KINGDOM EUMYCOTA - The True Fungi

Phylum Basidiomycota

Disclaimer: Keep in mind that new systems that new information is changing our current understanding of how fungi are phylogenetically-related and should be taxonomically arranged.

Basidiomycota

- Large phylum – 16,000 spp of higher fungi
- Characteristics
- 1-Hyphae are regularly septate
- 2-All produce a basidium club shaped structure (site of karyogamy & meiosis) that produces haploid basidiospores

- 3-Specialized type of pore can occur – dolipore septum with parenthesome
- Allows cytoplasmic movement but prevents nuclear migration from one compartment to the next

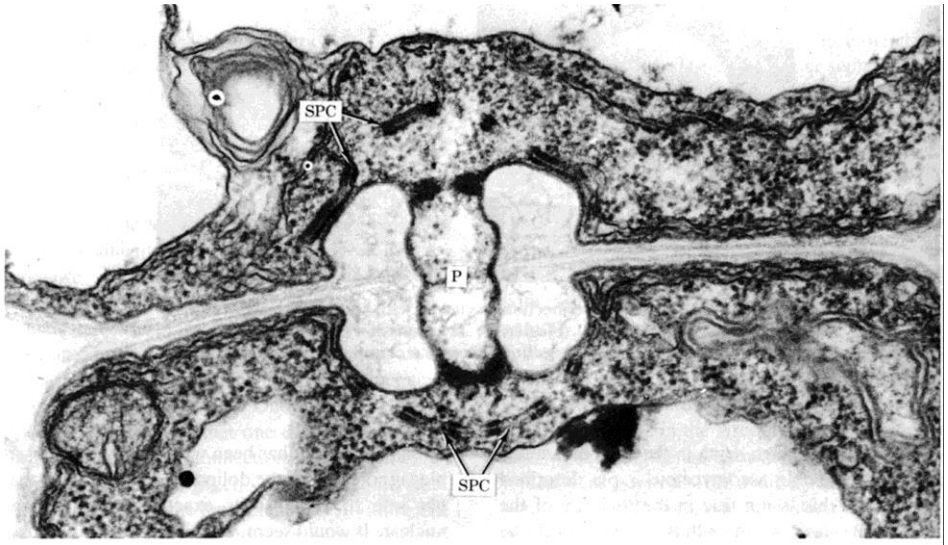
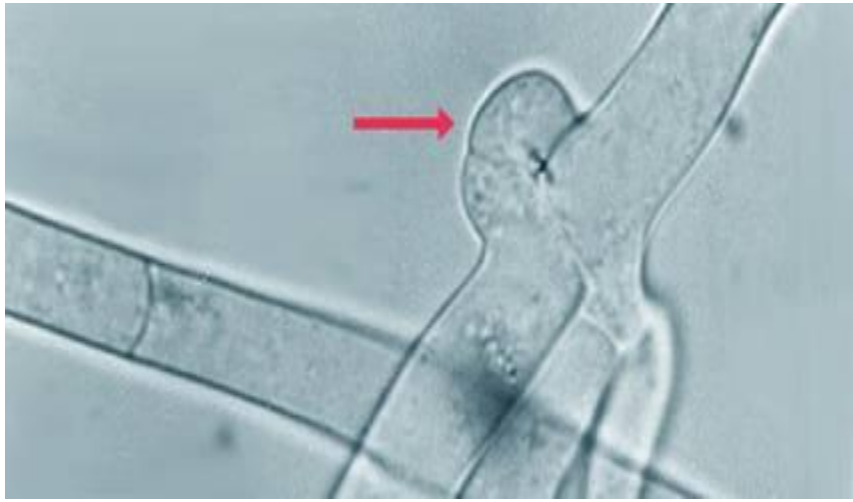


Figure 20-2. **Transmission electron micrograph of a median longitudinal section through a dolipore septum. Note the central pore (P) and portions of the septal pore cap (SPC). Photograph by M. A. Rogers.**

4-Basidia and basidiospores

5- Clamp connections.
Not all Basidiomycetes produce these, but when a fungus does it will always be a basidiomycete.



Life cycle

- Haploid basidiospores germinate to produce haploid mycelium = primary mycelium
- In some species, the primary mycelium contains one nucleus in each compartment, in others, there may be multiple nuclei/compartment – also called monokaryon since it contains nuclei of one genotype
- Primary mycelium exhibits limited growth

Life cycle

- Plasmogamy occurs shortly after basidiospore germination
- Most Basidiomycetes are heterothallic
- Plasmogamy occurs between two compatible hyphae (somatogamy) – no specialized sex cells
- Plasmogamy initiates dikaryotic phase or the secondary mycelium (dikaryon)
- After plasmogamy, nuclei migrate into monokaryotic cells to establish dikaryotic condition

Dikaryon

- As mycelium grows, nuclei divide conjugately to maintain dikaryotic condition in cells
- Dolipore septum prevents nuclear migration so that each compartment contains two nuclei, pore is 0.1-0.2 μm in diameter
- Under certain conditions (e.g. after plasmogamy), dolipore septum breaks down to allow nuclear migration

Basidiomycetes

Characteristics:

4. Two main groups, based on morphology of basidia.
   a. Basidia are septate and deeply lobed

      Order Uredinales – the rusts

      i. Produce all five spore stages – aeciospores, uredospores, teliospores, basidiospores and spermatia (aka pycniospores)
      ii. Important geneus – *Puccinia,*

      iii. Order Ustilaginales – the smuts

      iv. Produce only basidiospores and teliospores
      v. Important genera – *Ustilago, Tilletia*

Basidiomycetes

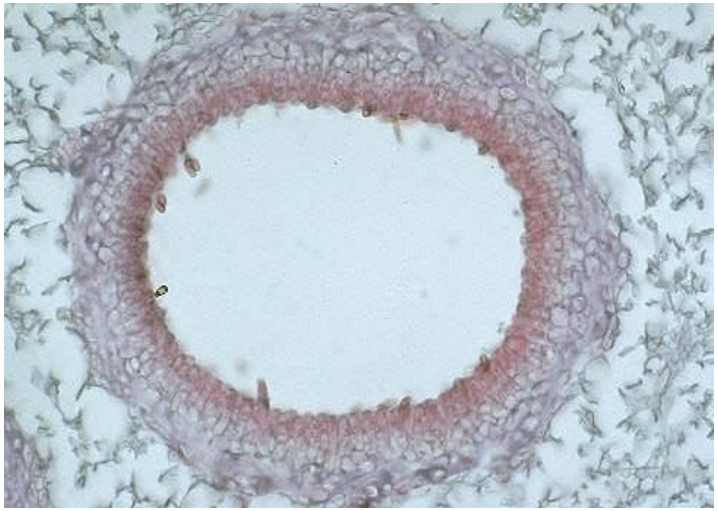
b. Basidia are unicellular, non-septate: wood decay fungi

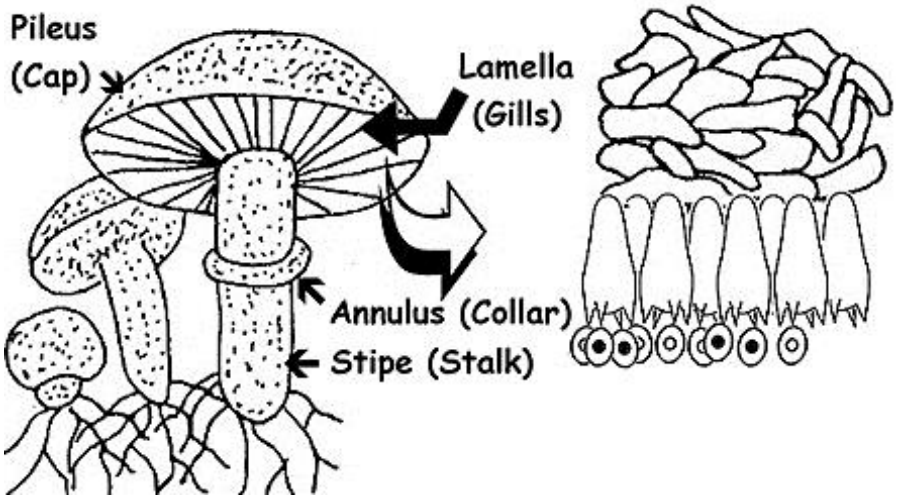
Order Aphyllophorales (aka Polyporales) – the bracket fungi

i. Hymenium lines small pores on underside of sporophore
ii. Important genera – Ganoderma, *Polyporus, Fomes*

Order Agaricales – the mushrooms

i. Hymenium lines gills (lamellae)
ii. Important genera – *Armillaria, Agaricus, Agrocybe*

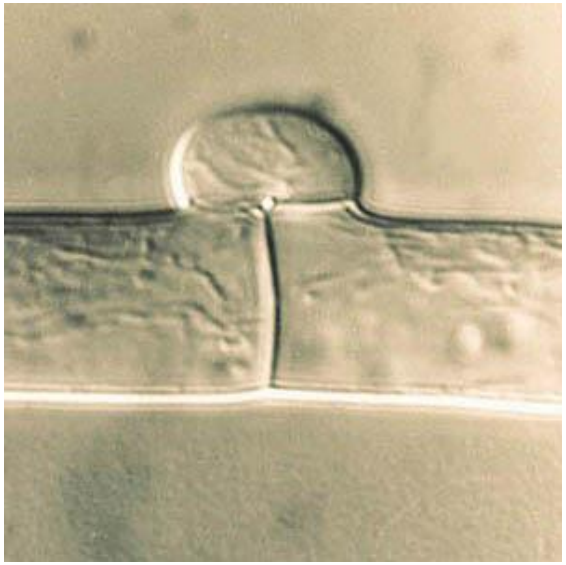


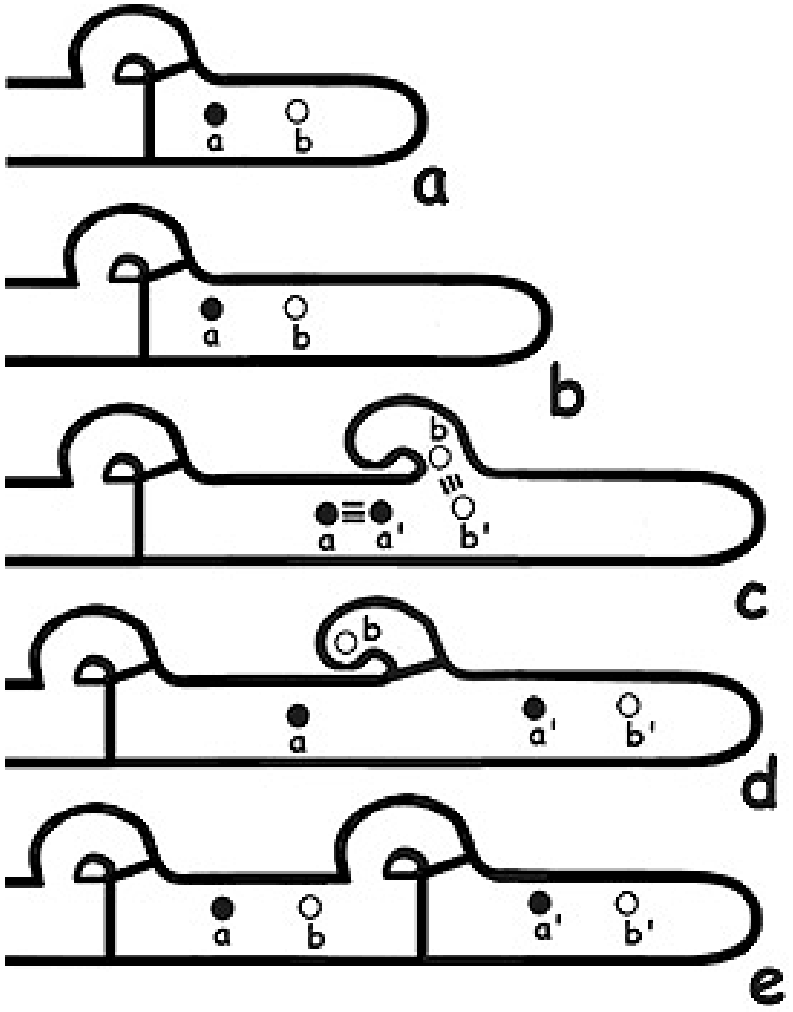


Aphyllophorales

Agaricales

The formation of a clamp connection and maintenance of the dikaryon in a basidiomycete





