An introduction to bryophyte biology

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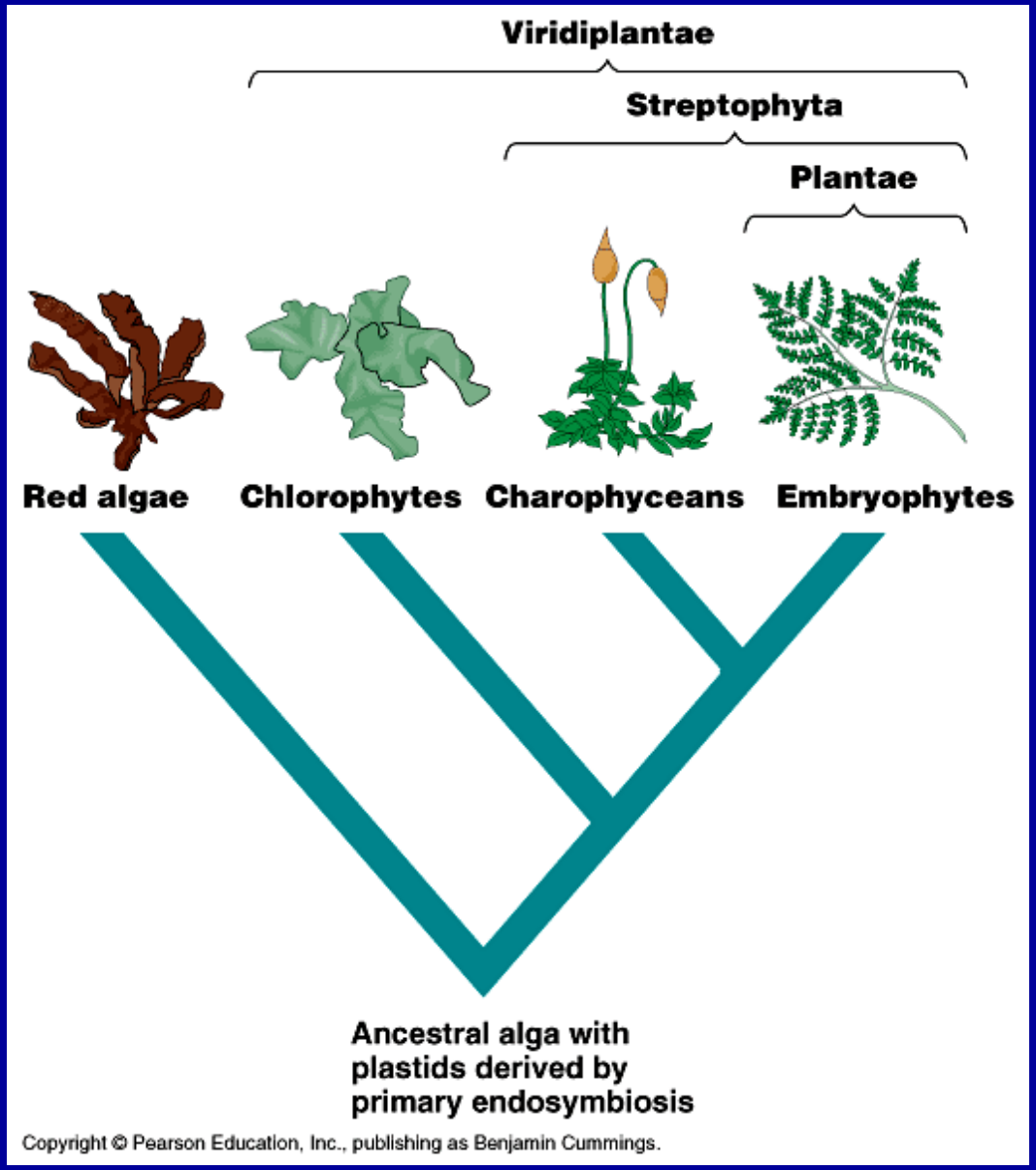
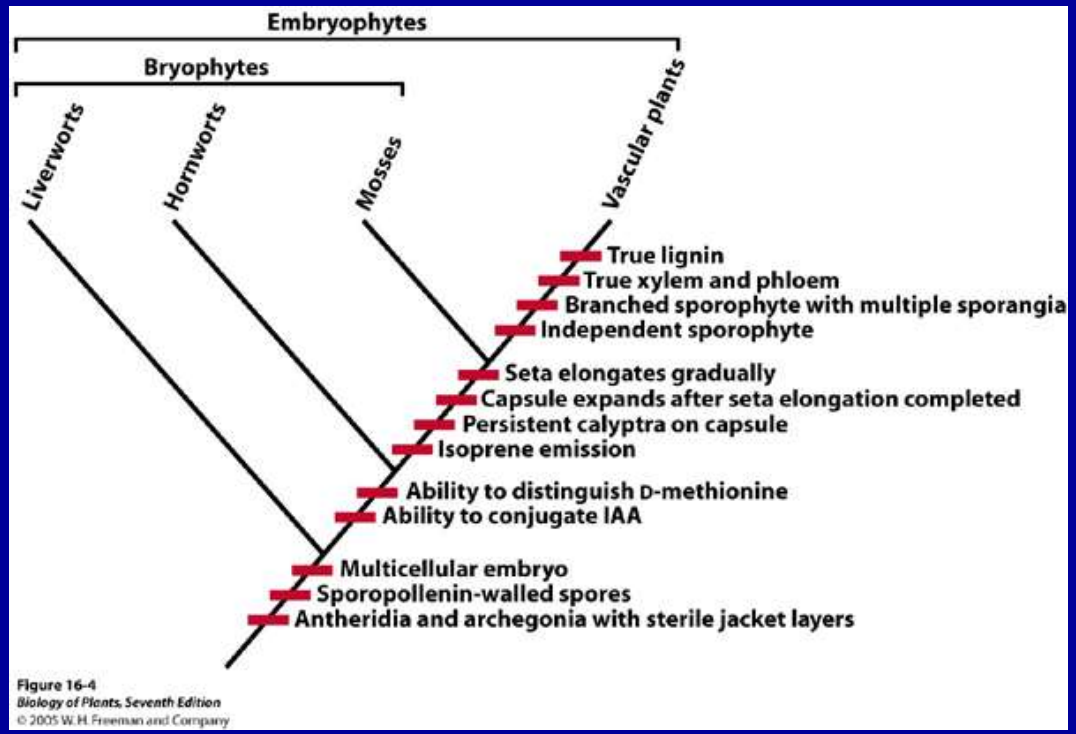
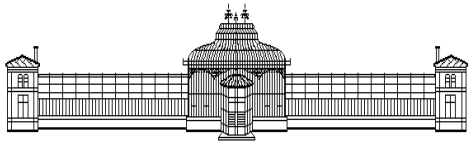


Bryophytes

- the second largest group of terrestrial plants (15000-25000)
- very heterogeneous group of paraphyletic origin
- their ancestor were among the first land plant



Amphibians among land plants



Overview of land plant evolution

Four main groups of land plants

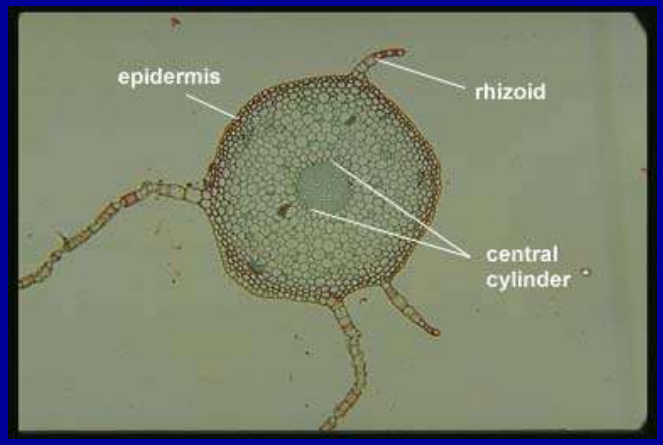
Bryophytes

•Pteridophytes

•Gymnosperms
and
•Angiosperms

→ Groups are distinguished from algae by reproduction (life cycle) that involves the development of a multi-cellular embryo attached to the mother plant for its protection and nourishment.

Bryophytes – liverworts, hornworts, mosses



- Bryophytes have no vascular tissues.

- The rest three groups are all vascular plants (tracheophytes).

  - Vascular plants have cells that are joined to produce tubes that transport water and nutrients throughout the plant.

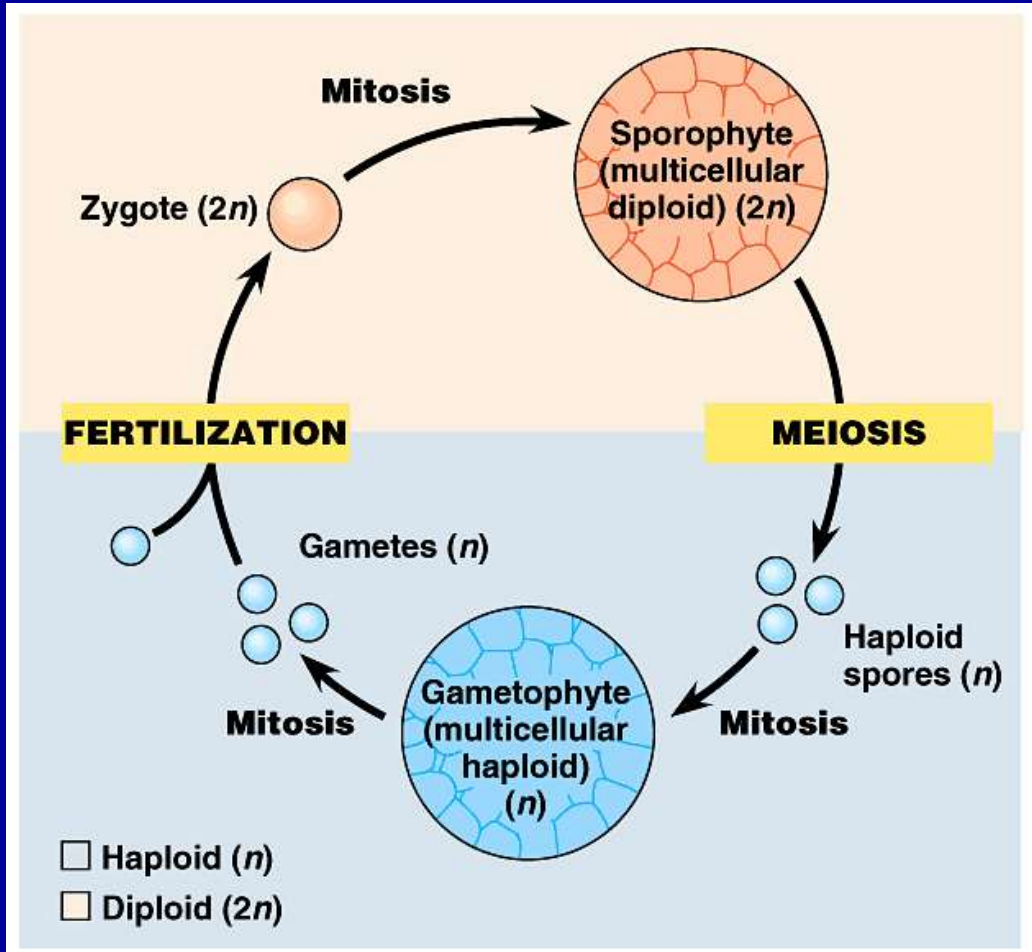
- Bryophytes live in damp/moist environments and are small due to not having vascular tissue. They are sometimes called non-vascular plants.

Alternation of generations

Two multi-cellular body forms:

a. Gametophyte (haploid) that produces gametes. Gametes fuse to form zygotes that develop into…

b. Sporophytes (diploid) that produce spores. Spores are haploid cells that can develop into a new organism without fusing with another cell.

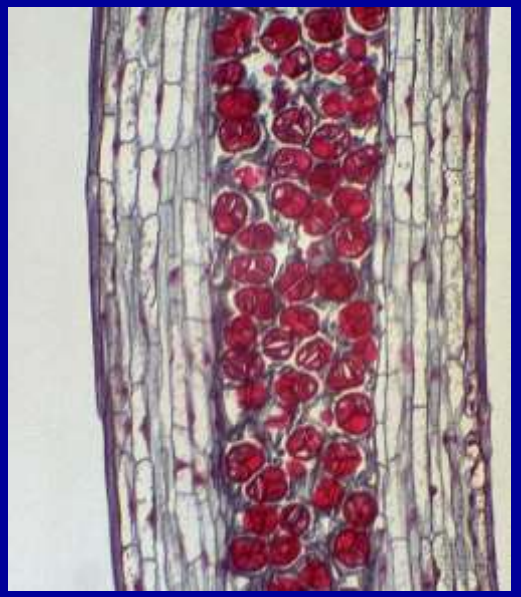


Spore walls contain sporopollenin

a. Sporopollenin is a polymer that makes the walls of plant spores very tough and resistant to harsh conditions.

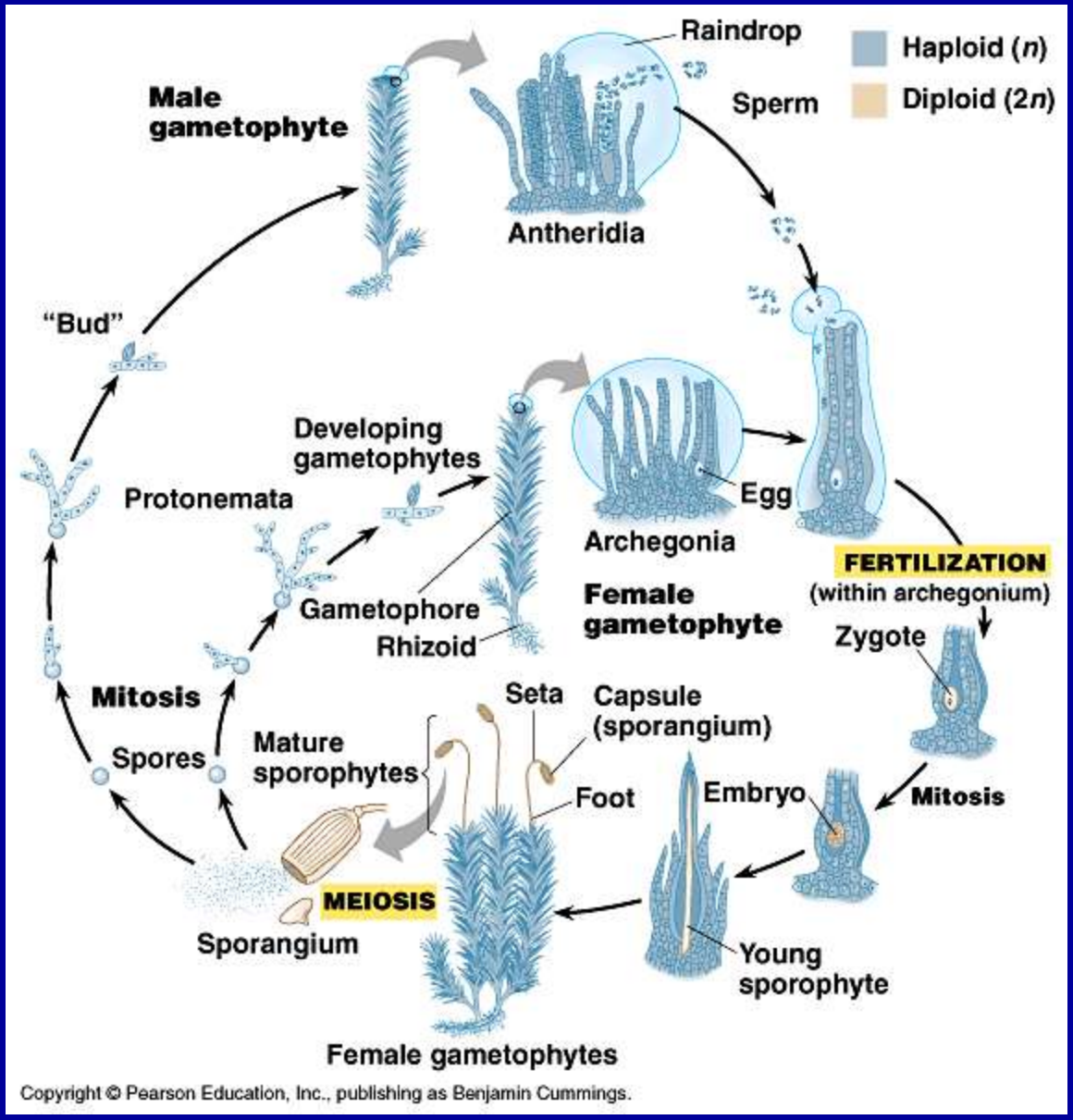
b. Sporopollenin is the most durable organic material known.

c. Spores are produced by sporangia (cells in the sporophyte) through the process of meiosis.



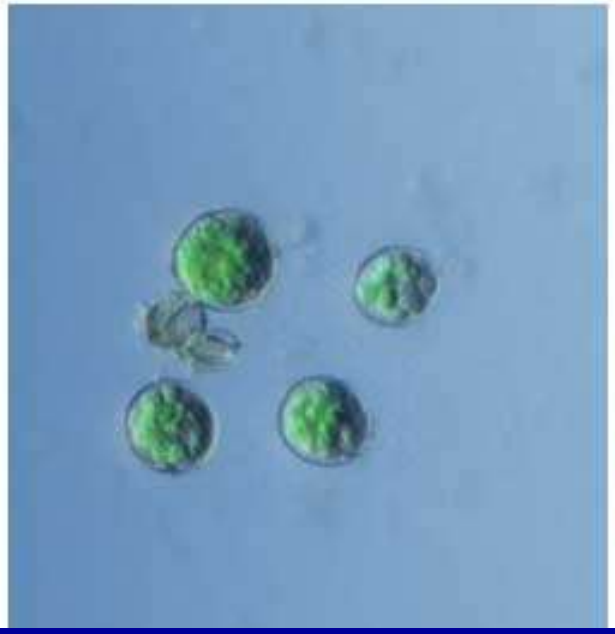
d. Durable spores are an adaptation for surviving on land.

- Can withstand long periods of adverse conditions.
- Easily transported by wind and water.





