TERRESTRIAL ALGAE

TERRESTRIAL ALGAE
Algae That Live In Terrestrial Habitats

- Algae originally had their evolution in aquatic environments (sea, rivers, lakes, streams, etc.)
- However, several groups of algae evolved mechanisms which allowed them to withstand desiccation and survive out of water.
- Terrestrial algae occur worldwide and colonize all types of terrestrial habitats, including the most hostile.

Economic importance

- Potential tools as bioindicators of air pollution
- Biodeterioration
- Parasites on Magnolia trees or other important cultivars in the SE USA
- Chemicals with biotechnological applications

Oxygen vs Carbon Dioxide

- The colonisation of terrestrial habitat helped algae to adapt to the declining atmospheric CO2 concentrations

- The diversification in rubisco structure and function. (CO2 Specifity)

FACTORS THAT ARE IMPORTANT FOR THE DISTRIBUTION OF TERRESTRIAL ALGAE

- Humidity and moisture;
- Light;
- Temperature;
- Substratum and pH of the surface;
- Availability and type of nutrients.

HUMIDITY AND MOISTURE

Algae are originally aquatic organisms. Terrestrial algae are able to live out of water, but they usually require high humidity and cannot tolerate desiccation for a very long time.

Liquid water is necessary for photosynthesis. Many terrestrial green algae reproduce by spores, gametes or other cells provided with flagella; in order to move and swim, these cells need a thin film of liquid water.

Terrestrial algae are usually most abundant and diverse in damp places and in regions with a rainy and humid climate

Tintenstriche = ink stripes
Black crusts formed by blue-green algae in damp places
(note broken rainpipe)

The green alga *Klebsormidium* growing at the basis of old walls and corners

How do terrestrial algae cope with lack of water?

Blue-green algae are usually more tolerant to desiccation than green algae and are able to colonize very arid environments, either hot or cold (for example, rocks in the deserts).

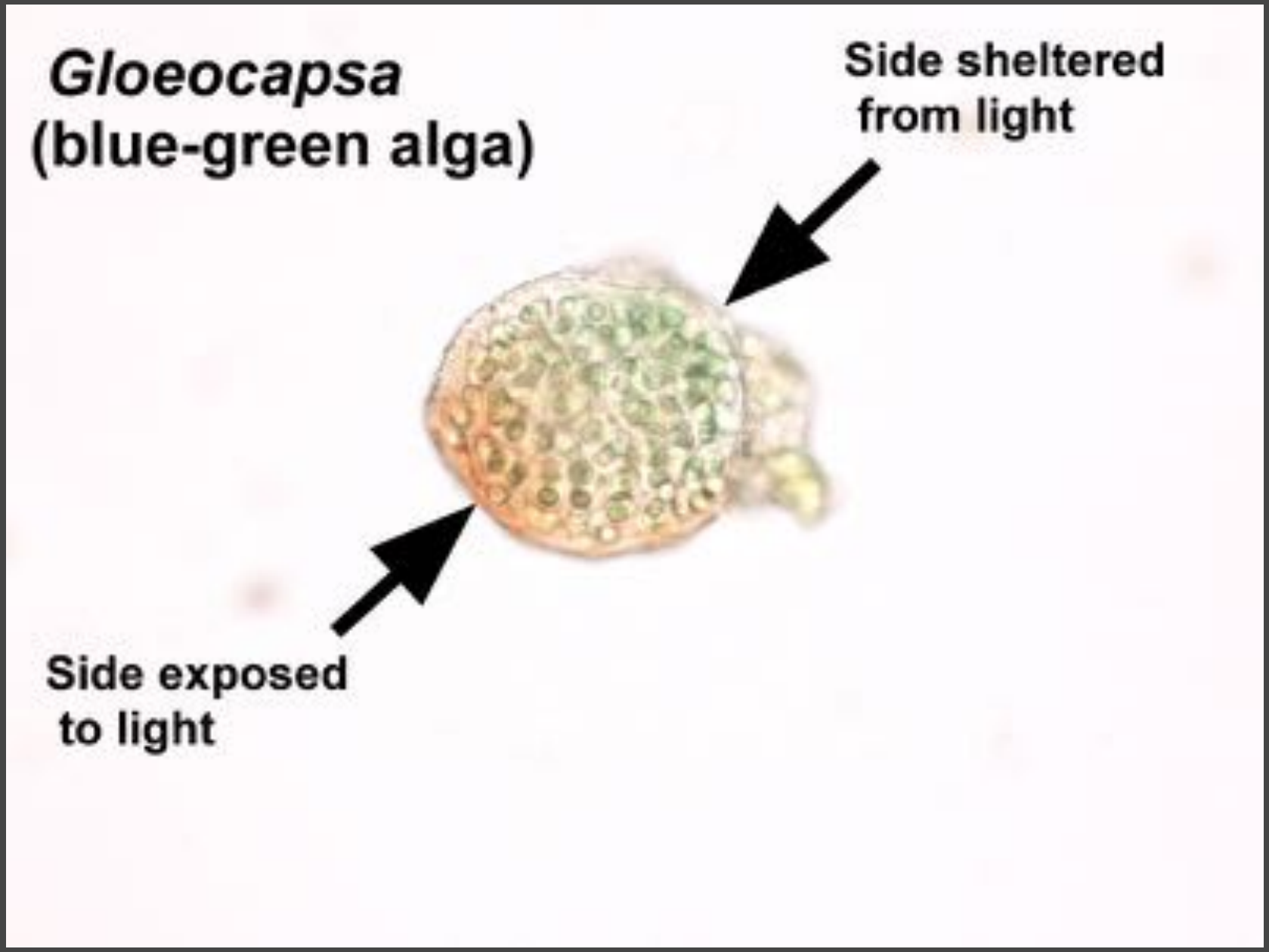
- Colonization of habitats where humidity is retained (for example, cavities or cracks of rocks)
- Capacity to use forms of water different from rain (for example, condensation of dew or melting snow)
- Metabolic adaptations: some terrestrial algae are able to survive almost dehydrated
- Morphological structure: some terrestrial algae have gelatinous sheaths that retain water
- Production of **resting stages** that regenerate new algae when liquid water becomes available