Clamp connections

- Branch that grows back

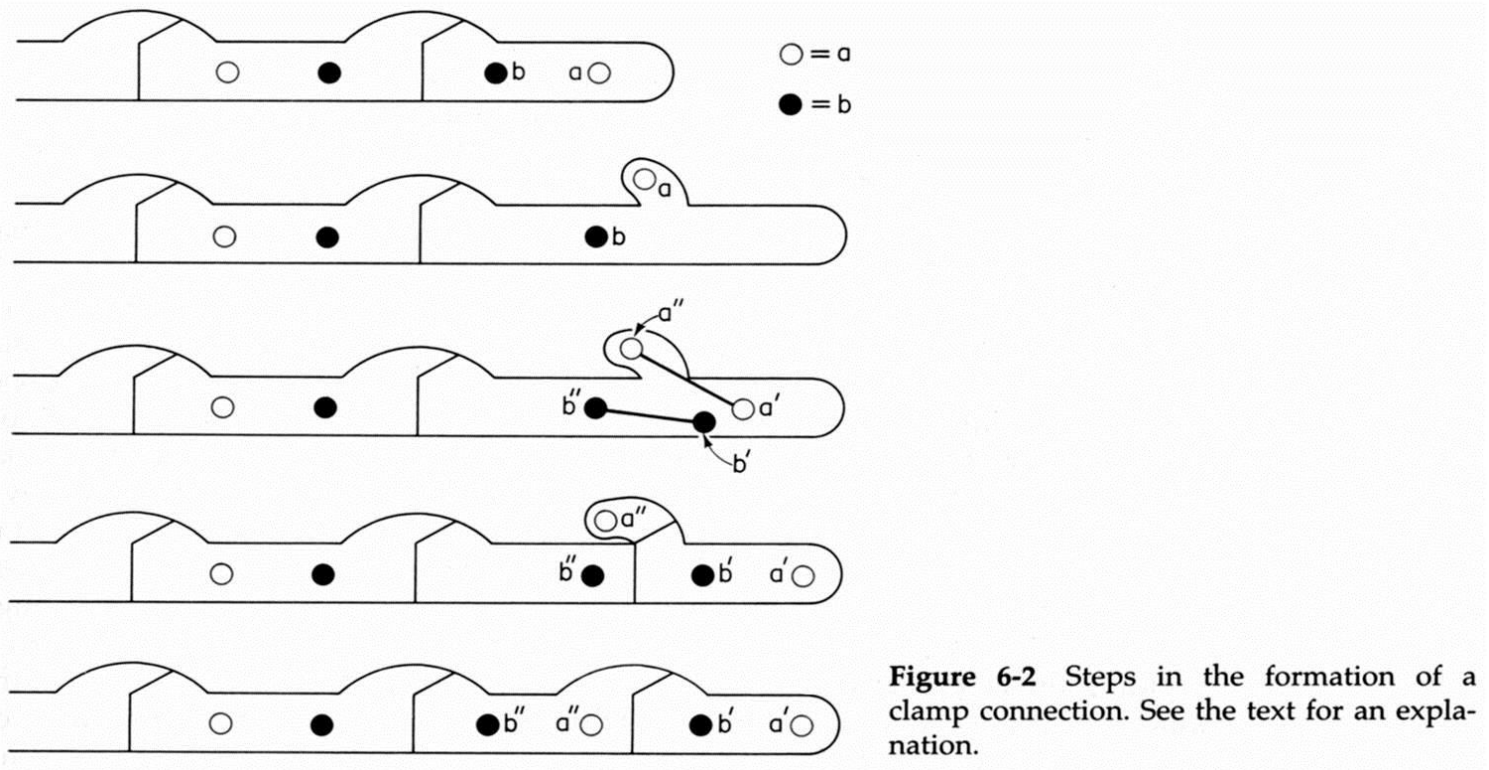
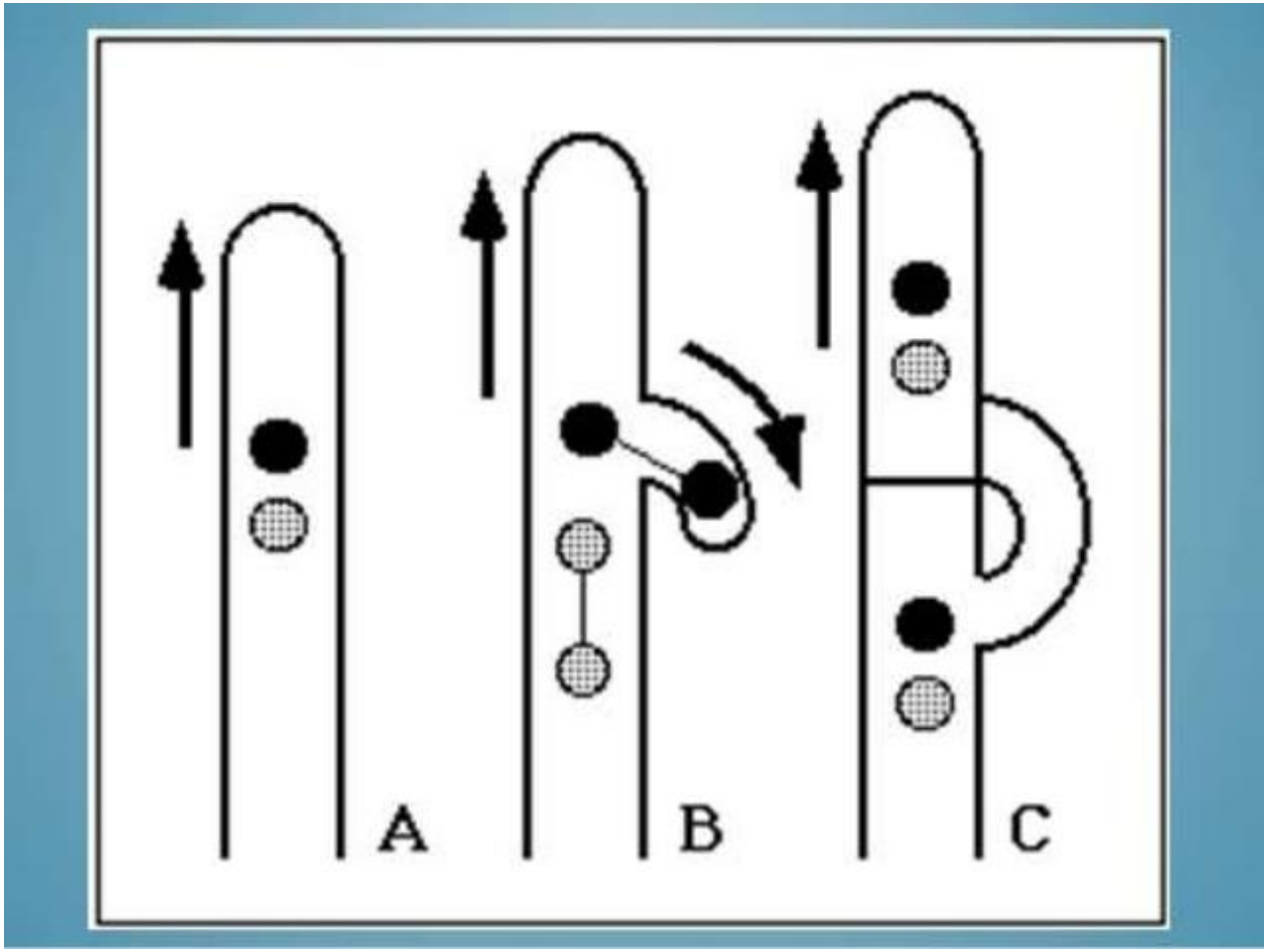


Figure 6-2 Steps in the formation of a clamp connection. See the text for an explanation.


A
B
C

Clamp connections

- Thought to be a mechanism to maintain dikaryotic condition
- Only found in dikaryotic hyphae, but not all dikaryotic hyphae form them

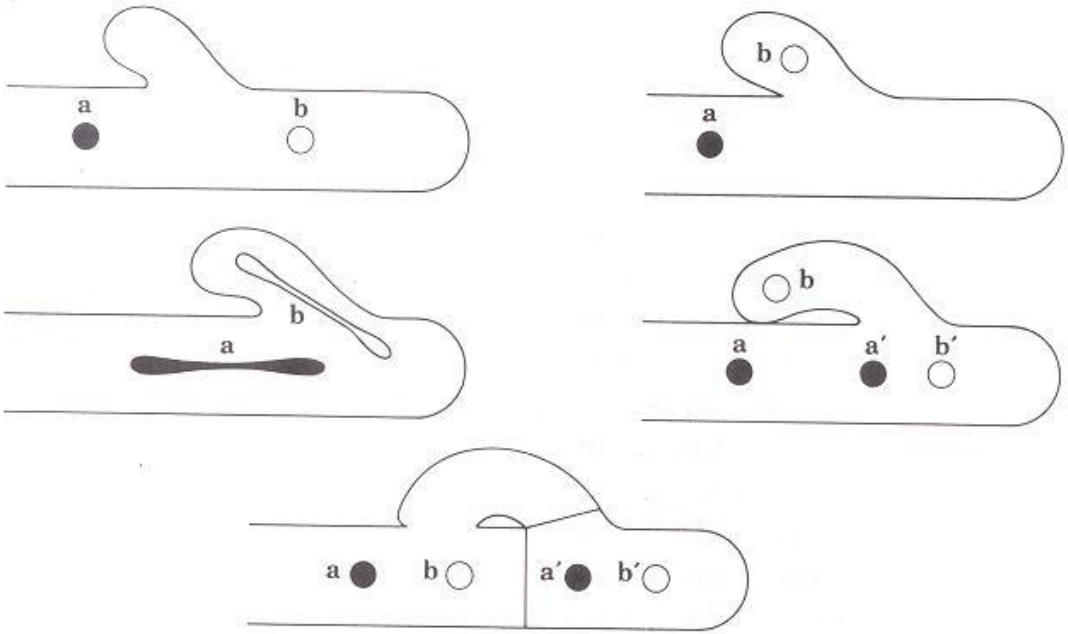
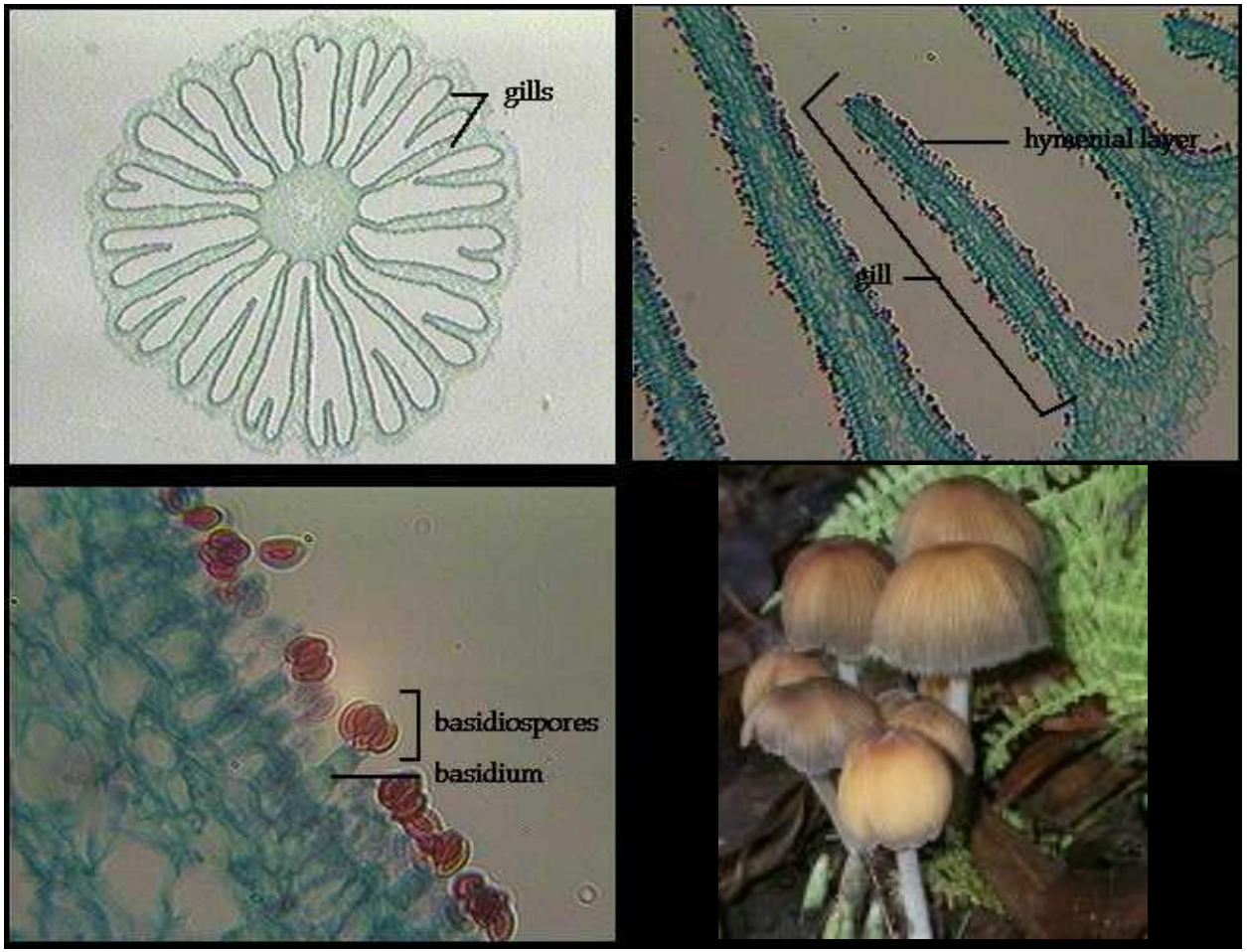


Figure 16-2 Diagrammatic summary of the nuclear events associated with clamp connection formation that operate to ensure the maintenance of the dikaryotic condition in some basidiomycetes.

Dikaryon

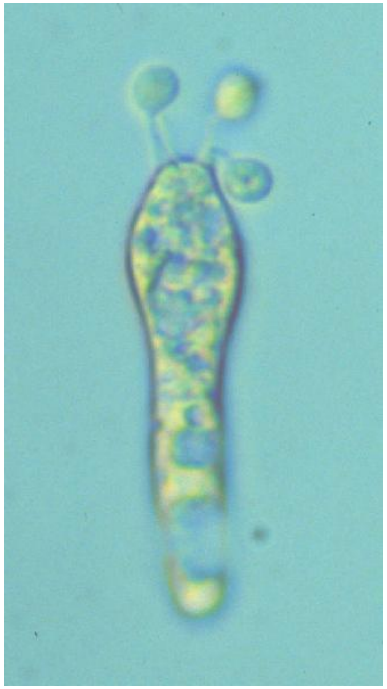
- Dikaryon grows – may reproduce asexually, but asexual reproduction is not widespread in Basidiomycetes
- Favorable environmental conditions stimulate formation of basidiomata

