Lichen reproduction in lichens

Rather than “genetics” which is a problem in lichens as we cannot cultivate or grow lichens experimentally

Presentation prepared for the
BLS Lichen Chat and Improvement Group (LCIG)
7 & 8 November 2023

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Plan

- Reminder about asexual or vegetative reproduction
- Comparing plants and animals with lichens and fungi
- Lichen life cycle
- Sexual reproduction in lichens – how it works
- Evidence of lichen reproducing sexually
- Mating types and heterothallism
- Asexual reproduction by the mycobiont only
- Summary
- Related topics

Reproduction in lichens

Vegetative reproduction

- Soredia
- Isidia
- Other forms of assisted fragmentation
- Offspring are all genetically identical

Sexual reproduction

- Two genetically different individuals participate
- Exchange of genetic information
- Genes from the two individuals are mixed and shared out to the offspring
- Offspring are all genetically different

For example consider
Pertusaria albescens thalli

This species reproduces vegetatively. So populations tend to made up of individuals which are genetically identical.

When offspring meet, they do not recognise each other as different

So the thalli merge as though they were all the same individual – which in a way they are. This is the clue to vegetative reproduction taking place.

All lichens can reproduce vegetatively

- Lichens like some other organisms such as mosses are what we call ***totipotent.***
- So, if we take any small bit of the vegetative part of the thallus, it can potentially grow into a new individual
- Mites and slugs etc also may move thallus fragments
- In lichens, the presence of soredia, isidia, or other aids to fragmentation makes this means of reproduction preferential and quick
- E.g in common species such as *Parmelia sulcata*, *Physcia tenella* or *Lecanora orosthea*
- BUT it does not mean these lichens cannot also reproduce sexually
- (Most species don't reproduce vegetatively but just with fungal spores)

Vegetative versus sexual reproduction

- Most vegetatively reproducing macrolichens are common
- Proportion of species obviously reproducing asexually varies from genus to genus e.g.
  - *Xanthoparmelia* in Australia out of 145 spp, only 4 are sorediate.
  - *Usnea* in Europe most species are sorediate
- Most crustose species reproduce sexually
- In species which produce soredia or isidia, ascomata production is usually inhibited or when these species have ascomata, soredia or isidia production in usually inhibited. (Exceptions, for example, *Fuscidea lightfootii* and *Pyrrhospora quernea.*)
- The extent of vegetative vs sexual reproduction in lichens is very difficult to assess. Unaided thallus fragmentation may be commoner than we think – we just do not know – yet (mites and molluscs?)

In plants and animals

- Each individual has **two sets of chromosomes** (and termed “diploid”)
- Each gene on has 2 copies, one on each chromosome
- A mutation in a gene on one chromosome is paired with the original version on the other
- Each gene can exist in different forms e.g. mutated and unmutated, or in normally different forms called **alleles**.
- The expression of a gene is complicated by there being these two forms.
- Some disfunctional mutations are masked by the good gene on other chromosome. Some other disfunctional genes override the good version.

In fungi and lichens

- Each individual has only **one set of chromosomes** (and termed “haploid”)
- There is only one functional copy (allele) of each gene (unless a gene is duplicated along the chromosome)
- Mutation in a gene in unmasked by that on another chromosome
- Each gene can exist in different forms but only one in each individual
- A mutation will have an immediate effect

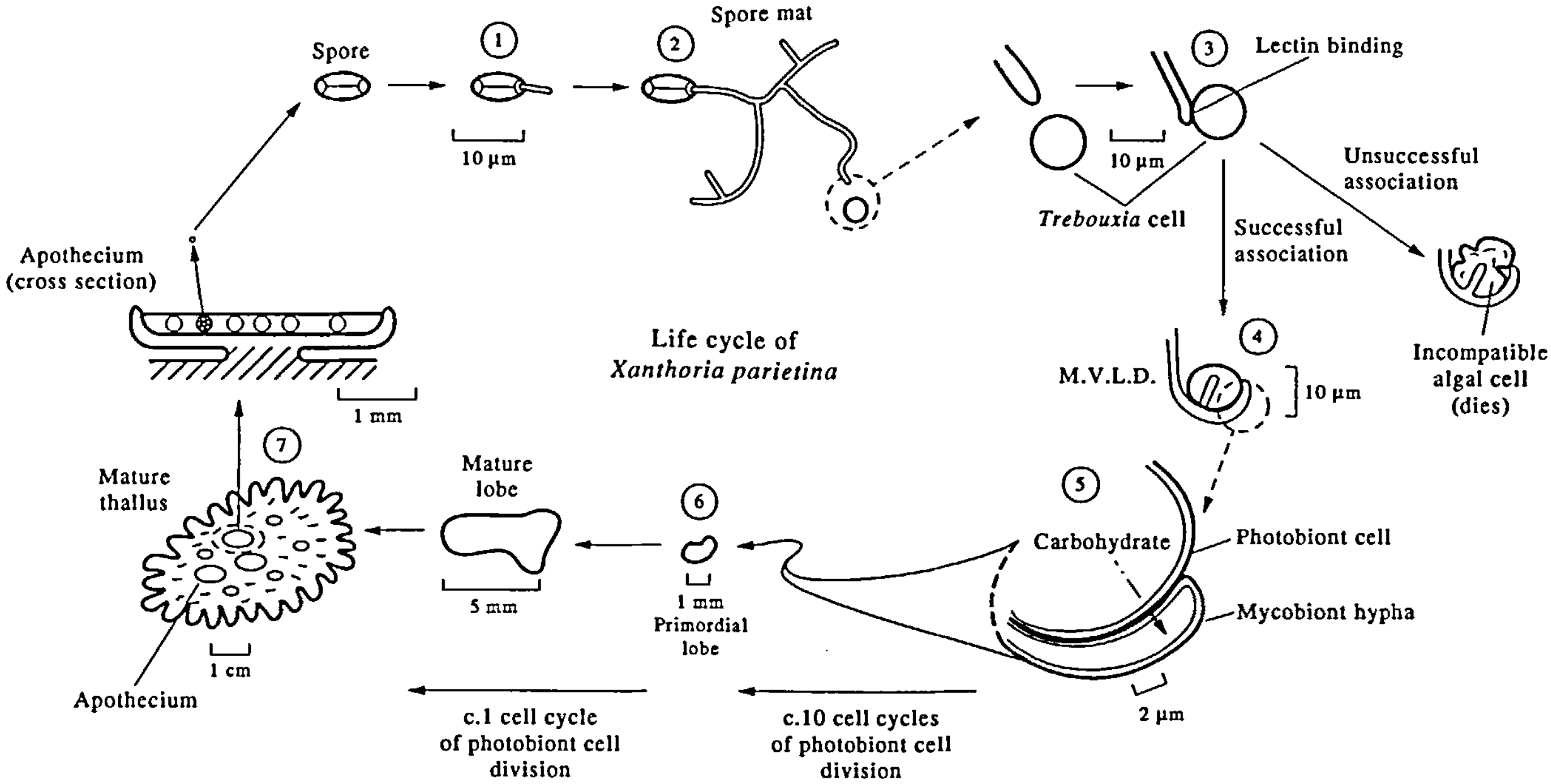
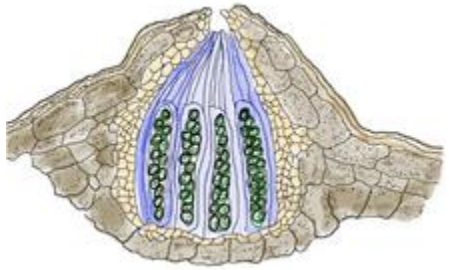


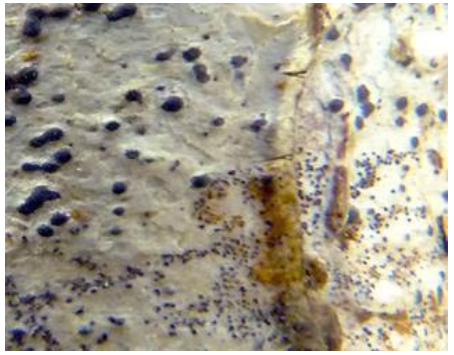
Figure 15 The life cycle of the lichen *Xanthoria parietina* (figure 7). The numbers refer to Table 1.

Sexual reproduction involves….