LIGHT

As marine and freshwater algae, terrestrial algae are autotrophic organisms and need light for the photosynthesis. However, strong light intensities may be limiting for terrestrial algae.

Different species are adapted to different light intensities. Algae that live in caves or crevices of rocks are adapted to very weak light. Algae that grow on fully exposed surfaces are adapted to strong light.

Algae that live in exposed habitats may produce pigments that act as a protection against strong light. Some have colored sheaths; stronger the intensity of the light is, stronger the intensity of the colour of the sheath is.


Gloeocapsa
(blue-green alga)
Side sheltered
from light
Side exposed
to light

TEMPERATURE

In terrestrial habitats, temperature is subjected to stronger variation than in aquatic habitats. Consequently, terrestrial algae are generally more tolerant to variations of temperature than aquatic algae.

Terrestrial algae are highly adapted to the temperatures of the habitats in which they live. Species of hot deserts can tolerate very high temperatures (up to 113°C), whereas algae of polar regions are adapted to very low temperatures (up to -195°C).

The terrestrial algal vegetation of tropical regions is generally dominated by blue-green algae, whereas the vegetation of temperate and polar regions is dominated by green algae.

SUBSTRATUM AND pH

- Some species of terrestrial algae are widespread and occur on many different substrata (rock, concrete, bark of trees, woodwork, etc.)
- Other species are highly specific and occur only on one type of substratum, even usually the reasons of this are unknown
- Some species of epilithic algae (especially blue-green) are reported to occur only on one type of stone. The pH of the stone is considered to be the most important factor
- Several species occur only on alkaline stones (such as limestone), whereas other species occur on acidic rocks (such as granite)
- Some species have a preference for artificial substrata, such as concrete

Walls of buildings colonized by *Trentepohlia* in Ireland

NUTRIENTS

- Nutrients are necessary for the growth of algae and in the soil they usually occur in abundance. But in other terrestrial environments, especially on rock, they are available in small amounts and may be limiting for the growth of algae

- Some species of blue-green algae have the capacity to fix nitrogen from the air