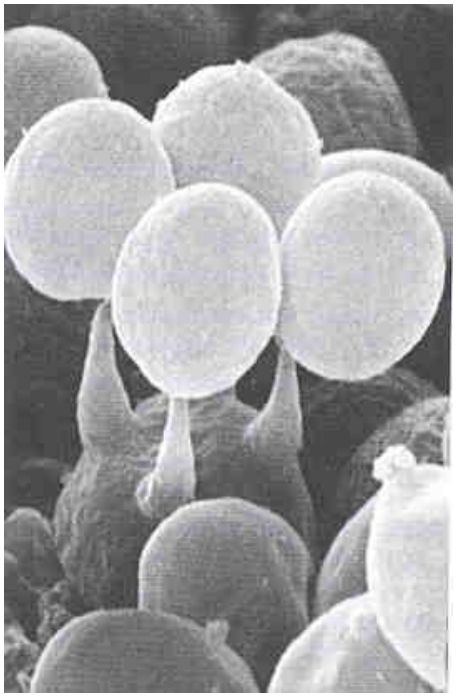
Hymenium, Basidia,and Basidiospores



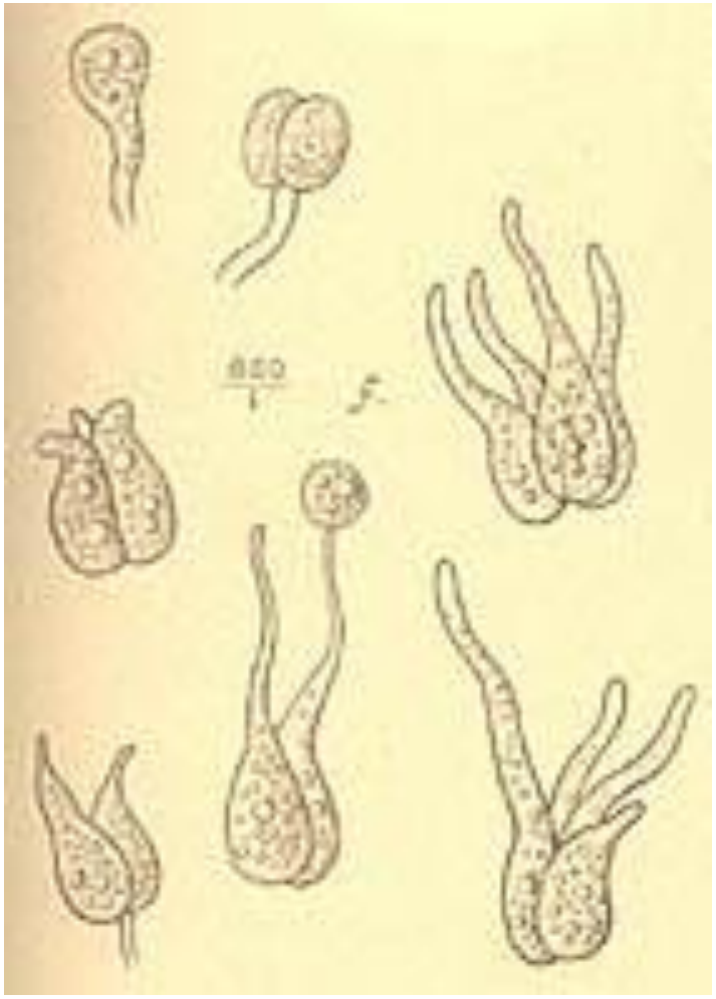
TWO BASIDUM TYPES

HOLOBASIDIA

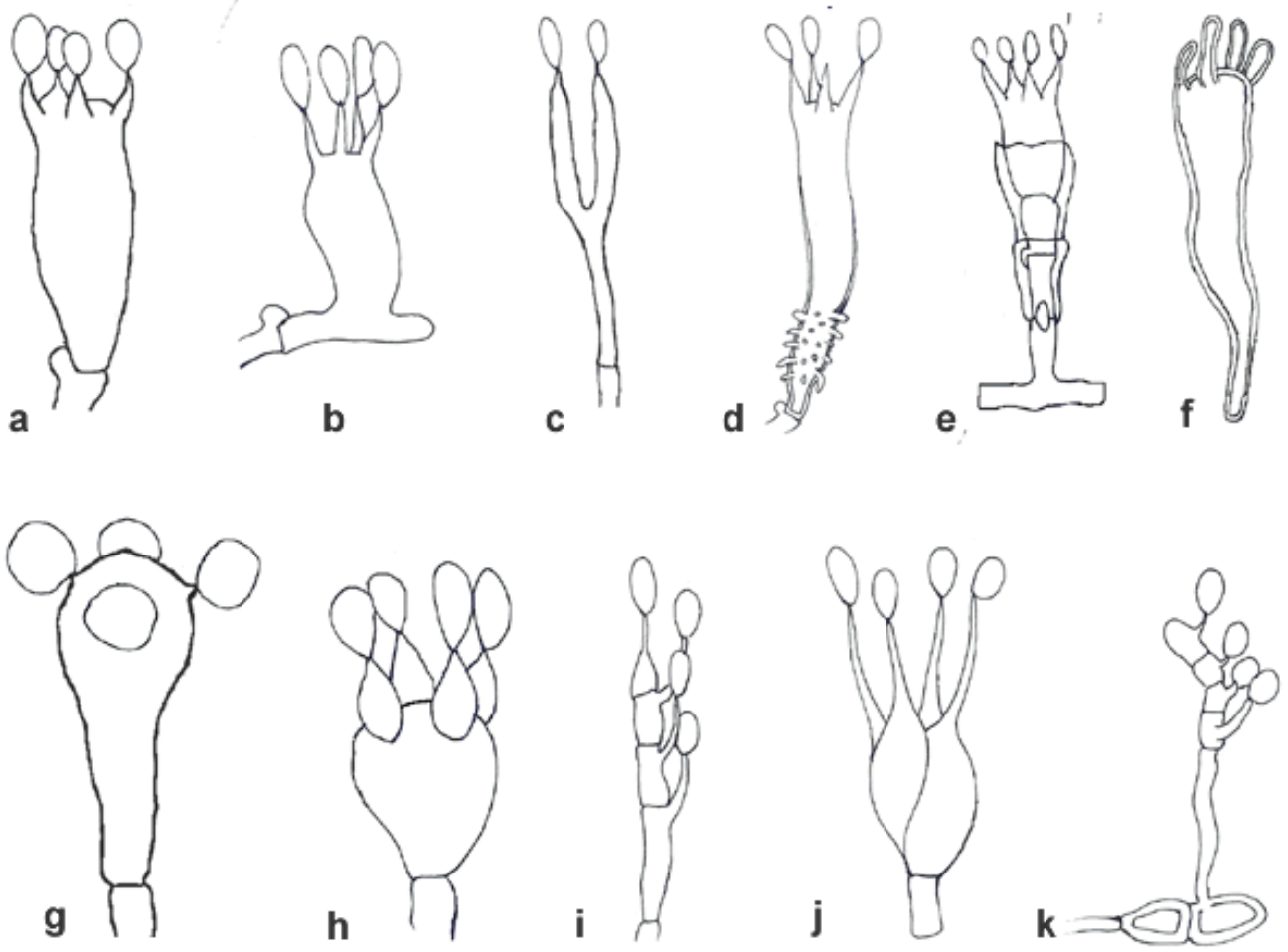




PHRAGOMOBASIDIA

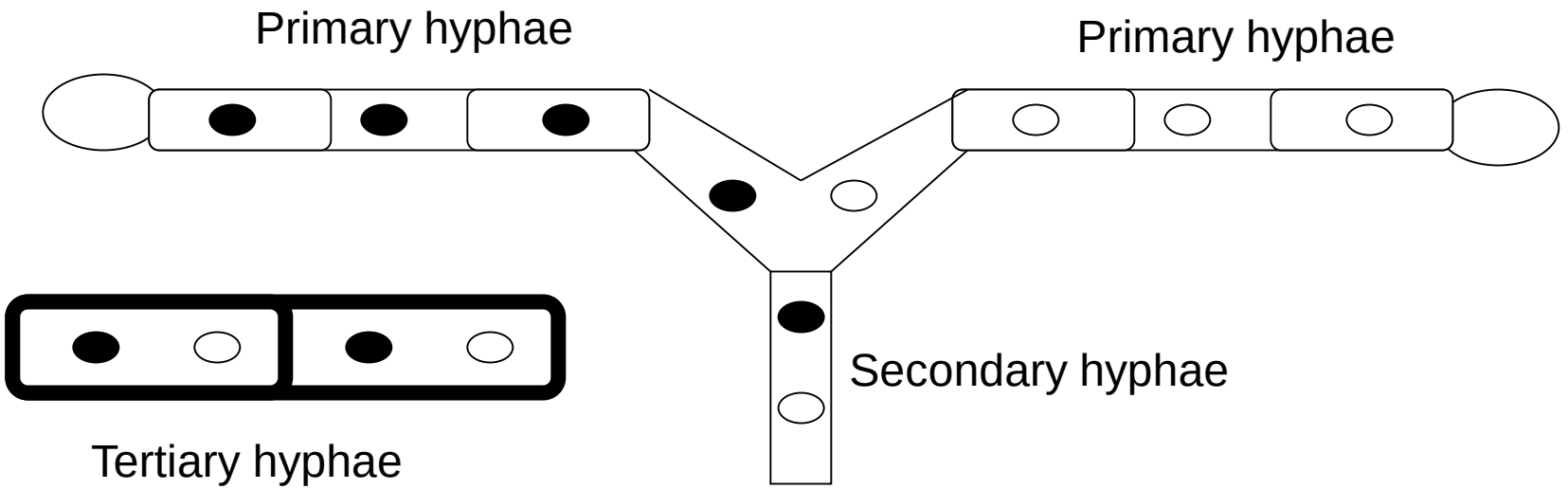


OTHER EXAMPLES OF HOLOBASIDIA AND PHRAGMOBASIDIA



Basidiomvcetes

5. Three types of hyphae
    a. Primary hyphae – develops from a germinating basidiospore. Nuclear status = n
    b. Secondary hypha – results from fusion of two primary hyphae. Yields a n+n cell that continues to grow as a n+n hyphae



    c. Tertiary hypha – exactly the same as secondary hypha. n+n However it has thick walls that enable production of fleshy and wood sporophores

Phylum Basidiomycota: Three major classes

- **Class Basidiomycetes**
  - Order Uredinales - The Rusts
- **Class Ustomycetes - The Smuts**
  - Order Ustilaginales
- **Class Basidiomycetes**
- Order Aphyllophorales - chanterelles, tooth fungi, polypores, coral fungi.
  - Order Agaricales - the boletes, gilled mushrooms - inky caps, oyster mushrooms, etc.

The Rusts

These are obligate parasites. Generally these require two host to complete their lifecycle.

Primary hosts – the host on which basidia and basidiospores are produced.

Alternate host – the other host in the life cycle on which spermagonia and aecia are produced

Heteroecious – organisms with a primary and alternate host.

Autoecious – organisms that have only a single (primary) host.

Macrocyclic rust – long cycle rust. Produce all 5 spore types.

Demicyclic rust – medium cycle rust. Omits uredia.

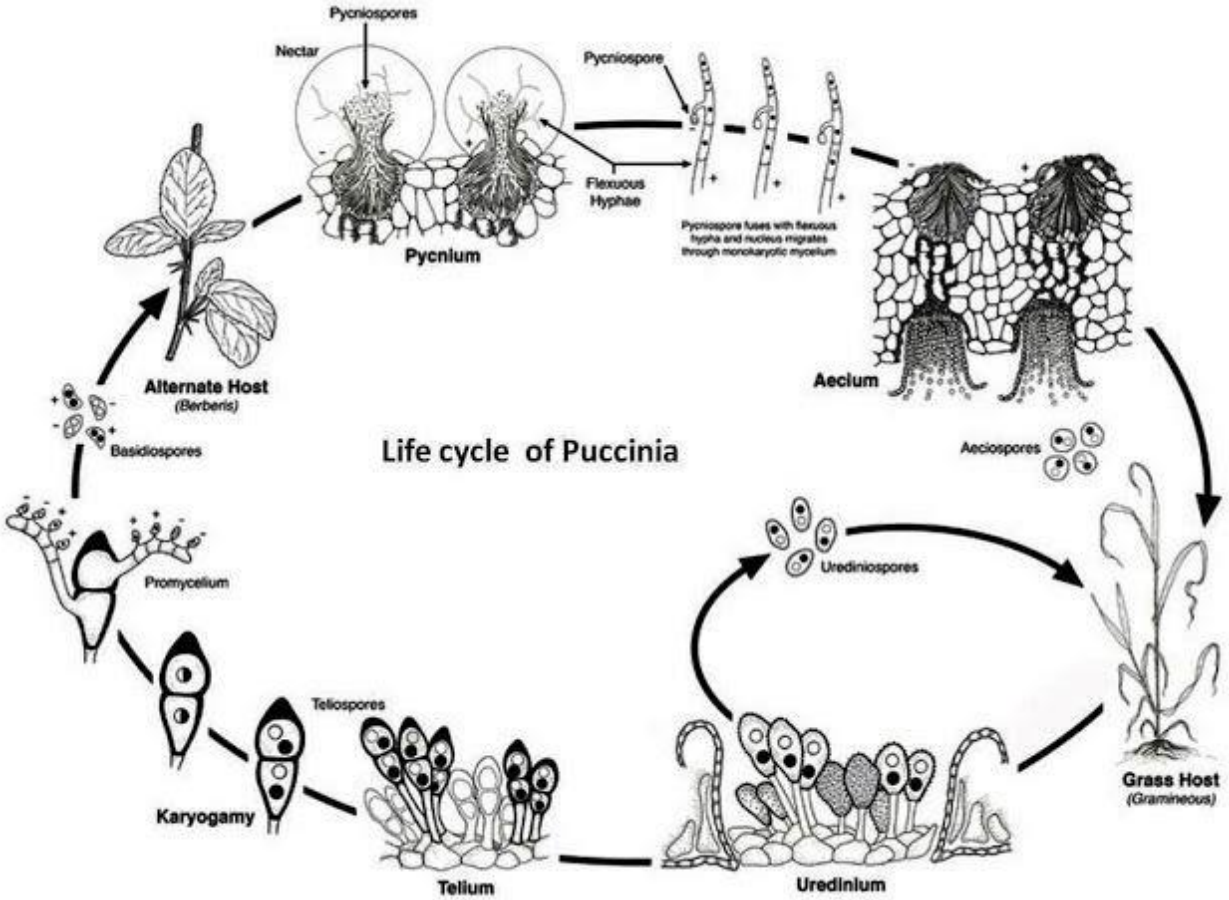
Microcyclic rust – short cycle rusts. Produces basidiospores, teliospores and spermatia.

Order Uredinales

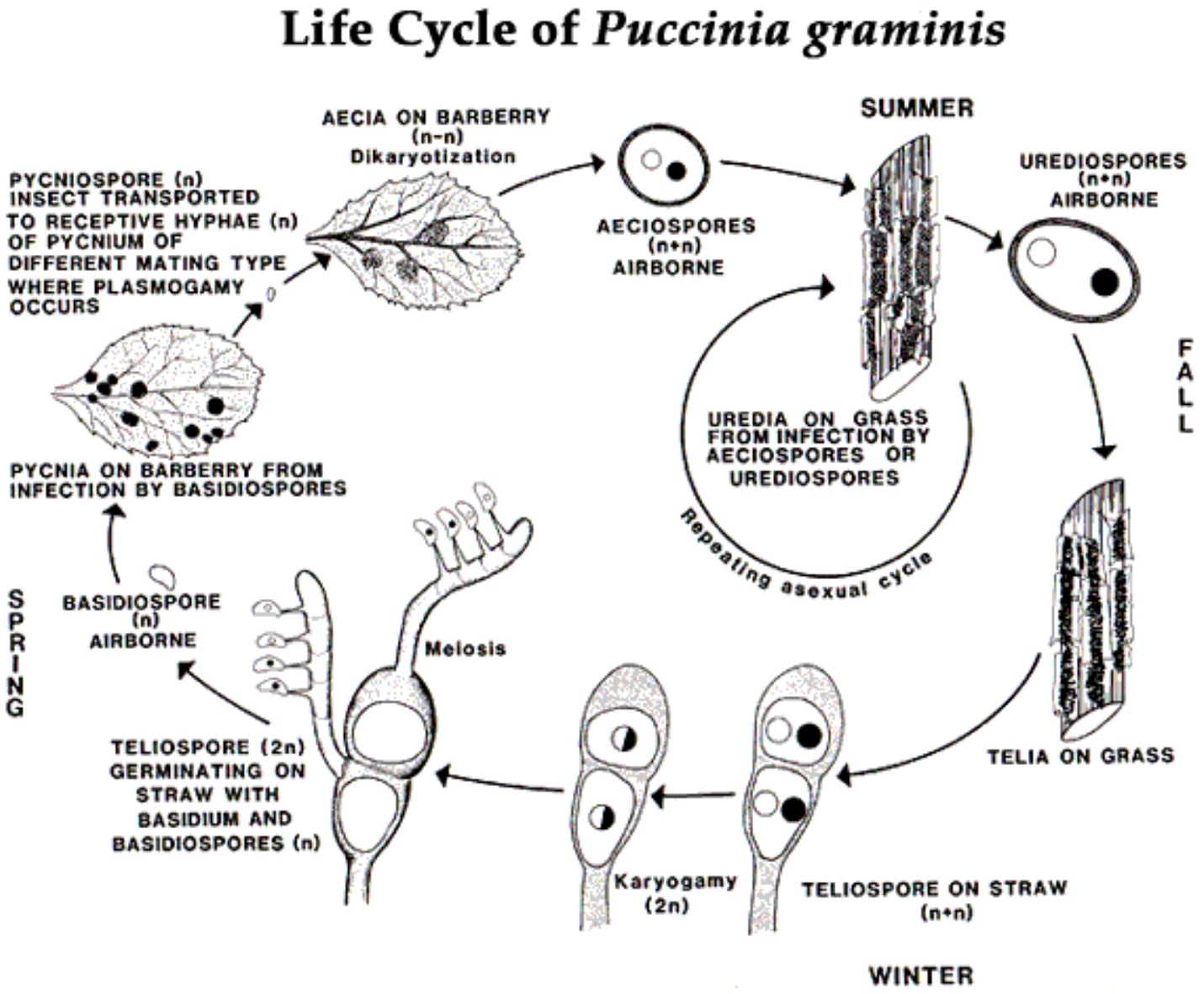
Order Ustilaginales

The Rusts

- Stem Rust of Wheat caused by *Puccinia graminis*
  - Reduces yield and quality of grain; fungus causes lesions or pustules on wheat stems.
  - Management - remove alternate host (i.e., barberry); use resistant cultivars of wheat