- Ascomata: Perithecia, apothecia etc
  - Which produce asci and ascospores

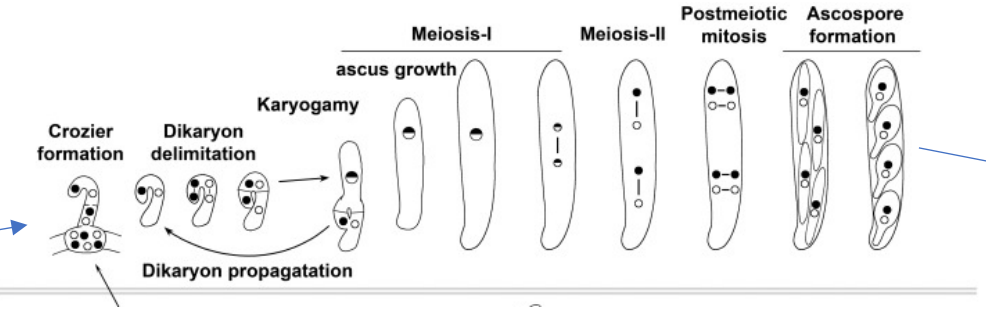


- Pycnidia
  - Which produce conidia

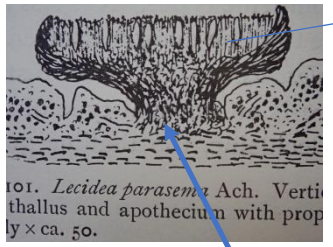


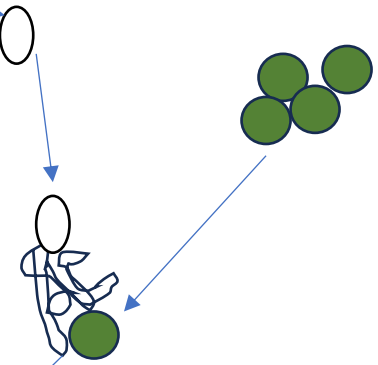
- It goes like this……

Sexual cycle in lichens



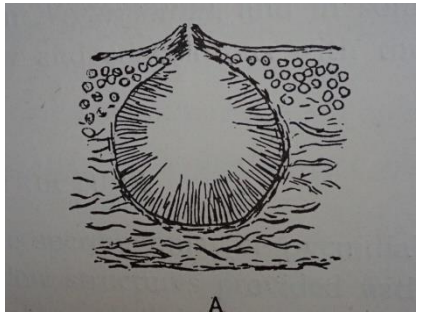
ascoma

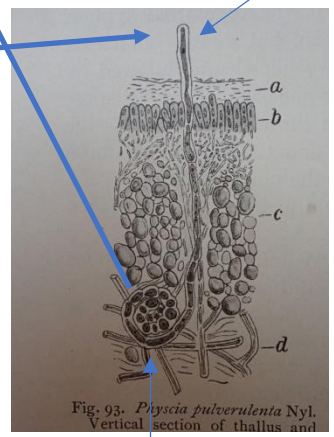




trichogyne

microconidia

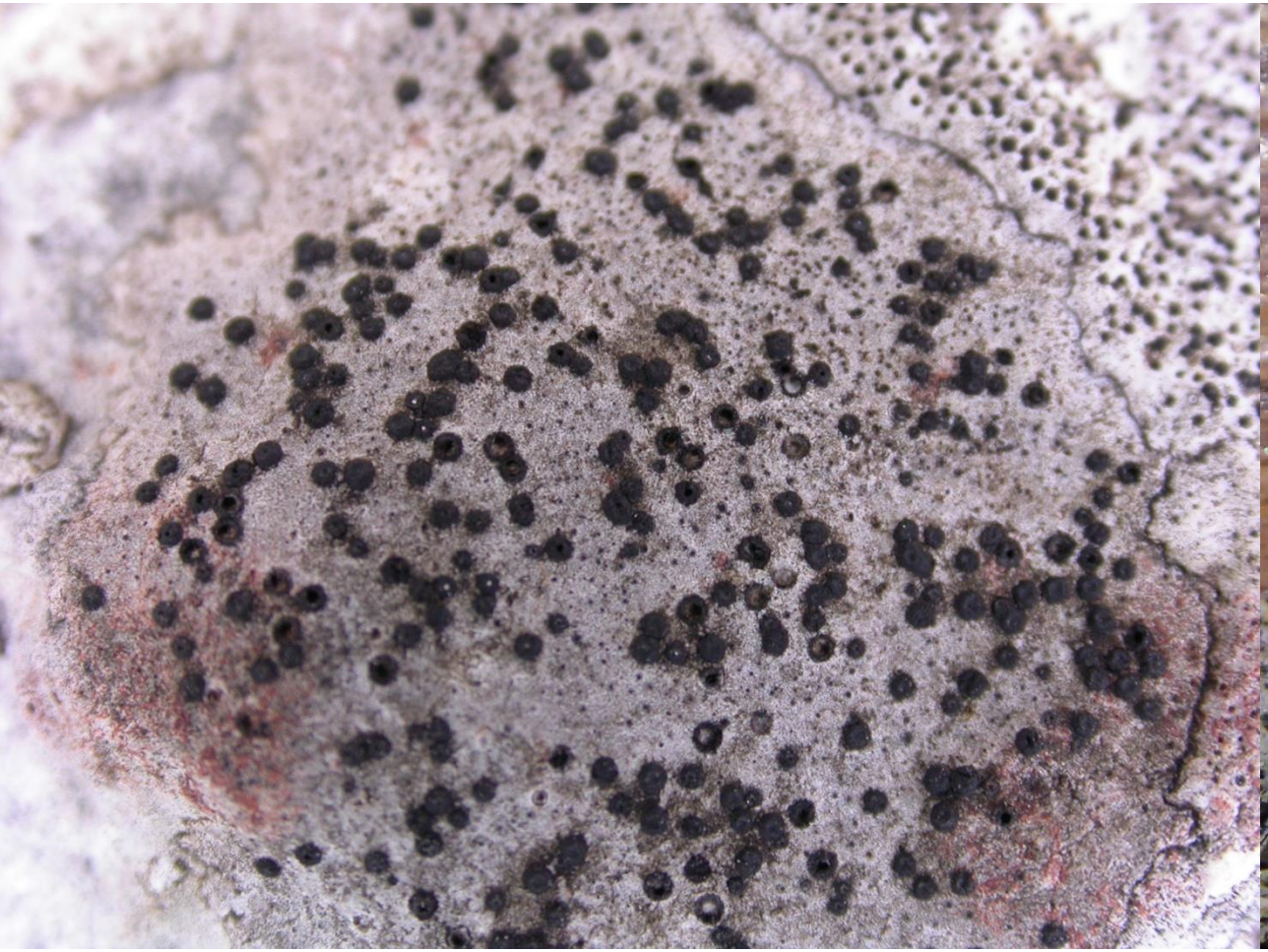




pycnidium

ascogonium

Parabagliettoa dufourii and *Alyxoria varia*



Pycnidia producing microconidia

- Different types
- Different positions
- Different formation
- Different conidia

