthropods)

most multicellular forms have vegetative portion and reproductive portion.

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.

except for yeasts, bodies consists of filaments called hyphae

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

in most the hyphae consist of chains of individual cells

primitive fungi have aseptate hyphae (=coenocytic)

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**

grow rapidly, up to 1km 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 cell wall at tips must remain elastic long enough to allow for wall extension and rigid enough to contain protoplasm and to allow streaming of nutrients to other parts of the fungus body)

the hyphae form an interwoven mat = **mycelium**

mycelium represents the *individual organism*

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?

some hyphae become specialized into:
haustoria –hyphal tips of parasitc fungi that invade cells of host
rings and **traps** – that predatory soil fungi use to capture prey
fruiting bodies – usually the most visible part of the fungus body that produces spores

Physiology:

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

at same time that they are secreting enzymes they are also secreting **mycotoxins** (include antibiotics) which inhibit growth of other microbes
→ possibly to discourage competition for food

many of the chemicals that fungi routinely produce cannot be synthesized in the laboratory

grow best in dark, moist habitats

but found wherever organic matter is available many fungi are less sensitive to acidic pH’s and to temperature 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

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

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 spore-bearing body

<u>Bioluminescence</u>

>40 fungal species glow in the dark

don’t know why

in some cases may improve reproductive success

eg. 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. other fungi have mycelia that are bioluminescent
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

all but 1 small group lack flagellae and are nonmotile

Reproduction:

most fungal reproduction involves the production of **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 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

some fungi reproduce asexually only

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

In most multicellular organisms:
"parents" produce sex cells by special kind of cell
division called **meiosis**
meiosis produces cells with half the number of
chromosomes as original cells
typically, 1 cell, the sperm, fuses with another cell,
the egg to produce a zygote
their chromosomes combine to produce a
genetically unique individual
which then grows into an "adult"

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

the single mycelium now has at least two different kinds of nuclei in its cells

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

then these cells undergo meiosis to produce genetically unique spores

parent→ meiosis→ sex cell ↘
cells fuse→ zygote→ offspring
parent→ meiosis→ sex cell ↗

vs

parent ↘
fuse→ nuclei fuse (zygote)→ meiosis→ spores→ offspring
parent ↗

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 form no embryos

Fungus Life Cycle:
as in algae and bryophytes – the sexual phase is generally haploid
(ie. gametophyte generation)

(but in basidiomycetes the cells are commonly dikaryotic)
in most fungi, nuclear fusion does not occur until shortly before meiosis and development of the sexual spore

the life cycle of many fungi includes three distinct phases:

haploid: most of fungal life cycle is haploid
dikaryotic: during the sexual cycle nuclei from the two parents pair up in same cell but don't combine => dikaryon
diploid: diploid is transient stage that occurs just before sexual sporesare produced

a. when fungal hyphae grow together they sometimes share nuclei from both organisms
b. nuclei may intermingle and even exchange genes or whole chromosomes
c. or sometimes the different nuclei stay in different parts of the fused mycelium
   => the mycelium becomes a mosaic of the two genotypes and phenotypes
d. finally nuclei fuse (=karyogamy) and form a diploid cell that immediately undergoes meiosis to produce sexual spores

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

sexual spores are generally much less commonly produced than asexual spores

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

such as mushrooms and bracket fungi

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

in most, sexual spores are produced only after nuclei from compatible individuals fuse and undergo **meiosis**

	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 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

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

Chytrids

1000 species (~100 genera) described

most primitive group of fungi

some are unicellular

each vegetative colony is essentially a single cell with many nuclei (no crosswalls) coenocytic hyphae
- vegetative structures is “thallus” like

like other fungi most are saprobes –absorptive

others are parasites of plants, animals and other fungi

mostly aquatic, a few are terrestrial

have chitin in cell wall

thallus bears numerous reproductive “organs”

the only true fungi with swimming spores (=zoospores)
- originally not considered fungi because some cells have flagella
  - (no other fungi have flagella)
- all produce flagellated zoospores for sexual reproduction
- some of these develop asexually into new individuals
- some zoospores are produced sexually after fusion of compatible nuclei

molecular evidence suggests that they are a direct link between protists and fungi

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

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
within this fused structure the 2 nuclei come together but do not fuse
compatable nuclei may coexist in same mycelium for hours, days or weeks before sexual reproduction occurs
in most, they form a cuplike fruiting body (=ascocarp) in which **asci** develop
in ascus cells the nuclei fuse to form zygote
zygote undergoes meiosis and sometimes additional mitosis to yield 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

Club Fungi
(Basidiomycota)

22300 - 25,000 species

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

hyphae always septate

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 followed by meiosis and production of (usually) 4 basidiospores on the *outside* of a generative cell (= the basidium)

compatible nuclei can coexist for weeks or months before fusing and undergoing sexual reproduction

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 produces the haploid basidiospores

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

a few basidiomycetes produce lichens

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

<u>Benefits of alcohol</u>

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

mid 80's

moderate use → reduces heart disease

reduces chances of clotting and blockages of vessels

<u>Costs of overconsumption</u>

regular overindulgence linked to:

high blood pressure

heart disease

obesity

liver damage & cancer

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

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

Symbiotic Fungi

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

bacteria (b-g)	lichens (bacteria, algae)
algae	
plants	mycorrhizae
animals	domesticated by insects and humans

<u>Lichens:</u>

~>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 can tolerate extreme temperatures and lack of moisture

absorb minerals mainly from the air and rainwater

they can grow virtually anywhere but are especially noticeable in the arctic and in deserts or dry areas

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

grow virtually everywhere

often first organisms to colonize an area; facilitate weathering process

lichens very abundant in tundra:
    350 sp lichens
    2 sp flowering plants

are an important food source for caribou and reindeer:
    reindeer moss is not a moss but a lichen

some provide pigments for dyes

litmus is a lichen pigment used as a pH indicator

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

Mycorrhizae

(means “fungus root”)

1st discovered in mid 1800’s

symbiosis of fungus with plant root hair cells

over 95% of all vascular plants (most perennial plants) have mycorrhizae

members of all three major phyla can form mycorrhizae but mainly basidiomycetes

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 may protect from soil pathogens (fungi & nematodes)	refuge from hostile conditions withstand drought and cold free organic food [up to 25% of food made by plant is “given” to fungus]

greatly extend the absorptive ability of roots

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

very important in natural ecosystems and in agriculture

these plants usually grow poorly when deprived of their mycorrhizal symbiont

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

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