Pycniospores
Nectar
Pycniospore
Flexuous Hyphae
Pycniospore fuses with flexuous hypha and nucleus migrates through monokaryotic mycelium
Pycnium
Aecium
Alternate Host
(Berberis)
Basidiospores
Life cycle of Puccinia
Aeciospores
Urediniospores
Promycelium
Teliospores
Karyogamy
Telium
Uredinium
Grass Host
(Gramineous)

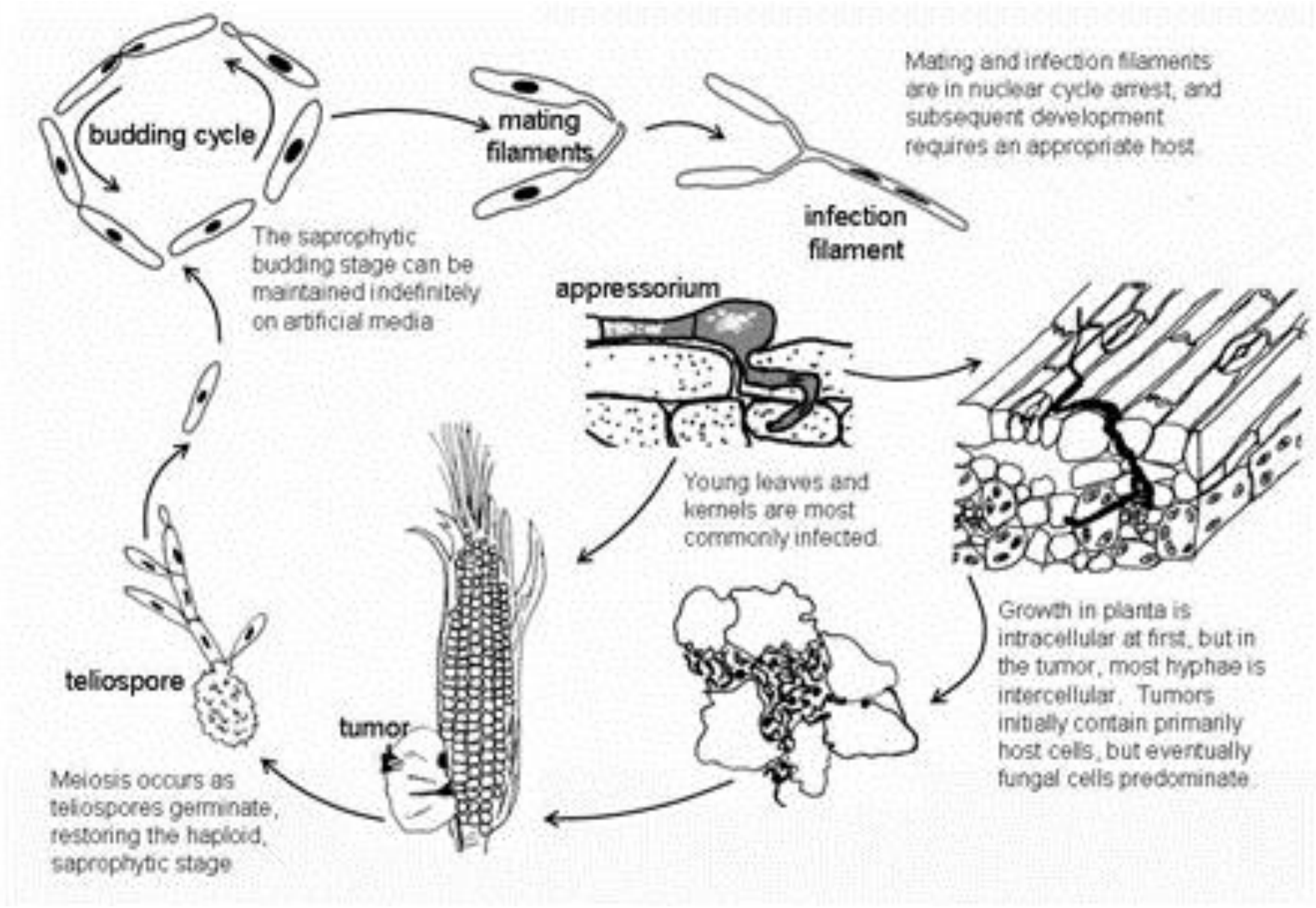
Wheat stem rust



The Smuts

- Corn smut caused by *Ustilago maydis*
  - Galls develop on male and female (ear) inflorescences.
  - No major methods of control recommended; tends to be a chronic but relatively insignificant disease.
- Loose smut of cereals by *Ustilago avenae*, *U. nuda*, and *U. tritici*
  - Flowering parts of plants develop spore-filled galls (teliospores)
  - infected seed treated with fungicides before planting; use of certified smut-free seeds and systemic fungicides; hot-water treatment of seed to kill fungus.

Corn smut caused by *Ustilago maydis*



Comparison of Rust & Smut Fungi

Uredinales (rusts)	Ustilaginales (smuts)
1. Teliospores terminal.	1. Teliospores intercalary.
2. Basidiospores 4, discharged from sterigmata.	2. Basidiospores variable in number, not on sterigmata, not discharged.
3. Spermagonia produce dikaryotic stage.	3. No spermagonia; dikaryotic stage. stage arises from fusion of any two compatible cells.
4. Clamp connections absent.	4. Clamp connections common.
5. Many species require two hosts for complete life cycle.	5. Never requires two hosts.
6. Most species unculturable on artificial media.	6. Most species readily culturable.
7. Infections usually localized.	7. Infections usually systemic.
8. Teliospores in telial sori, usually on stems or leaves.	8. Teliospores replace host host organs, usually ovaries and anthers.

Basidioma

- Composed entirely of dikaryotic hyphae (unlike ascoma)
- May be considerable tissue differentiation
- Typically macroscopic, forms button then expands

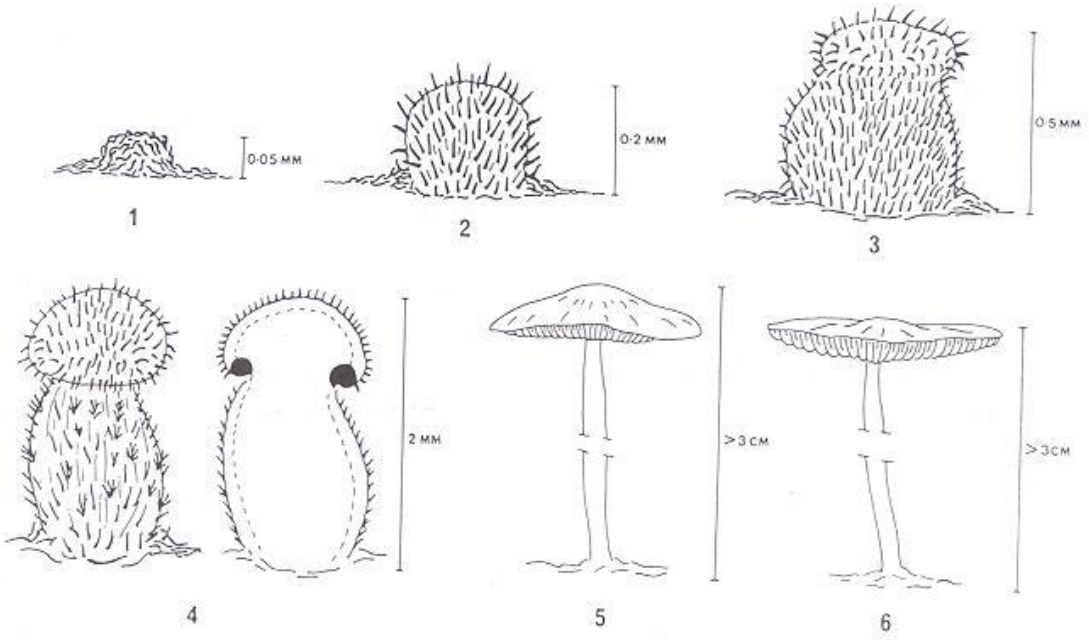
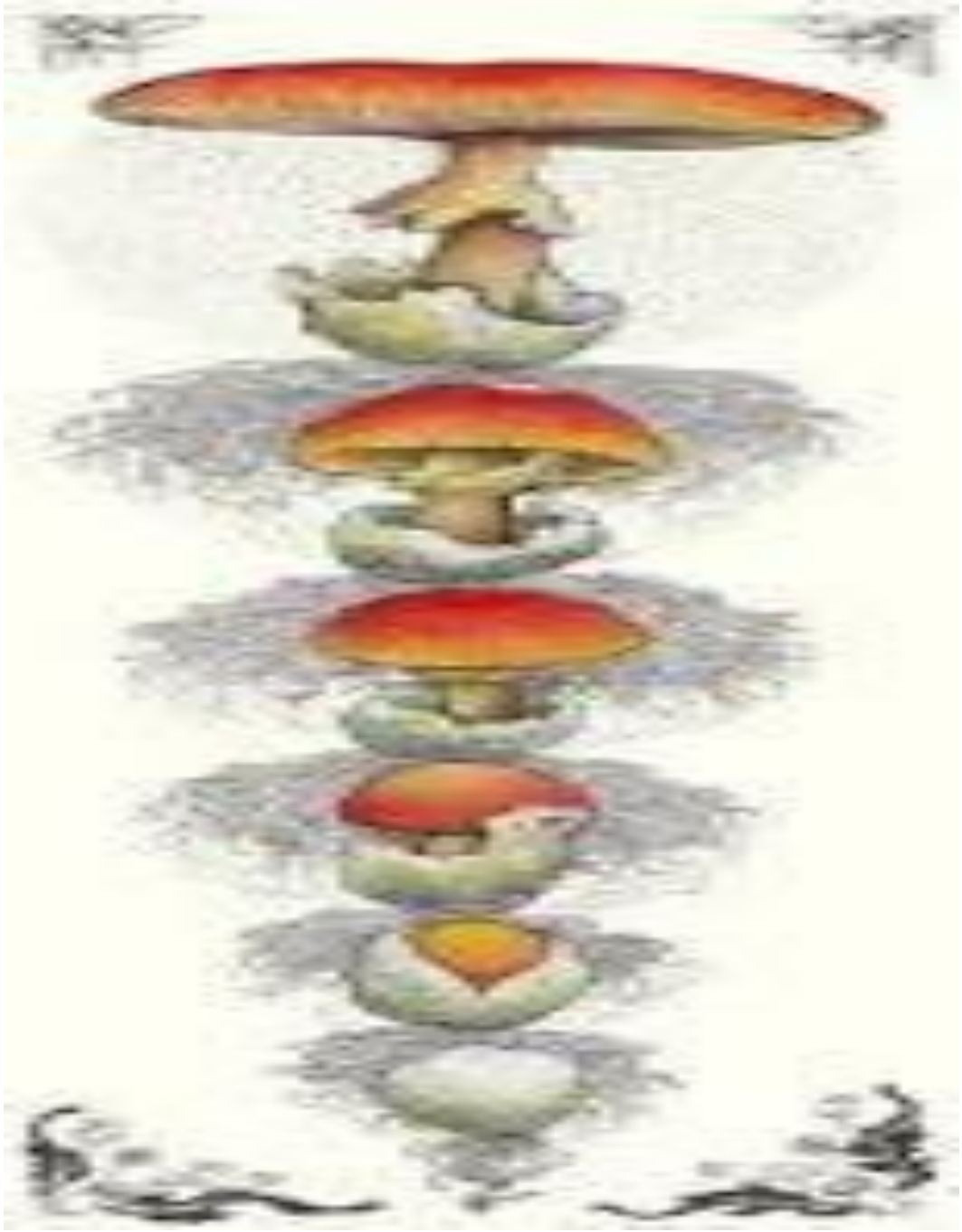


Figure 17-6 Basidiocarp development in *Flammulina velutipes*. [From Williams et al. (1985). Courtesy M. A. Williams and A. Beckett.]



Basidioma

- Within the basidioma, cells in fertile regions – the hymenium - will develop into basidia and produce basidiospores
- As the basidium develops, karyogamy and meiosis take place

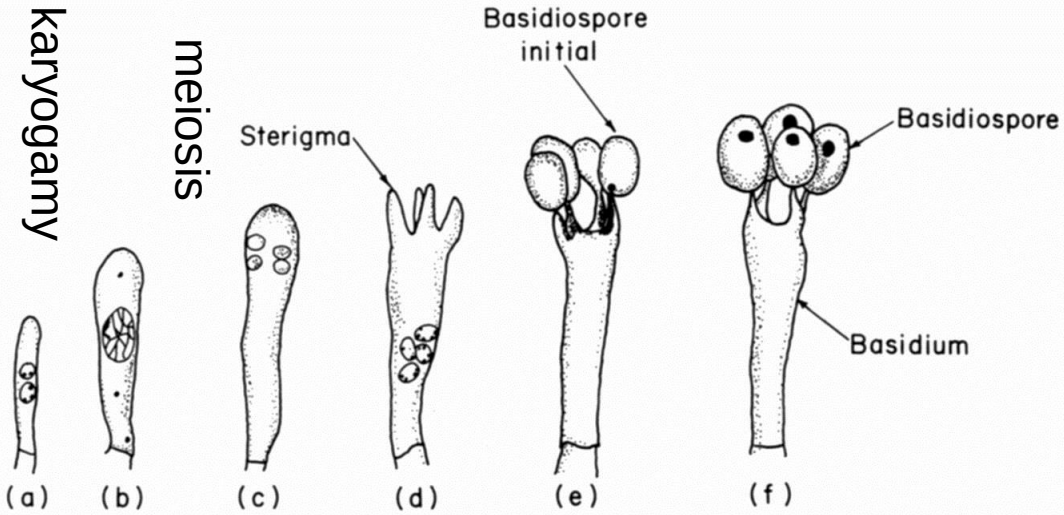
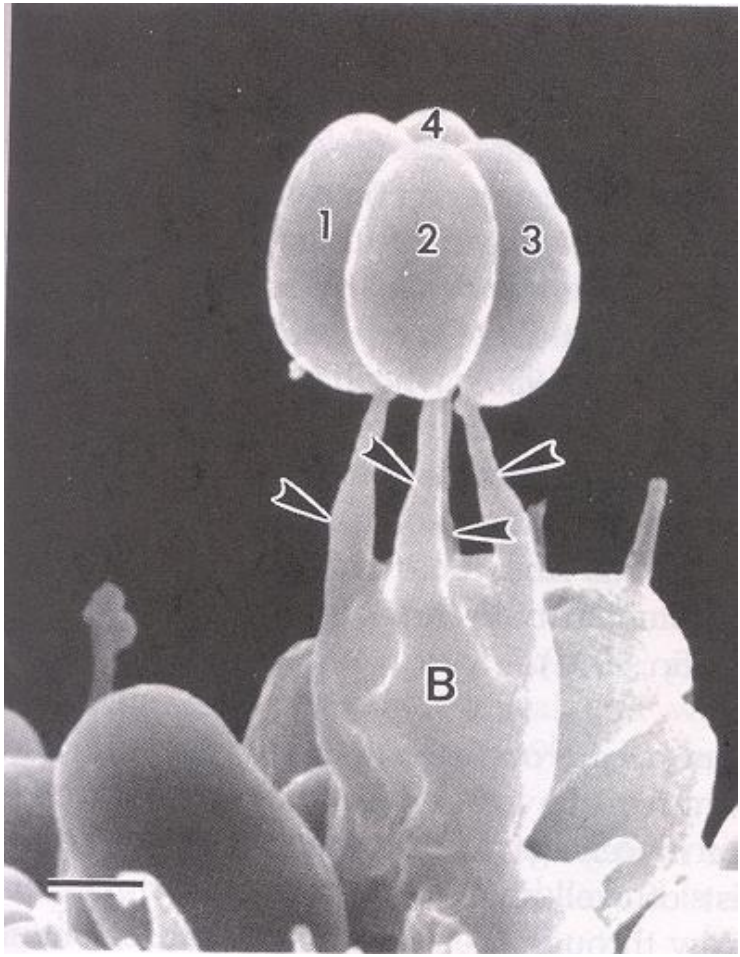


Figure 6-5 Development of a typical basidium: (a) young dikaryotic basidium; (b) diploid basidium; (c) basidium with four nuclei resulting from meiosis; (d) basidium after development of sterigmata; (e) migration of nuclei into basidiospore initials; (f) mature basidium with basidiospores.