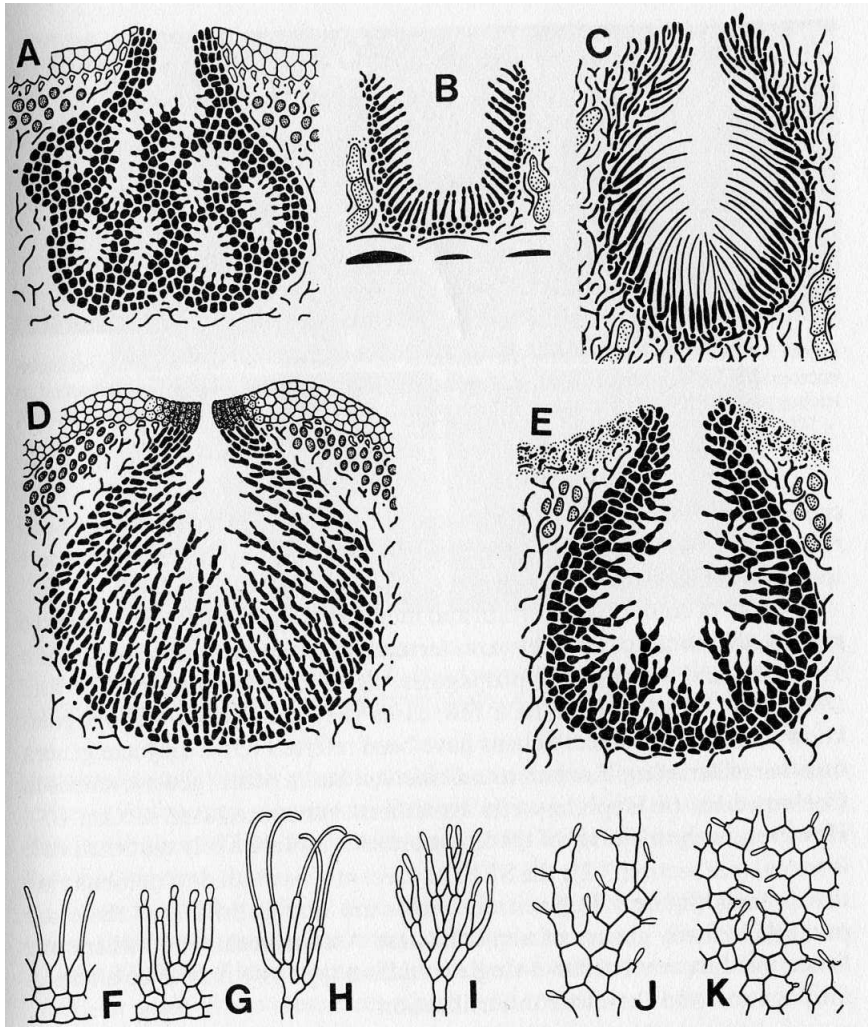
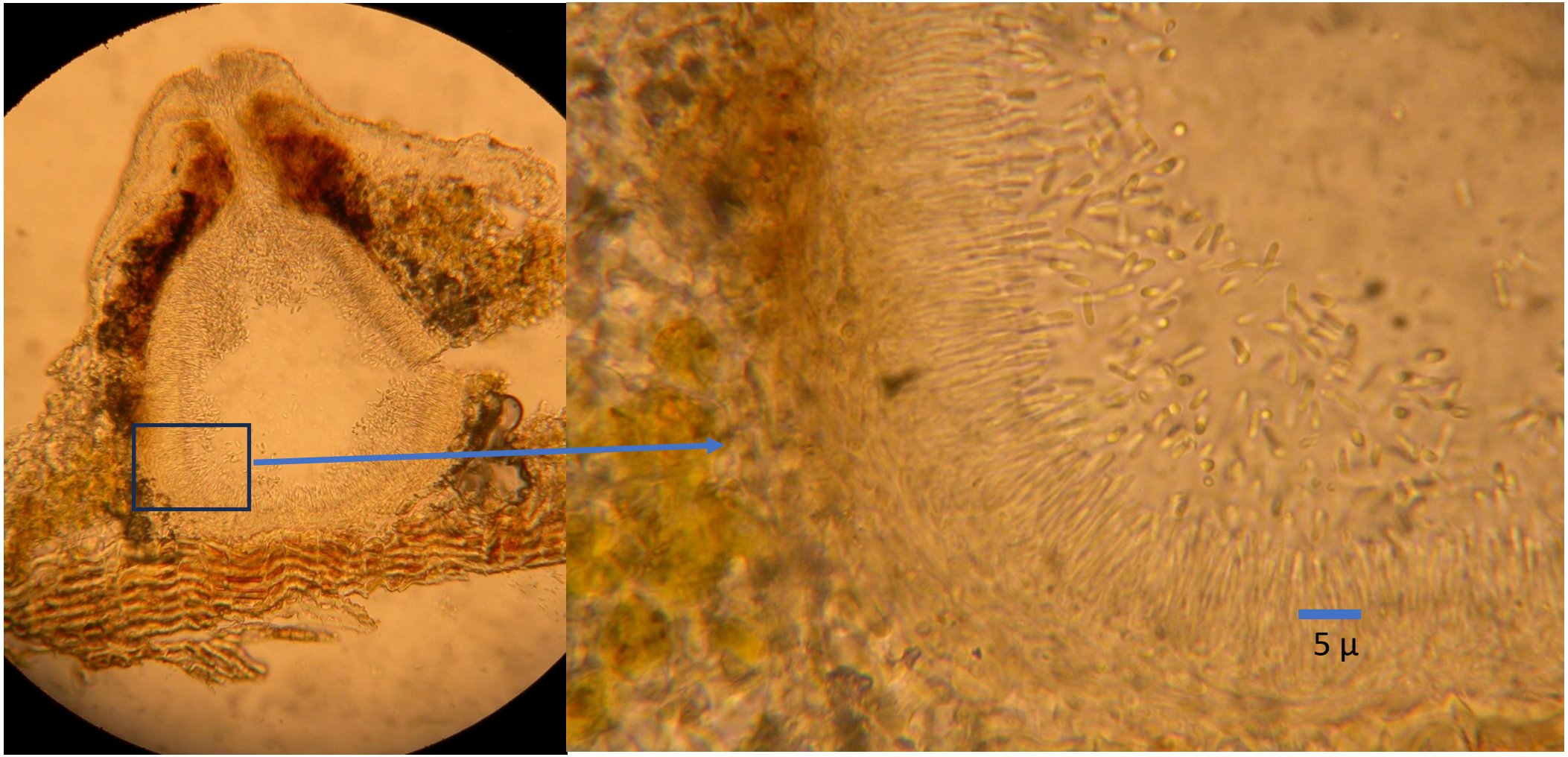
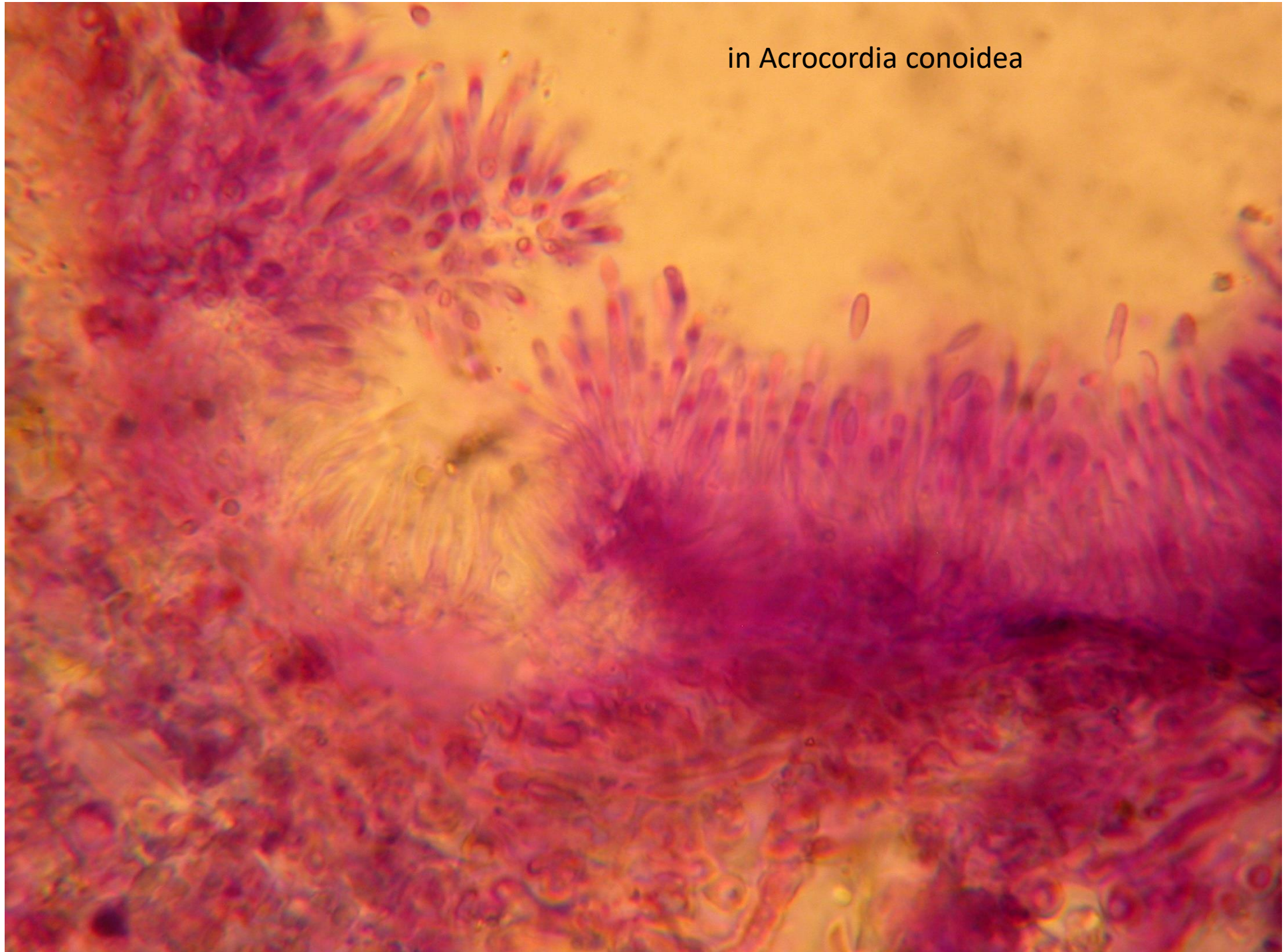


Figure 3.7 Examples of pycnidium (*A-E*) and conidiophore (*F-K*) types in lichens. *A, Xanthoria*-type. *B, Lecanactis*-type. *C, Roccella*-type. *D, Lobaria*-type. *E, Umbilicaria*-type. *F,*

Alexoria varia pycnidium and conidia




in Acrocordia conoidea

Conidia - Microconidia

- 2-25µ long and 1-2µ wide
- One nucleus
- No obvious food reserves
- Apparently only function is in sexual reproduction i.e. to transfer a nucleus
- Usually formed in pycnidia
- Dispersal – how do they get to the trichogyne? In water (mist and rain) or in air or vectors (e.g.insects)? No one knows.