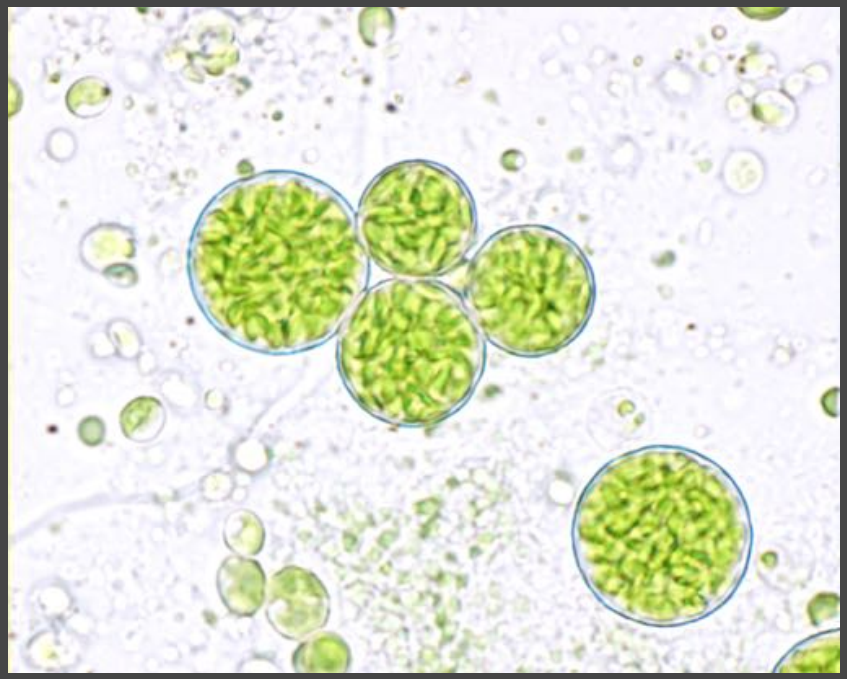
- Nutrients may be conveyed to the algae by rain, snow and atmospheric fallout. On trees or other plants, accumulation and decay of organic matter can be a source of nutrients

- Some species of terrestrial algae, such as *Prasiola* and *Rosenvingiella*, are known to be highly nitrophilous. They are able to use the nitrogen obtained from animal and human urine and are abundant in dirty places

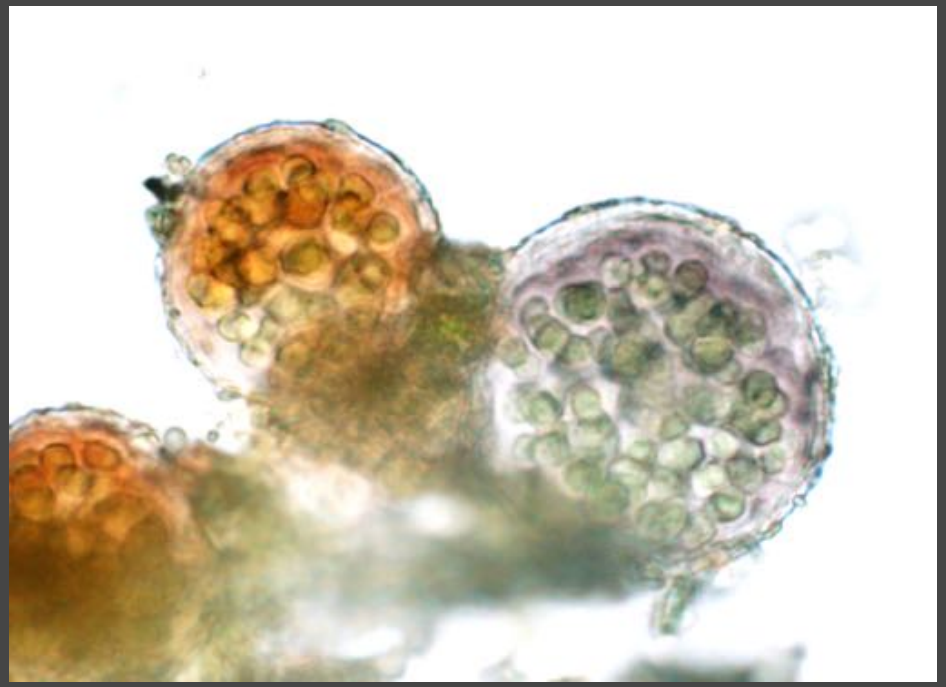
Algal Adaptations to Terrestrial Habitats:

- Morphological convergence
- Capacity to utilize water in the form of vapour
- Mucilaginous envelopes retaining moisture
- Resistance stages such as akinetes
- Pigments acting as a protection from solarization
- Anti-freezing compounds
- Mycosporine-like amino acids as protection from UV radiation

Terrestrial algae belong to two main groups



Green algae
(Chlorophyta and
streptophyta)



Blue-green algae
(Cyanophyta)

GREEN ALGAE

- Eukaryotic (presence of a nucleus).

- Characteristic set of accessory pigments and characteristic structure of chloroplast; starch as storage polysaccharide.

- More closely related to land plants than to other groups of algae (e.g., red or brown).

- Usually green in color (red, orange or yellow in some groups, due to accumulation of carotenoid pigments).

