Thanks to Joanna Masel

Biology & Diversity of Fungi

18 February 2010
ECOL 182R UofA
K. E. Bonine

VIDEOS
30.1, 30.2, 30.3
YouTube
Upcoming Syllabus (middle third)

18 Feb KB - Fungi, Ch31

23 Feb KB - Prokaryotes & Protists, Ch28&29
25 Feb KB - Plant Diversity, Form, Function, Ch30&40

2 Mar KB - Plant Form and Function, Ch36&37
4 Mar KB - Plant Function, Ch38&39

9 Mar KB - Plant Ecology, Ch50,52,53
11 Mar KB - Ecology, Ch50,52,53

13-21 Mar Spring Break

23 Mar KB - Biology of the Galapagos
             Wikelski 2000 and http://livinggalapagos.org/
25 Mar KB - Part 2. Discussion and Review.

30 Mar KB - EXAM 2
Kevin Bonine, Ph.D.

Tucson ~native
University of Arizona (undergrad)
- Ecology & Evolutionary Biology
- Economics
University of Wisconsin, Madison (graduate)
Zoology, Evolutionary Physiology
Reptiles & Amphibians
Teaching at UA since 2002
Herpetology
Vertebrate Physiology
Conservation Biology
Environmental Biology
Introductory Biology
Sonoran Desert Discovery

Middle-Third of this course (fungi, plants, ecology...)
Text readings are highly encouraged

kebonine“at”u.arizona.edu
Kevin Bonine
182 Office Hours

11-11:50 Tuesdays
BSE 113

-also M 1:10-2 and W 11:10-noon-
-464, 437, and 206 students competing-
Life can be divided into 3 domains

- **Prokaryotes** = bacteria + archaea
- Prokaryote was ancestral and only form for billions of years
• Prokaryotes = bacteria + archaea

are Prokaryotes **monophyletic, paraphyletic, polyphyletic**?
Eukarya = protists, plants, animals, fungi

are Protists monophyletic, paraphyletic, polyphyletic?
Protists are DIVERSE & ABUNDANT

We will talk about them on Tuesday...
Animals and Fungi are Closely Related Eukaryotes

You wrapped up a discussion on animals with Dr. Schaffer last week. We will therefore start with fungi, then move to prokaryotes and protists, then to plants, etc...
Tree of Life

3.8 bya
Common ancestor of all organisms

2+ bya

~1 bya

BACTERIA

ARCHAEA

EUKARYA

Fungi

Time

Ancient → Present
Opisthokonts
(Fungi and Animals are closely related)

Absorptive nutrition, chitin in cell walls
Common ancestor ~965 mya
Flagellum, if present, is single and posterior

Opisthokonts
Synapomorphies (shared, derived traits)

1. Flagellum - movement
2. Glycogen - sugar storage
3. Chitin - cell walls and other structures

Where did these three traits evolve on the tree?
Chitin
(tough but flexible nitrogen-containing polysaccharide)

• Production of chitin is a shared derived trait for
  - fungi
  - choanoflagellates
  - animals

• Evidence that fungi are closer to animals than plants
Fungi
5 or 6 major groups
How fungi live

- All use **absorptive nutrition**, secreting digestive enzymes and absorbing the breakdown products

- **Most are saprobes** *(feed on dead matter)*
  - Earth’s main **decomposers** *(with bacteria)*
  - principal decomposers of **cellulose & lignin**
  - nutrient *(re)cyclers*

- Some are **parasites**

- A few are **mutualists**
Saprobic fungi (and bacteria)
Cell structure of multicellular fungi

Vegetative body = mycelium (plural mycelia)

Composed of threadlike hyphae (singular hypha)
Fungus structure

• **Hyphae** may
  - disperse to look for nutrients
  - clump together to exploit a food source

• **Mushrooms are a fruiting (reproductive) structure**

• Most **Unicellular fungi** are called **Yeast**
Why are hyphae useful for a decomposer?