Ascoma Initials and Trichogynes in Lichen Fungi

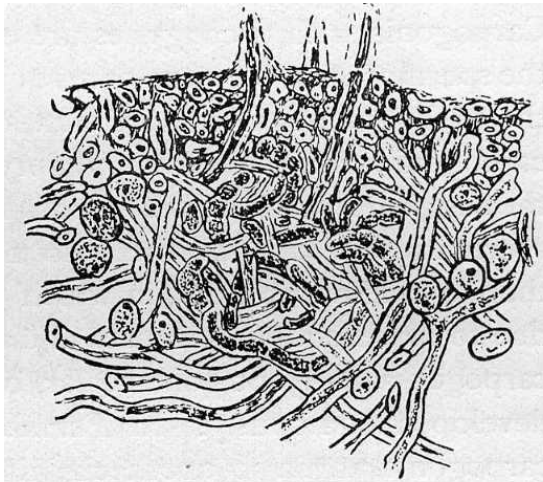


Fig. 96. *Parmelia acetabulum* Dub. Vertical section of thallus and carpogonial group × 550 (after Baur).

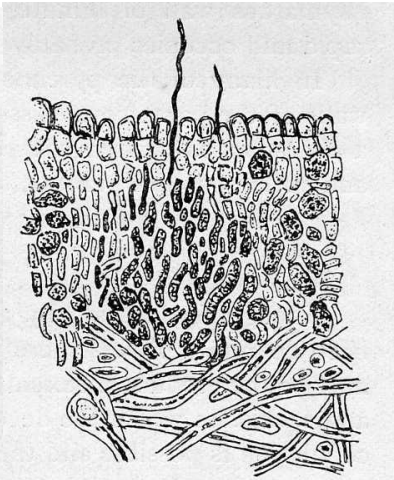


Fig. 99. *Dermatocarpon miniatum* Th. Fr. Vertical section of thallus and carpogonial group × 600 (after Baur).

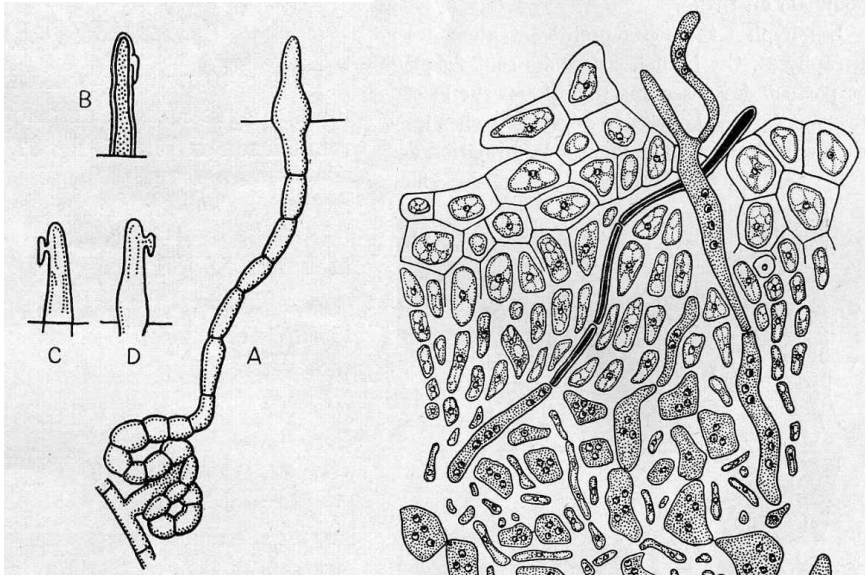


Fig. 86. — Organe femelle et fécondation chez *Collema microphyllum* ACH.

A. Ascogone et trichogyne. — B, C, D. Fusion d'une spermatie et du trichogyne (d'après STAHL).

Fig. 88. — Jeune ascogone de *Peltigera horizontalis* HOFFM. à cellules multinucléées ×750 (d'après MOREAU).

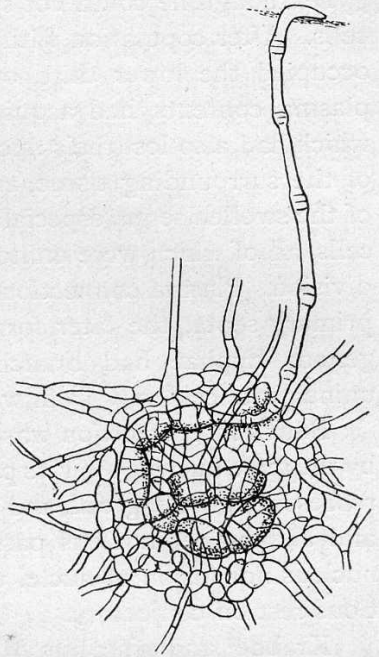


Fig. 92. *Collema microphyllum* Ach. Carpogonium and trichogyne after copulation × 500 (after Stahl).

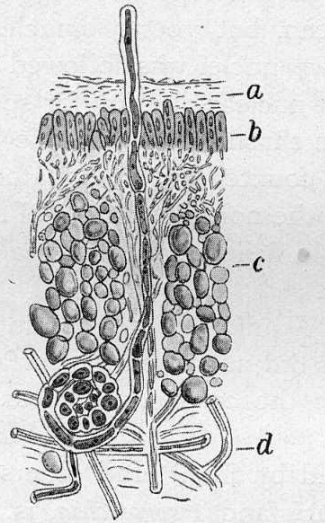


Fig. 93. *Physcia pulverulenta* Nyl. Vertical section of thallus and carpogonium before fertilization. *a*, outer cortex; *b*, inner cortex; *c*, gonidial layer; *d*, medulla. × ca. 540 (after Darbishire).

From Smith (1921) and Des Abbayes (1951)