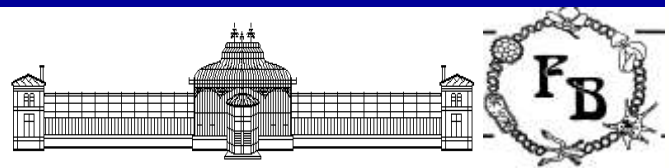




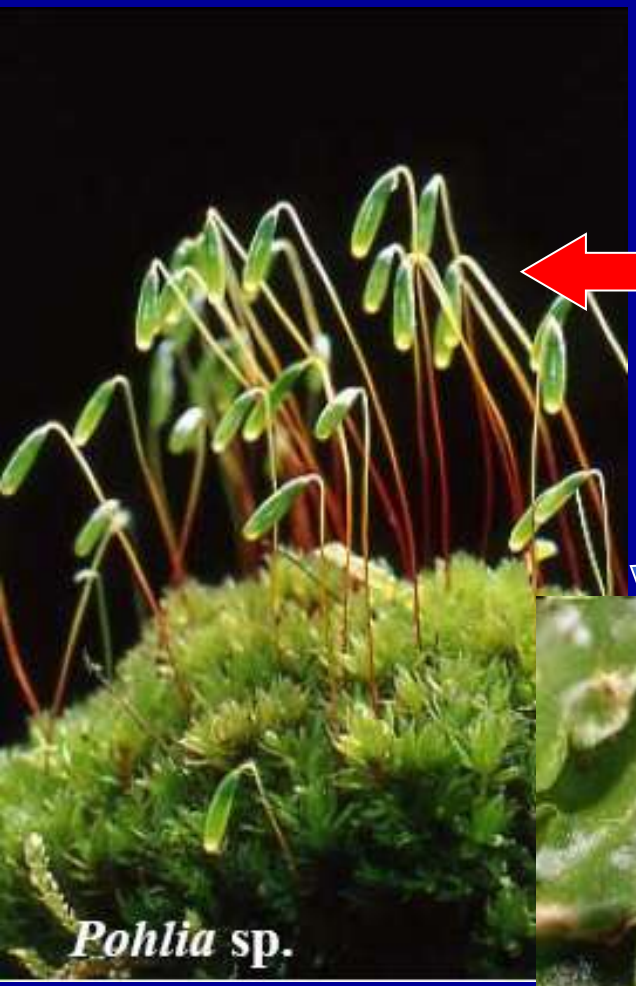

Terms:

Bryophytes (subkingdom Bryobiotina) include phylla:

- Mosses (Bryophyta)
- Hornworts (Antocerotophyta)
- Liverworts (Marchantiophyta)
- haircup mosses(Polytricho-phyta/psida)
- peat mosses(Spagno-phyta/psida)
- lantern (Andreaeao-phyta/psida)
- takakia mosses (Takakio-phyta/psida)



Bryophytes – *sensu lato*



Mosses

Liverworts

Hornworts

Liverwort representatives

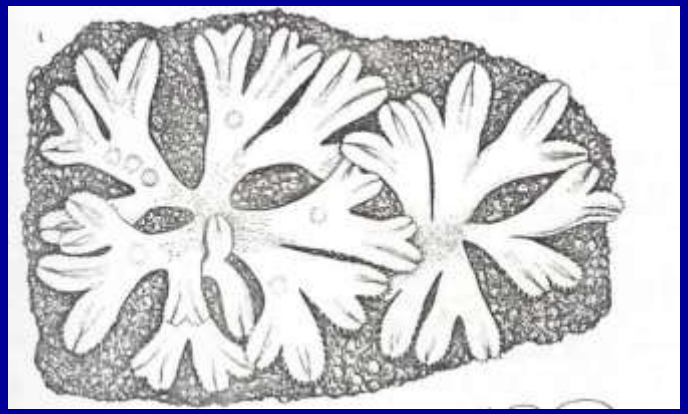
Marchantiophyta - the Liverworts

* So-called because the thallus of many liverworts resembles the lobes of a liver ”Doctrine of Signatures”

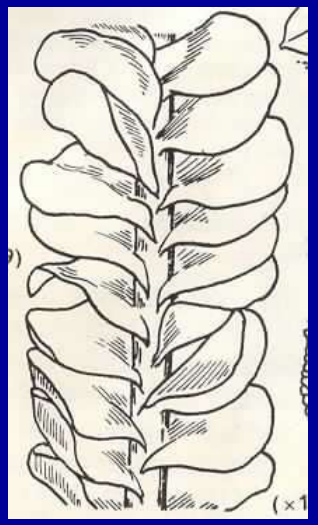
* The Anglo-Saxon ending “wort” (originally *wyrt*) means “herb”

* Liverworts lack conducting elements, a cuticle and stomata

* The gametophyte can be “thallose” or “leafy” (Order Jungermanniales)



Thallose liverwort - *Riccia*



Leafy liverwort *Mylia*

Thallose Liverworts - Order MARCHANTIALES

* The thallus usually has some internal differentiation in the form of photosynthetic cells, air chambers and storage tissues

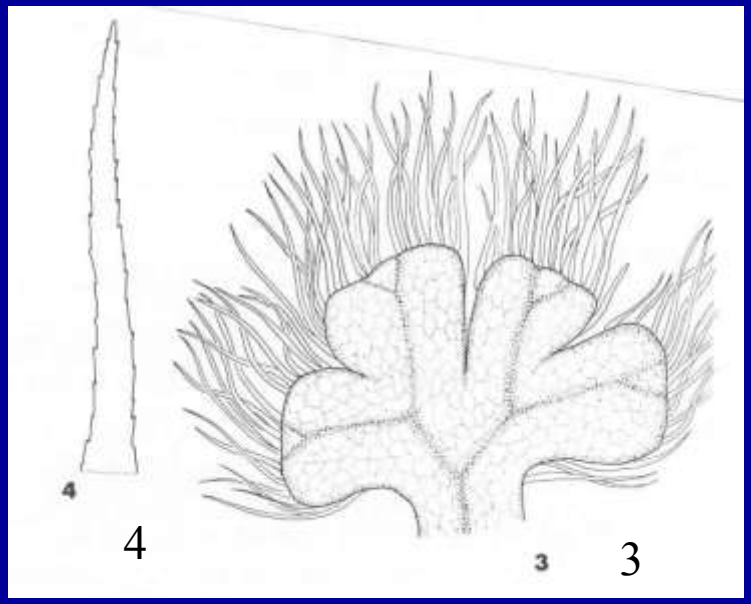
* The sporophyte is compact, with no seta (stalk) or a short one

* The capsule (sporangium) has a single-layered wall

Ricciocarpus natans

This liverwort is amphibious and grows readily in laboratory culture.

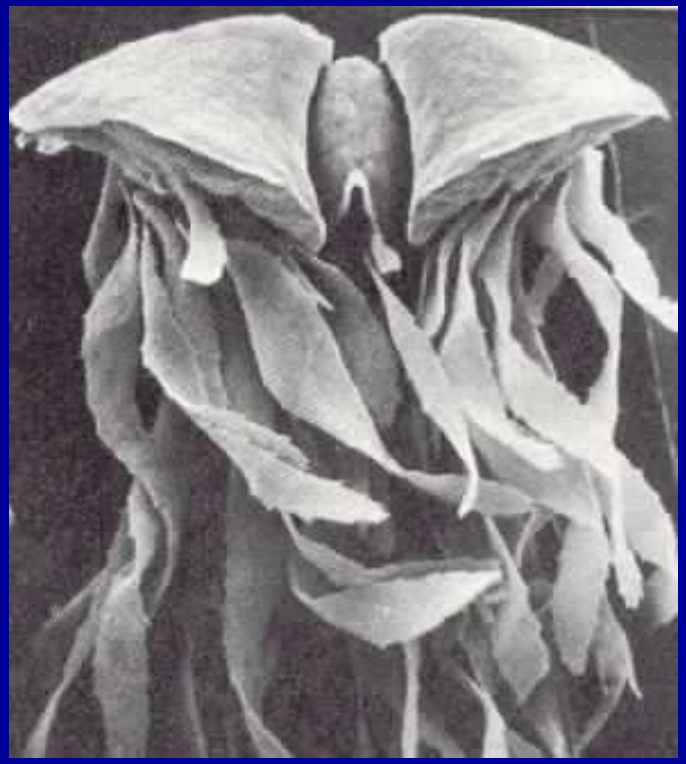
Floating thalli of *Ricciocarpus*



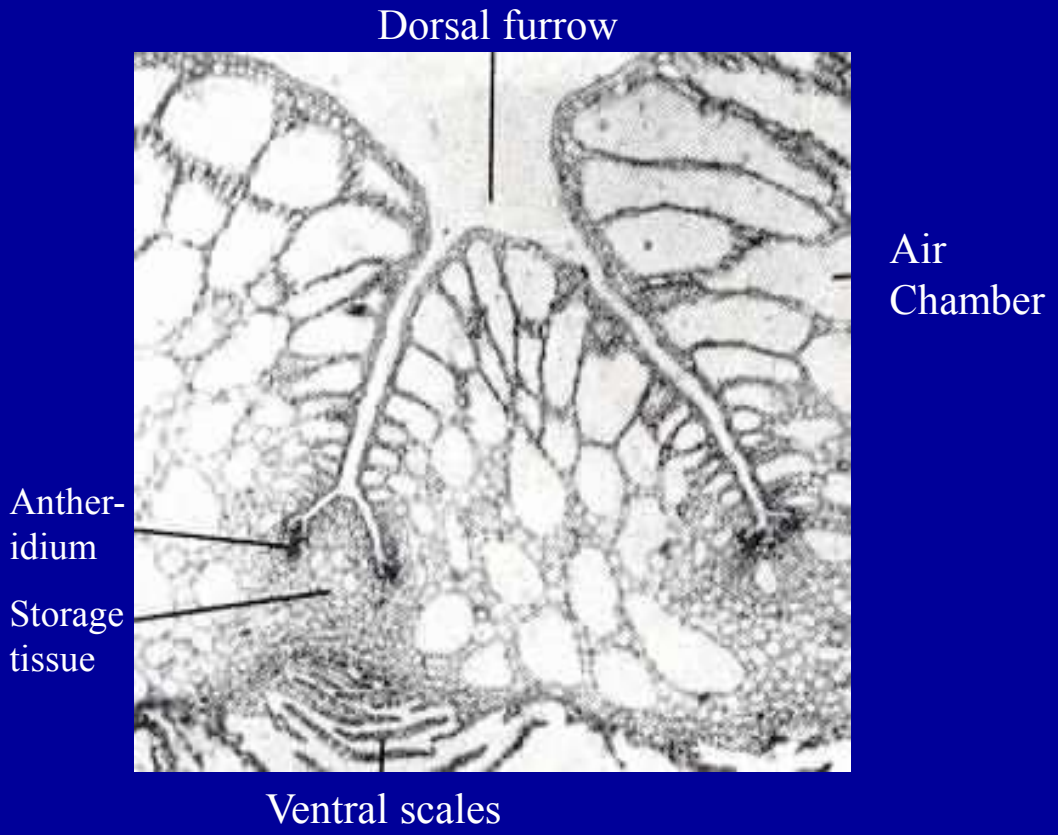
3. Thallus from above showing ventral scales and dorsal furrow

4. Ventral scale

Ricciocarpus - the Dorsal Furrow

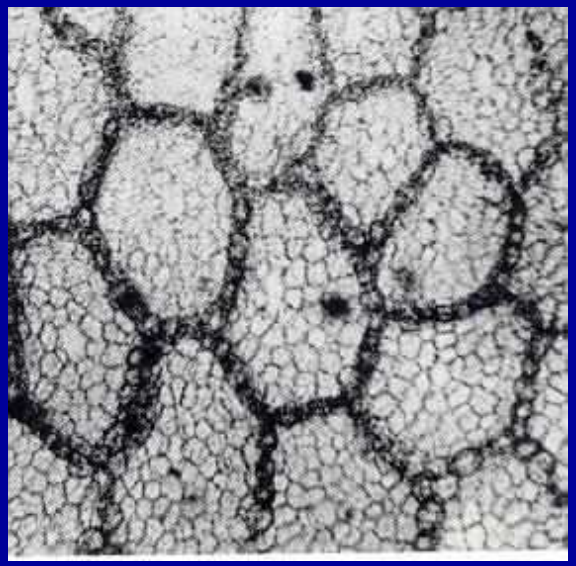


Closeup of Dorsal Furrow and Ventral Scales

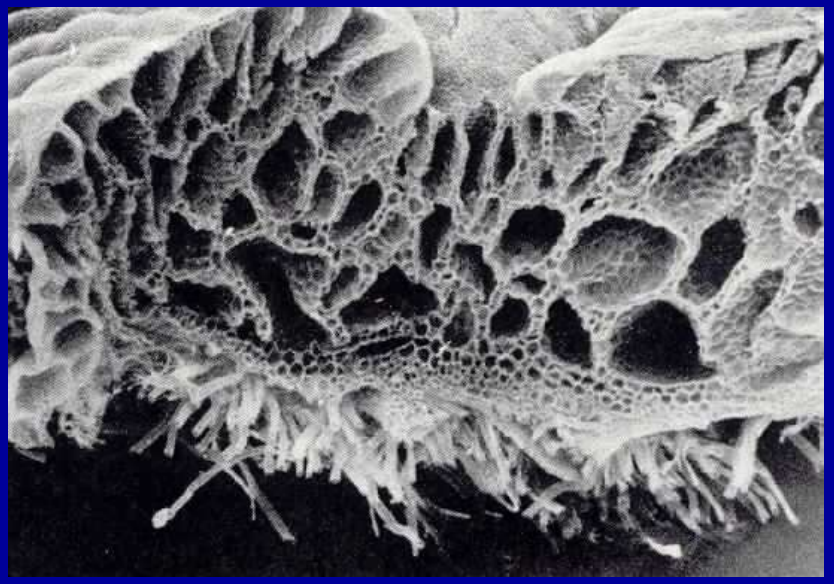


Section in Region of Dichotomy

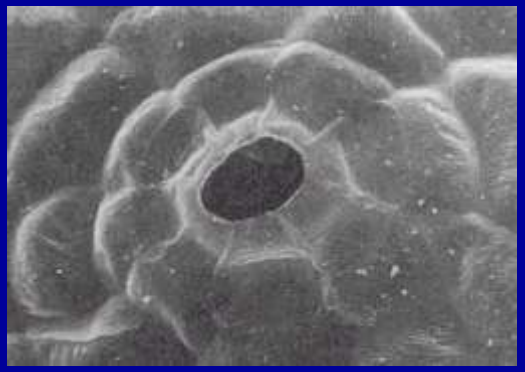
Ricciocarpus - Air Chambers and Rhizoids



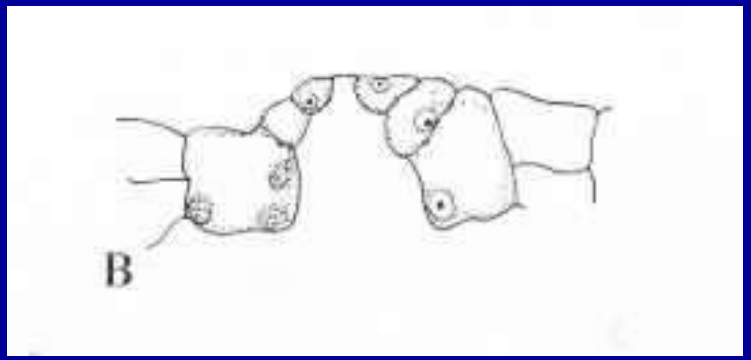
Pattern of Air Chambers from Above



Section showing Air Chambers and Rhizoids



Pore from Above



Pore in Section

Ricciocarpus - Gametangia

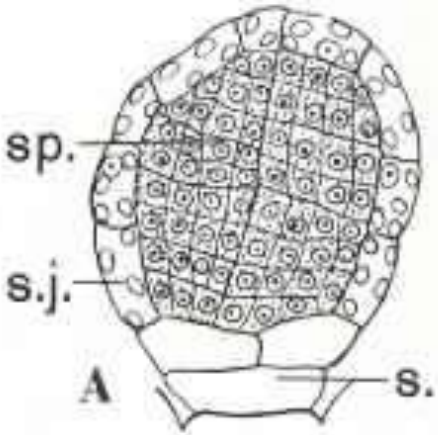
* Gametangia only occur in floating plants

* Gametangia are sunken within the dorsal furrows

* Antheridia and archegonia occur on the same plants (i.e. the plants are monoecious)

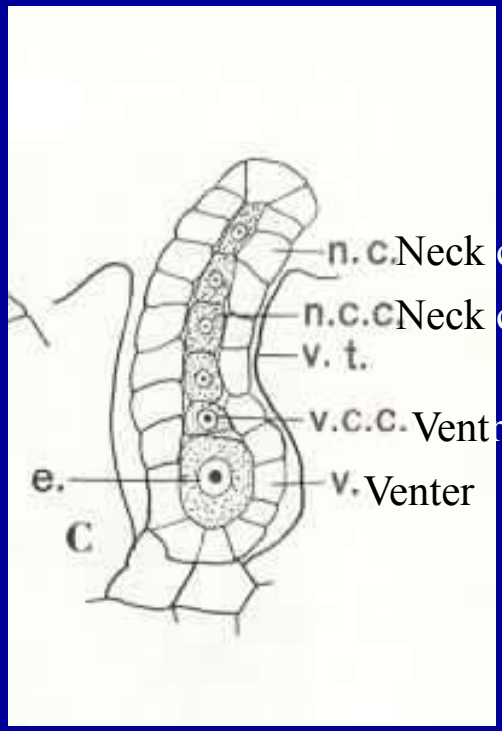
* Antheridia appear before the archegonia (i.e. the plants are protandrous)

sp. = spermatogenous tissue



s.j.=sterile jacket
s =stalk

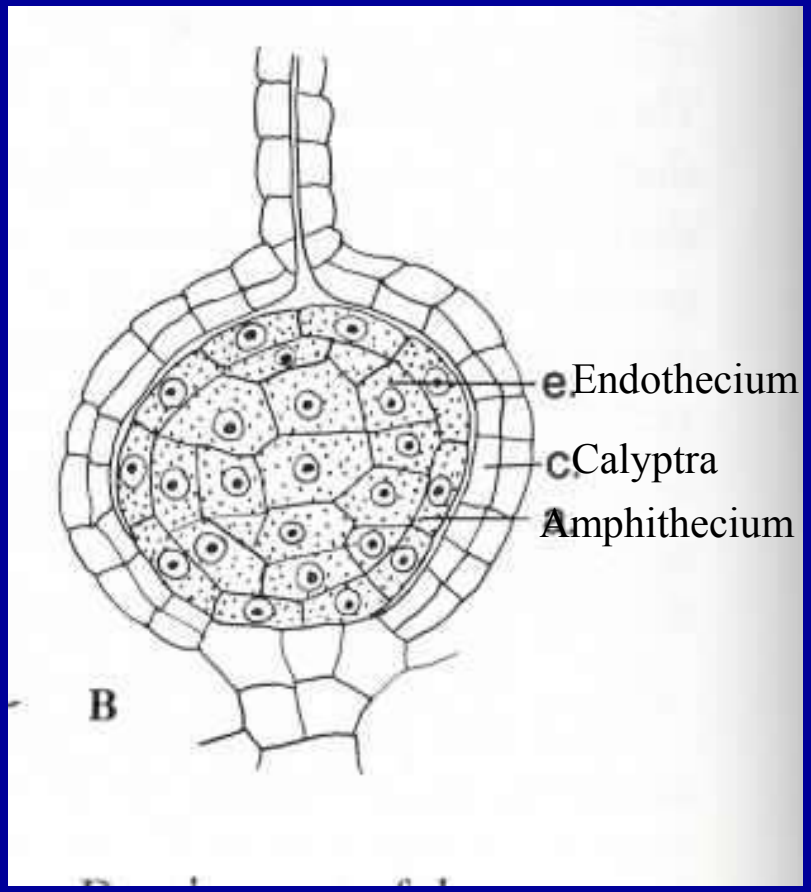
Antheridium, l.s.



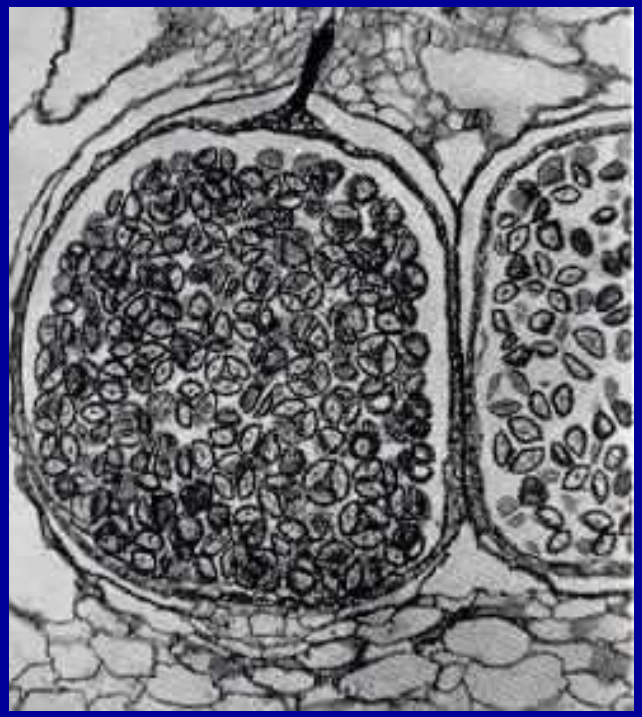
Archegonium, l.s.