- Morphology variable, but generally simple.

Morphological types of terrestrial green algae: 1 - **Unicellular**

Examples:

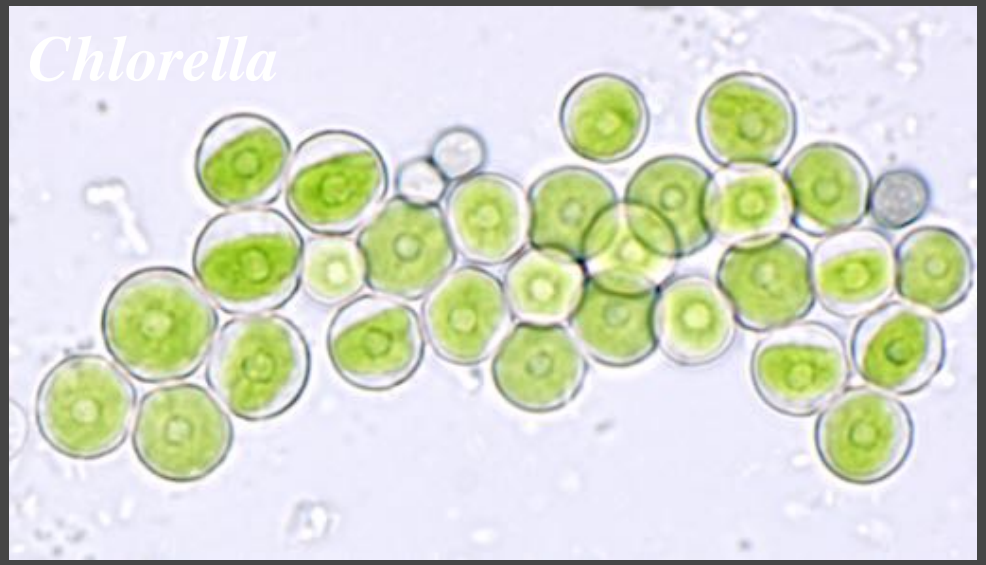
- *Chlorella* (Trebouxiophyceae)

- *Stichococcus* (Trebouxiophyceae)

- *Chlorococcum* (Chlorophyceae)

-*Trebouxia* (Trebouxiophyceae)

- *Spongiochrysis* (Ulvophyceae)



Morphological types of terrestrial green algae: 2 – **Sarcinoid colonies** (= packets of cells with quadrate shape, more or less regular)

Examples:

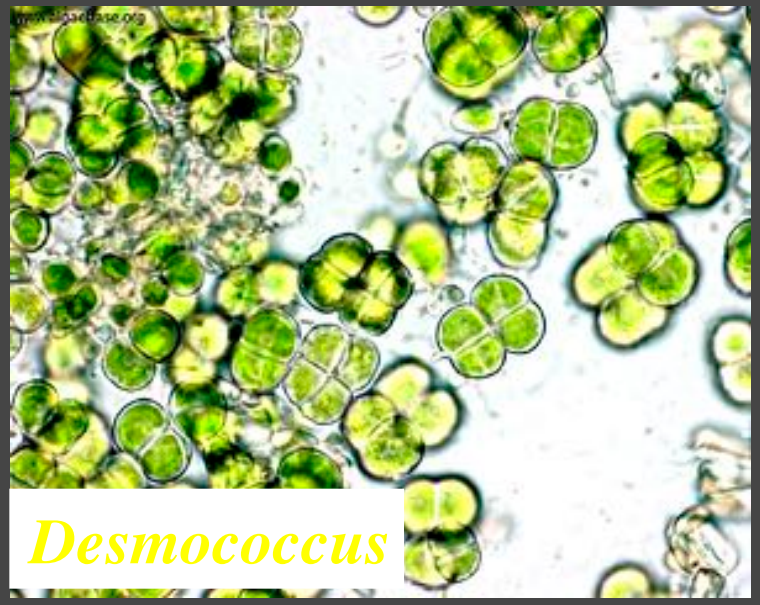
- *Desmococcus* (Trebouxiophyceae)