Ascus formation – at base of hymenium

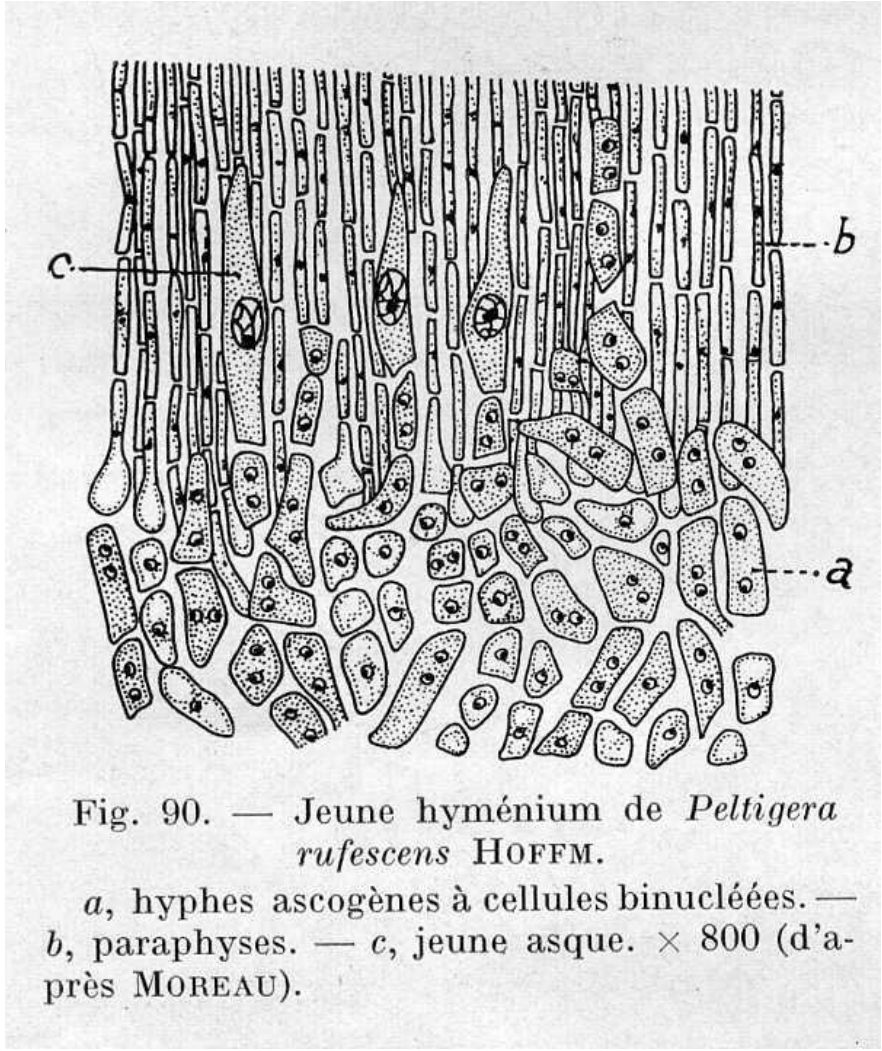
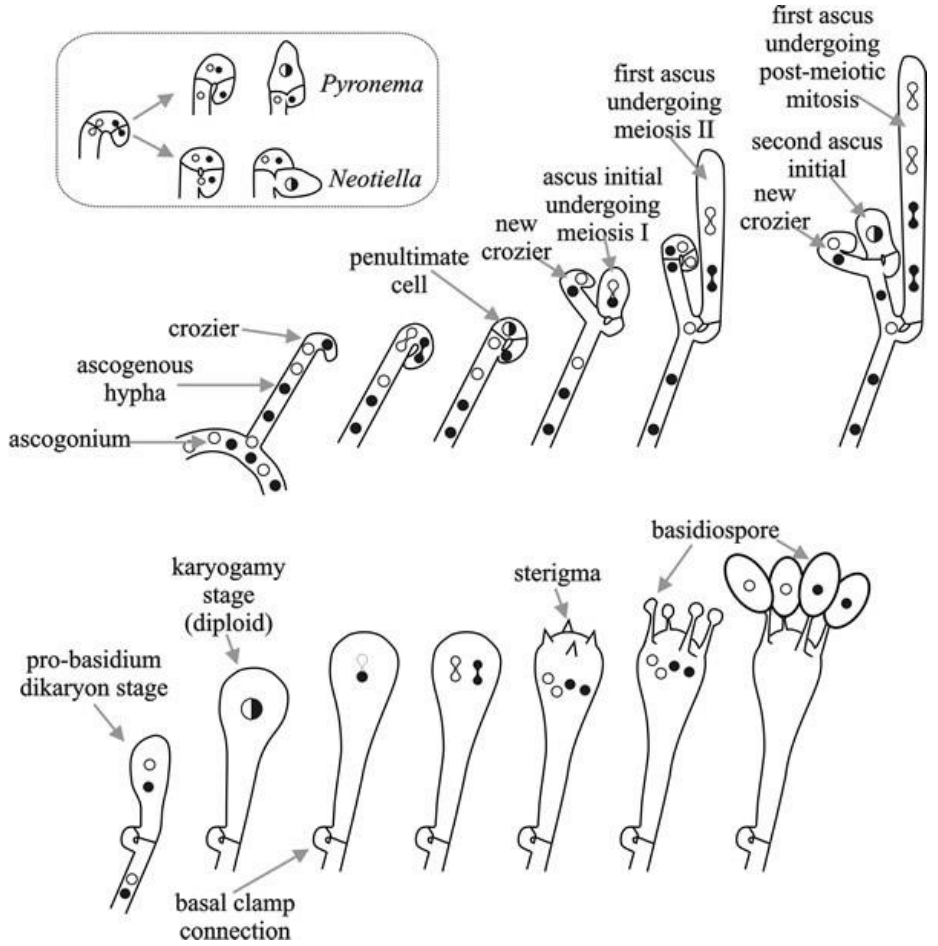
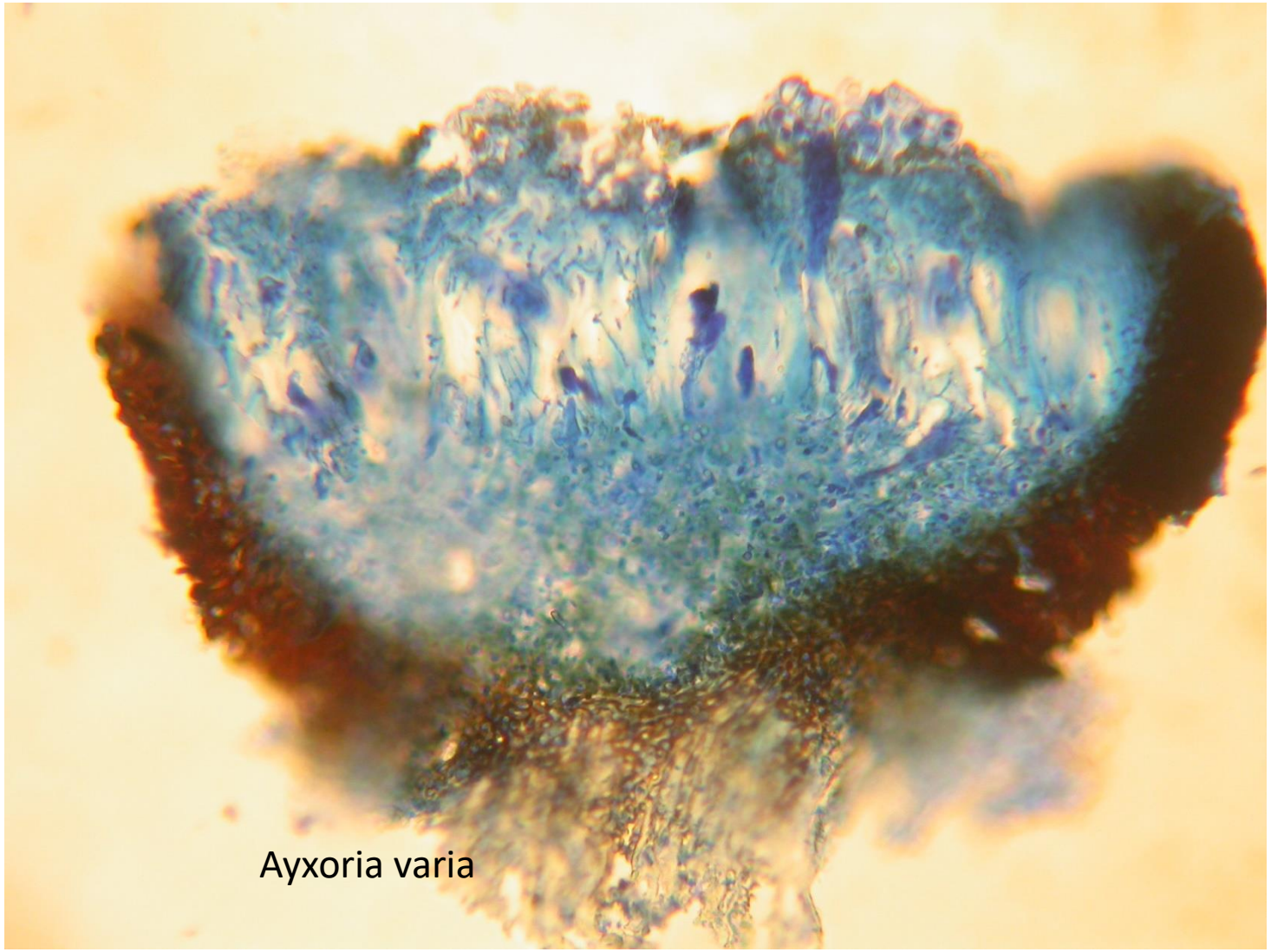


Fig. 90. — Jeune hyménium de *Peltigera rufescens* HOFFM.