Ricciocarpus - Sporophyte and Sporangium Development

* The sporophyte develops within the gametophyte tissues
* The archegonial tissue growth keeps pace to form a calyptra



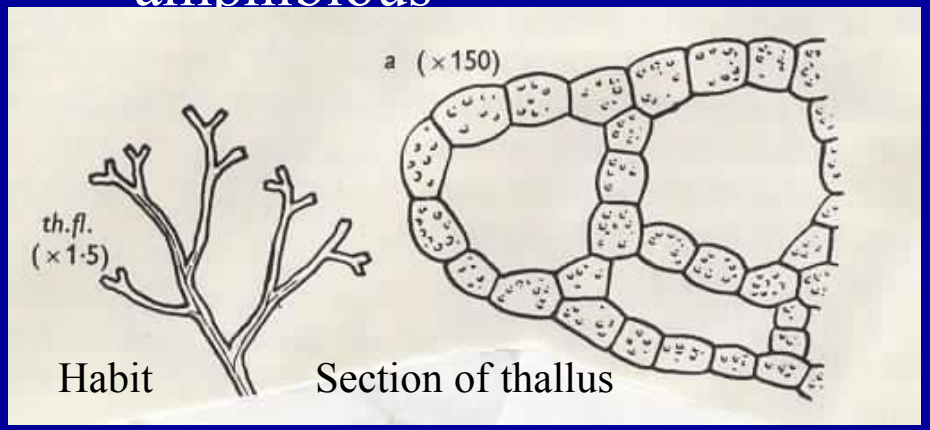
Longitudinal Section of developing sporophyte



Section of sporophytes with spore tetrads (n.b. lack of mechanism for spore dissemination)

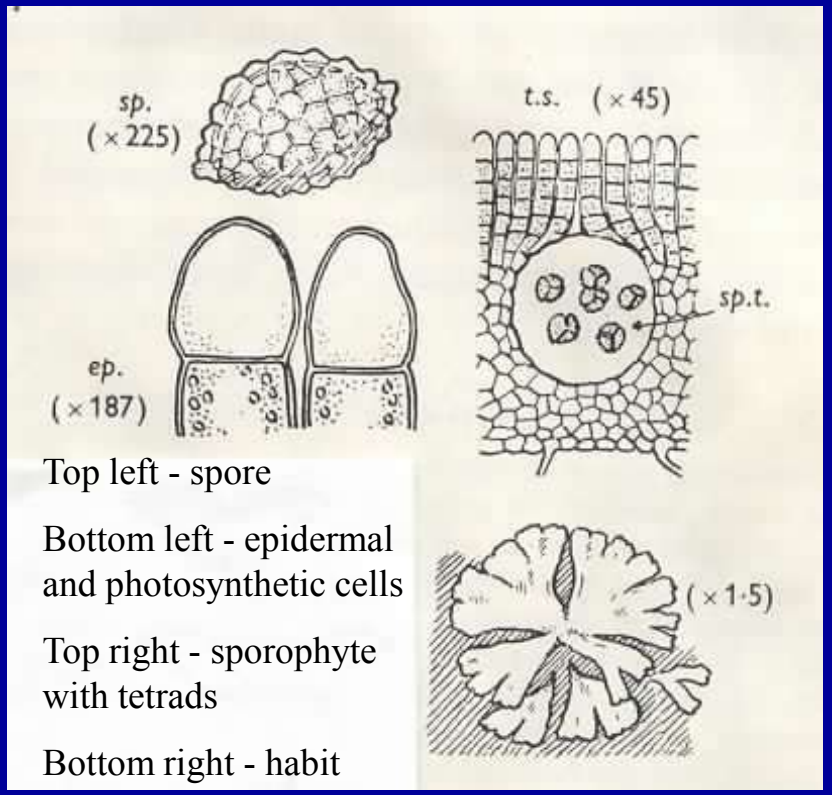
Riccia

* Most species of *Riccia* are terrestrial, but *Riccia fluitans* is amphibious



Riccia fluitans (floating)

Note large air chambers



Top left - spore

Bottom left - epidermal and photosynthetic cells

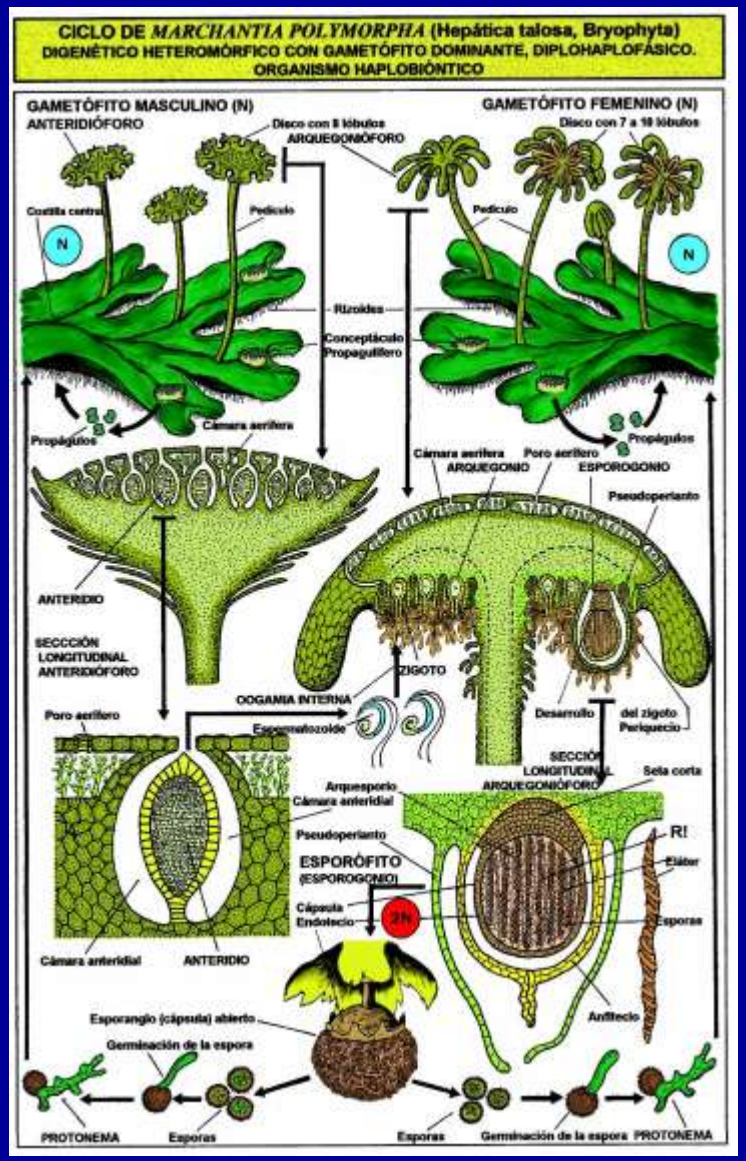
Top right - sporophyte with tetrads

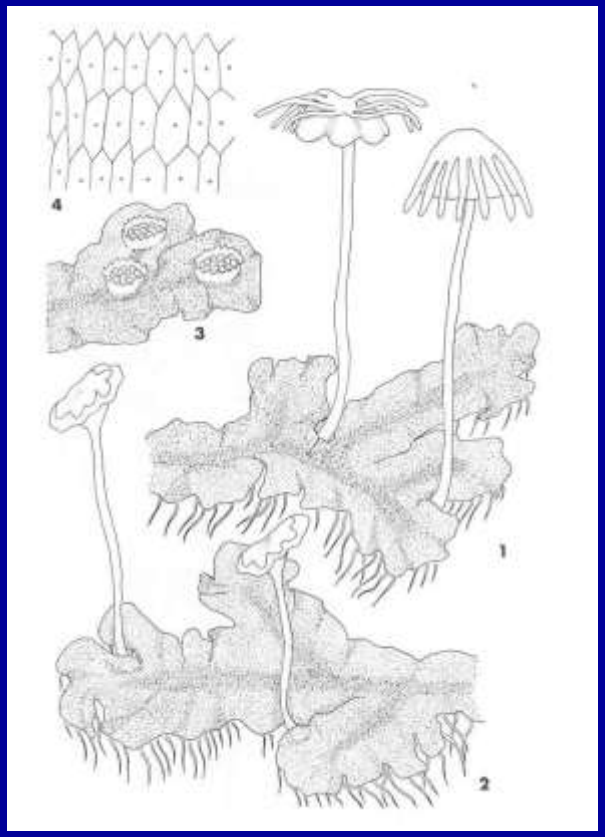
Bottom right - habit

Riccia glauca (terrestrial)

Air spaces are narrow and slit-like

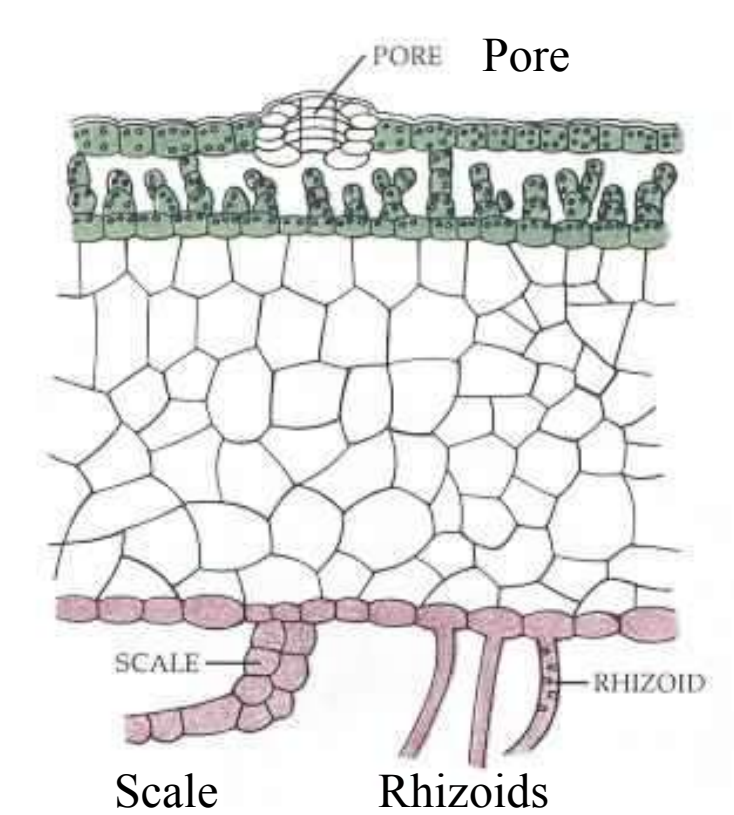
Marchantia polymorpha



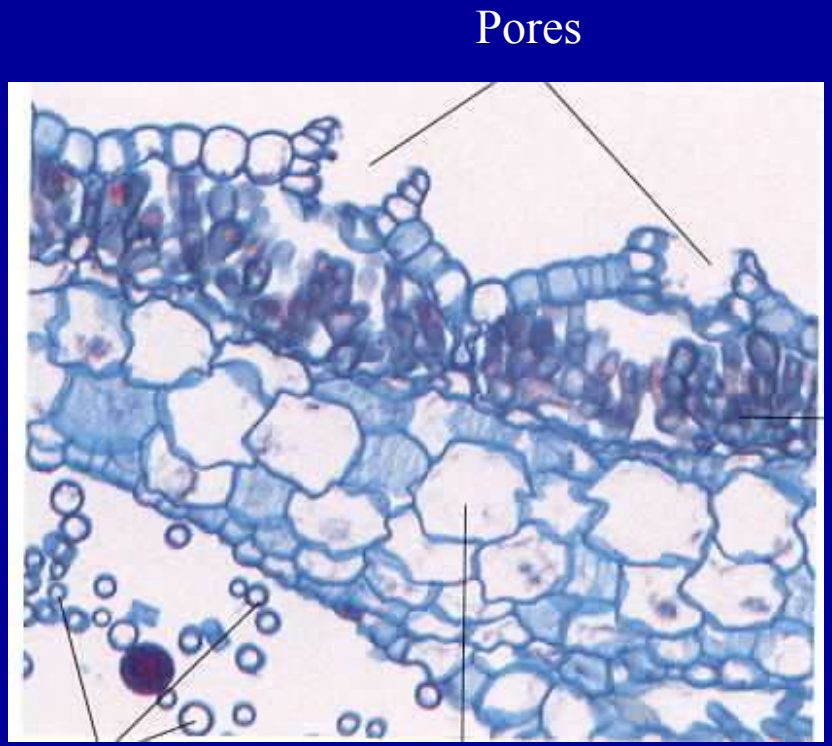


1. Female plant with archegoniophores
2. Male plant with antheridiophores
3. Gemmae cups
4. Dorsal surface of thallus showing air chamber outlines and pores

Marchantia - thallus structure



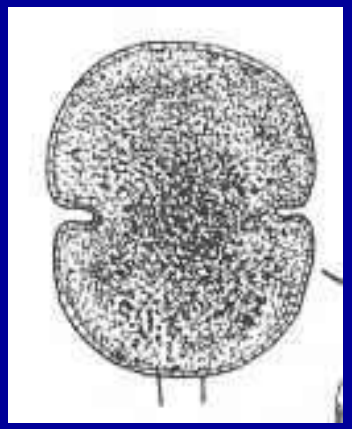
Drawing of cross-section



Photomicrograph of cross-section

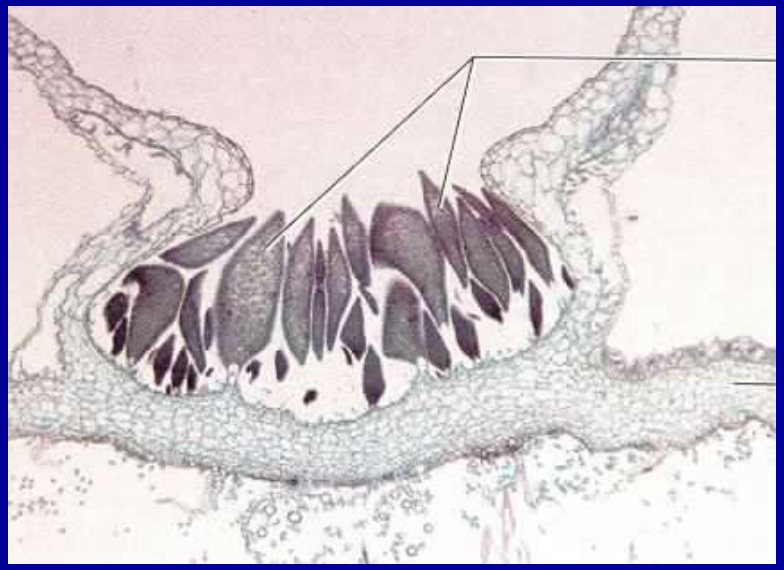
Marchantia - Asexual Reproduction by Gemmae

n.b. these are “splash cups”



Single gemma, with its two meristems

Gemma cups on dorsal surface

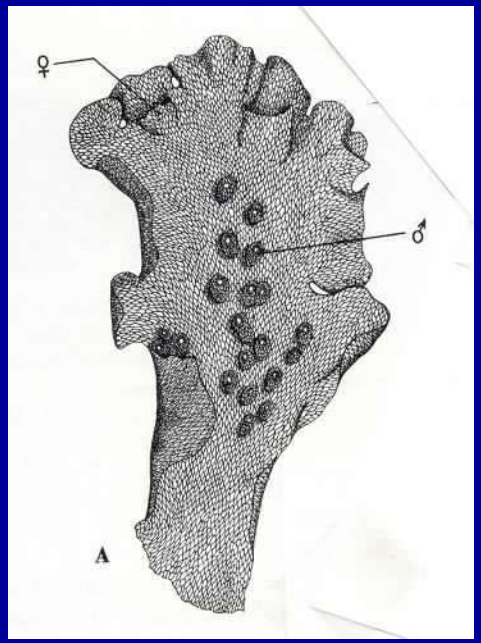


Gemmae

Longitudinal section through gemma cup

Thallose Liverworts - Order METZGERIALES

* Lack air chambers, pores, ventral scales
* Gametangia and sporophytes are sessile on the gametophyte
* Elevation of the capsule (sporangium) is accomplished by elongation of the seta (stalk) of the sporophyte
* Sporangia contain elaters



Pellia thallus from above

Antheridia are submerged in a central position, protected by a mound-like layer of cells with a pore

Archegonia occur nearer the apex under a flap-like involucre

Thallus with sporophyte

Leafy Liverworts - Order JUNGERMANNIALES

* The largest order of liverworts (7500 species)

* Dorsiventral growth habit

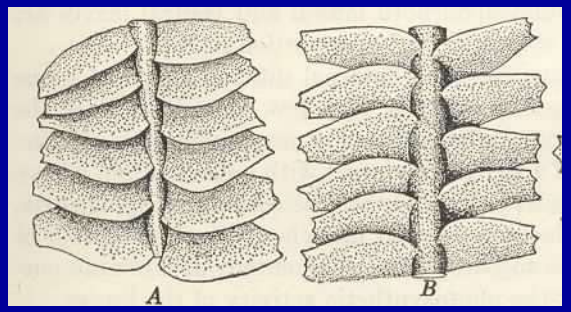
•Two rows of lateral leaves

and one row of ventral leaves (amphigastria)

* Two manners of overlap of lateral leaves - incubous or succubous (the latter being like shingles on a roof)

* Usually in conditions of high humidity

Succubous (*Plagiochila*)

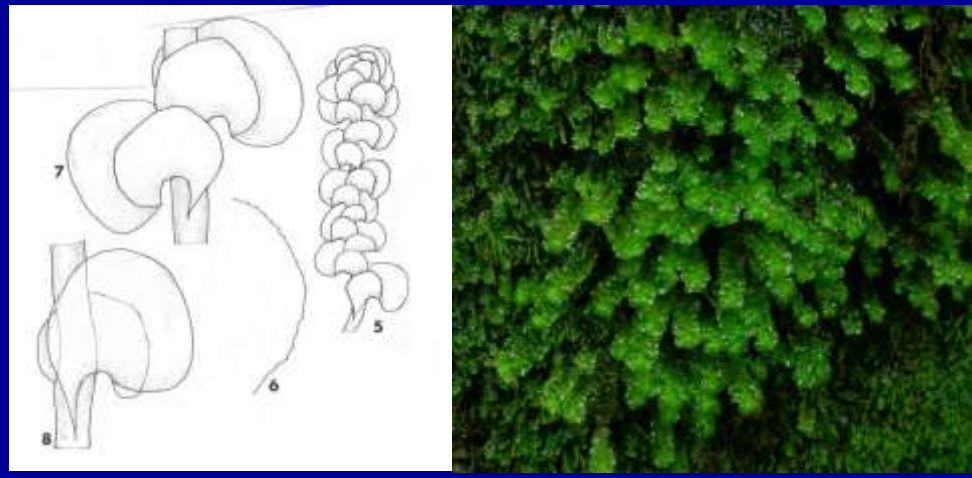


Incubous (*Bazzania*)