Basidium

- Sterigma (pl. –mata) – projections from basidium to basidiospores
- Basidia may or may not produce sterigmata



Basidioma

- Basidia are produced in hymenia – fertile regions in the basidioma (will discuss position in different basidiomata)

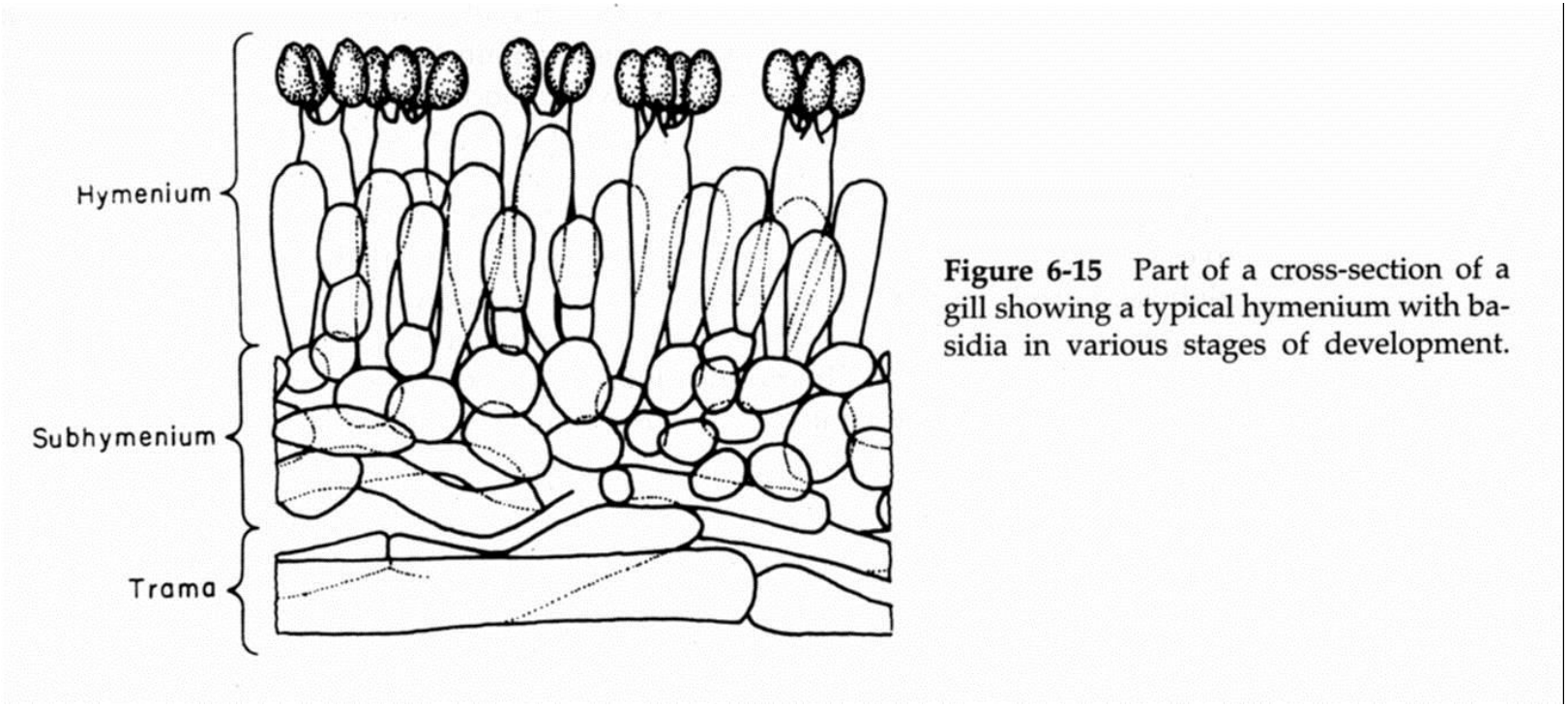
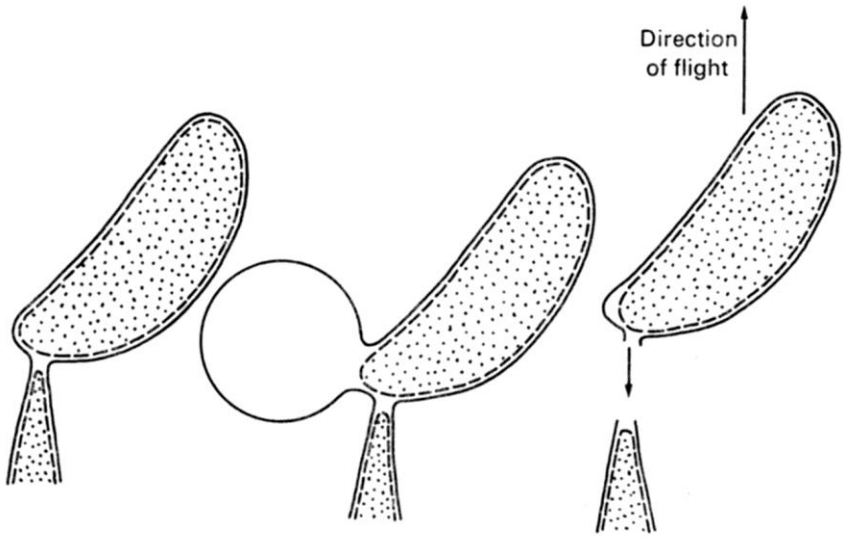


Figure 6-15 Part of a cross-section of a gill showing a typical hymenium with basidia in various stages of development.

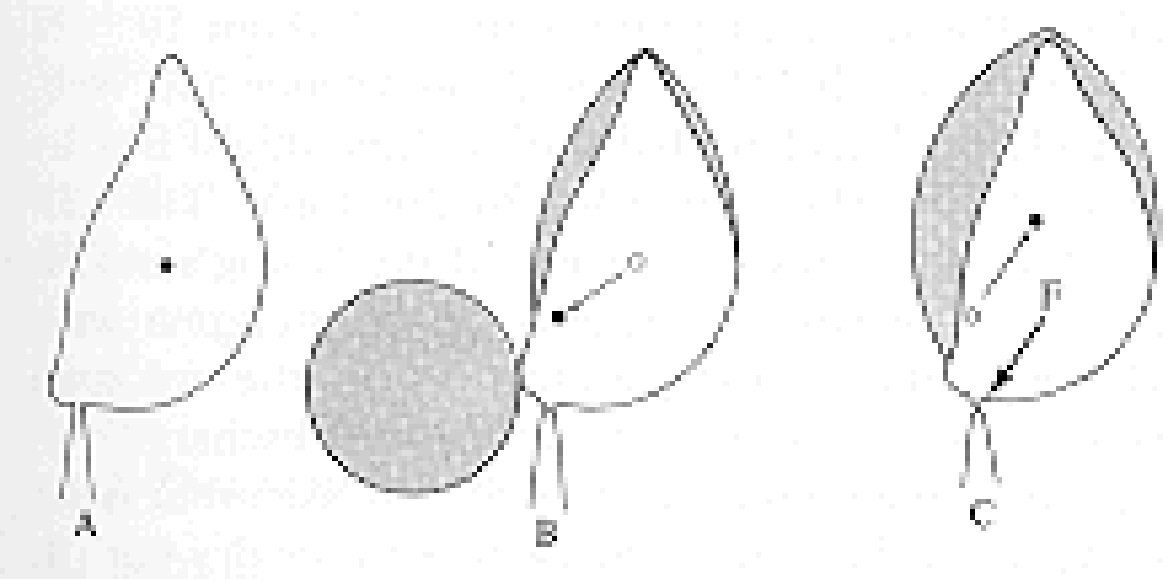
Basidia

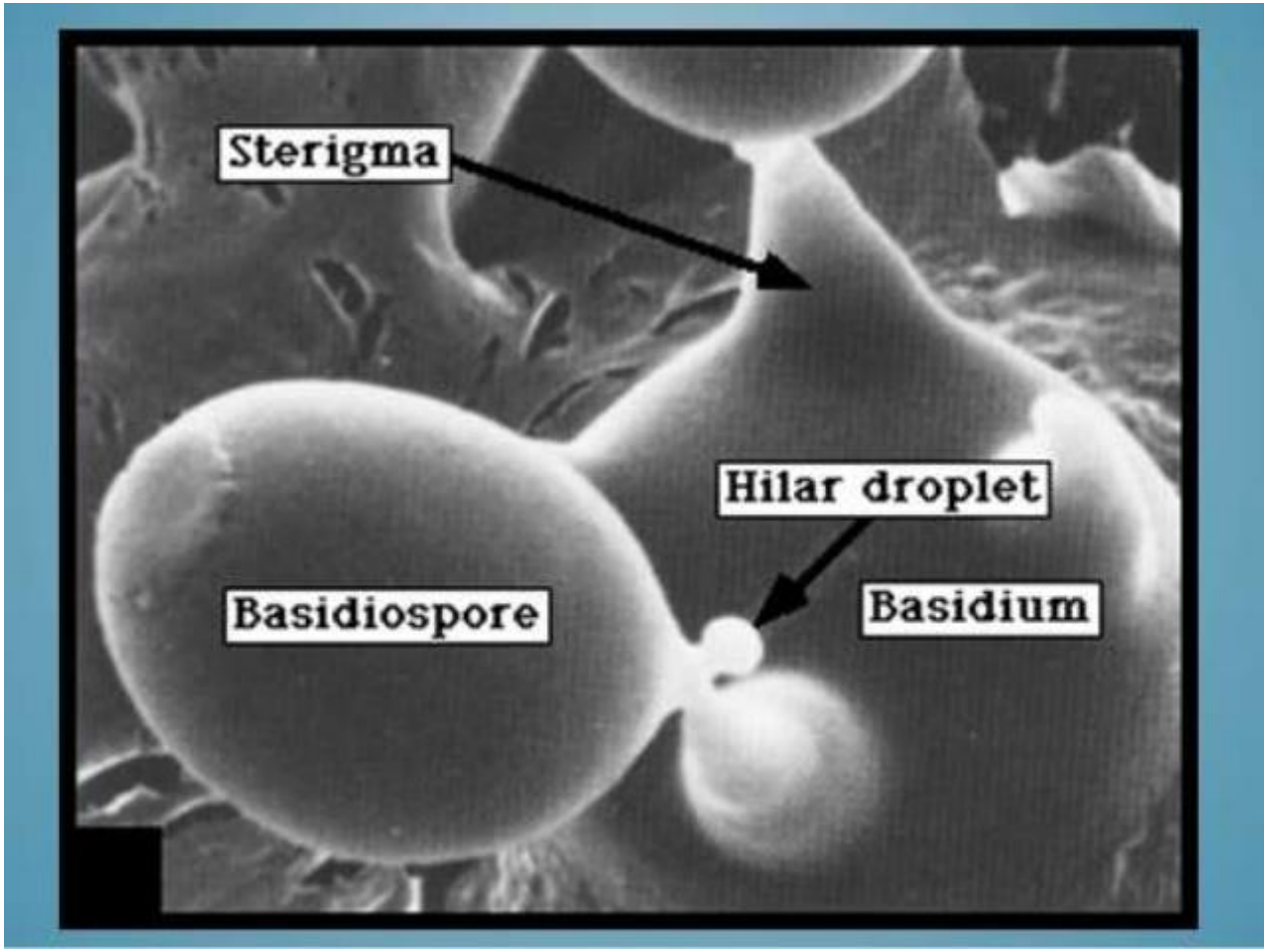
- Basidia with sterigmata can actively discharge basidiospores
- Basidiospores are positioned at a 45 angle
- 5-10 seconds before discharge a droplet forms



Basidia

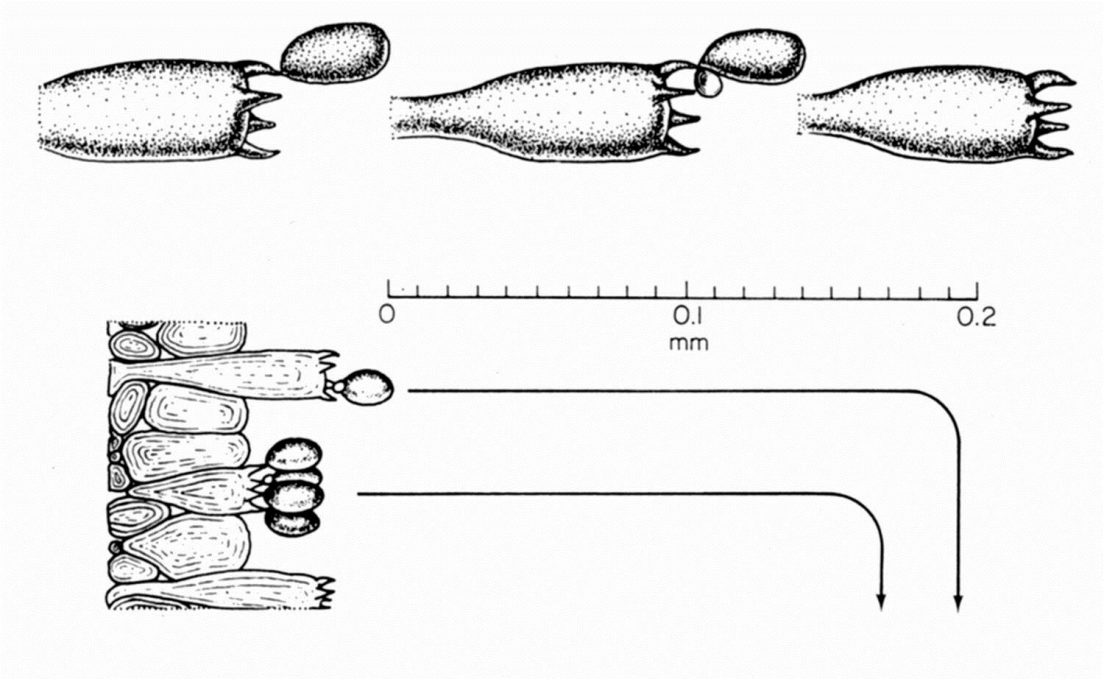
- Thought that force to discharge spore comes from droplet flowing around the spore form a hydrophobic region to a wettable region
- Change in center of mass of spore rapidly is thought to provide the force to discharge it
- Drop of fluid accompanies the spore