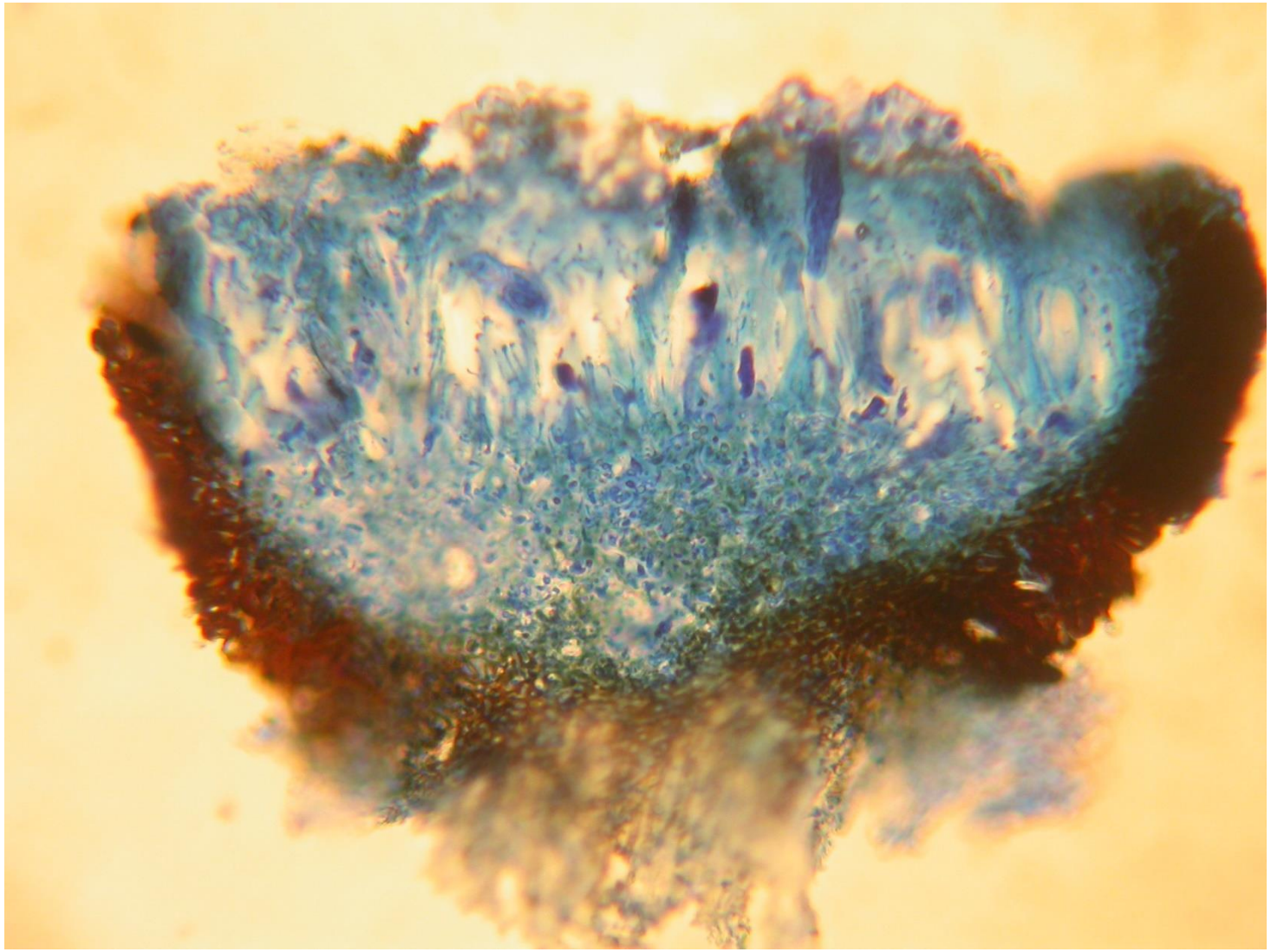
a, hyphes ascogènes à cellules binucléées. — *b*, paraphyses. — *c*, jeune asque. × 800 (d'après MOREAU).