Leafy liverwort epiphytic on leaf of rainforest tree in Amazon basin

Underleaves, Rhizoids and Leaf Lobing

Calypogeia fissa, showing underleaves and rhizoids

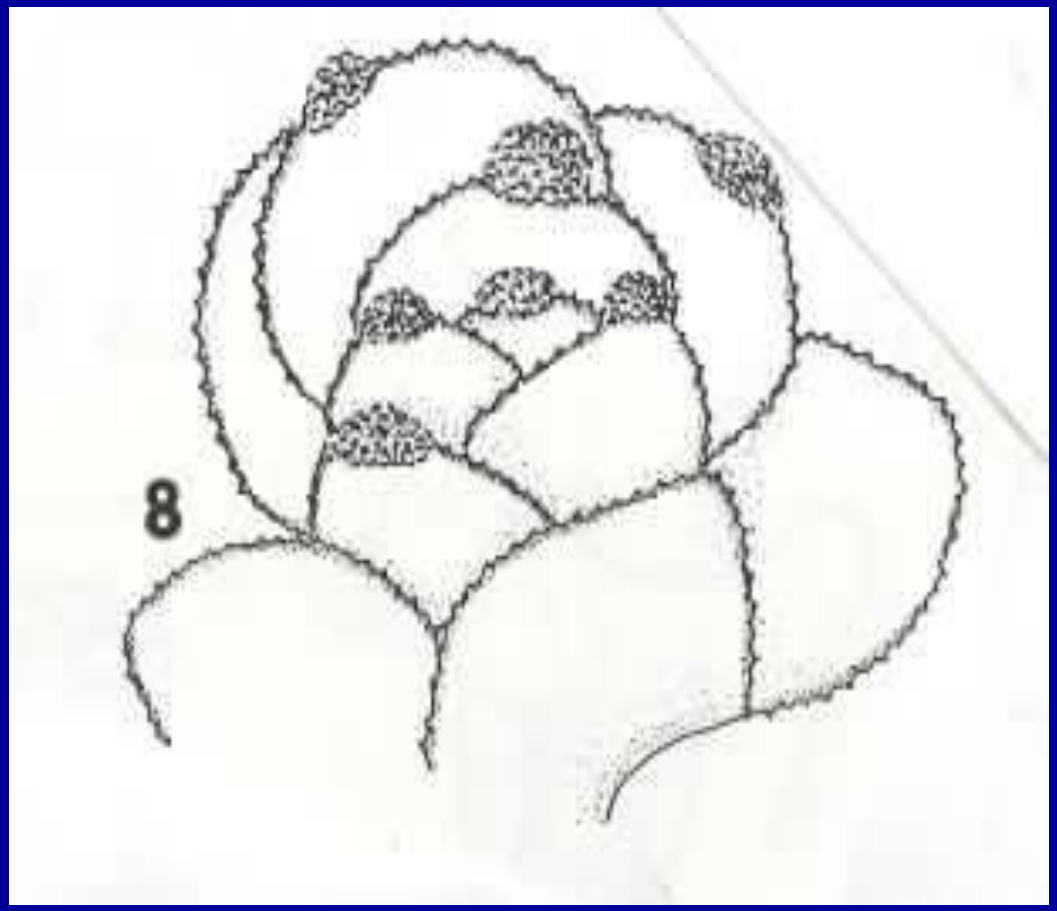


Scapania nemorea, showing bilobed dorsal leaves

Diplophyllum albicans, showing bilobed dorsal leaves

Belpharostoma trichophyllum, showing trichophyllous leaves

Asexual Reproduction in Leafy Liverworts

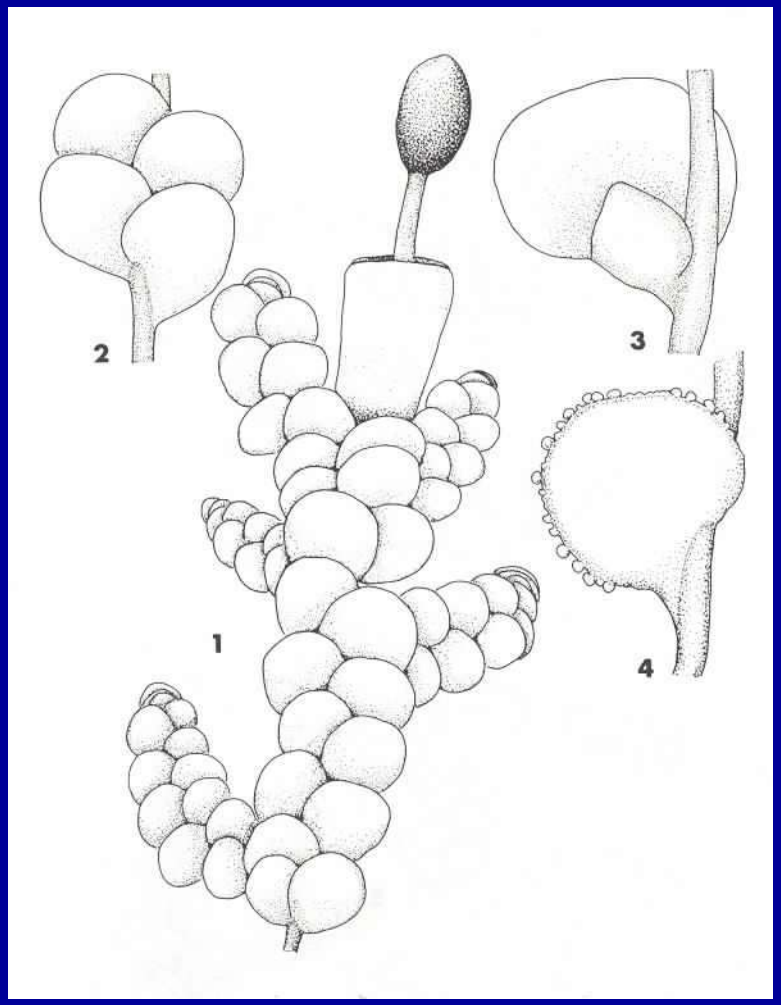


Gemmae of *Barbilophozia hatcherii*

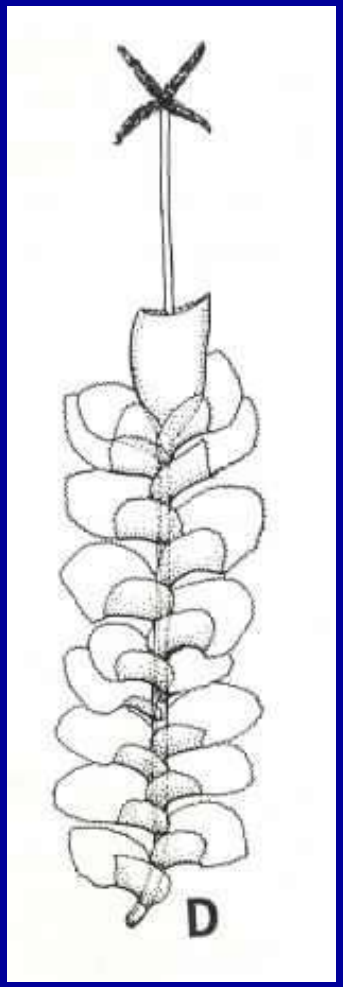
Sexual Reproduction in Leafy Liverworts

* Most leafy liverworts are dioecious
* Antheridia and archegonia are formed on short side-branches
* The seta of the sporophyte undergoes elongation at maturity
* Elaters are present in the sporangium
* Sporangium dehiscence usually occurs along four vertical rows of thin-walled cells

Sporophyte Form and Dehiscence in Leafy Liverworts



Radula, showing (1) sporophyte and (4) gemmae



Scapania, showing dehisced sporangium

Phaeoceros sp.

Anthoceros sp.

Notothylas sp.

Hornworts representatives

ANTHOCEROPHYTA - the Hornworts

Hornworts are separated from the liverworts on the basis that:

* The sporophyte is shaped like a tapered horn

* The sporophyte has an intercalary meristem, so can grow indeterminately

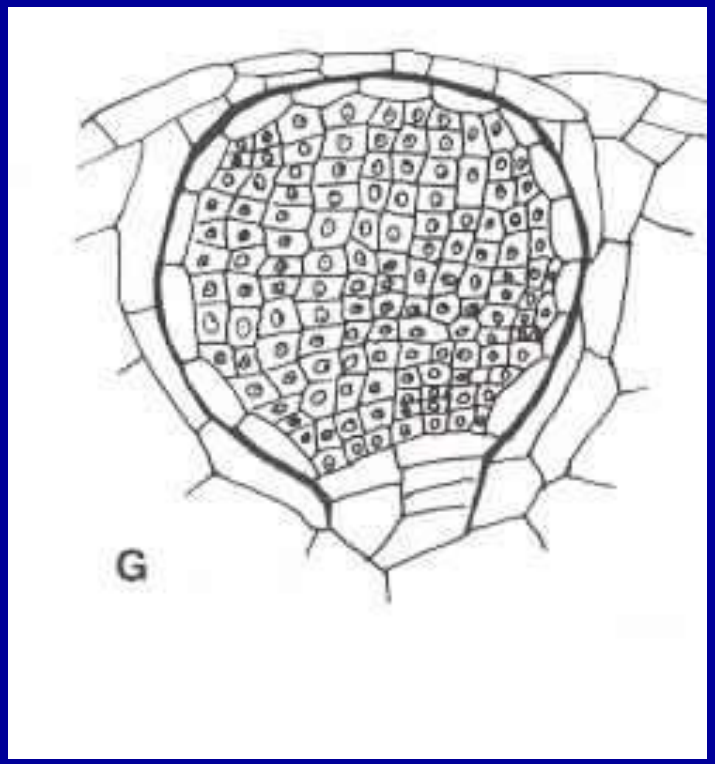
* The thallus has stoma-like structures, the only known occurrence in a gametophyte

* Each photosynthetic cell contains a single chloroplast

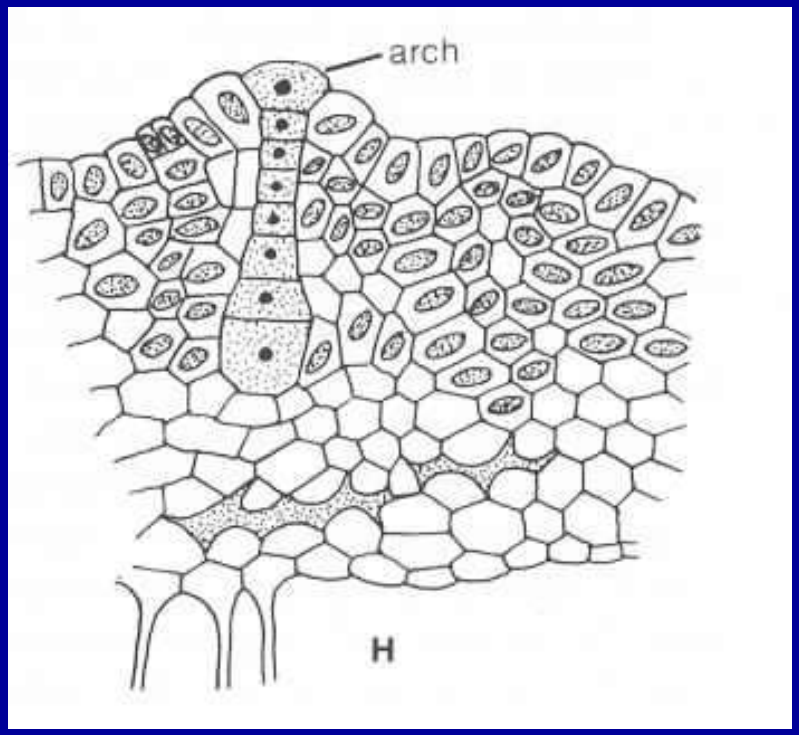
*Archegonia are embedded in the thallus and in contact with surrounding vegetative cells

* Cavities are filled with mucilage containing *Nostoc*

Sexual Reproduction in the Hornworts



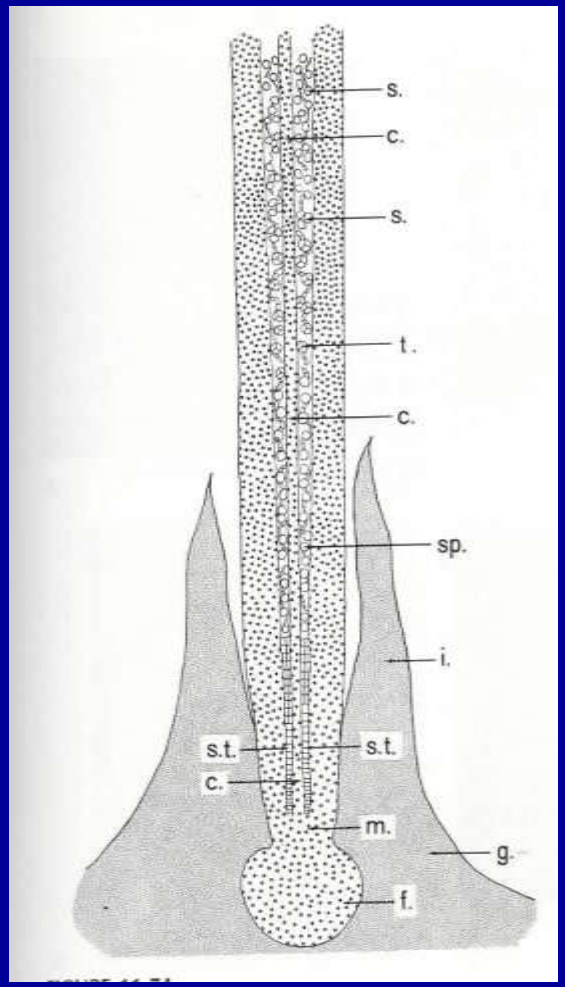
Young antheridium in antheridial chamber



Longitudinal section through archegonium. n.b. single lenticular chloroplast in each cell

The Hornwort Sporophyte

Dehiscence



Longitudinal section of sporophyte

Pseudo-elaters

s - spore

c - columella

t - tetrad

sp - sporocyte

i - involucre

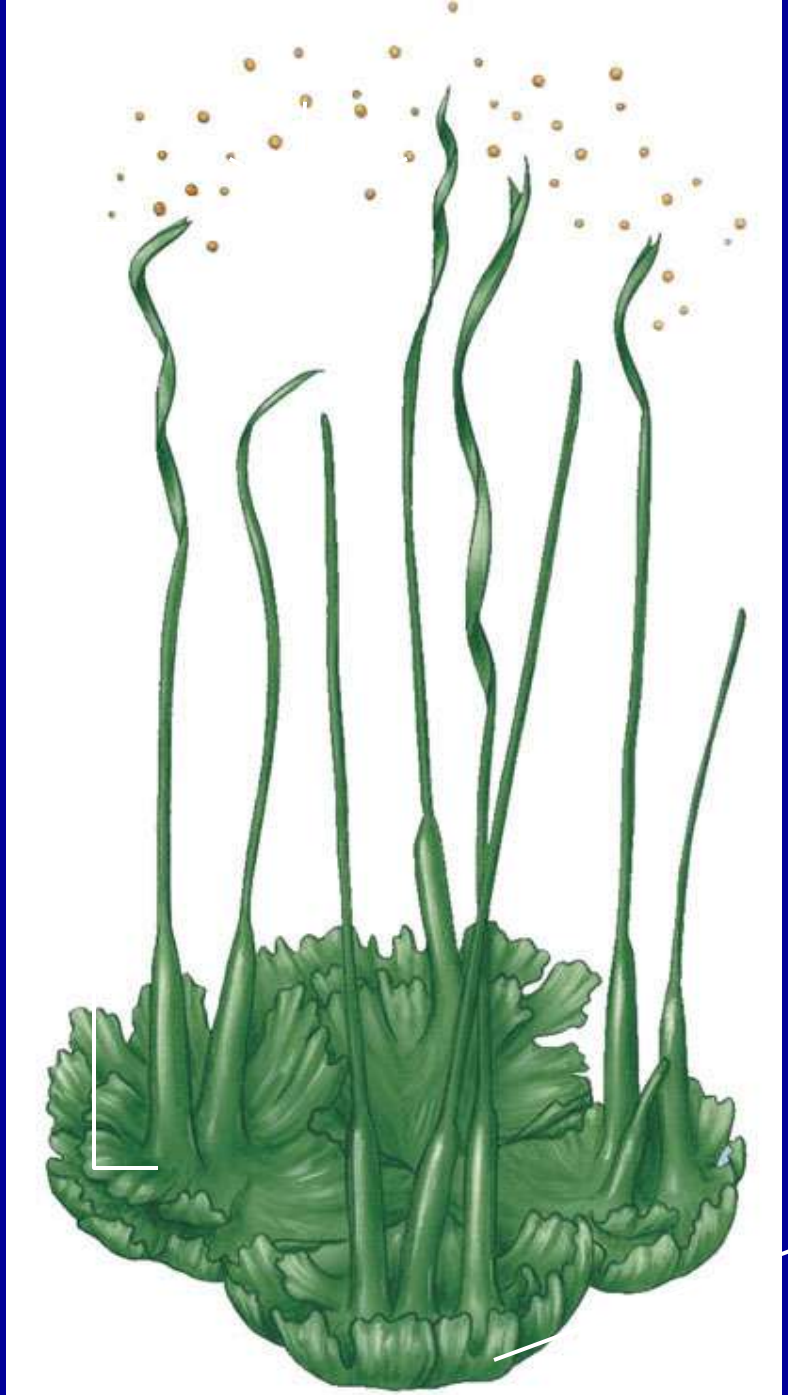
g - gametophyte

f - foot

m - meristematic zone

s.t. - sporogenous tract

Sporophyte



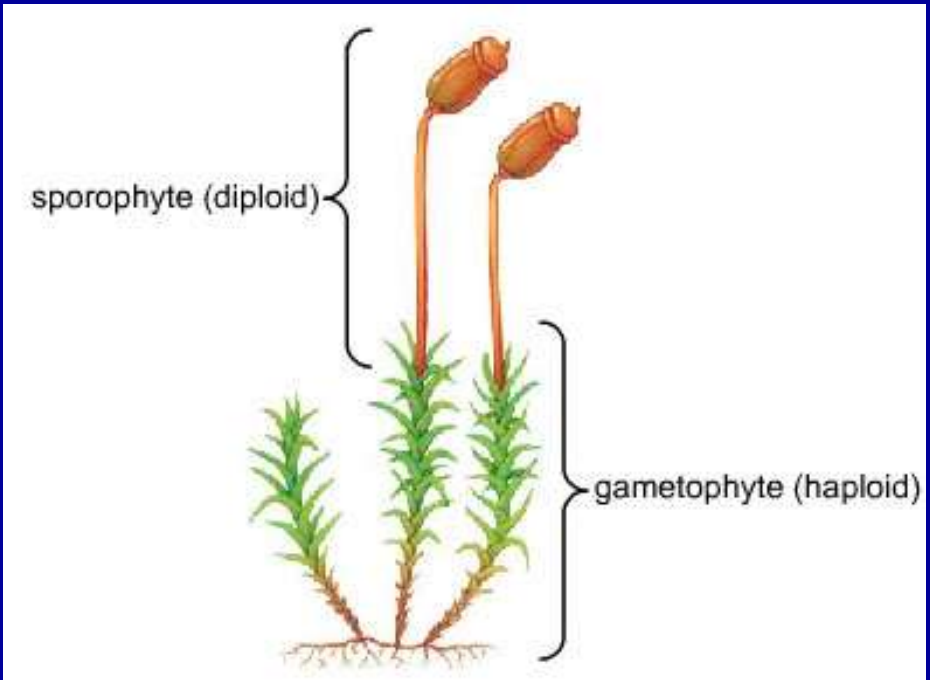
Mature sporangium splits open

Gametophyte with embedded archegonia and antheridia

Fig. 22-11b, p. 441

Mosses

- Leafy moss gametophytes develop from a **protonema**
- A moss sporophyte consists of a **capsule**, a **seta**, and a **foot**



KEY TERMS

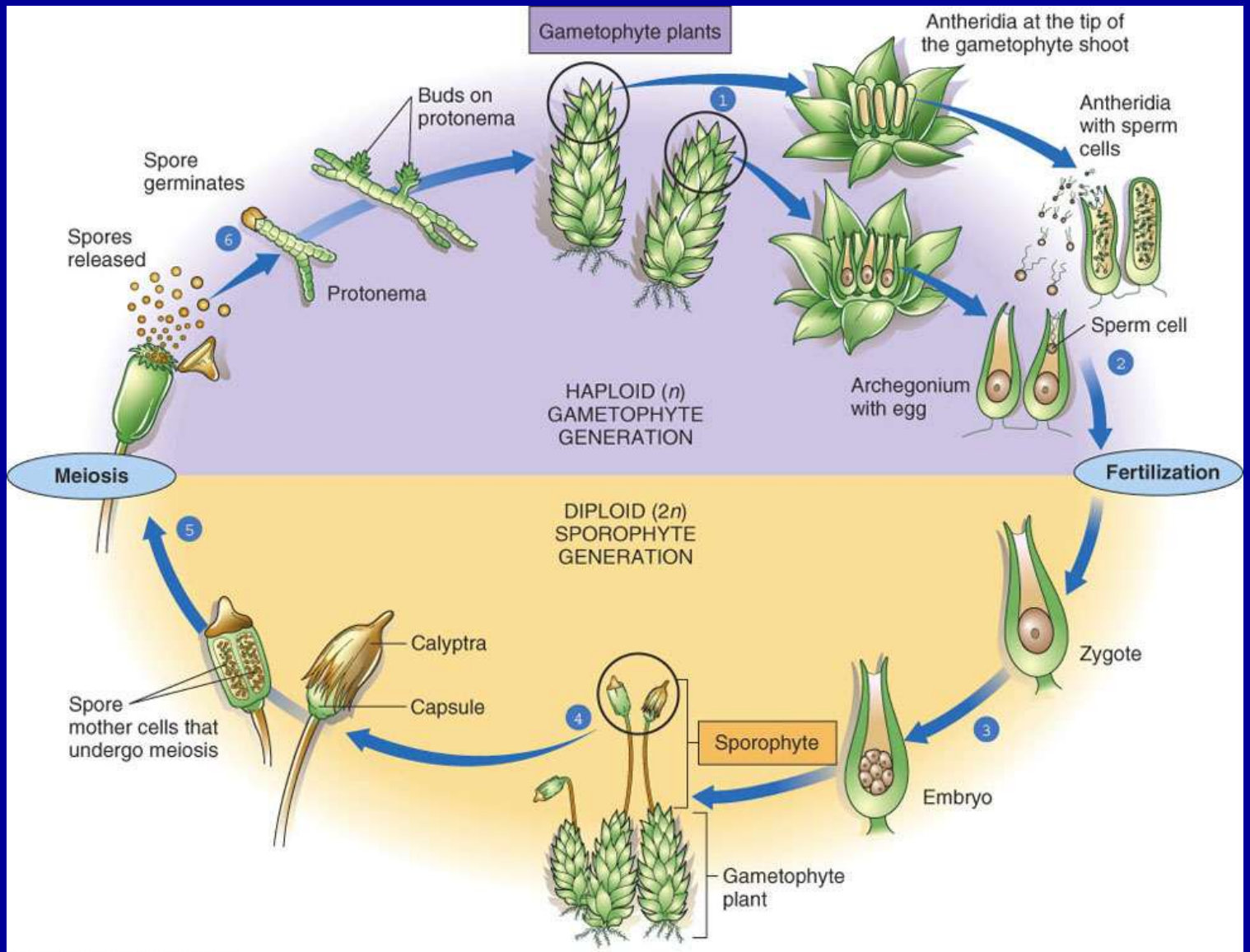
- **PROTONEMA**
  - In mosses, a filament of *n* cells that grows from a spore and develops into leafy moss gametophytes

- **CAPSULE**
  - Portion of the bryophyte sporophyte in which spores are produced

Mosses

(b) A close-up of moss gametophytes. Mosses grow in dense clusters.