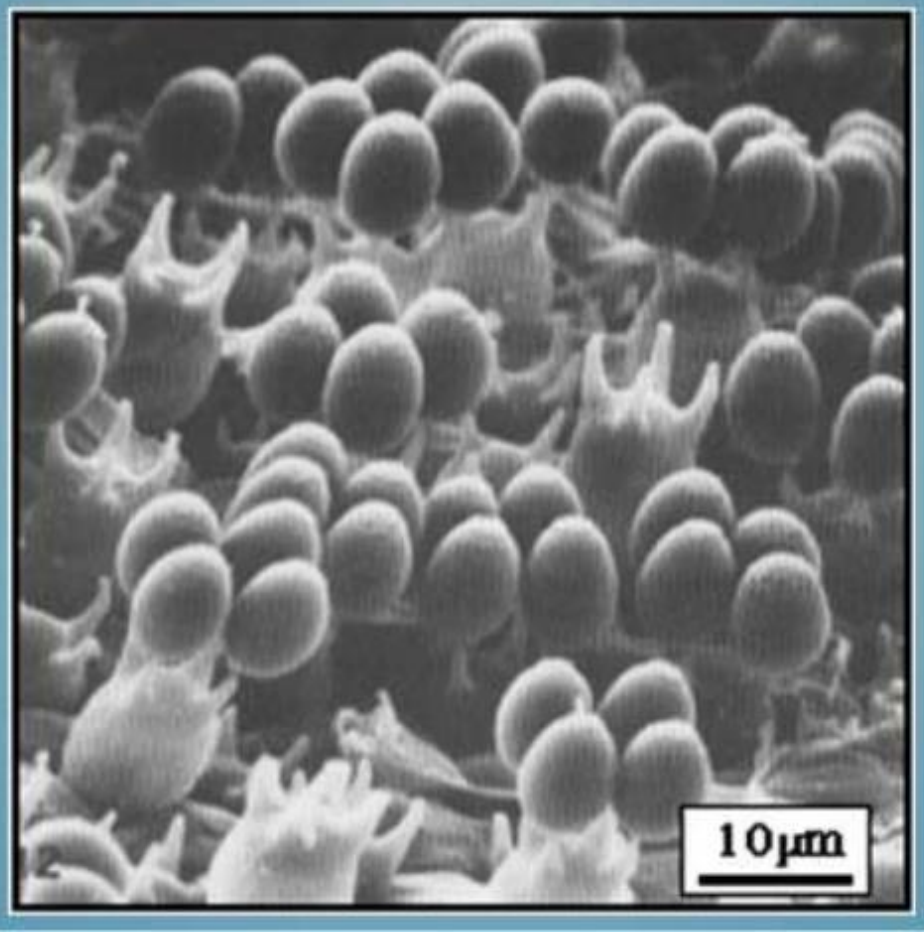



Sterigma
Hilar droplet
Basidiospore
Basidium

Basidia

- Spore is discharged less than a mm, then drops straight down
- Hymenia must be vertical with respect of gravity




10μm

Basidioma

- Many basidiomata exhibit geotropism
  - Hymenium exhibits positive geotropism
  - Basidioma exhibits negative geotropism

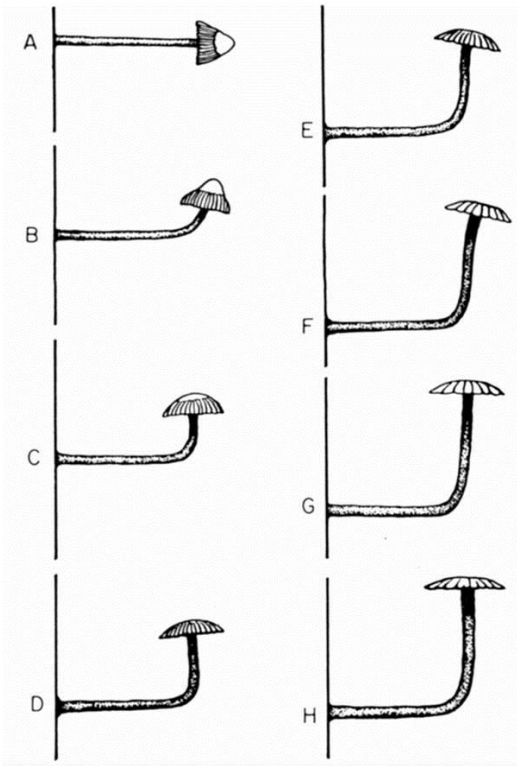


Figure 12-13 Gravitropic swinging and adjustment of the pileus in space. A basidioma was placed in the position shown in (A), and after $2\frac{1}{2}$ hours it assumed the position shown in (B). The remaining drawings were made at intervals of 1 hour, until finally the basidioma assumed the final position in (H) in which the gills are perpendicular to the ground. [Adapted from A. H. R. Buller, 1909, Researches on fungi, Vol. 1, Longmans, Green & Co. Ltd., London.]

Basidioma

- Composed entirely of dikaryotic hyphae
- Basidioma is generally divided into 3 zones
  - Hymenium – layer of basidia with basidiospores
  - Subhymenium – distinct area that gives rise to hymenium
  - Trama – comprises the bulk of the basidioma, separates hymenia
  - May also have cuticle – skin like layer on surface of some

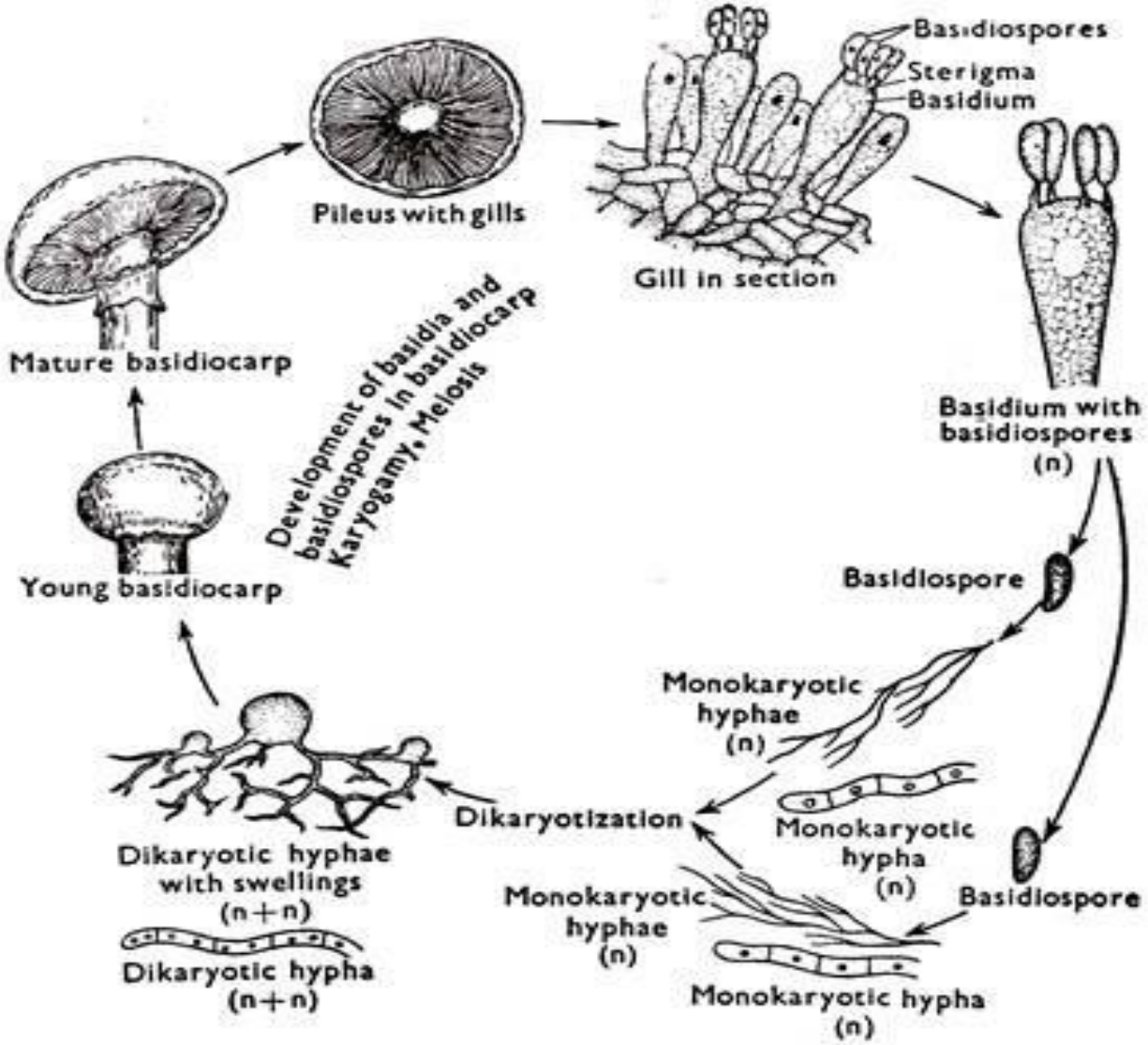
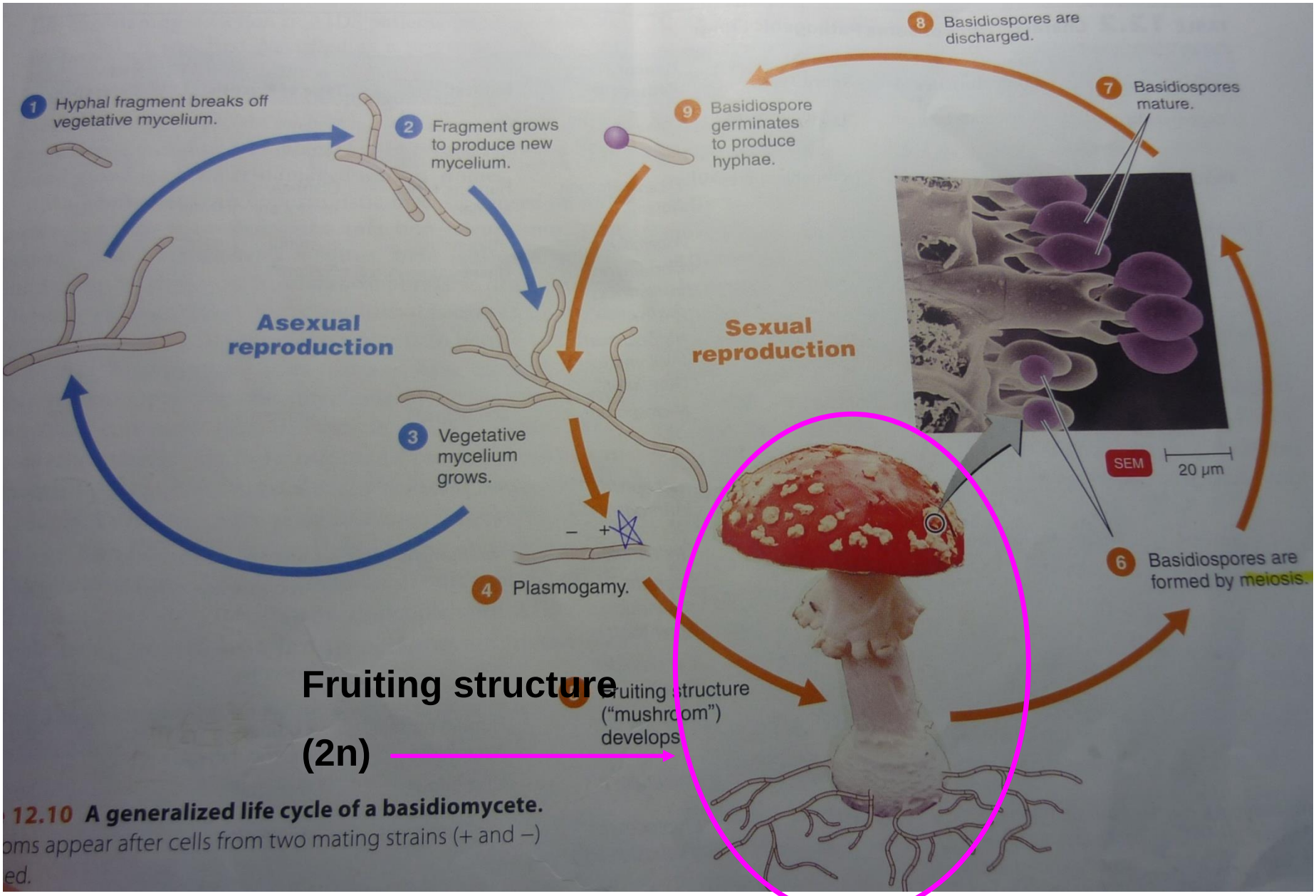


Fig. 290. Life cycle of a heterothallic species of *Agaricus*.