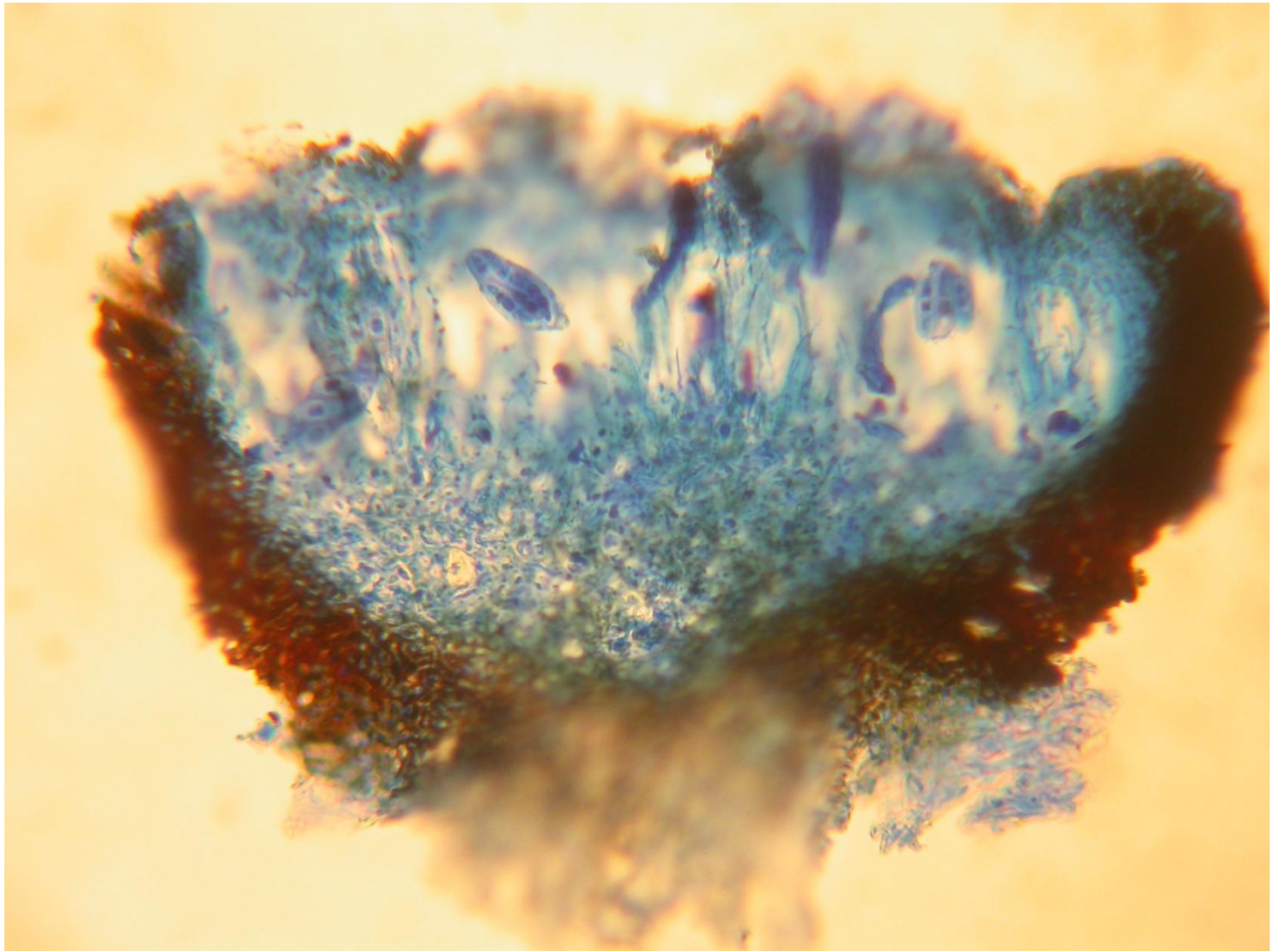


From: Moore et al. (2011) *21st Century Guidebook to Fungi*. CUP

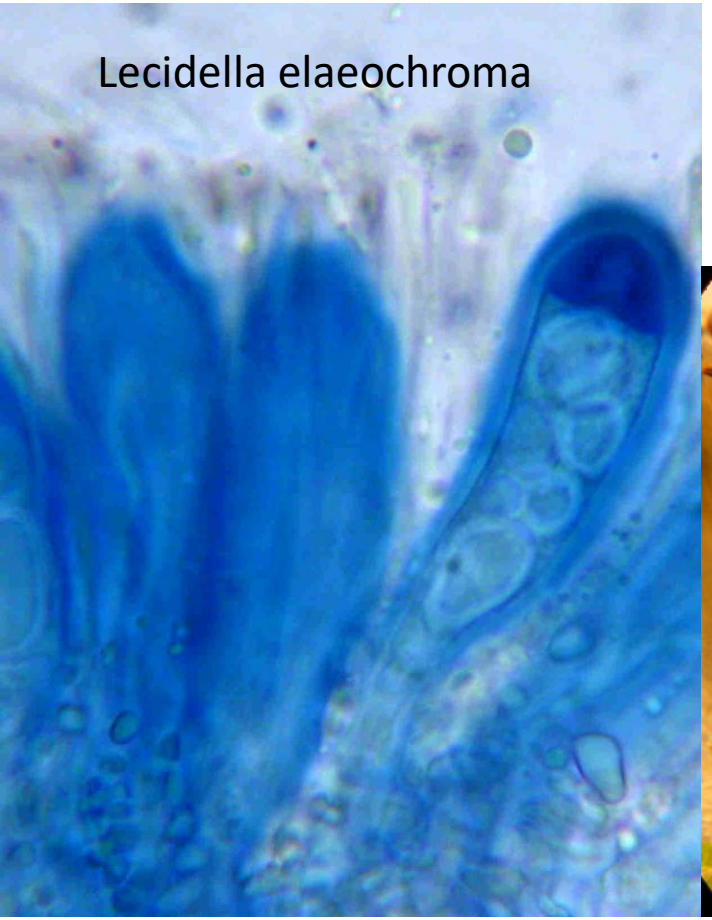


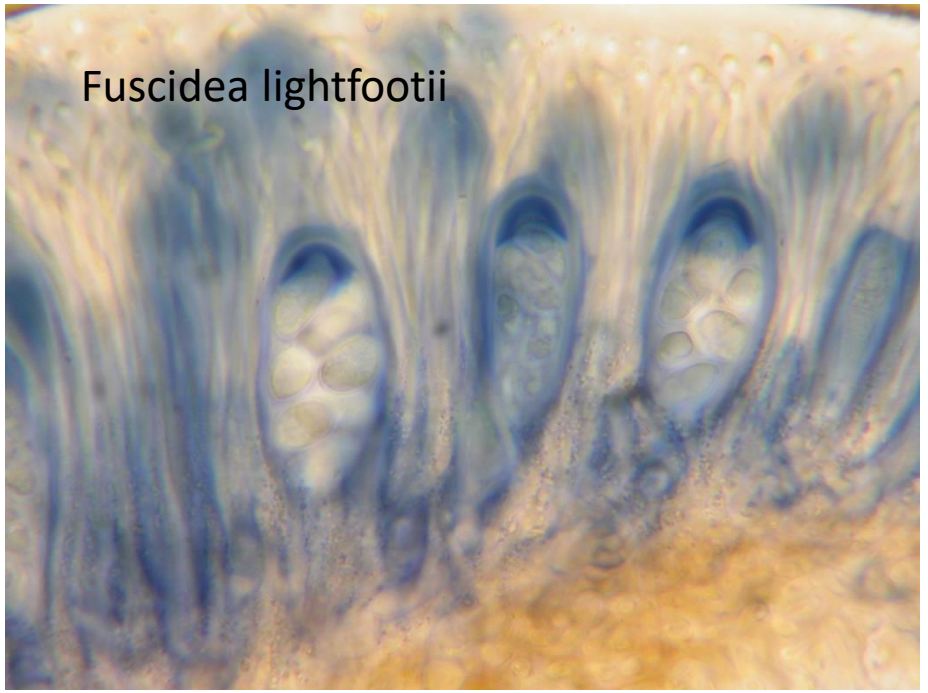
Ayxoria varia

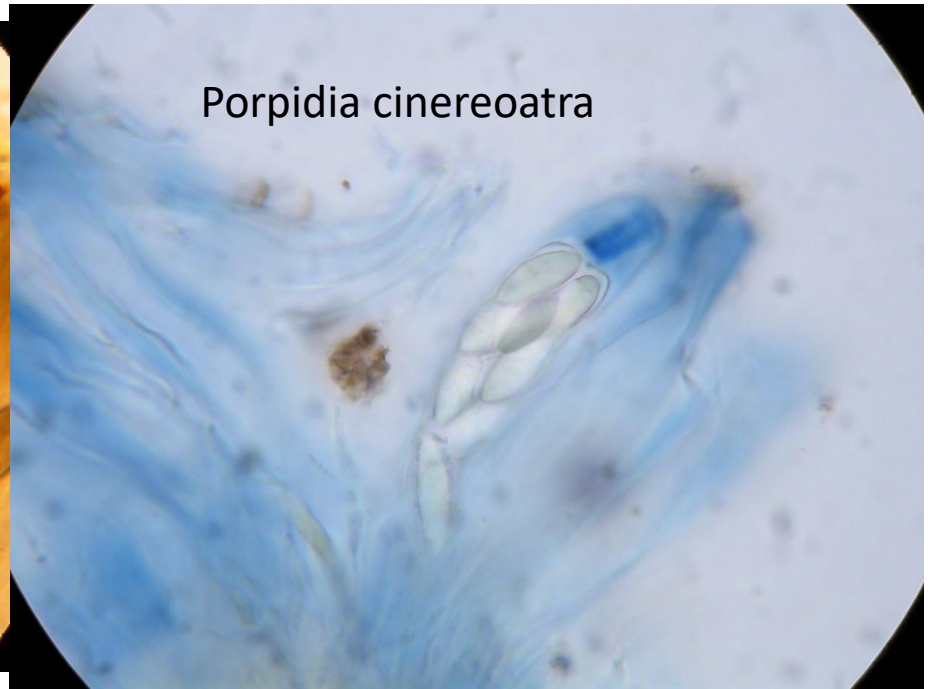




Asci with 8 ascospores







Glaucomeria rupicola mosaics

Heterothallism and homothallism

- Two thalli (one producing conidia and the other ascogonia) can result in the formation of ascocarps if
- A) they belong to different genotypes having appropriate alleles of the mating type genes and a functioning self-incompatibility mechanism i.e they are a heterothallic species
- B) if they are self-fertile – not having any self-incompatibility i.e. they are homothallic
- C) if ascogonia do not need the addition of a second nucleus to produce an ascus i.e. the thallus produces ascomata asexually

Xanthoria parietina and *Lobaria pulmonaria*

- *Xanthoria parietina* is self fertile. It does not need another partner to make effective apothecia. Hence it always has apothecia. Compare this with *Xanthoria calcicola* which is often sterile.
- *Lobaria pulmonaria* is heterothallic. This means there are two or more mating types and one has to have one of each to make apothecia. One for making conidia and one for making ascogonia and trichogynes which when fertilised leads to apothecia. Hence apothecia are usually only found with larger populations of this species.

Homothallic lichens

- Graphis scripta and Ocholechia parella (Murtagh, G., Dyer, P. & Crittenden, P. Sex and the single lichen. *Nature* **404**, 564 (2000). https://doi.org/10.1038/35007142)
- Xanthoria parietina (Scherrer S, Zippler U, Honegger R. Characterisation of the mating-type locus in the genus Xanthoria (lichen-forming ascomycetes, Lecanoromycetes). Fungal Genet Biol. 2005 Dec;42(12):976-88. doi: 10.1016/j.fgb.2005.09.002. Epub 2005 Nov 2. PMID: 16266815.)
- Endocarpon pusillum (Genome Biol. Evol. 11(3):721–730 (2019))

Interesting case of *Lecidea fuscoatra* At Selborne churchyard recently

Lecidea grisella today at Yate churchyard

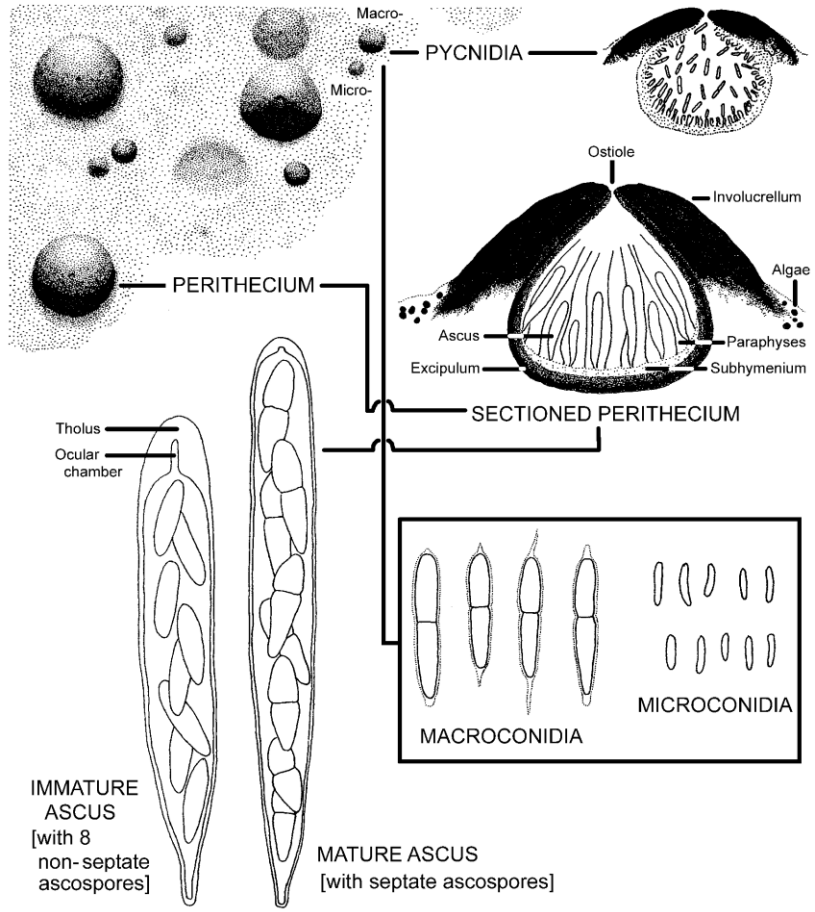
Vegetative reproduction by the mycobiont

- Apart from vegetative reproduction by the lichen including the photobiont as with soredia etc. Fungi do it by making a sexual spores
- In lichens these are seen and described in the books as macroconidia
- As the name implies, they are larger than microconidia
- Not all mycobionts in lichens produce macroconidia.
- These function like spores in that in colonising a new site, they have to find a suitable photobiont