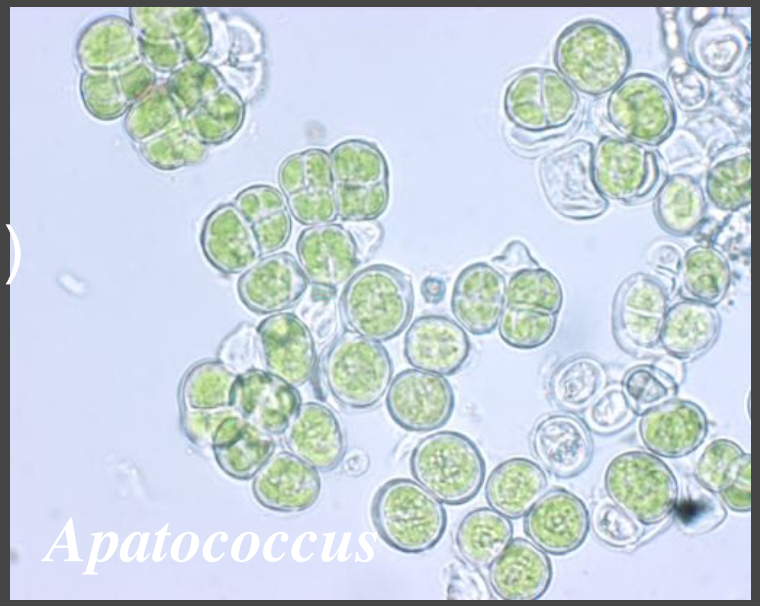
- *Apatococcus* (?)

- *Chlorosarcina* (Trebouxiophyceae)

- *Prasiococcus* (Trebouxiophyceae)

- *Chlorokybus* (Klebsormidiophyceae)





Morphological types of terrestrial green algae: 3 – **Uniseriate unbranched** filaments (= filaments formed by one row of cells with no branches)

Examples:

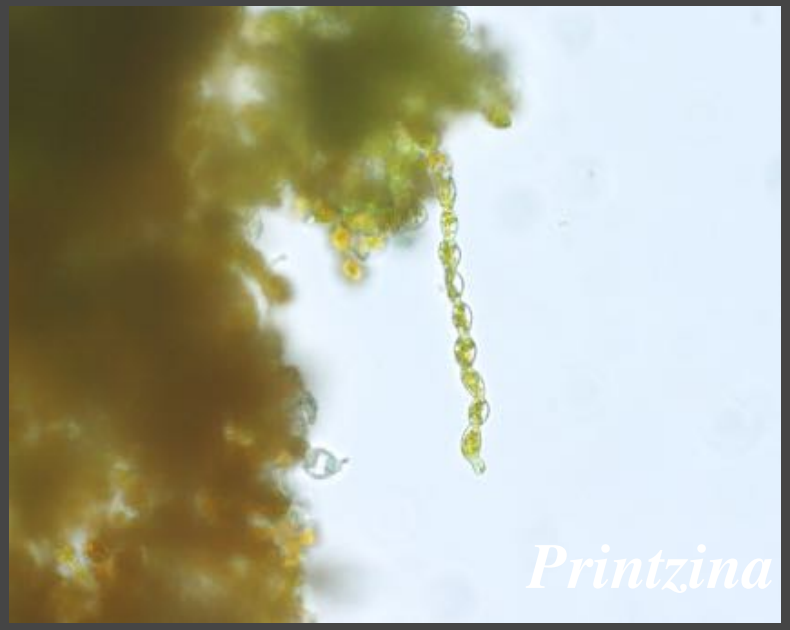
- *Klebsormidium* (Klebsormidiophyceae)

- *Rosenvingiella* (Trebouxiophyceae)

Morphological types of terrestrial green algae: 4 – **Uniseriate branched filaments** (= filaments formed by one row of cells with branches)

Examples:

- *Trentepohlia* and *Printzina* (Ulvophyceae)

