Review Definition of Fungi

Eukaryotic, heterotrophic and absorptive organisms, which have cell walls, typically reproduce asexually and/or sexually by producing spores, and grow either reproductively by budding or nonreproductively by hyphal tip elongation.

Definition excludes:

1. bacteria & blue-green algae (prokaryotes)
2. slime molds
3. true algae & higher plants
4. animals
5. etc.

Definition may include some non-fungi

1. Oomycetes (water molds)
2. etc.

About Fungal Thalli (pl), Thallus (sing):

Many fungi characterized by a distinctive, multinucleate, vegetative (somatic) thallus (body) called

the mycelium* (singular)

mycelia* (plural).

The mycelium consists of a branching system of walled tubes called

hyphae (plural)

hypha (singular)

Mechanisms of hyphal growth** are

apical extension &

lateral branching.

* term usually used with filamentous fungi

**nonreproductive growth vs reproductive yeast growth

Vegetative hyphal growth
vs yeast growth

hyphal growth = apical extention

yeast growth= budding

hyphal growth= nonreproductive

yeast growth = reproductive

Fungal nutrition

A. Absorptive mode

1. over whole surface or

2. via restricted absorbing regions , e.g.

a. rhizoids in "lower" fungi

b. substrate hyphae* in "higher" fungi

c. apical tips of hyphae

*The substrate hyphae of molds nourish the aerial hyphae and reproductive hyphae

B. Extracellular digestion

Fungi secrete enzymes that depolymerize complex natural products (proteins, carbohydrates, lipids, etc.) so they can be absorbed as sources of carbon and energy.

Question: What are fungi?

1. Because of nutritional mode they are ecologically considered among the primary decomposers*.

2. Because of size, nutrition and history, they are considered to be microbes by microbiologists.

3. Because of structure and history, they have historically been considered to be plants by botanists.

Question: Are fungi plants?

No!…opinions of Whitaker, Margulis, Cavalier-Smith, Kendrick, PJS, etc.

* Reducers

Reasons Fungi not Plants:

1. Ultrastructural studies suggest uniqueness

    - certainly more "primitive" fungi (Chytridiomycota) are not plants

    - flagellation patterns of Chytridiomycota and other fungal-like protists suggest independent origins*

    - derivation from nonphotosynthetic ancestors

    * polyphyletic

2. Fungal organization is different from and nonhomologous with that of plants.

    - convergent evolution—similar structures and life cycles.

    - tissue-like structure of hyphal origin*

    * hyphal aggregates

3. Nutrition - fungi and most fungal-like protists were most-likely never photosynthetic.

    Therefore, no more related to higher animals than higher plants.

        Fungal Nutrition - Absorptive

        Plant Nutrition - Photosynthetic

        Animal Nutrition - Endocytotic or ingestive and absorptive

If not plants, then what?

Kingdom Systems

Systems	Kingdoms
1. 2 kingdoms	1. Plantae
	2. Animalatae
2. 3 kingdoms	1. Protista*
	2. Metaphyta
	3. Metazoa
3. 4 kingdoms	1. Monera
	2. Protista*
	3. Metaphyta
	4. Metazoa
4. Whittaker's 5 kingdom system (~ 1969)	

*Concept #1 Protista = unicells or their colonial associations

*Concept #2 Protista = unicells or/and other organisms which lack tissue specialization of higher plants.

What are fungi? - Question

Fungi are fungi. - Answer!

1) Fungi are accepted as the third kingdom of higher organisms whose origins flow naturally from a primitive eucaryotic protist.

2) Fungal origins are obscured but probably flowed from the Chytridiomycota, a group that we will study in this course, together with a few other fungal-like protists tradition ally studied by mycologists.

*Chytridiomycota are currently said to be most likely ancestor group

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Questions

1. What was the pre-molecular biology basis for the reclassifications among the pre-Whittaker "fungi?"

2. What is the reality of the molecular revolution to the "new taxonomy" of the Kingdom Fungi?

2-1(new)

Subdisciplines of taxonomy

1. Identification

   Recognition of organism

2.* Classification

   Recognition of relationships

   (or nonrelationships)

3. Nomenclature

   Correct naming of organisms (use of rules of botanical nomenclature)

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Classification hierarchy and fungal classification suffixes

Kingdom- Fungi

Subkingdom- mycotera

Division/phylum- mycota

Subdivision/subphylum- mycotina

Class- mycetes

Order- ales

Family- aceae

Genus, *Saccharomyces*

Species, *S. cerevisiae*

Organisms in the same taxon are more related than are organisms in different taxa.