• SURFACE AREA
  - for EXTRACELLULAR digestion
  - for ABSORPTION
Fungal hyphae attack a leaf

Hyphae give a large surface:volume ratio, which helps with absorptive nutrition
Symbiotic fungi

Lichens are symbiotic associations of a fungus with a
- unicellular photosynthetic eukaryote (algae)
- cyanobacterium
- or both

Lichens are important pioneer species
Symbiosis

What is it?

The term *symbiosis* (from the Greek: σύν syn "with"; and βίωσις biosis "living") commonly describes close and often long-term interactions between different biological species. The term was first used in 1879 by the German mycologist Heinrich Anton de Bary, who defined it as "the living together of unlike organisms." The definition of symbiosis is in flux, and the term has been applied to a wide range of biological interactions. The symbiotic relationship may be categorized as mutualistic, commensal, or parasitic in nature. Others define it more narrowly, as only those relationships from which both organisms benefit, in which case it would be synonymous with mutualism.
Symbiotic fungi

• **Mycorrhizae** are mutualistic associations of fungi and plant roots
• The fungus obtains organic compounds, while the plant is provided with water and soil nutrients
• Some plants can’t grow without them

Lots of surface area!
Symbiotic fungi

Mycorrhizae = mutualistic associations of fungi and plant roots
Fungi increase surface area for nutrient and water absorption by plant

(a) Ectomycorrhizal fungi (EMF) form sheaths around roots and penetrate between root cells.

(b) Arbuscular mycorrhizal fungi (AMF) contact the plasma membranes of root cells.
Fungi are very important cyclers of nutrients. Especially Carbon, Nitrogen, Phosphorus.
Nitrogen and Phosphorus often LIMITING in ecosystems.
Fungi are way cool...

coprophilous

...so is biology!
Each video clip was compiled from ≤100 image files extracted from recordings consisting up to 1 million images captured in ≤4 s (e.g., 1 million image files captured with 2 µs shutter at 250,000 fps in 4 s)

Zygomycota
Pilobolus kleinii
50,000 fps

2 to 25 m s⁻¹
Corresponding accelerations of
20,000 to 180,000 g

Propelled spores over
distances of up to 2.5 meters

The fastest spores travelled more than 1 million times their own body length in one second

180,000 G vs.
Predatory fungus!

Nematode

Fungal ring

Fungus capturing a nematode worm
Fungal reproduction can be complex

- Sexual OR asexual
- Life cycles distinguish 4/5 phyla
What parts of you are Diploid?

Haploid?
Alternation of Generations

Sexual Reproduction Depicted Here (Meiosis & Fertilization)

Haploid (N) (~gametes) ↓
Fertilization ↓
Diploid (2N) ↓
Meiosis ↓
Haploid (N) Etc.
Alternation of Generations

Both the haploid and the diploid have multicellular forms.

Compare to Haplontic and Diplontic.

Return to in Plant Lectures...
Fungal Sexual reproduction

- Some fungi have more than 2 mating types
- Mating types don’t look different
- Mating can only occur between different mating types, preventing self-fertilization
- Sexual reproduction when hyphae (or motile cells in chytrids) of different mating types meet and fuse
Haplontic life cycle

- **Haploid** is dominant, multicellular structure
- Often **diploid** only very briefly as a **zygote**
- **Meiosis** produces **haploid** nuclei again
- Haploid spores divide **mitotically** to form haploid hyphae
Dikaryotic Lifestage

- Unique to fungi
- Two haploid (n) cells fuse, but not their nuclei
  \[= \textit{n + n dikaryote}\]
- Plasmogamy (cell fusion)
  followed later by Karyogomy to produce
  Diploid (2n) Zygote

- Life cycles distinguish 4/5 phyla...
Alternation of generations

**Chytrids** (no dikaryote)

- Sporangium
- Haploid zoospores
- Multicellular haploid chytrid
- Female gametangium
- Male gametangium
- Zygote
- Fertilization

**Zygomycetes**

- Sporangium
- Sporangiophore
- Female and male gametangia
- Zygosporangium
- Multi-nucleate zygosporangium

**Ascomycetes**

- Germinating ascospores
- Mating structure
- Ascus
- Mating type a (+)
- Mating type A (+)

**Basidiomycetes**

- Basidiospores
- Basidium
- Gills lined with basidia
- Developing basidium
- Dikaryotic mycelium
- Plasmogamy