Macrocosmic view - mushroom

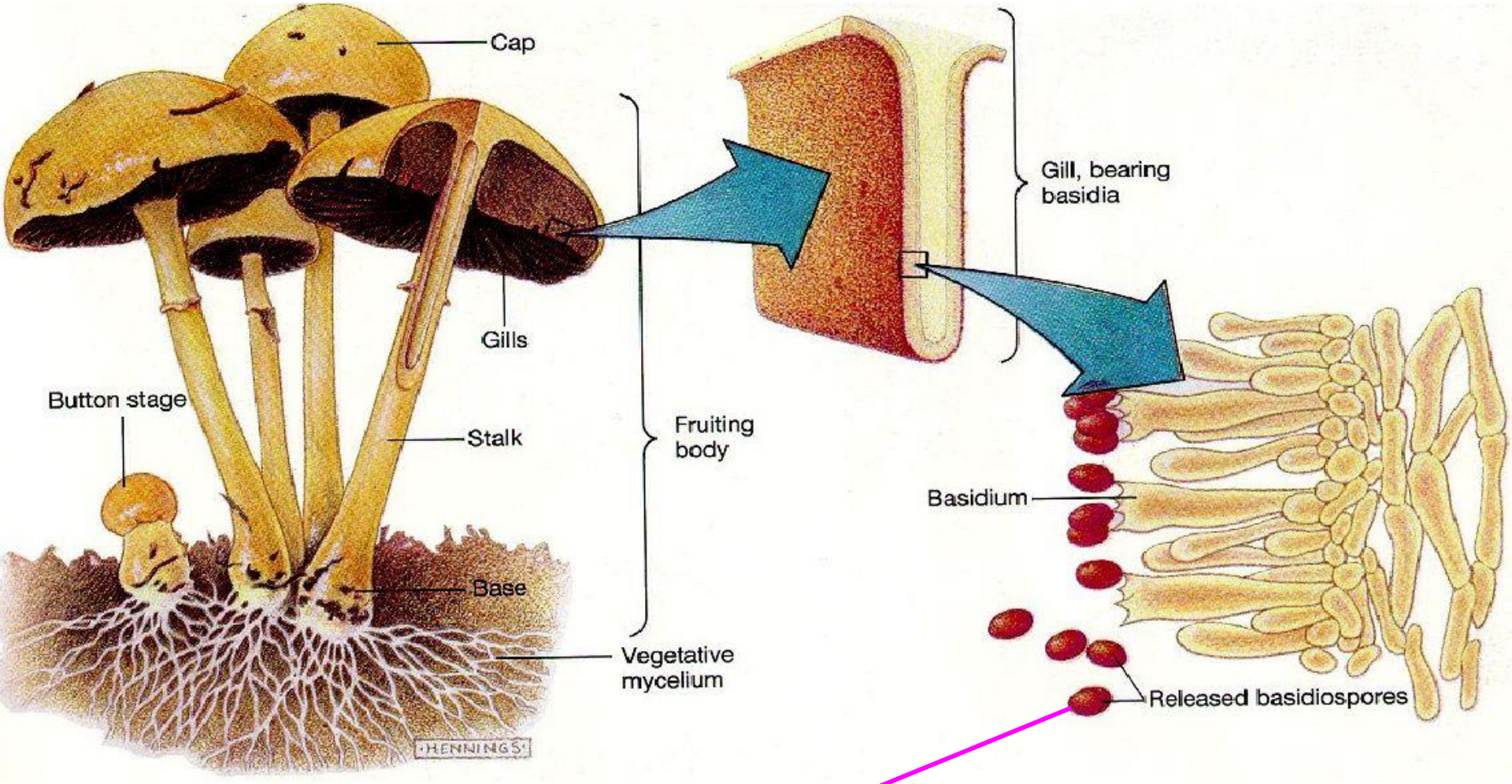


Fruiting structure

(2n)

12.10 A generalized life cycle of a basidiomycete.

oms appear after cells from two mating strains (+ and –)
ed.



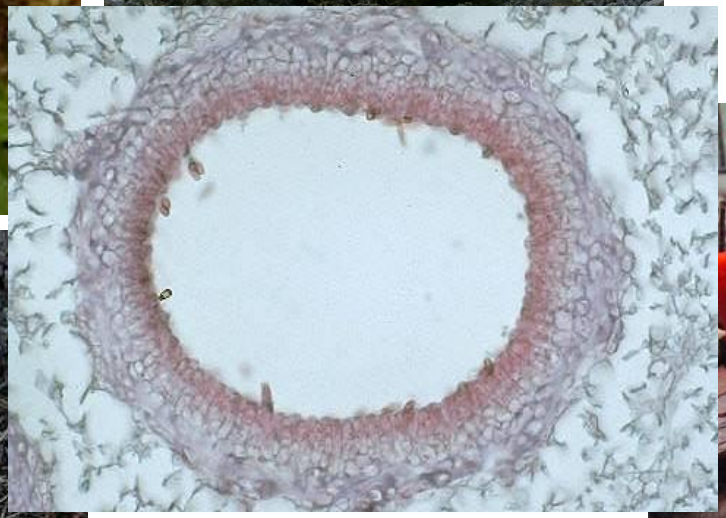
Basidiospores(n) are formed by meiosis.

Order Tremellales - jelly fungi

Order Auriculariales - fungus ears

Auricularia auricula-judae, Judasohr © www.mykonet.ch

Order Aphyllophorales



Aphyllophorales

- Large order - ~2000 spp.
- Includes species that primarily produce dry, woody, corky basidiomata (some may be fleshy)
- Produce holobasidia
- Hymenium is on the surface of the basidioma in some; surface may be smooth, ridged or spiny
- Hymenium may line tubes or gills – if the hymenium lines tubes or gills then the basidioma is always woody, never fleshy

Toothed fungi

- Others

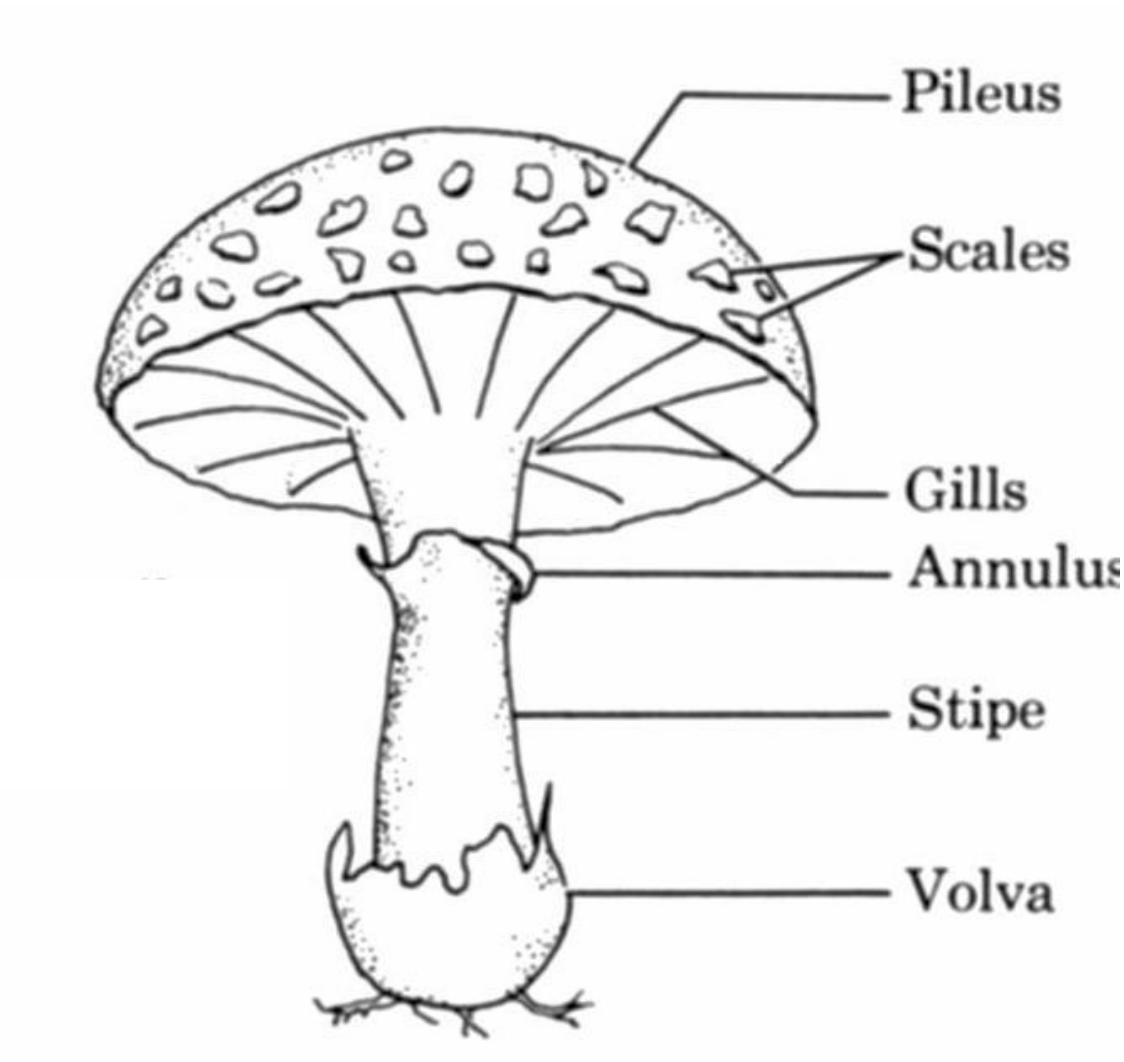
Order Agaricales

Agaricales

- Large order - ~5000 spp
- Hymenium lines surfaces of gills in fleshy basidiomata
- Includes the mushrooms and boletes
- Primarily saprotrophs in soil, litter or wood
- Many are biotrophic – form mycorrhizal associations with trees
- Economically important as cultivated mushrooms and mycorrhizae (used in forestry)

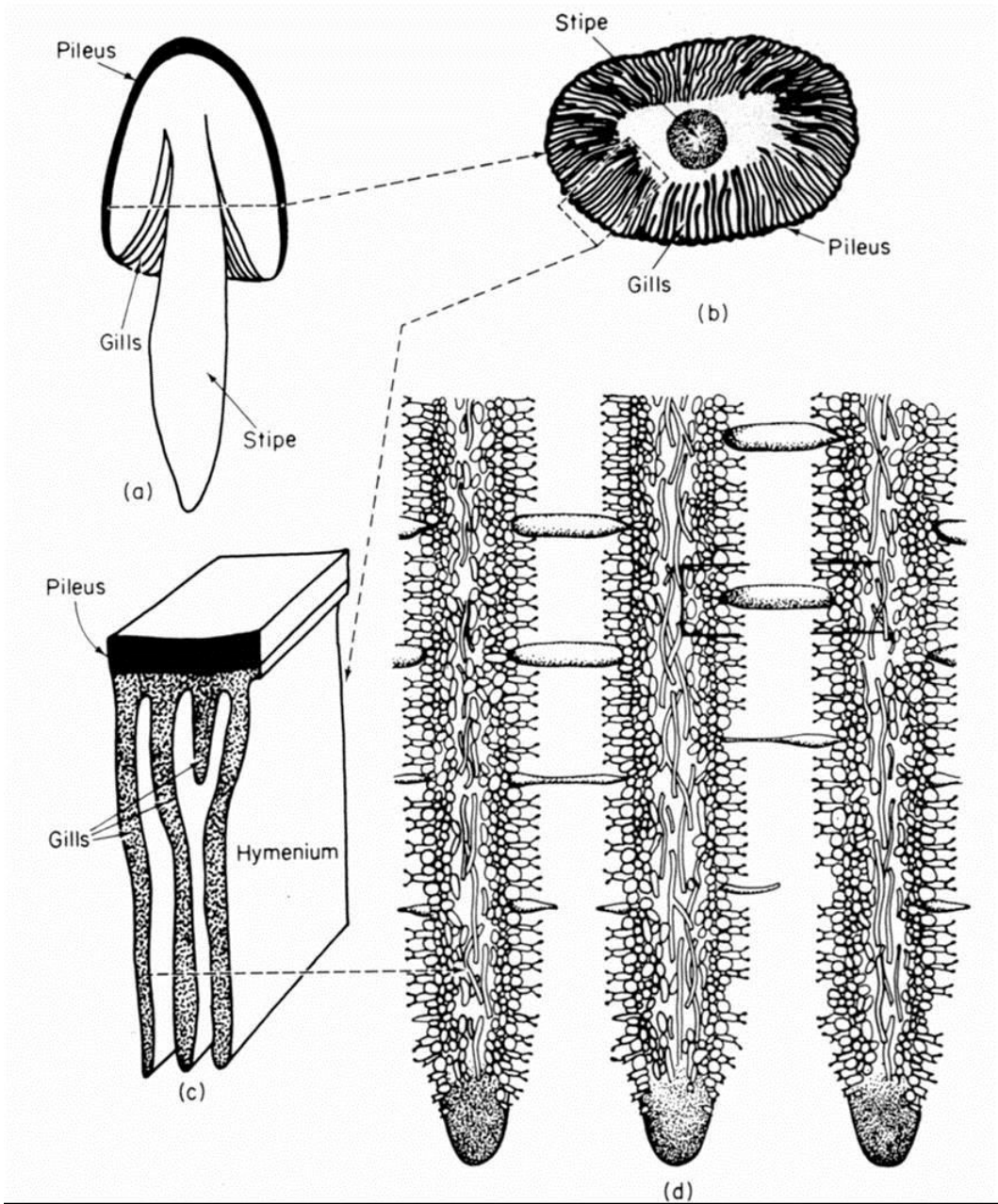
Agaricales

- Basidiomata arise from extensive perennial mycelia
- Overall structure of basidioma



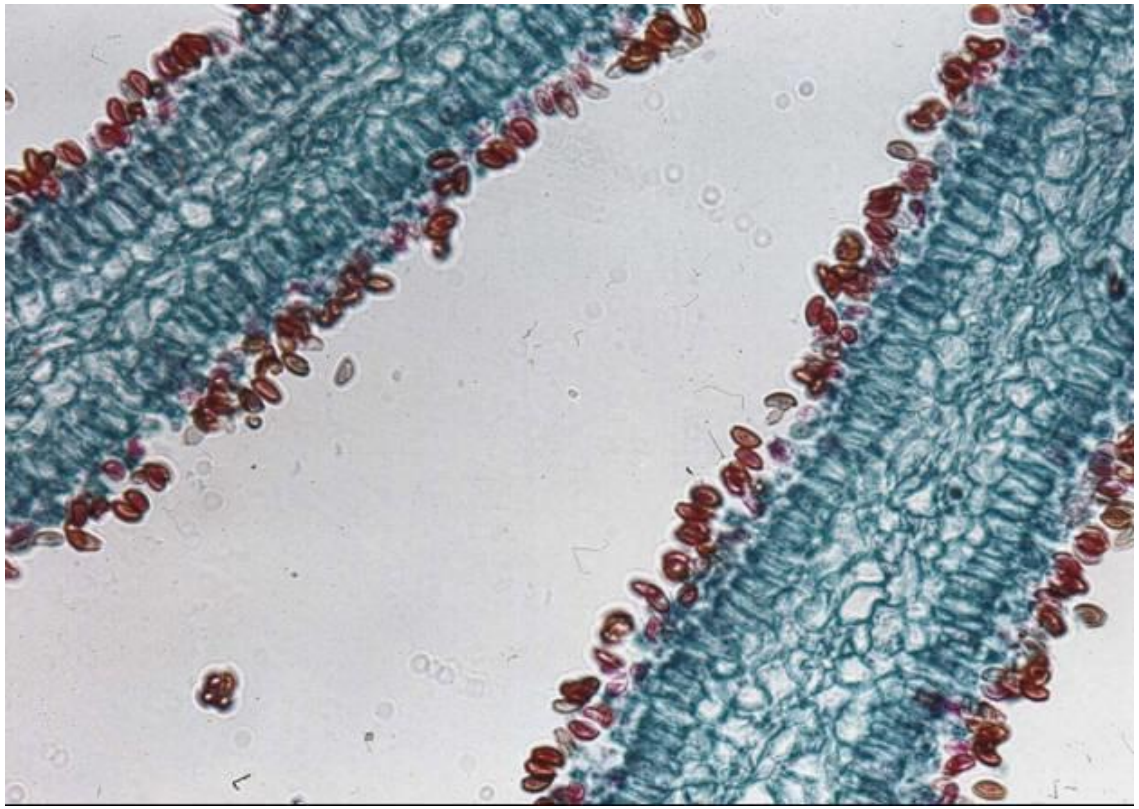
Basidioma structure

- Basidia produced in hymenia on gills – flat plate like structures
- Cystidia extend out from hymenia
- In many, the gills are geotropic – parallel to force of gravity so that basidiospores can fall out once they leave the basidia