17=2b(rev)

Pre-Whittaker fungal classification (1969)

Kingdom - Plantae (Metaphyta)

Division - Eumycota

Class - Phycomycetes*

Class - Ascomycetes

Class - Basidiomycetes

Class - Deuteromycetes (Fungi Imperfecti)

*The so-called traditional "lower fungi"

*All produce their mitotically-derived reproductive cells in a cell called a sporangium. (sporangia)(pl)

*Lumping into single class erroneously suggested relatively close relationships

2-4 (rev)

Where are the Phycomycetes* today?

Kingdom - **Protozoa****

Division - Plasmodiophoromycota

Kingdom - **Chromista**

Division - Hyphochytridiomycota

Division - Oomycota

Kingdom - **Fungi**

Subkingdom - Mastigomycotera*** }

Division – Chytridiomycota } today's lower fungi?

Subkingdom – Amastigomycotera }

Division – Zygomycota }

*The traditional lower fungi

**see lab manual, appendix a, for members, etc. or handout

***Historically also:

Acrasiomycota - cellular slime molds

Labyrinthalomycota - gliding slime molds

Myxomycota - plasmodial slime molds, etc. (see other materials on reserve)

Factors that originally led to the grouping of these different kinds of organisms into single class "Phycomycetes."

1. Their tendency to be vegetatively aseptate & multinucleate (coenocytic)
2. Their tendency to produce their mitotically derived, reproductive propagules (zoospores or sporangiospores) in a cell called a sporangium/sporangia (pl).
3. Their tendency to look alike and have superficially similar biologies that were clearly different than those of "higher fungi".

Major diagnostic characteristic of sporangial fungi and of some sporangial fungal-like protists

Phylum/Division	**Sporangial Propagule-Type**
Plasmodiophoromycota	Zoospore* (1 whip-lash flagellum and 1 stub-type flagellum rudiment)
Hyphochytridiomycota	Zoospore (1 tinsel-type anterior flagellum)
Oomycota	Zoospore (1 tinsel- and 1 whip-lash flagellum)
Chytridiomycota	Zoospore (1 whip-lash posterior flagellum)
Zygomycota	Sporangiospore**

*Zoospores are mycotically-derived reproductive cells lacking dormancy qualities and cell walls, and having undulopodia.

**Sporangiospores have dormancy qualities and cell walls, but lack undulopodia.

Kingdom Protozoa

Division – Plasmodiophoromycota

Class - Plasmodiophoromycetes

Order - Plasmodiophorales**

* both hyphal and nonhyphal types

** intracellular plasmodial parasites of plants, algae and fungi - maybe more similar to animals than higher fungi

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Kingdom Chromista

Division - Hyphochytridiomycota*

Class - Hyphochytridiomycetes

Order - Hyphochytridiales

* Mostly parasites of algae and fungi or saprophytic plant and insect materials

* Nonhyphal and rudimentary hyphal representatives

Division - Oomycota**

Class - Oomycetes

Order - Saprolegniales

Order - Leptomitales

Order - Lagenidiales

Order - Olpidiopsidales

Order - Peronosporales

Order - Pythiales

** nonhyphal and hyphal members, orders in transition

Kingdom Fungi

Kingdom - Fungi

Subkingdom - Mastigomycotera*

Division - Chytridiomycota**

Subkingdom - Amastigomycotera***

Division - Zygomycota

Subkingdom – Eumycotera****

Division – Ascomycota } or Dikaryomycota

Division – Basidiomycota } "

Division - Fungi Imperfecti
(or Deuteromycota)

*members produce zoospores

** presence of sporangia led to original inclusion among Phycomycetes

*** members produce sporangiospores

**** members do not produce sporangia; the "higher fungi"

Orders of Chytridiomycota

Kingdom - Fungi

Subkingdom - Mastigomycotera

Division - Chytridiomycota*

Class - Chytridiomycetes

Order - Chytridiales

Order - Spizellomycetales

Order - Blastocladiales

Order - Monoblephariadales

Order - Neocallimasticales

Order - Harpocyhytriales

*Both hyphal and nonhyphal types; show parallel evolutionary trends with Oomycota members.