Life Cycle: Mosses

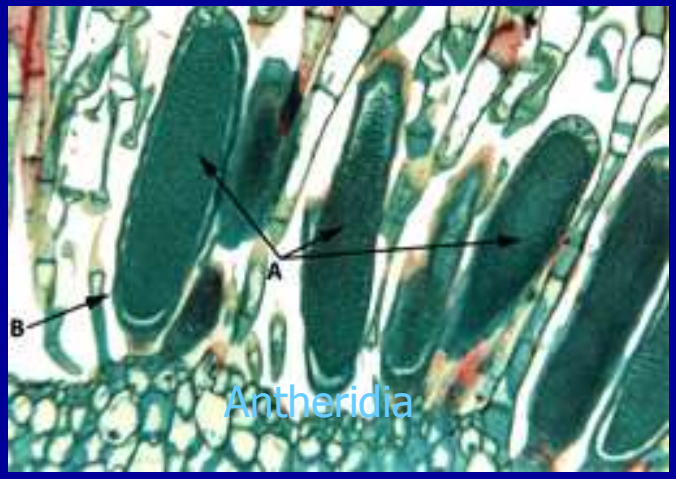


Characteristics

- Chlorophyll a, Starch, Cellulose
- No lignin
- Usually no conductive tissue, sometimes poorly developed tissue
- Gametophyte dominant, perennial
- Sporophyte parasitic on gametophyte
- NEED MOIST ENVIRONMENT, when active

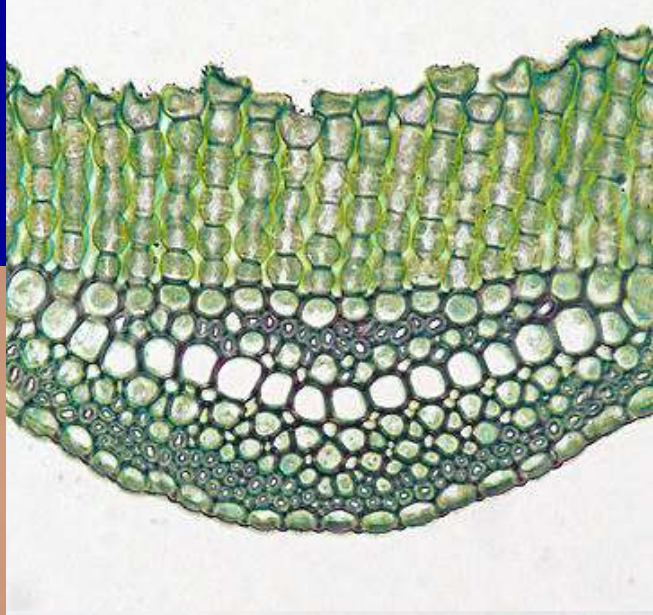
Sex!

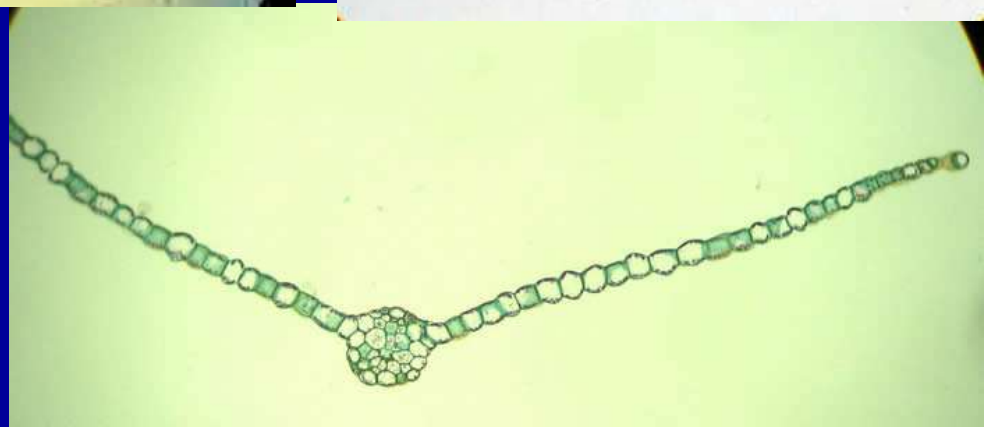
- Sperm swim from antheridia into archegonia and fertilize egg
- Sporophyte grows out of archegonium



Moss gametophytes

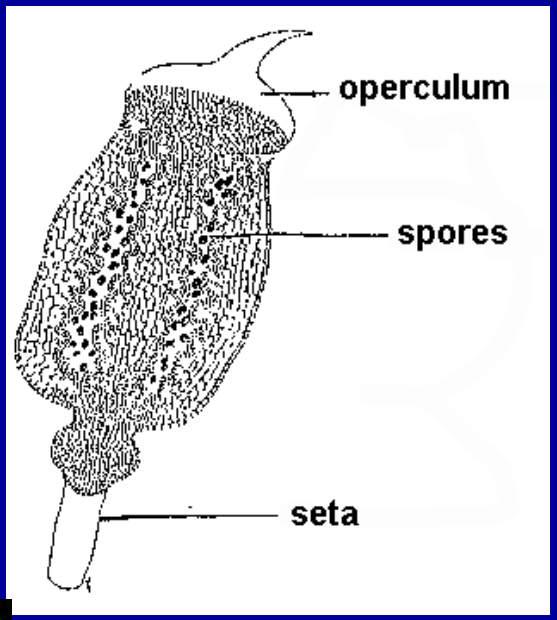
- Rhizoids, Cauloids, Phylloids
- Leaves 3-ranked
- Leaves not lobed, mostly 1 cell thick
- Leaves often with costa





Moss Sporophyte

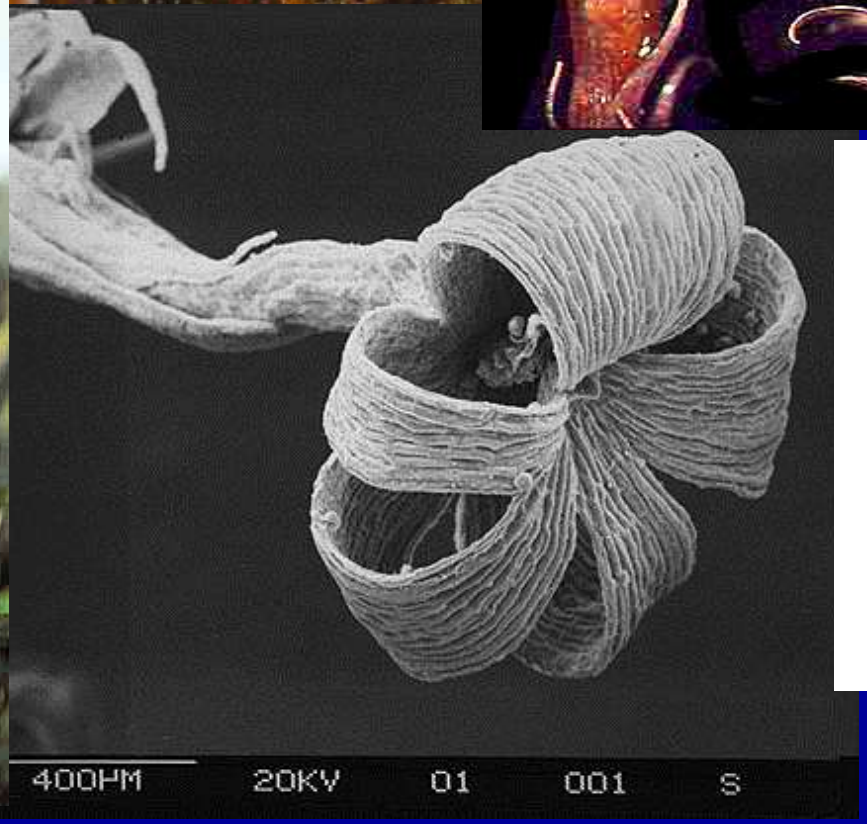
- Persistent
- Seta + capsule
- Capsule has:
  - Sporangium
  - Peristome teeth
  - Operculum
- Covered by calyptra
  - Calyptra = Top of archegonium

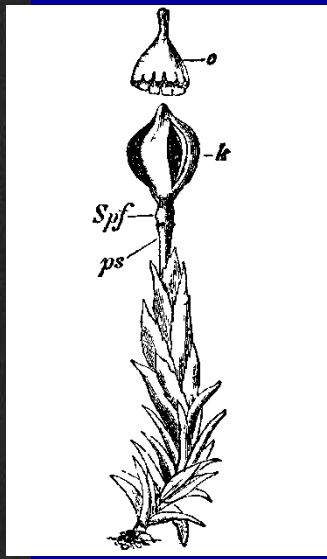




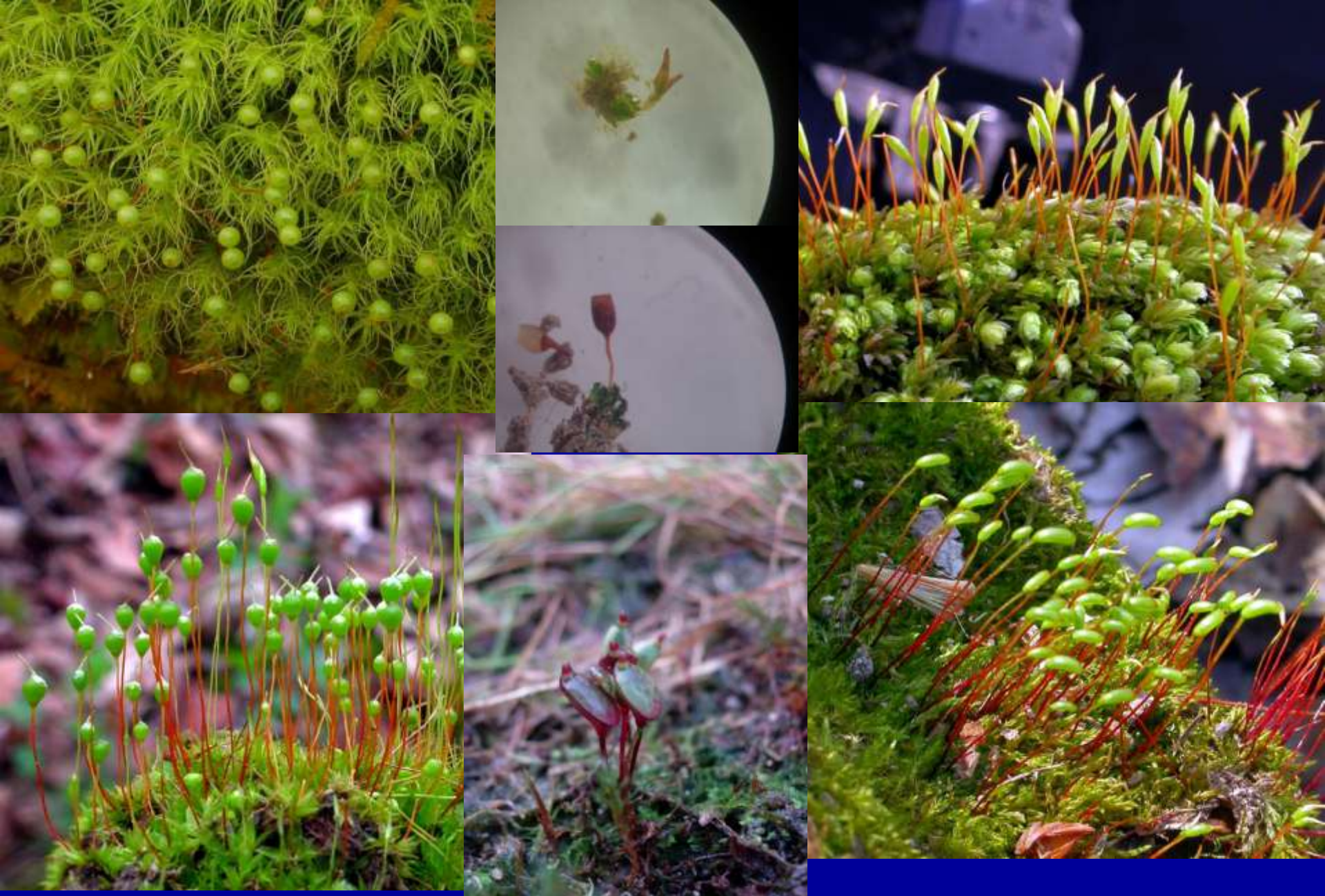

Peat mosses

Haircup mosses



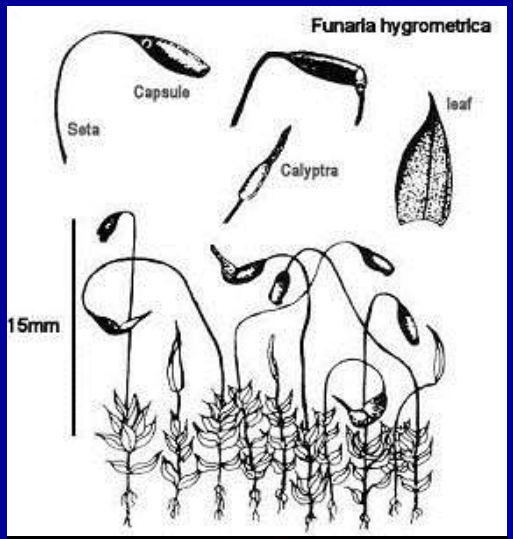


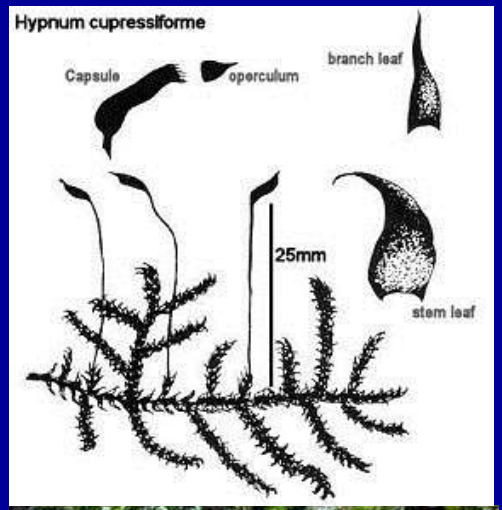
Latern mosses

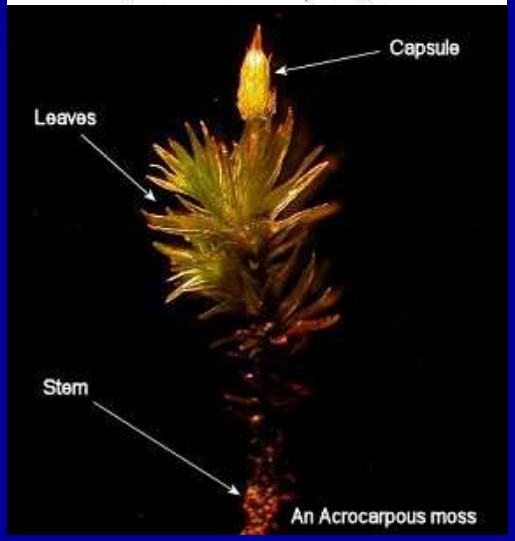


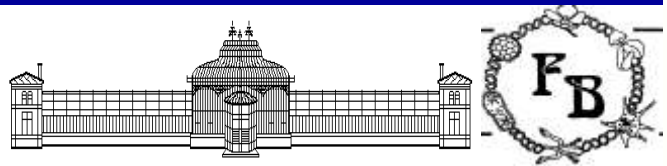
Genuine mosses

Acrocarpous vs. pleurocarpous mosses







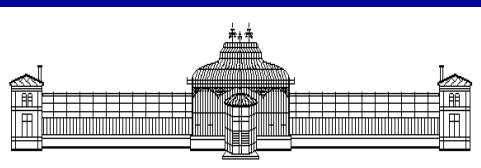


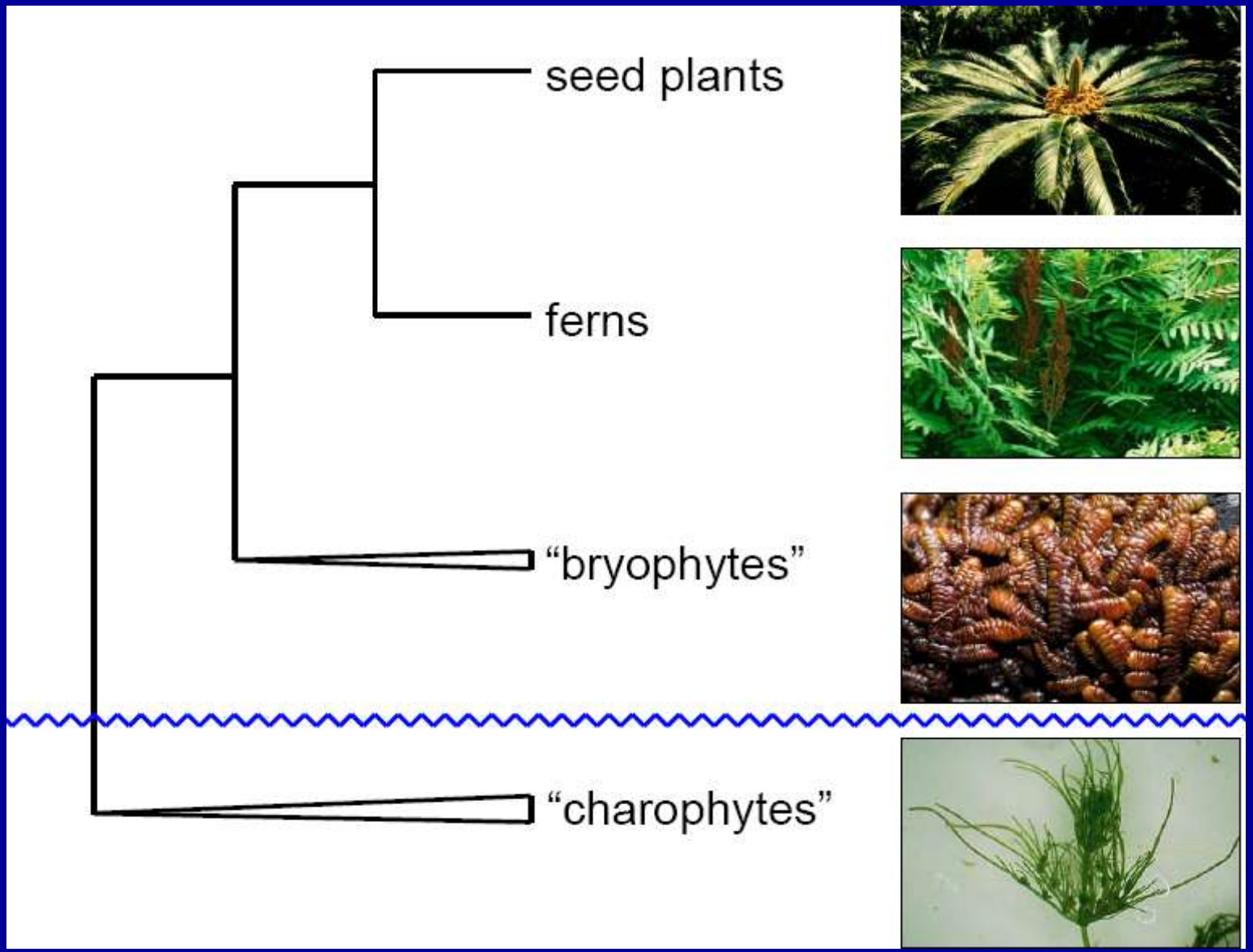
While the moss sporophyte does have photosynthetic plastids, they cannot live apart from the maternal gametophyte.

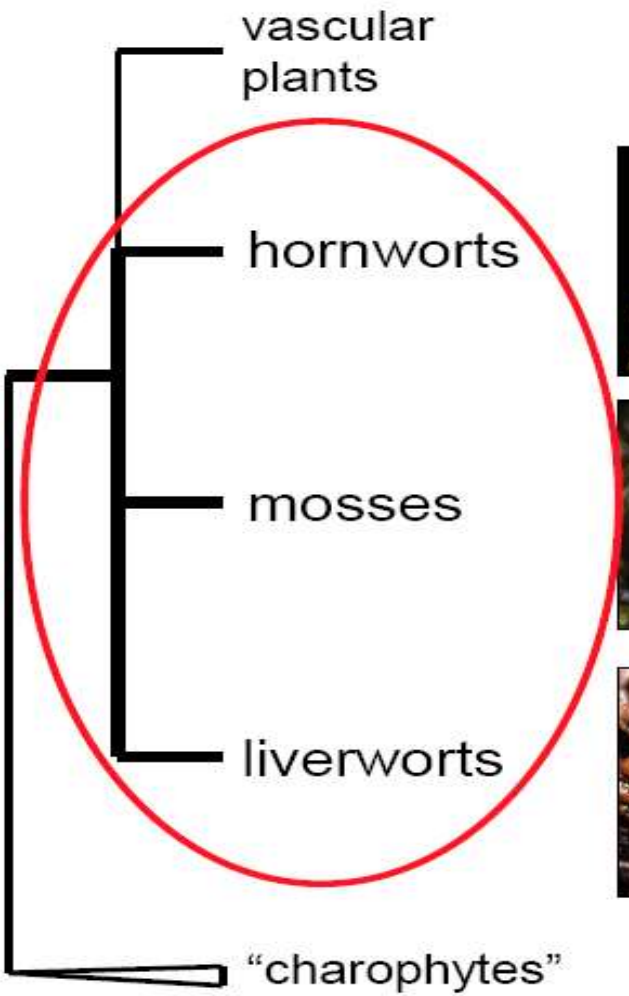
A moss sporophyte remains attached to its parental gametophyte throughout the sporophyte's lifetime.