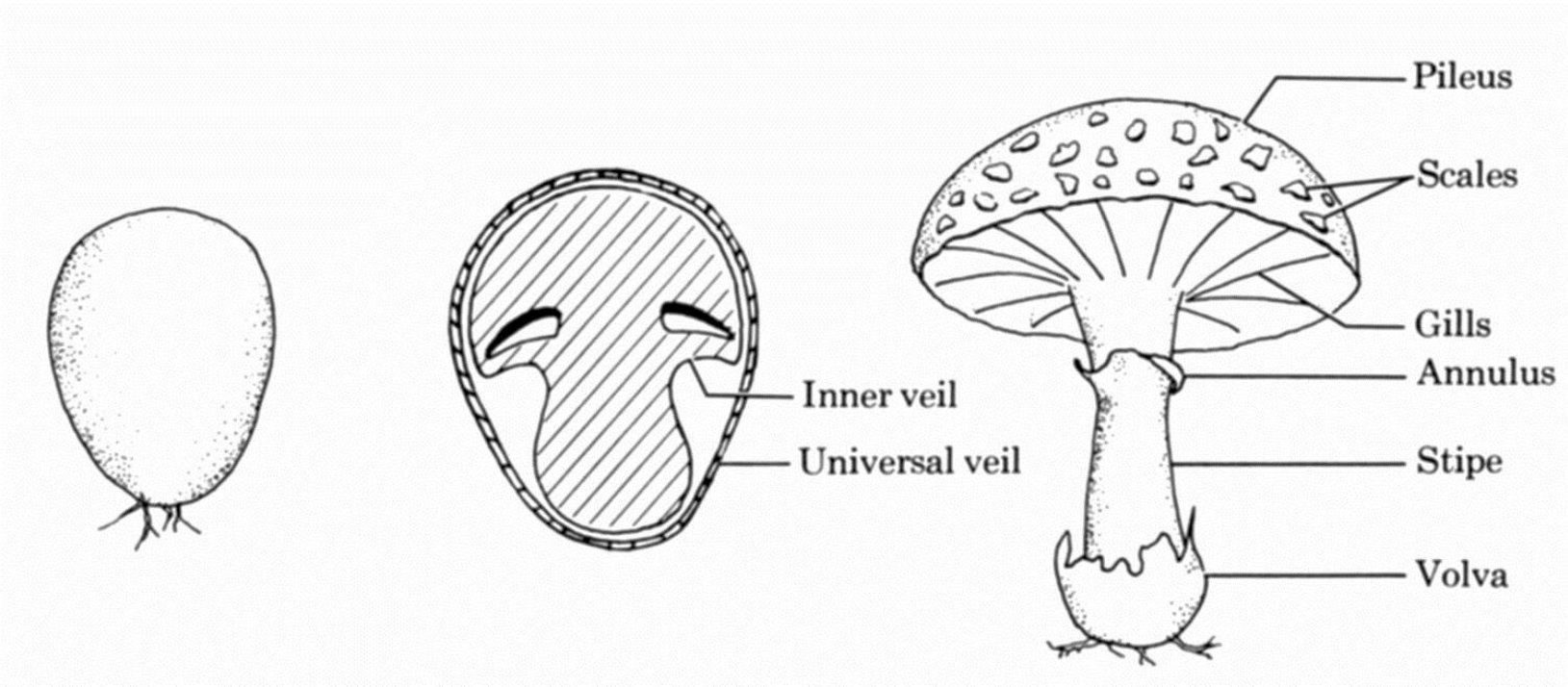
Gills

- Increased surface area for greater number of basidia



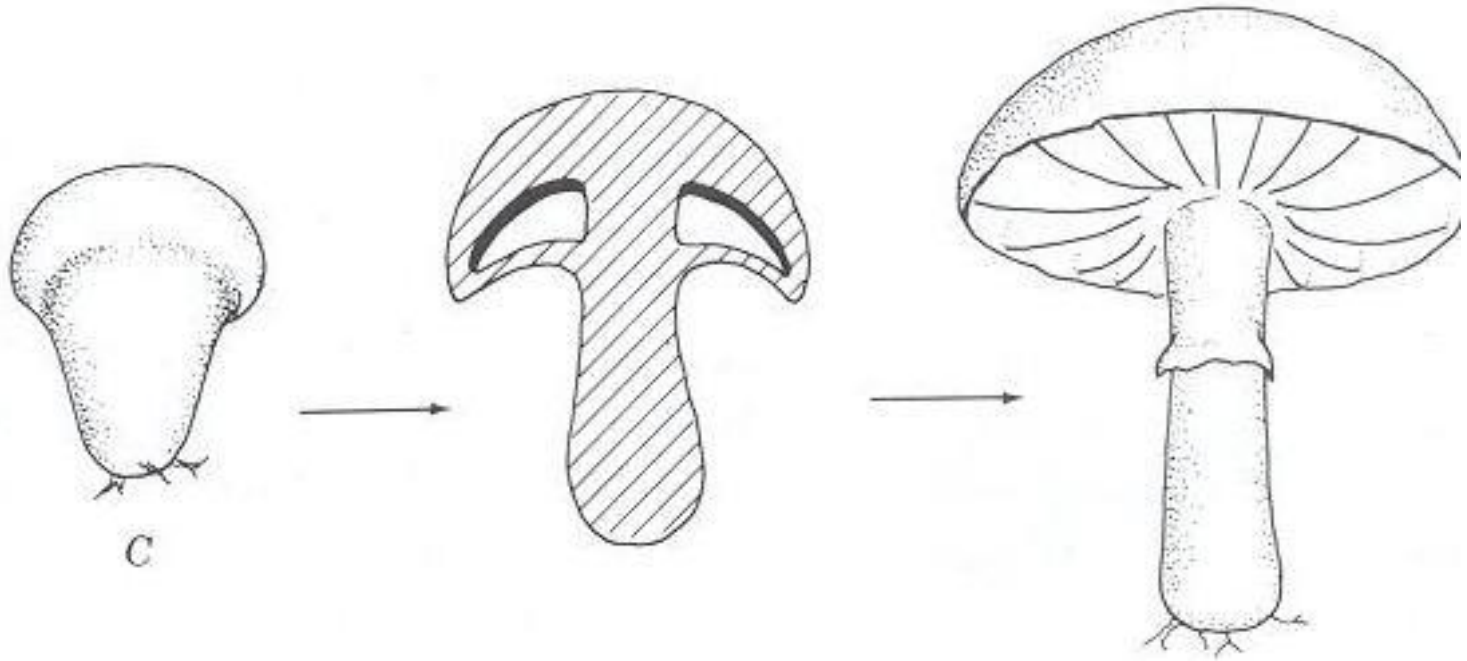
Basidioma development

- Hemiangiocarpic development – button is surrounded by a layer of tissue, the universal veil (forms the volva and scales) , also contains a partial veil (forms the annulus and cortina)



Basidioma development

- Pseudoangiocarpic development – button has only a partial veil (forms annulus and cortina)



Gasteroid Basidiomycetes

- Many Basidiomycetes bear their basidiospores internally – gasteroid
- May or may not form a hymenium
- If a hymenium is formed, the basidioma remains closed until basidia form basidiospores
- All produce holobasidia

Order Lycoperdales(Agaricales) – puffballs and earthstars

Basidiomata

- Are macroscopic
- Enclosed by one or more layers of tissue – peridium which may be papery, leathery, membranous or scaly
- Peridium surrounds the inner fertile tissue of the basidioma

– the gleba which consists of trama (sterile tissue) with the basidia

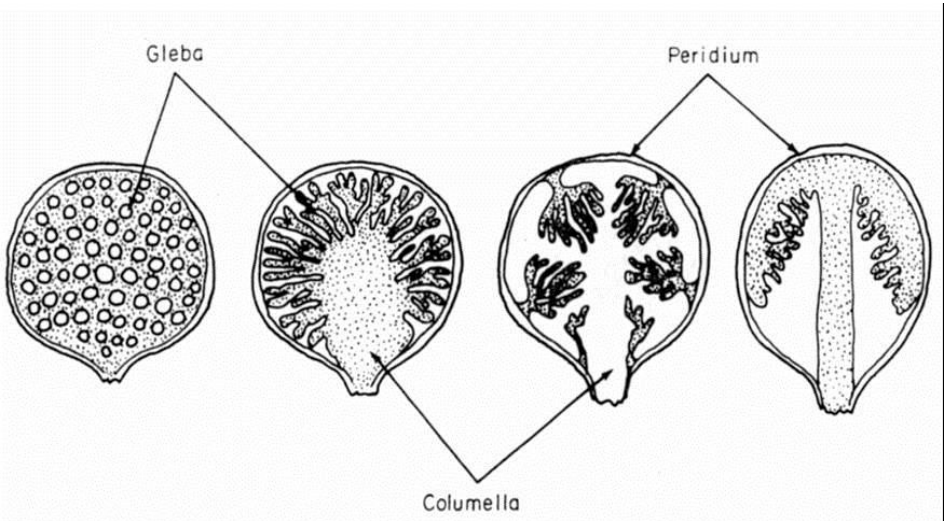


Figure 6-42 Gasteroid basidiomata having different arrangements of the gleba derived from distinctive developmental patterns. The lacunar form is at the left. The basidiomata are shown in longitudinal sections. [Adapted from E. Fischer, *in:* A. Engler and K. Prantl, Eds., Die natürlichen Pflanzenfamilien, Engelmann, Leipzig.]

Gasteroid Basidiomycetes

- Produce macroscopic basidiomata
- Generally saprotrophic on litter, wood or dung
- Some are mycorrhizal
- Orders are separated on characteristics of the gelba – whether it is dry, fleshy, slimy or compartmentalized.

Puffballs and earthstars

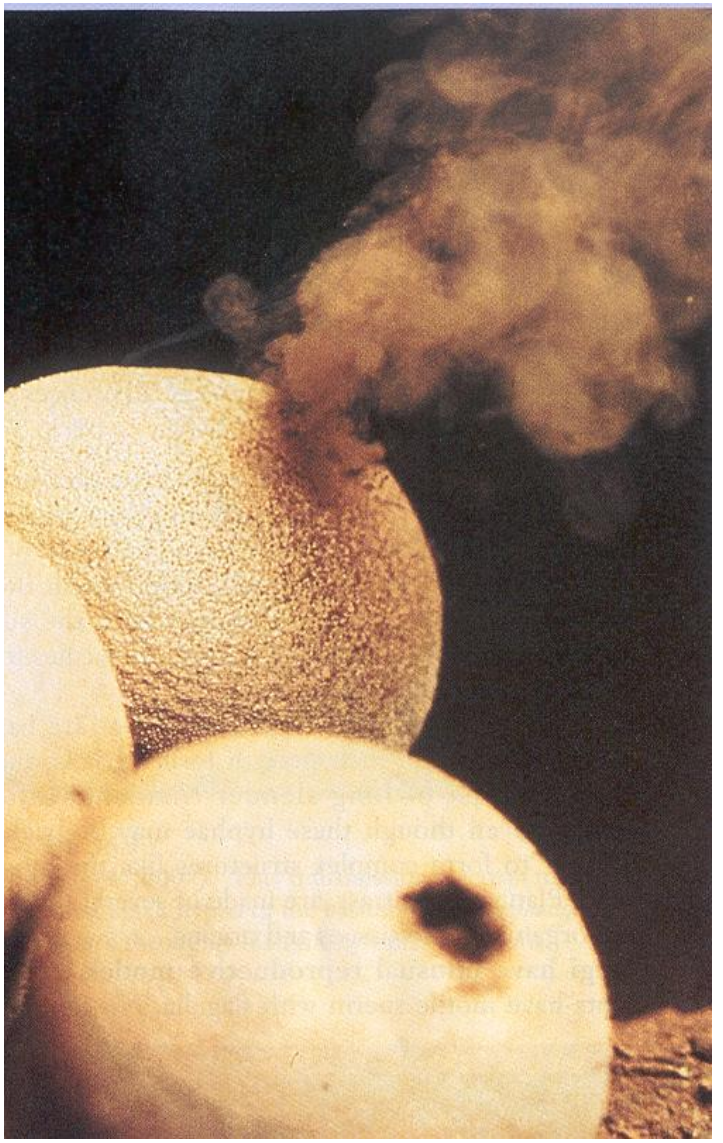
- A hymenium is present but may be highly convoluted to form a chamber like gleba
- At maturity, the glebal tissue disintegrates and becomes powdery and dry
- Certain hyphae (thick walled) persist and form a network – capillitium – interspersed with basidiospores
- Peridium is papery and has an pore - ostiole

Puffballs

- Large range in size
- Edible when young

Puffballs

- Rain on peridium or kicking allows spores to be released



Order Tulostomatales- stalked puffballs

Bird’s nest fungi

- Gleba is divided into separate chambers, each of which is surrounded by its own peridium = peridioles
- Peridium is funnel shaped and leathery

Order Nidulariales (Agaricales) - bird's nest fungi and sphere throwers

Mycophagy - To eat or not to eat?

- MYCOPHAGY - (Gr. mykes = mushroom + phagein = to eat) is a practice that dates back to antiquity.
- Edible mushrooms are good sources of protein (by dry weight), indigestible "fiber" (due to presence of chitin), some potential medicinal compounds, and add diversity to our omnivorous diet (e.g., true morels, oyster mushrooms, button mushrooms, shiitake).
- Mushrooms include the sporocarps of certain members of the Phylum Ascomycota and Basidiomycota.

Holomorph = Anamorph + Teleomorph

- Anamorph = asexual stages - mitosis - usually haploid
- Teleomorph = sexual stages - involves dikaryons, diploidy and meiosis

The anamorph-teleomorph problem

- In Ascomycetes, anamorphs and teleomorphs often develop at different times and places or in many cases not at all. Each stage is therefore often collected in ignorance of the existence of the other
- Normal classification is based on teleomorph stages, but mycologists have had to classify specimens in which they only find anamorph stages.
- Thus parallel systems of nomenclature have sprung up - we have teleomorph genera and anamorph genera and mycologists try to draw connections between them where possible.
- DNA analyses will make this much easier in future.

The anamorph-teleomorph problem

- In some cases it has been possible to 'connect' the anamorph name with the teleomorph name - but in many others this has not yet been done and may never be possible because the organism may have lost the ability to reproduce sexually.

- Of 30,000 known Ascomycetes only 5,000 have been 'connected' to their anamorphs - results often 'messy'
    - eg teleomorph genera, Nectria and Gibberella, both have anamorphs which have been classified in the anamorph genus Fusarium.

- Many anamorphs (85%) have no known teleomorph - are lumped in artificial group Deuteromycetes.

- The End of the Course
- Best Wishes
- The last two slides just for reading

Ascomycetes - the anamorph

- The typical anamorph spore in Ascomycetes = conidia produced outside a specialized hyphal cell.
- compare with Zygomycetes which produce sporangiospores inside a sporangium.
- conidia = asexual spores produced in vast numbers by mitotic divisions. They vary greatly in morphology, in septation and in how they are borne on the conidiophores.

Ascomycetes - the anamorph

classification of ascomycete anamorphs based on :-

- conidial features
  - **Hyphomycetes** - conidiophores never enclosed
  - **Coelomycetes** - conidiophores enclosed in a covering.
- conidial shape and septation
- conidiophore details also used