Classification of Zygomycota

Kingdom - Fungi

Subkingdom - Amastigomycotera*

Phylum - Zygomycota+

(cont below)

*Fungi that produce nonflagellate mitospores (sporangiospores**) in a sporangium (species once classified among the phycomycetes)

**Sporangiospores (vs zoospores) have cell walls, dormancy qualities, no flagella, & tend to be wind disseminated

+Also usually characterized by hyphae and the production of a karyospore (type of sexual spore) called a zygospore. In many cases, zygospore observation is as important diagnostically as sporangiospore and sporangium observation.

(cont from above)

Class - Zygomycetes*

Order - Mucorales (black bread molds)

Order - Entomophthorales (many insect pathogens)

Order - Zoopagales (insect predators, eg. nematode trappers)

Order - Endoganales (saprophytic root-associated fungi)

Order - Glomales (endomycorrhizal fungi)

Class – Trichomycetes**

* mostly hyphal organisms with a total of 7 orders

** 4 orders of poorly studied species that include numerous arthropod gut symbionts that are hyphal or rudimentarially hyphal. We will not study this group.

Eumycotera Classification

Division	Major Characteristics(s)
Ascomycota	Ascus/Asci & Ascospores
Basidiomycota	Basidium/Basidia & Basidiospores**
Fungi Imperfecti	Absence of Sporangia, Asci or Basidia, Ascospores or Basidiospores

* ascospores = endogenous meiospores***

** basidiospores = exogenous meiospores***

*** true spores with cell walls and dormancy qualities.

Eumycotera Classification (cont)

Kingdom Fungi

Subkingdom - Eumycotera*

Phylum - Ascomycota**

Phylum - Basidiomycota**

Phylum - Fungi Imperfecti***

* absence of mitosporangia (the higher fungi, the nonsporangial fungi)

** sometimes combined in one group (e.g. dikaryomycota).

*** a nonphylogenetic (artificial) phylum whose members may or may not be related (taxonomy does not reflect relationships) The relationships among these fungi are being clarified by DNA and protein sequencing.

Eumycotera Classification (cont)

Division	Major Characteristics(s)
Ascomycota	Meiosporangium called an ascus, which produces **endogenous** meiospores called ascospores
Basidiomycota	Meiosporangium called a basidium, which produces **exogenous** meiospores called basidiospores*
Fungi Imperfecti	No known or observed meiosporangia, therefore no ascospores or basidio-spores, therefore no absolute ability to classify morphologically.**

*true spores with dormancy qualities
**possibly can now by molecular biology

Also – no mitosporangia, \ no zoospores or sporangiospores

Ascomycota classification

Division - Ascomycota

Subdivision - Hemiascomycotina*

Class - Hemiascomycetes

Order - Saccharomycetales
(Ascus from diploid nucleus w/o N+N state) with 8 families, 270+ species

Class - Archaeascomycetes

Order - Taphrinales
(Ascus from N+N*** cell)

Order - Schizosaccharomycetales (fission yeasts)

Order - Pneumocystidales (for *Pneumocystis carinii*, etc.)

Order – Protomycetales (intracellular mycelial plant pathogens that are apparently diploids)

*Lack ascocarps (multihyphal tissue-like structures surrounding their asci. Both hyphal & nonhyphal members.