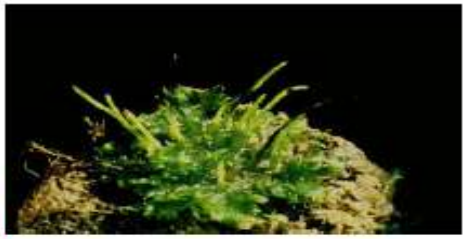
It depends on the gametophyte for sugars, amino acids, minerals and water.

Bryophytes have the smallest and simplest sporophytes of all modern plant groups.






vascular plants
hornworts
mosses
liverworts
“charophytes”



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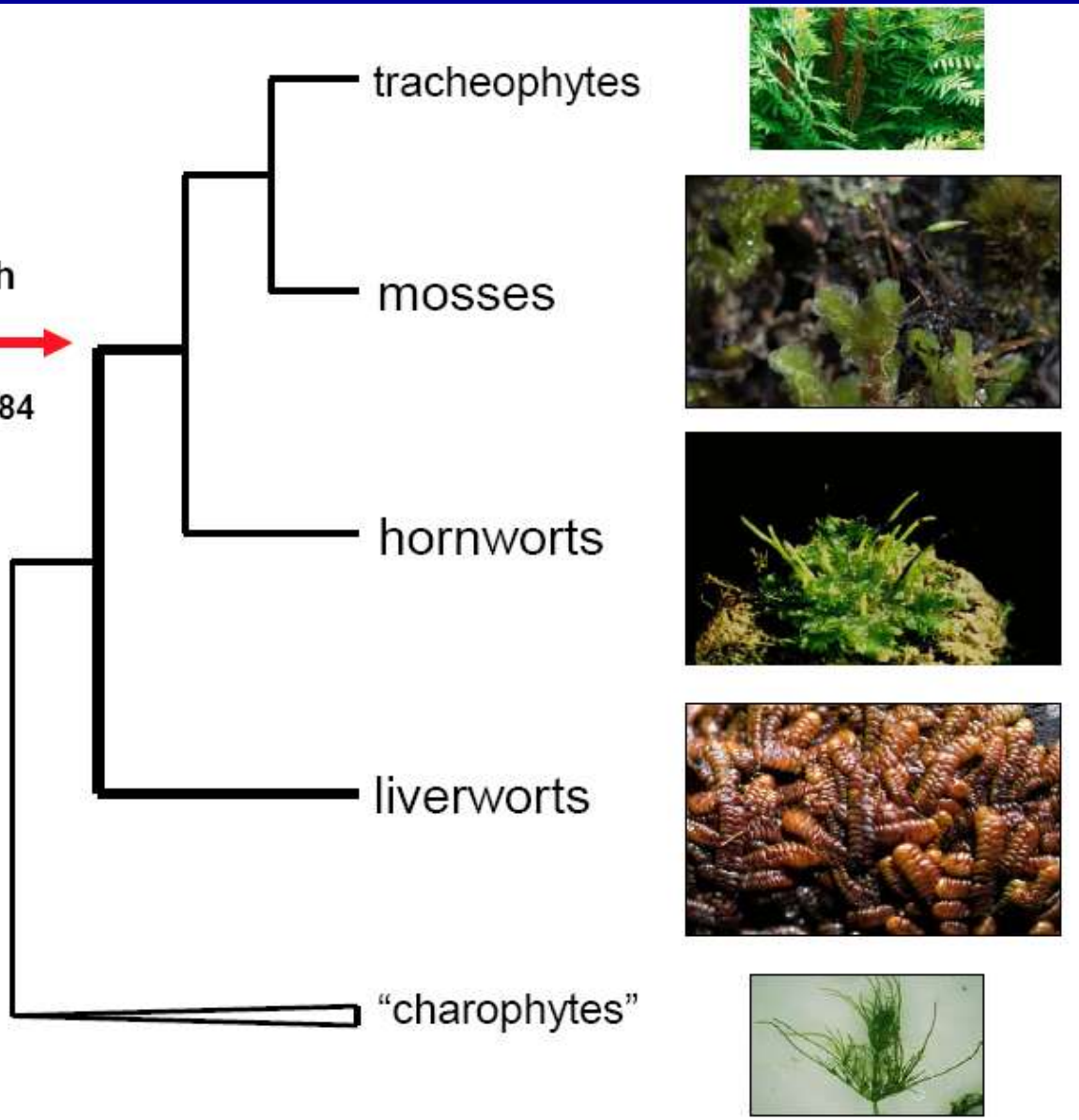
- stomata
- ability to distinguish D-methionine

Mishler & Churchill 1984
Bremer 1985
Kenrick & Crane 1991



vascular plants

hornworts

mosses

liverworts

“charophytes”

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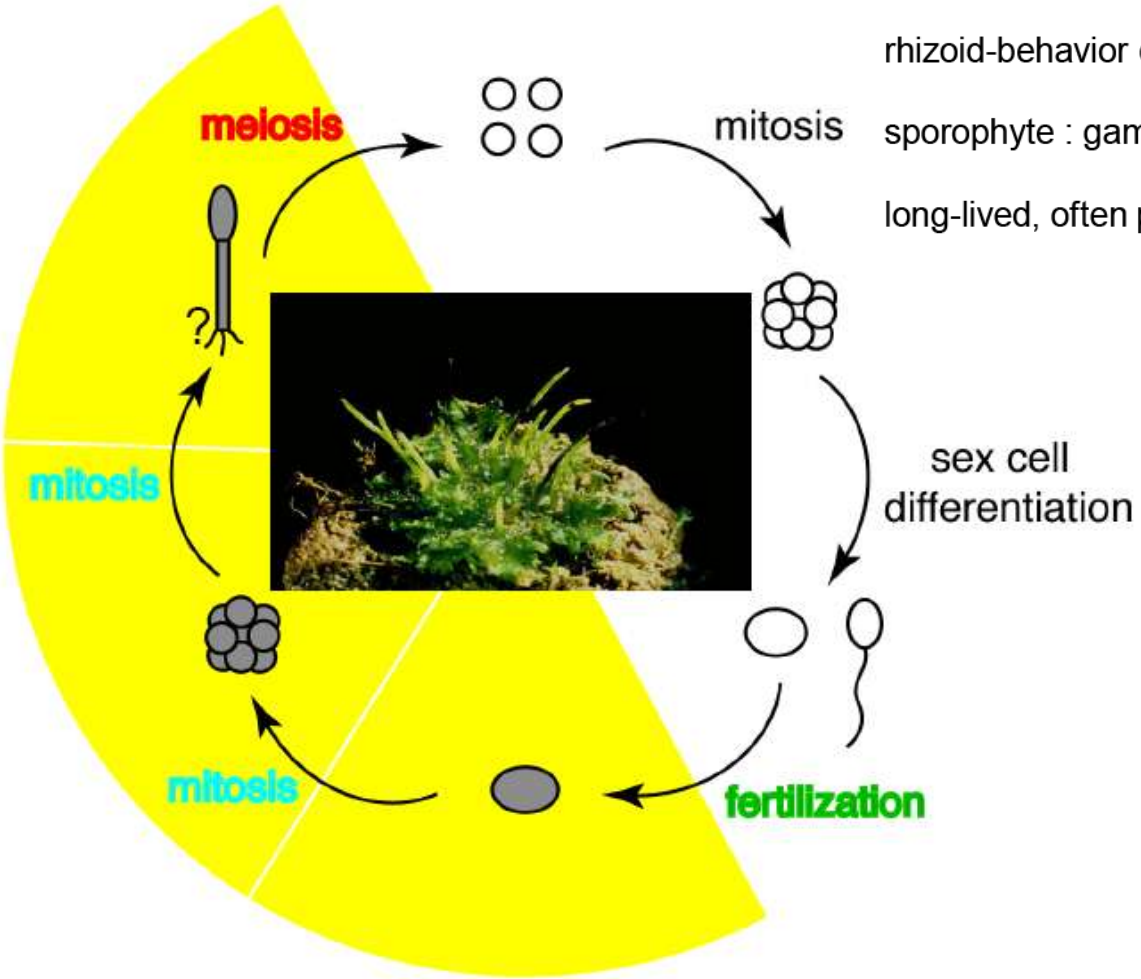
the sporophyte of hornworts on the way to be a free-living generation in the life-cycle?

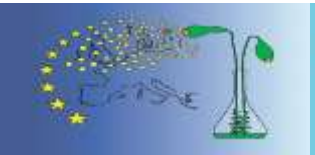
persistently chlorophyllous, nutritionally largely independent to the gametophyte

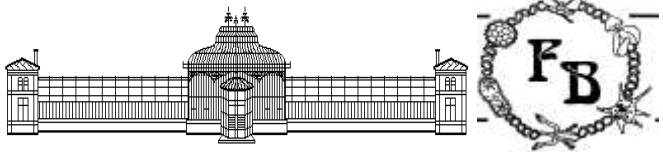
rhizoid-behavior of the foot

sporophyte : gametophyte = 1:1

long-lived, often persists for weeks and months







Anthoceros fusiformis, California

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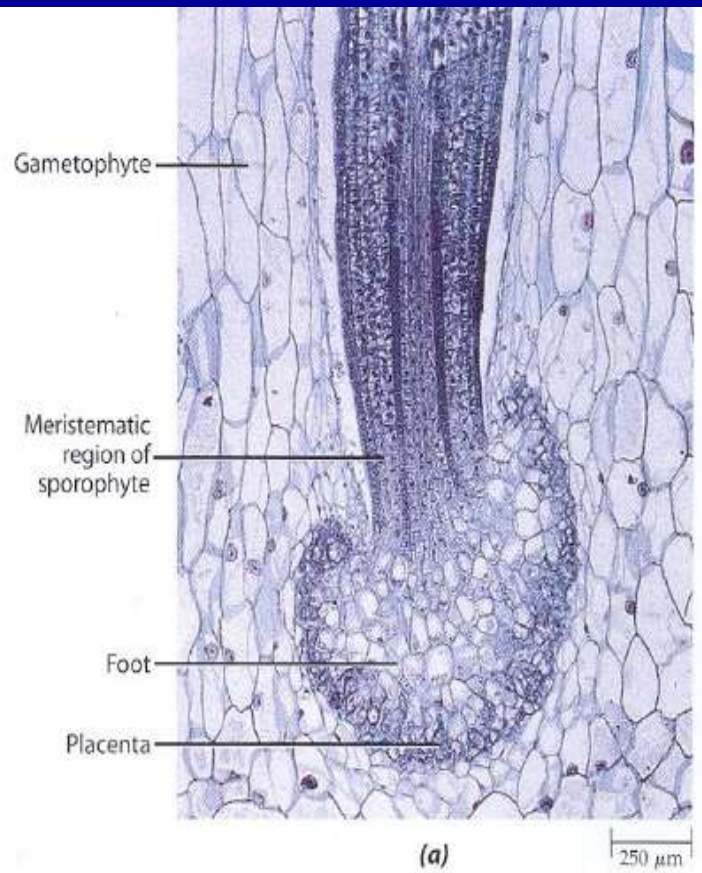

16–19 Anthoceros ***(a)*** *Longitudinal section of the lower portion of a sporophyte, showing its foot embedded in the tissue of the gametophyte.* ***(b)*** *Longitudinal section of a portion of a sporangium,*

Anthoceros fusiformis

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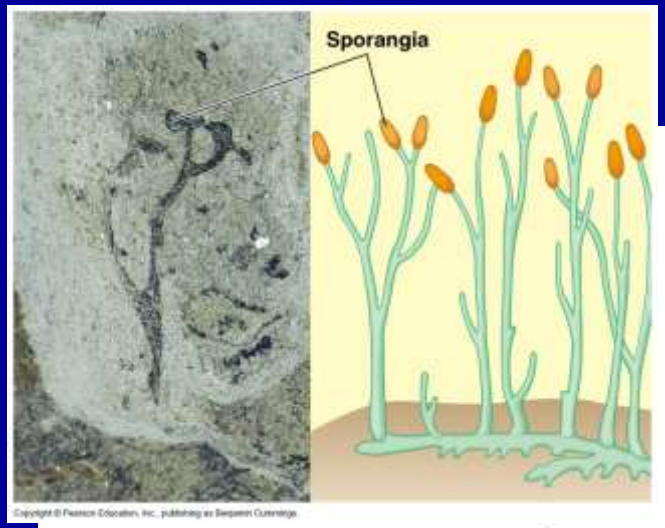

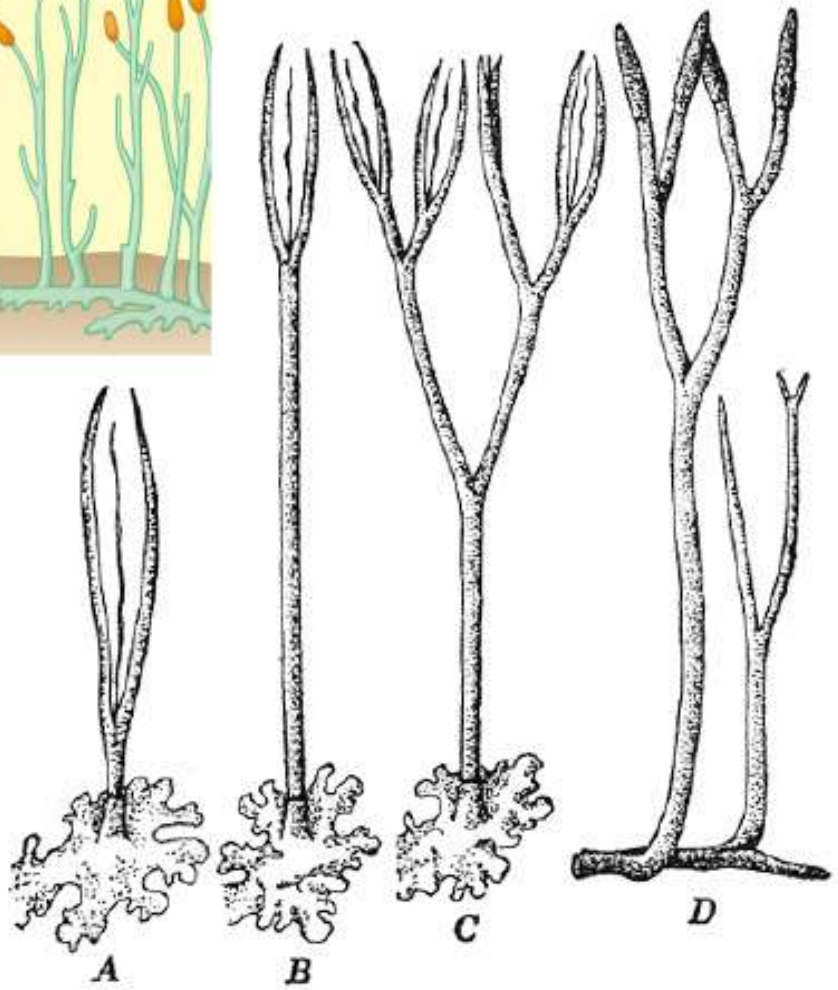

FIG. 82. Diagrams showing hypothetical sequence in the evolution of a semiparasitic anthocerotean type of sporophyte into a free-living psilophytan type of sporophyte.

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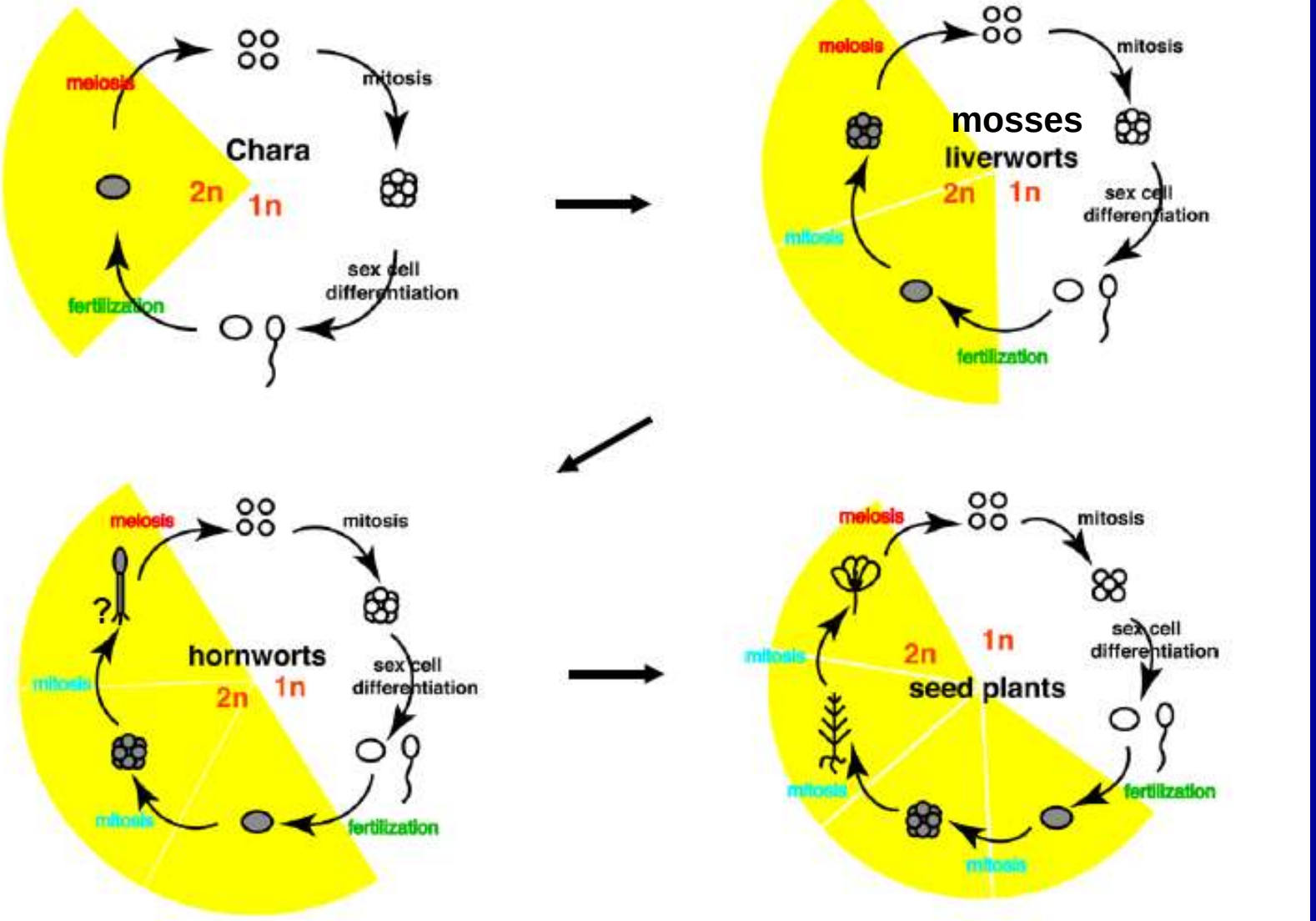

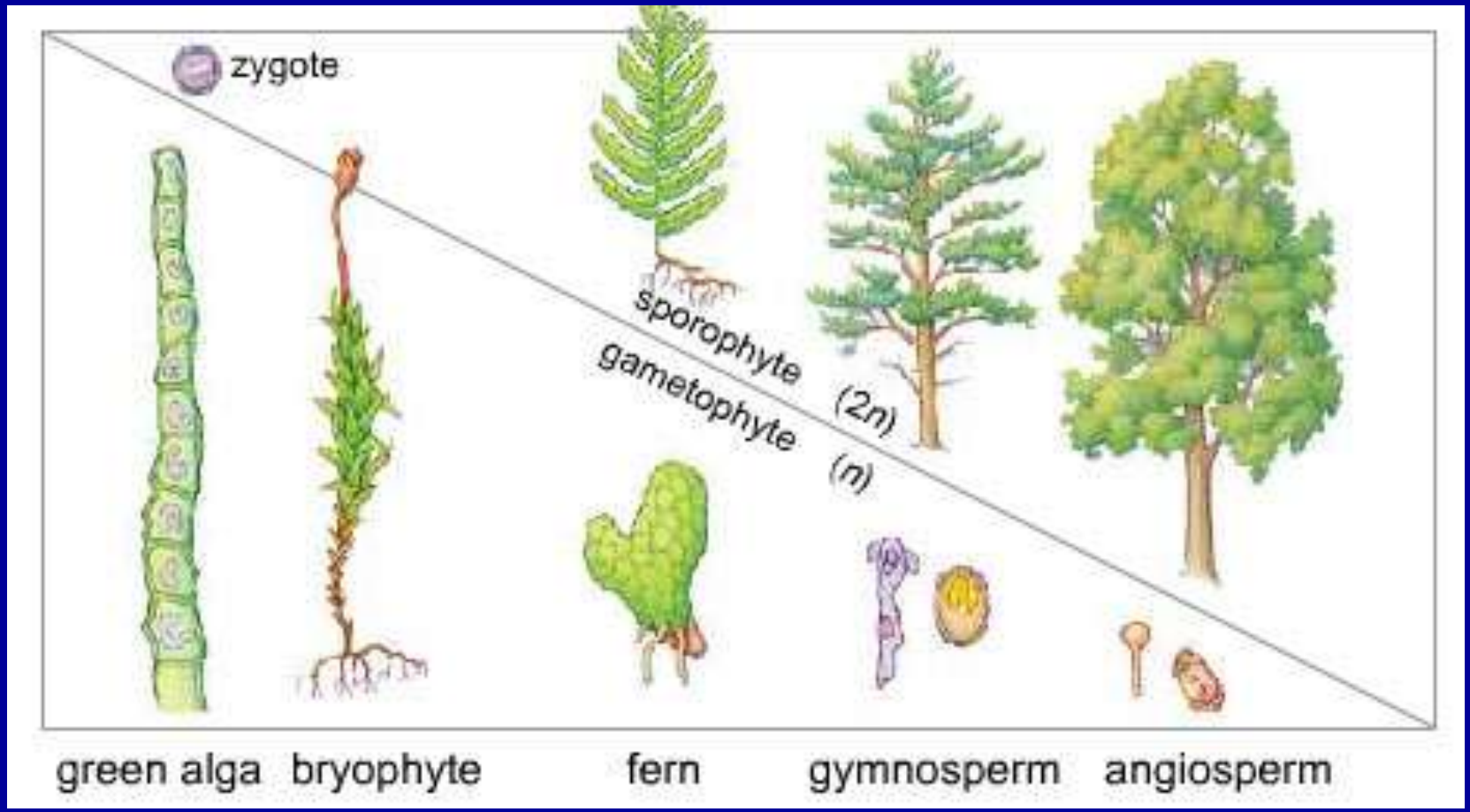

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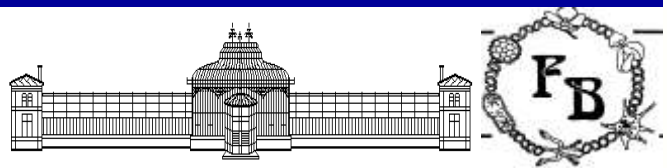
Why this life cycle evolutionary trend in land plants?

two advantages for carrying out photosynthesis on land (in comparison to in water)

- *CO2*
- light

major challenges plants face on land

- lack of water hindering sperm locomotion
- UV
- others ……



Bryophytes provide many ecological and economic benefits

- Wind dispersal of lightweight spores has distributed bryophytes around the world.
- They are common and diverse in moist forests and wetlands.
- Some even inhabit extreme environments like mountaintops, sea-shores and deserts.
  - Mosses can loose most of their body water and then rehydrate and reactivate their cells when moisture again becomes available.