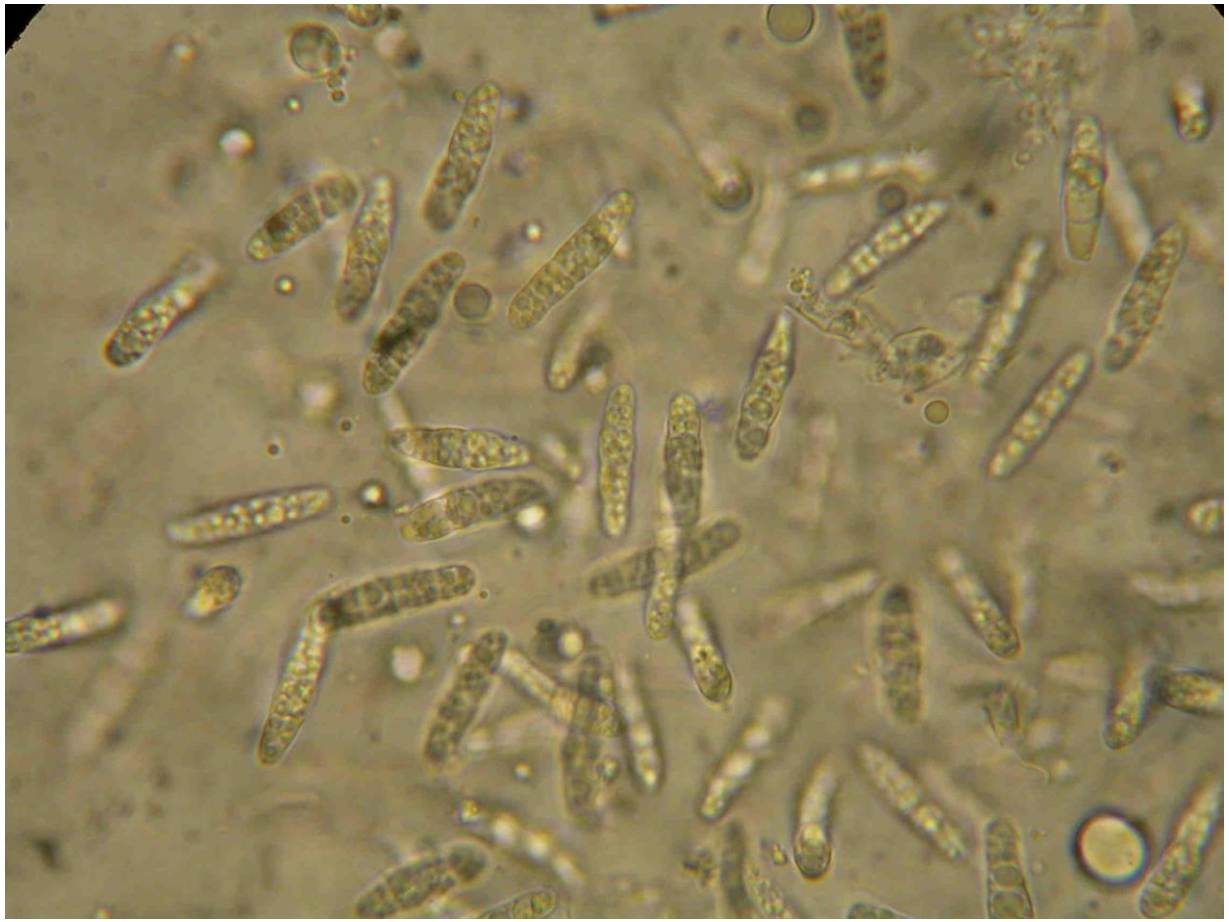
Macroconidia

- These are clearly different from microconidia. Many mycobionts produce both microconidia and macroconidia – you will have noticed this is in species descriptions when identifying lichens.
- Much larger – usually more than 2µ wide and 5µ long – large enough to have food reserves
- Can have more than one nucleus and be multicellular

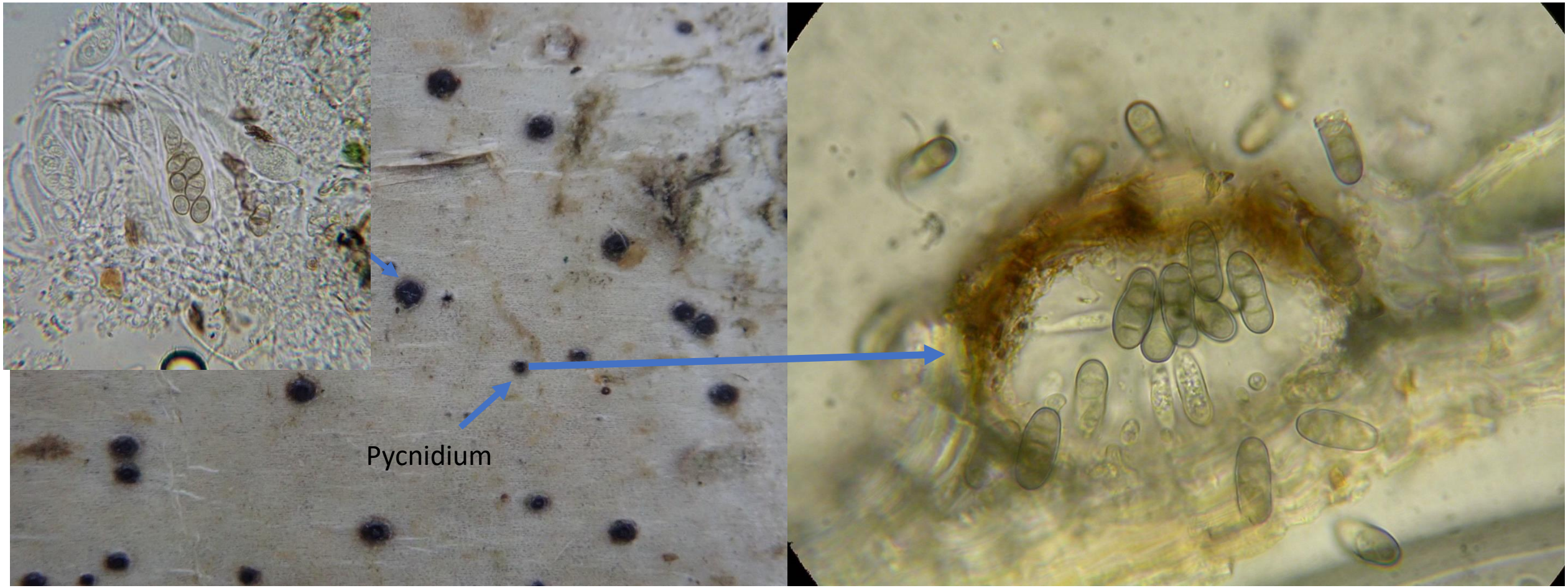
Strigula


Macro-
Micro-
PYCNIDIA
PERITHECIUM
Ostiole
Involucrellum
Algae
Ascus
Paraphyses
Excipulum
Subhymenium
SECTIONED PERITHECIUM
Tholus
Ocular chamber
MICROCONIDIA
MACROCONIDIA
IMMATURE ASCUS [with 8 non-septate ascospores]
MATURE ASCUS [with septate ascospores]

Swinscowia (Strigula) calcarea pycnidia and macroconidia



Eopyrenula grandicula pycnidia and macroconidia



More about macroconidia

- The similarity to the ascospores (eg *Eupyrenula grandicula*) suggests the mycobiont is using some of the same genes as those used for ascospores.
- Vegetative reproduction of the mycobiont
- Formed in pycnidia which are usually for microconidia. In other lichens can be formed in more diverse ways.

Macroconidia can be formed in other diverse ways

- Conidia-reproduction is common in ascomycetes. Think of *Nectria* and moulds like *Penicillium* and *Botrytis*
- In many, these are the main force for reproduction
- These conidia are not formed in pycnidia
- They are formed on conidiophores developed from on the fungal mycelium (hyphae)
- Conidiophores are in some cased produced all together in a stromatic structure

Complications - the parasexual cycle in fungi

- In the parasexual cycle two different individual fungal colonies meet
- A hypha from each colony meet and fuse (cell contents mix)
- A new cell forms with two nuclei one form each original colony – a very rare event
- Then at some stage, the two nuclei will fuse, then undergo meiosis (including exchange of genes by chiasmata) and reform haploid nuclei.
- So the genetic process of sexual reproduction occurs without the process of normal sexual reproduction.
- Has been only shown for a few cultivated moulds in the lab (ascomycota as well as basidiomycota)

End summary

- Sexual reproduction appears to be the most prevalent means of reproduction in lichens – but only for the mycobiont as far as we know
- Because fungi are haploid, lichens are genetically different from plants and animals
- There are no genders in fungi, but mating types
- Homothallic and heterothallic species
- Asexual reproduction in mycobiont
- Possibility of the parasexual cycle

Other related topics

- Seasonality of spore discharge
- Population sizes and reproduction – distance between individuals
- Spore dispersal
- Spore diversity and function
- Colonisation process

Early colonisers reproduce by spores

- Where do they get their photobionts from?
- *Xanthoria parietina* colonising a twig – presumably by spores?
- E.g. *Protoblastenia rupestris*, *Sarcogyne regularis* and *Clauzadea monticola* here in a disused quarry in Somerset