Haplontic stages:

- Haplontic
- Dikaryotic stage

Dikaryotic stage:

- Fused nuclei
- Ascocarp
- Mitosis
- Ascospores
- Ascomycetes

Plasmogamy:

- Dikaryotic mycelium
- Gills
- Basidiocarp

*Figure 30.13 (Parts 1-4)*
Important points about sex and reproduction

- **Sex** = 2 nuclei fusing, followed by meiosis
- **Reproduction** = one individual giving rise to multiple: can be sexual or asexual
- **Genetic recombination** = any gene exchange: not just sex, also nonreproductive processes such as conjugation
- **Dikaryotic** individuals include 2 fused individuals, but not fused nuclei
- “**Spores**” can be sexual or asexual, reproductive or not: normally a small, tough cell with potential to become new organism. Often capable of latency. Can be plant, bacterial, protist, or fungal.
Fungal asexual reproduction

- Cell division by unicellular fungi
  - equal division (fission)
  - production of a daughter cell (budding)

- Simple breakage of the mycelium
Asexual reproduction via spores

Production of haploid spores within sporangia

- Conidia
- Leaf
- Hyphae
- Sporangia
- Sporangiophores

*Erysiphe sp.*

*Pilobolus sp.*
Fungal spores are everywhere

• Every breath we take is full of fungal spores (~10,000/m³ of air)

• Most humans only succumb to fungal pathogens when immunocompromised

sporotrichosis  ring worm  some pneumonias
Plants are not so lucky...

Parasitic fungus *Ustilago maydis* (corn smut)

Fungus (aka mold, mildew, etc.) causes lots of crop damage

- Dutch Elm disease
- Chestnut blight
Neither was this ant

Spores of this fungus don’t germinate until ingested by an ant
Basidiomycete life cycle

The basidium is the characteristic sexual reproductive structure of the basidiomycetes. Basidiospores form outside the basidium.

Basidiospores give rise to haploid hyphae. Haploid hyphae of different mating types fuse, forming dikaryotic hyphae.

Mating type + Mating type

Basidiospores

Dikaryotic hyphae

Dikaryotic (n+n)

Haploid hyphae

Pileus

Basidiocarp (fructing structure)

The basidiocarp is topped by a cap, or pileus, which has gills on its underside.

Nuclear fusion and meiosis take place in the developing basidium.

Nuclei

Gills lined with basidia

Basidia develop on the surfaces of the gills.

Fused nucleus

Meiosis

Fertilization

Mushrooms
Basidiomycete life cycle

(d) Basidiomycota have reproductive structures with many spore-producing basidia.

Mushrooms

The mushrooms that we eat are dikaryotes!
Life cycle of the basidiomycete *Cortenellus shiitake*
Yeast are fungi

- All five fungal phyla have unicellular species
- Those of all phyla except chytrids are called yeasts
- The yeast *Saccharomyces cerevisiae* makes CO₂ and ethanol during fermentation
- Used for bread and beer
Five Fungi Phyla

~1 bya
Common ancestor

- Chytridiomycota
- Zygomycota
- Glomeromycota
- Ascomycota
- Basidiomycota

Crown fungi
Chytrids

~Aquatic
Only fungi group retaining flagella

Includes *Batrachochytrium dendrobatidis* (Bd) causing amphibian die-offs
Chytrid Fungi

A chytrid fungus (*Batrachochytrium dendrobatidis; Bd*) has been implicated in the worldwide decline of numerous *amphibian* species. Frogs infected with this fungus suffer *chytridiomycosis*, a disease affects amphibian skin and is often fatal. Chytrid zoospores can survive in damp conditions and may be transported between frog populations in muddy clothing and footwear.

- water balance
- respiration
- immune system
GLOBAL SPREAD OF CHYTRID FUNGUS, 2007

Chytrid fungus detected:
- Associated with mortalities
- Not associated with mortalities

African Clawed Frog?
Glomerocytes

Important mycorrhizae associations with plants
Ascomycetes

Basidiomycetes

Named after basidiocarp, Which we know as a mushroom