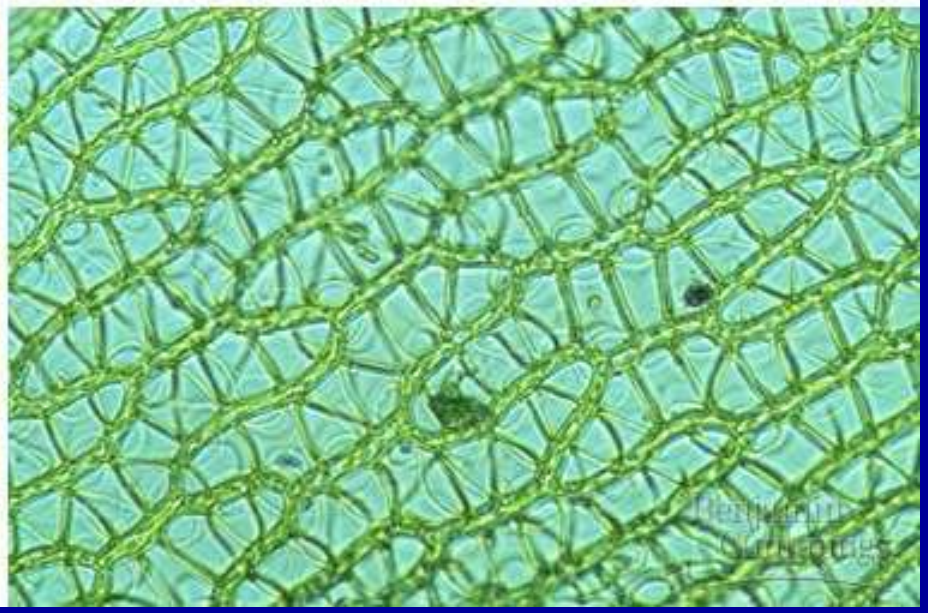
Ecological and economic benefits of bryophytes

1. Bryophytes were the world's only plants for 100 million years.

2. Peat bogs are made mostly of moss called *Sphagnum*. They contain 400 billion tons of carbon and cut down the amount of greenhouse gases. Peat is harvested, dried, and used as a fuel.

3. *Sphagnum* is harvested for use as a soil conditioner and plant packing material.

Sphagnum, or peat moss

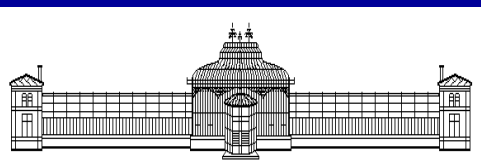


Bryophyte features

one set of chromosomes dictates its appearance and function

it means

small changes in the environment can be epigenetically easily expressed

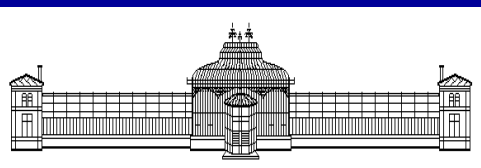


- poikilohydric

Syntrichia ruralis

- ectohydric/endohydric

Bryophytes
are used in biotechnological processes in quite a few cases but they have a huge potentials



Bryophyte potentials:

- new chemical compunds

- biological activity

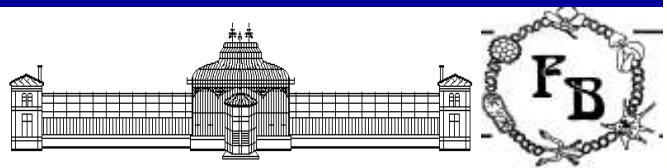
- fitoterapy

- AIDS and cancer?

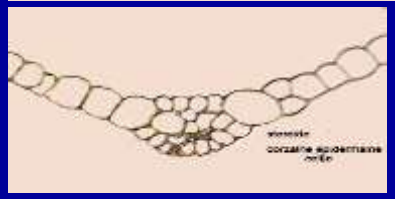
- bioindicators, microdust reduction (static electricity)

- ecosystem restauration, improvement and restauration of human environment

- Biopesticides, -insecticids, moluscicids, biorapelents...

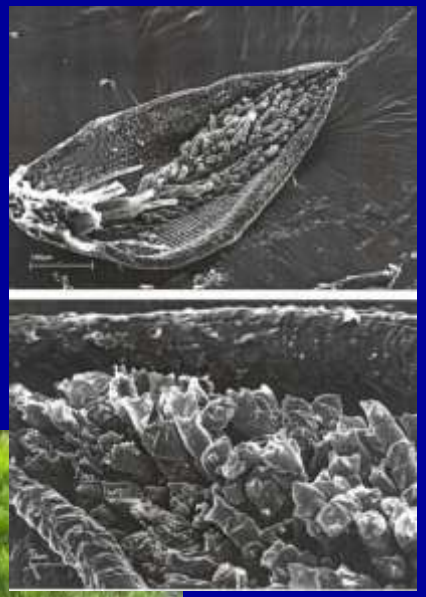


Disadvantages:



- not enough monotypic axenic materials
- *in vitro* establishment
- low level of knowledge on bryophyte biology
- endobionts

…



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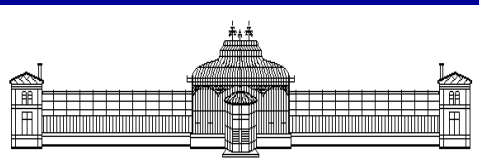

Monoculture?

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Advantages I:

- small plants, easy to manipulate (money, space)

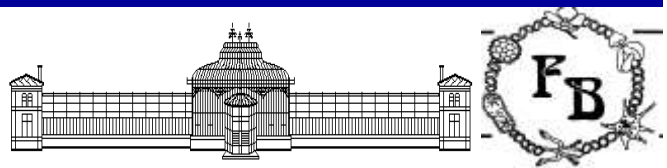
- dominant haploid phases (high ratio of homologous recombination)

- Single gene knockout (gene function not covered by counterpart allele)

- Gene targeting (mosses integrate transformed DNA with high frequency due to high level of hom. recombination)

- Complete genome sequenced (*Physcomitrella patens*), partly (*Marchantia polymorpha*)

- genetic pool – for the crop plant modification (stress support)



Advantages II:

- Molecular farming and metaboloc engineering

- cure, medicines, and pharmaceutical products naturally sintetized in plants (moss bioreactors)

- cryoconservation

-small size of plants (easier control of potential GMO runaway)

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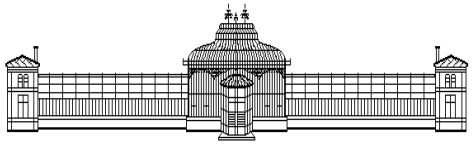
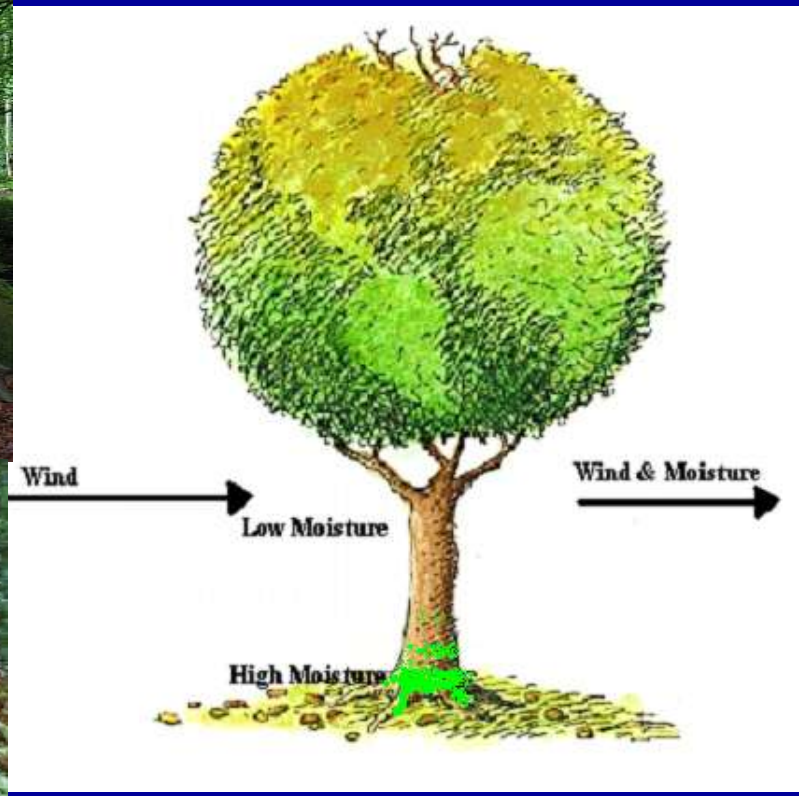
Bryopyte Ecology

- all world ecosystems except seas
- the hugest biomass in tundras and rain forests
- microhabitats





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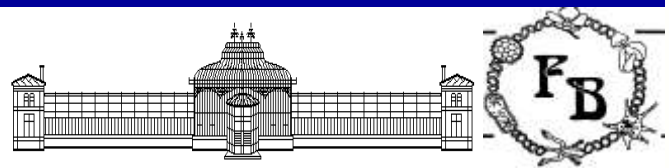
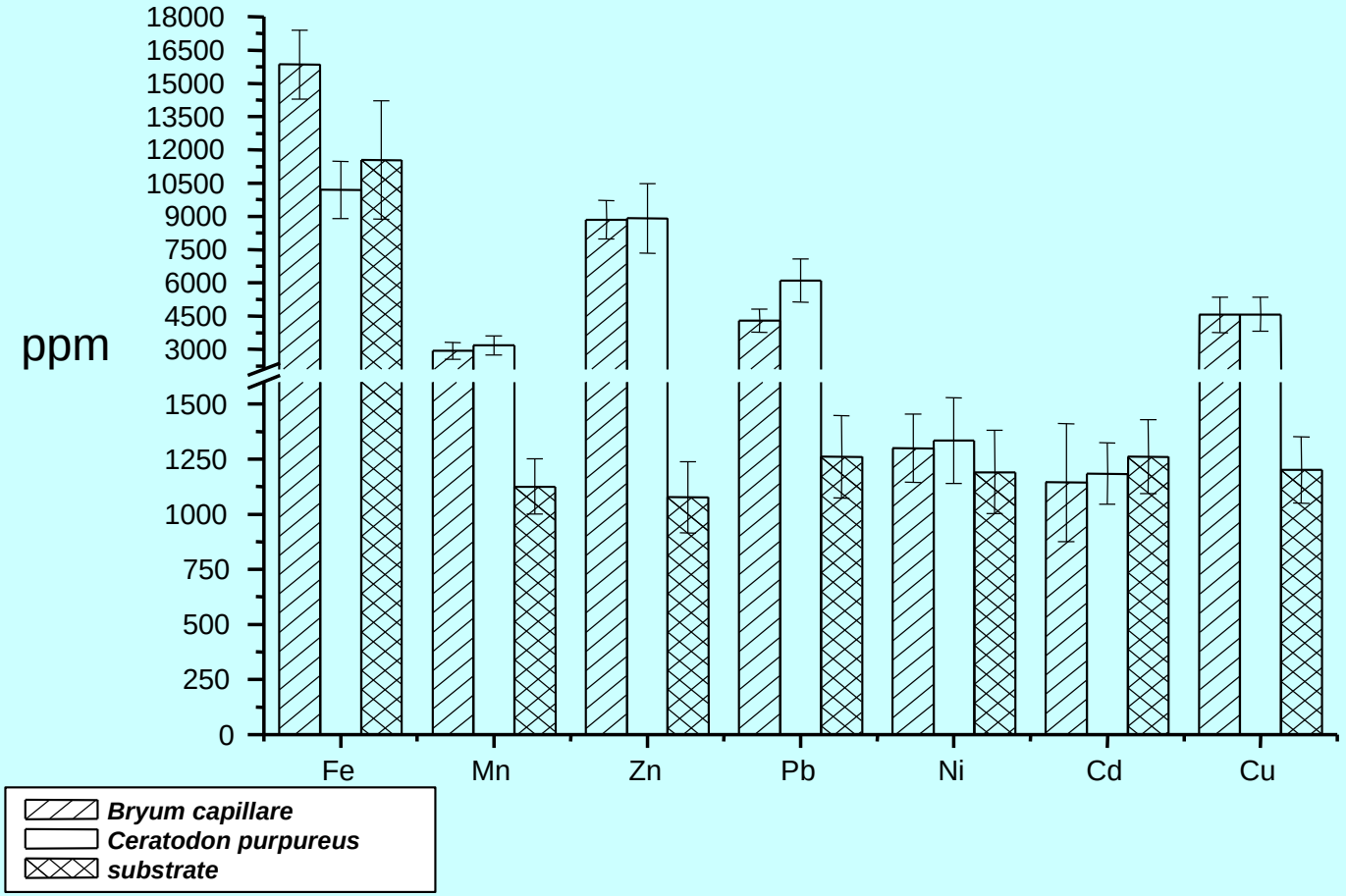
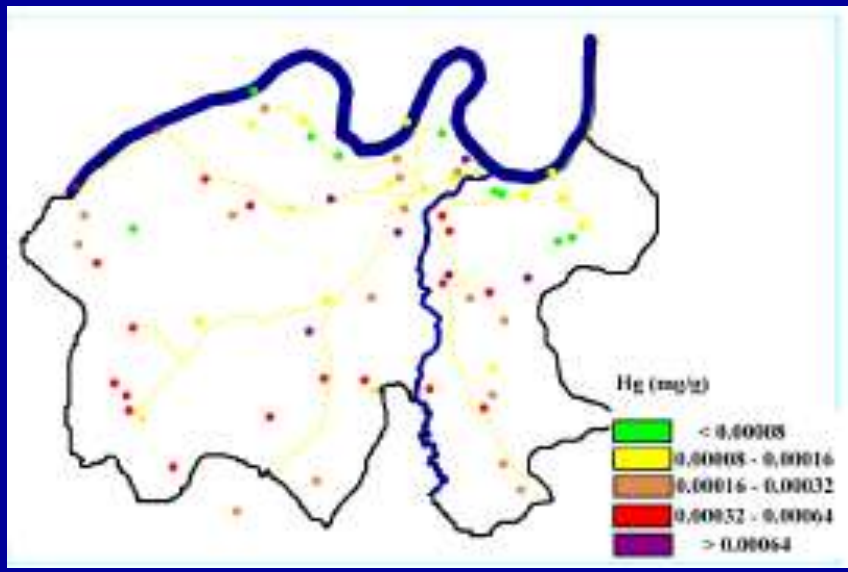
Moss Cation Exchange Capacity

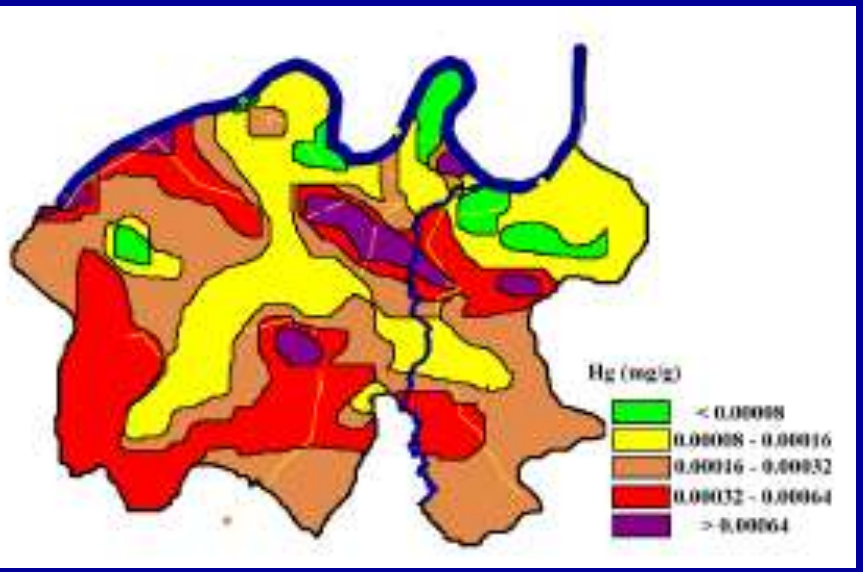
- a fenomena in mosses
- high degree to which a moss can adsorb and exchange cations





Heavy metal content in mosses and in substrate (ppm).