Subdivision - Euascomycotina**

**have ascocarps associated with their asci.

***N+N = dikaryon state

Classes of Euascomycotina

Class	Ascoma or Ascocarp type
1. Plectomycetes	Cleistothecia (a)
2. Pyrenomycetes	Perithecia (b)
3. Discomycetes	Apothecia (c)
4. Loculoascomycetes	Ascostroma (d)
5. Laboulbeniomycetes	Very specialized Perithecia

a. closed ascocarps
b. flask-shaped ascocarps
c. cup or goblet shaped ascocarps
d. stroma with locuoles (cavities)

Basidiomycota Classification

Subkingdom - Eumycotera

Phylum - Basidiomycota

Subphylum - Heterobasidiomycotina*

Class - Uredinomycetes (rusts)

Order – Uredinales

Order -- Septobasidiales

Class - Ustomycetes (smuts)

Order - Ustilaginales

* basidia from teliospores (dikaryotic spores)

Subphylum - Holobasidiomycotina

Class - Phragmobasidiomycetes* (5 orders)

Order - Tremellales
(have cruciately septate Basidia)

Order - Auriculariales
(have transversely septate Basidia)

* have septate basidia

Basidiomycota Classification (cont.)

Subphylum - Holobasidiomycotina * (cont.)

Class – Holobasidiomycetes (27 orders)

Order - Dacrymycetales
(have tuning-fork type basidium)

Order - Tulasnellales (have holobasidia with swollen sterigmata)

Order - Agaricales (the mushrooms)

Order – Boletales (the fleshy pore fungi)

Order – Cantharelles (chantarelles, and tooth fungi, etc.)

Order - Exobasidials

Order - Gautieriales

Order - Hymenogastrales

Order - Lycoperdales (the puffballs, earth stars, etc.)

Order - Melanogastrales

Order - Nidulariales (the bird's nest fungi)

Order - Phallales (the stinkhorns)

Order - Porales (woody shelf fungi or woody bracket fungi)

Order – Thelephorales (the coral and leather fungi)

Order – Sclerodermatales (the earth balls)

* most have typical holobasidum, but different kinds of basidiocarps

Review - Kingdom Fungi

Kingdom – Fungi

- Subkingdom - Mastigomycotera
  - Phylum - Chytridiomycota
- Subkingdom - Amastigomycotera
  - Phylum - Zygomycota
    - Class - Zygomycetes
      - Orders- Mucorales (etc)
    - Class - Trichomycetes
      - Orders - 1 to 4
- Subkingdom - Eumycotera
  - Phylum - Ascomycota
    - Subphylum - Hemiascomycotina
      - Class - Hemiascomycetes
        - Order - Saccharomycetales
          (Ascus from diploid nucleus w/o N+N state)
      - Class - Archaeascomycetes
        - Order - Taphrinales
          (Ascus from N+N cell)
        - Order - Schizosaccharomycetales (fission yeasts)
        - Order - Pneumocystidales (for *Pneumocystis carionii*, etc.)
        - Order – Protomycetales
    - Subphylum - Euascomycotina
      - Class - Plectomycetes
      - Class - Pyrenomycetes
      - Class - Discomycetes
      - Class - Loculoascomycetes

Review - Kingdom Fungi (cont.)

Subkingdom - Eumycotera

Phylum - Basidiomycota

Subphylum - Heterobasidiomycotina

Class – Uredinomycetes/Teleomycetes

Order – Uredinales

Order -- Septobasidiales

Class - Ustomycetes

Order - Ustilaginales

Subphylum - Heterobasidiomycotina

Class - Phragomobasidiomycetes

Orders - Tremelales

Order - Auriculariales

Class - Holobasidiomyetes

Orders - Dacrymycetales, Tulasnellales, Exobasideals, Aphyllophorales, Hymenogastrales, Gautieriales, Phallales, Lycoperdales, Tulostomatales, Sclerodermatatales, Nidulareales, Agaricales, Melanogadstrales, Porales

See my reference guide to Fungi & Fungal-like Protists (circa 2000), & handout

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FUNGI IMPERFECTI
(Deuteromycota)

Nonphylogenetic group of fungi without known sexual cycles or with unobserved sexual cycles.

Unique Phylum/Division

1. Groupings may or may not represent phylogeny e.g., species in same genus may be less related than species in different genera

2. Most members probably should be included in another Division, particularly Ascomycota and Basidiomycota

3. Members often have two and sometimes more acceptable scientific names

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WHY FUNGI IMPERFECTI?

1. Recognition that sexual cycles of fungi, particularly of Ascomycota and Basidiomycota, were important for understanding relationships created the problem

2. Problem was what to do taxonomically with fungi that had no known sex cycles?*

3. Problem solved by creating a Division of fungi in which fungi are named with little regard for relationships. Identification without regard to classification; based on observations and naming of asexual states.

*majority

Question - Why are asexual states usually known before sexual states?

1. If organism grows then it usually exhibits its asexual (anamorphic) phase first.

asexual (anamorphic) phase first

vegetative growth ------> asexual

reproduction ----------> sexual reproduction

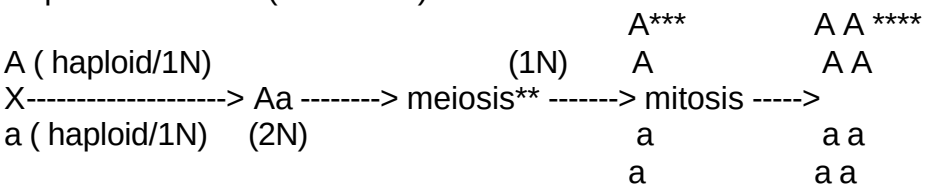
2. With practically important fungi, one can identitfy and work with fungus without knowing about sexual stage.

3. Induction of sexuality is often dependent upon inducing sex in mated strains.

Homothallism vs Heterothallism

Many fungi are heterothallic*

Haploid self-sterile (nonsexual) strains



Only a few are homothallic (self-fertile)

* sex requires = pairs of opposite mating strains
** meiosis often requires special physiological conditions
*** meitotic nuclei incorporated into
meiospores
ascospores
basidiospores

**** somtimes, etc.

ASEXUAL STATES = IMPERFECT STATE

Therefore: Fungi Imperfecti = Deuteromycota

1. Fungi Imperfecti named according to rules of Botanical Nomenclature for asexual fungi

2. When perfect states (sexual) become known they are classified and renamed according to rules of Botanical Nomenclature for sexual fungi

Older Fungi Imperfecti names usually better known

Review The Fungi Imperfecti

1. Fungi having no known or observed sexual state (teleomorph)

2. Usually asexual states (anamorphs) of Ascomycota or Basidiomycota

3. When sexual state of an imperfect (asexual) fungus is observed and described the fungus is

    a. renamed according to rules of botanical nomenclature

    b. reclassified according to characteristics of the holomorph = whole fungus considering biology of both anamorph and teleomorph

4. Until discovery of teleomorph fungus is a member of the Fungi Imperfecti and included in its "hierarchy" of categorization.

FUNGI IMPERFECTI

Hierarchy of Categorization*

Form - Class

Form - Order

Form - Families

Form - Genera

Form - Species

*System useful for communication and identification, but does not necessarily reflect relationships (phylogeny)

*Not a classification system

1. Form class - Blastomycetes

   nonsexual yeasts

2. Form class - Hyphomycetes

   Mycelial (hyphal) conidial fungi

3. Form class - Coelomycetes

   Mycelial (hyphal) conidial fungi with conidiogenous structures associated with multihyphal aggregates.**

4. Form Class - Mycelia sterilia

   nonsporulating hyphal fungi.

**
Conidioma

Examples of common anamorphic genera (Fungi imperfecti) whose teleomorphic names are often established but seldom used.

Anamorphic name	**Teleomorphic name**
Penicillium	*Telaromyces*, etc.
Aspergillus	*Eurotium*, etc.
Rhodotorula	*Rhodosporidium*
Trichophyton	*Arthroderma*
Microsporum	*Arthroderma*
Blastomyces	*Ajellomyces*
Cryptococcus	*Filobasidiella*
Candida	*Saccharomyces*
Pichia	*Hansenula* etc

Today's Problems with Division Fungi Imperfecti

Good News - perfect states of many fungi have been, and continue to be, discovered

Bad News - hundreds of common fungi have new names

More Bad News - great resistance to learning and understanding about why we are having reclassifications*

Great resistance to use of new names by non-mycologists and professionals.

Both imperfect and perfect names of sexual fungi commonly used.

Particularly true in regard to applied fields like

- medical mycology
- plant pathology
- industrial mycology

* will be compounded by molecular classifications