Hg (mg/g)
< 0.00008
0.00008 - 0.00016
0.00016 - 0.00032
0.00032 - 0.00064
> 0.00064


Hg (mg/g)
< 0.00008
0.00008 - 0.00016
0.00016 - 0.00032
0.00032 - 0.00064
> 0.00064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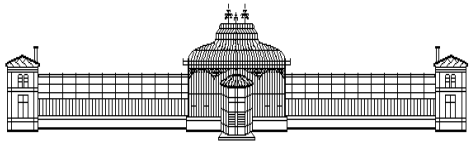


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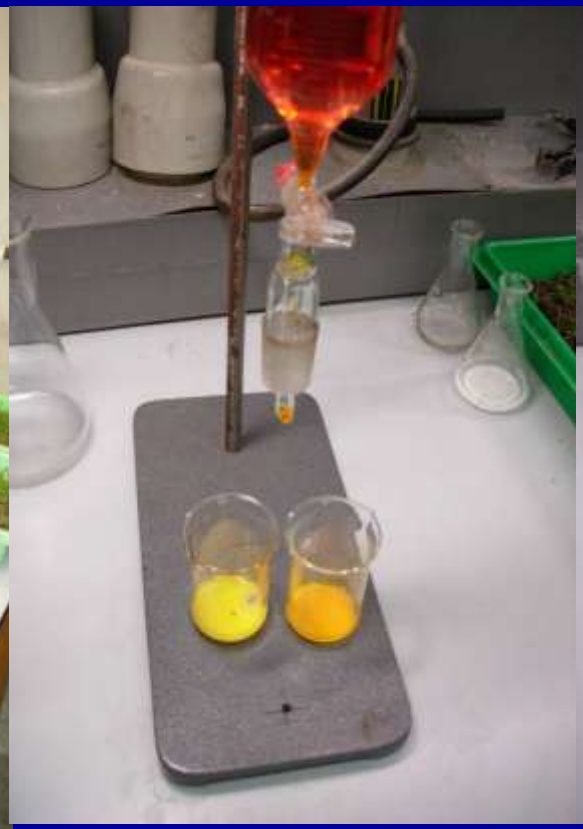

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$PbCl_2 + 2\,KCr_2O_7 \rightarrow 2\,KCl + PbCr_2O_7\downarrow$ (green-yellow soot)

$BaCl_2 + 2\,KCr_2O_7 \rightarrow 2\,KCl + BaCr_2O_7\downarrow$ (orange-yellow soot)

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FB

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Indication


Lady in red


FreeFoto.com


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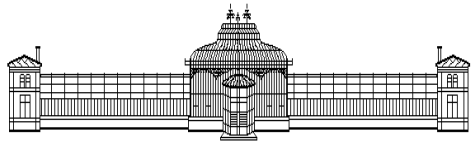


FB


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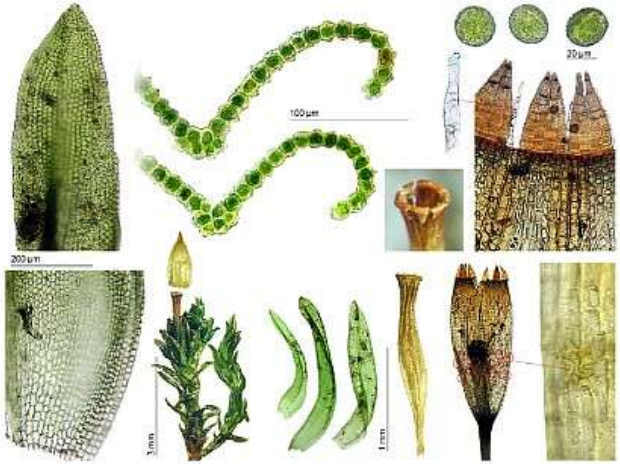
Orthotrichum rogeri Brid.

Freiburg, Schauinsland



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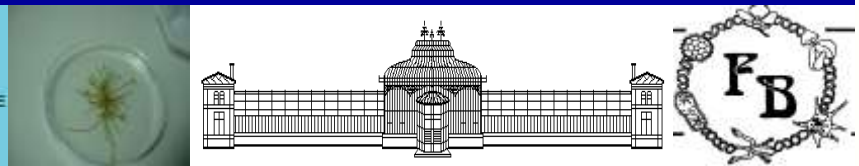

Indicators – lead moss
Ditrichum plumbicola

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Indicators – Copper moss

Entosthodon hungaricus salinity indicator

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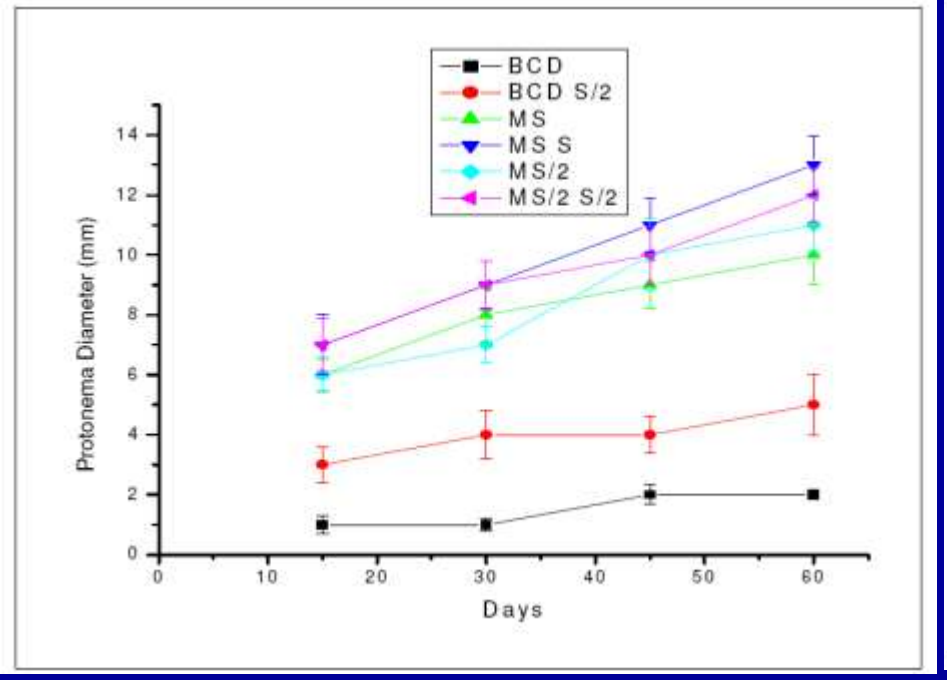
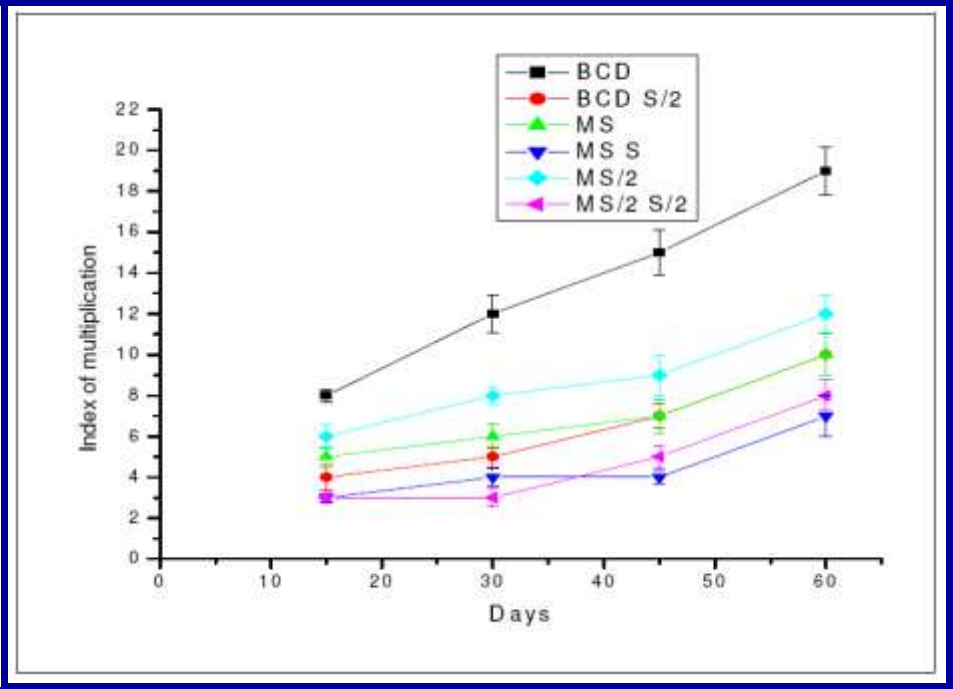
Entosthodon hungaricus





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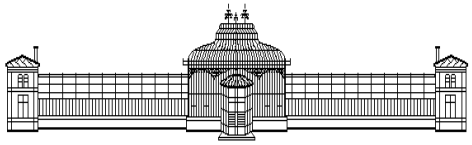

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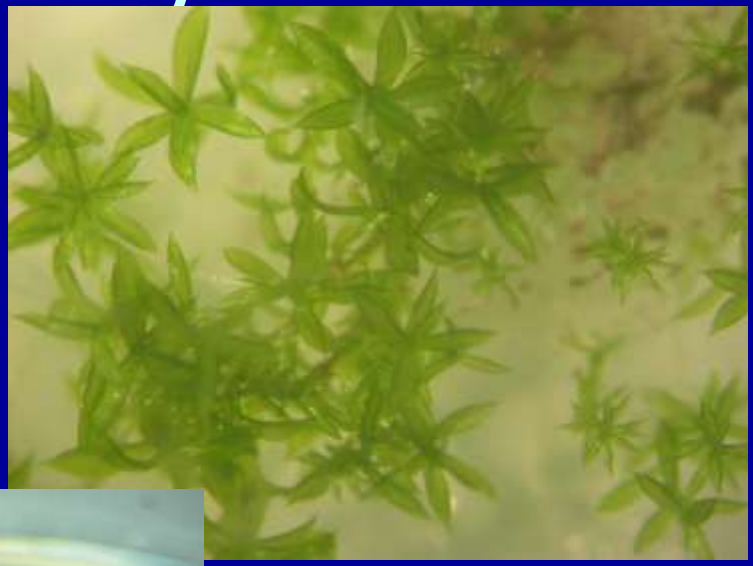
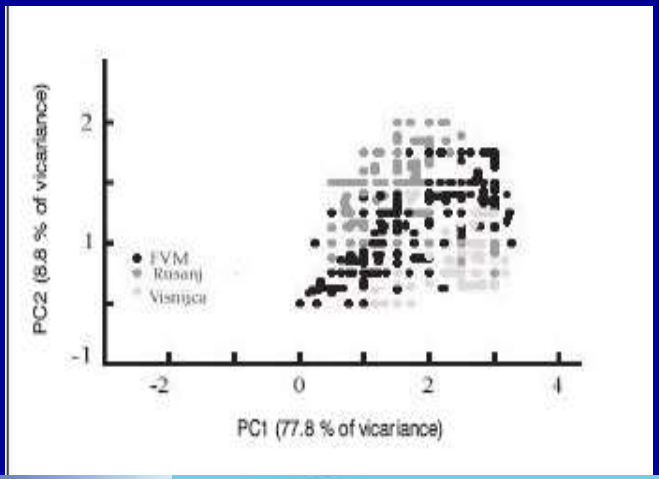
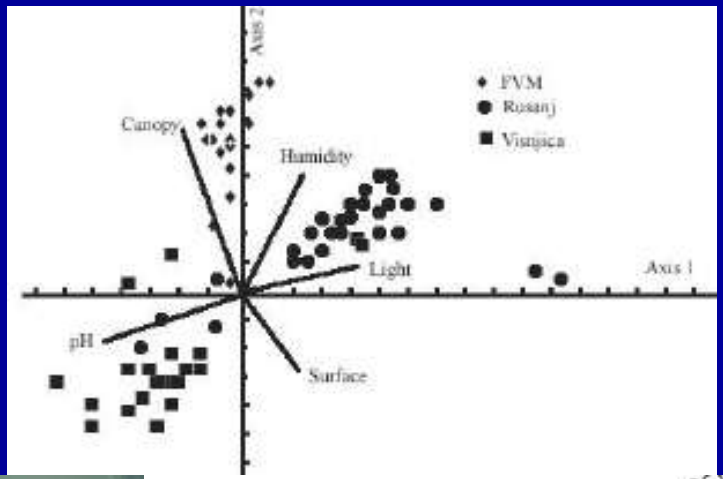


Entosthodon hungaricus apogamy

Signal species





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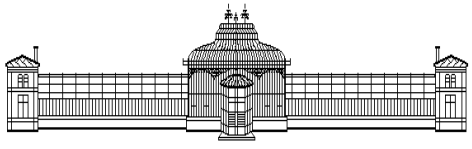
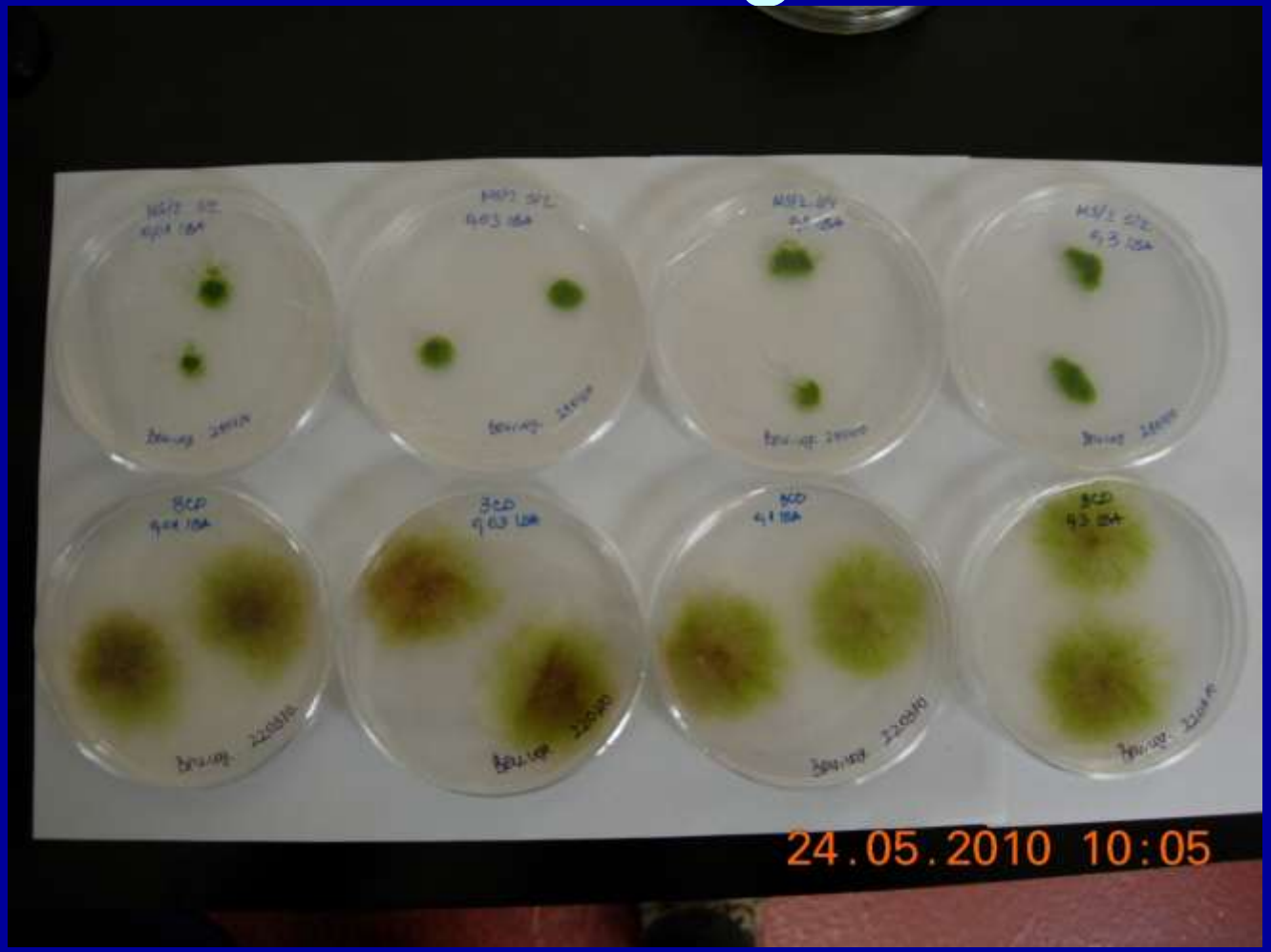


Bruchia vogesiaca



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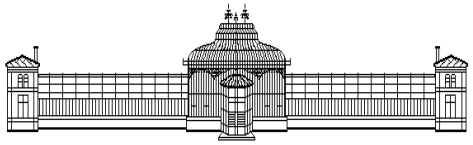

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Ecosystem restorations

Bryophyte Biology Group Belgrade

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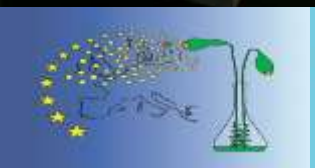
MOSS WALL, Budapest, Hungary 2004



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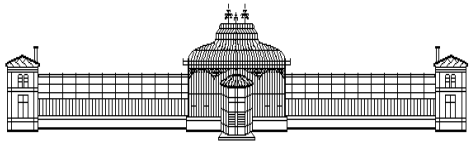

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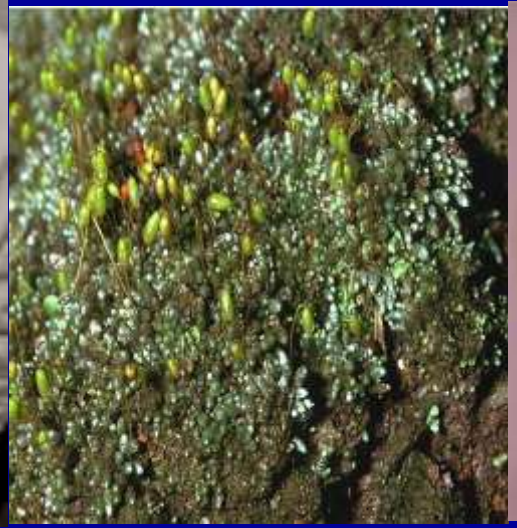
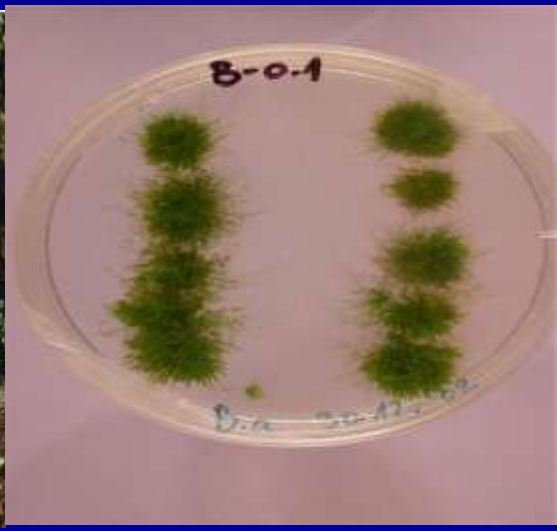
Laboratory and field experiments





- *in vitro studies*

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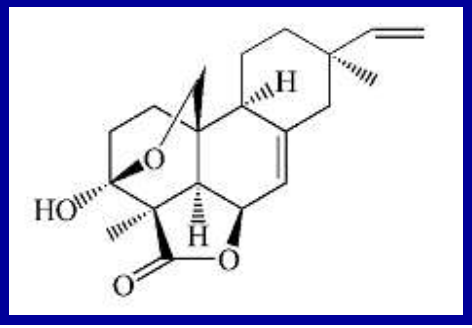
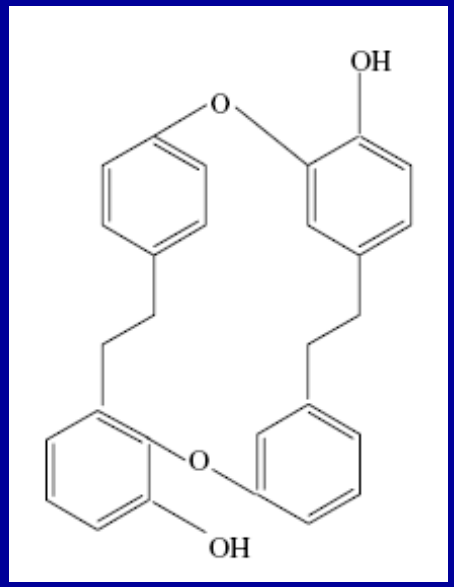
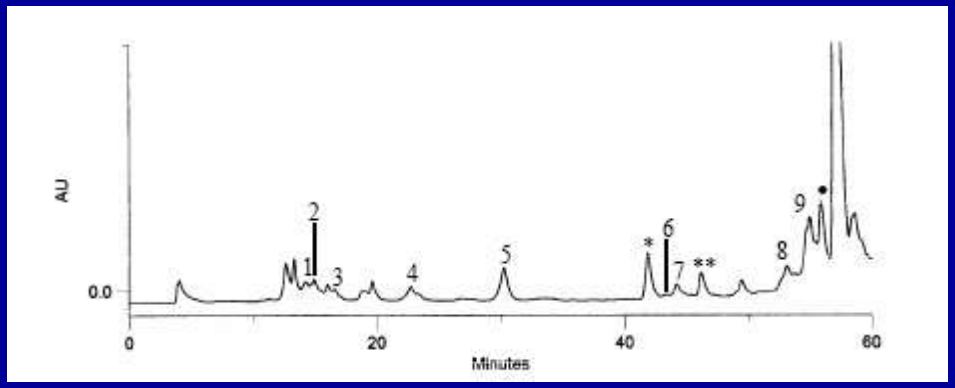
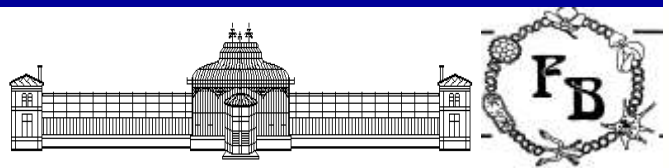
Alelopathy

- ***Chemical contents***
- ***Bioactive components***









Sphagnum palustre

German population of ***Dichelyma capillaceum***

2005

2009

2012?

2020??

THANK YOU FOR ATTENTION