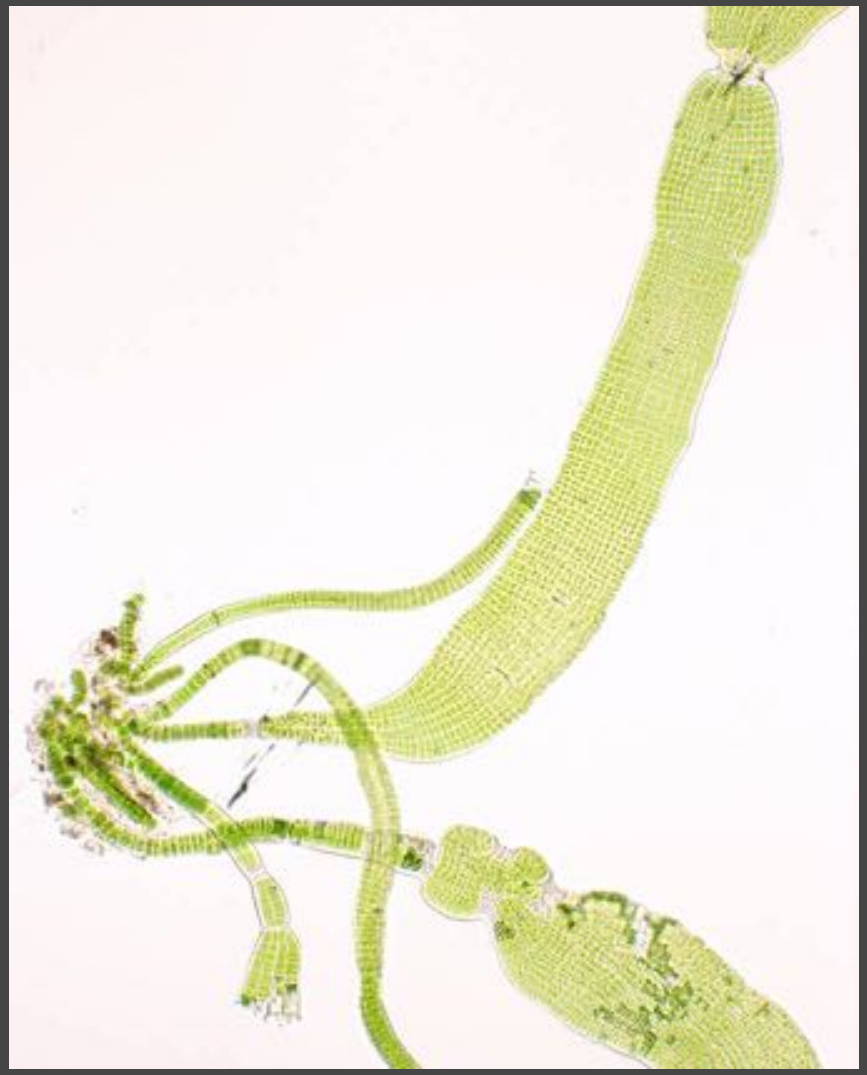


Morphological types of terrestrial green algae: 5 - **Monostromatic blades** (= blades formed by 1 layer of cells)

Examples:

- *Prasiola* (Trebouxiophyceae)

Prasiola crispa



Prasiola calophylla

BLUE - GREEN ALGAE, OR CYANOBACTERIA

- Prokaryotic: absence of nucleus and organelles; DNA lies free in the center of the cell.

- Photosynthetic pigments located in thylakoids, which lie free in the cytoplasm; cyanophycean starch as storage polysaccharide.

- Strictly related to bacteria (and, more properly, called Cyanobacteria).

- Very diverse in color: usually blue-green to violet, but also grey, blue, purple, brown, red and yellow.

Morphological types of terrestrial blue-green algae: 1 - **Unicellular**

Examples:

- *Synechococcus* (Chroococcales)

- *Synechocystis* (Chroococcales)

- *Cyanothece* (Chroococcales)

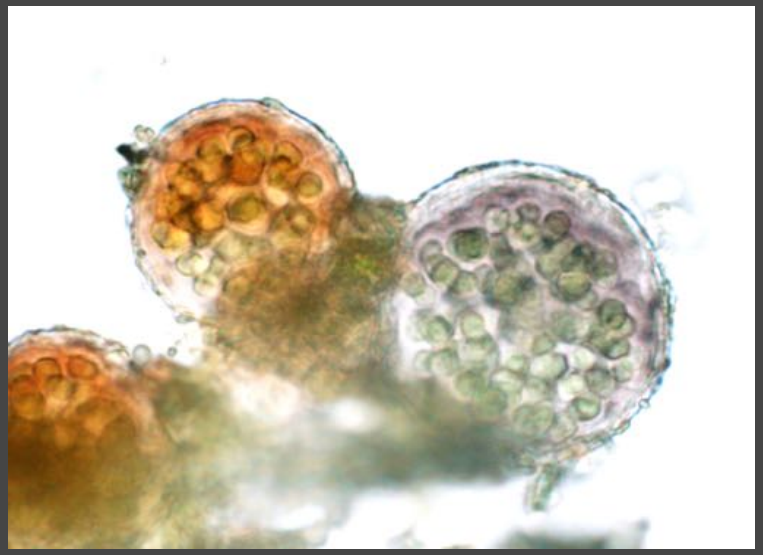
Morphological types of terrestrial blue-green algae: 2 - **Colonies enclosed in a mucilaginous envelope**

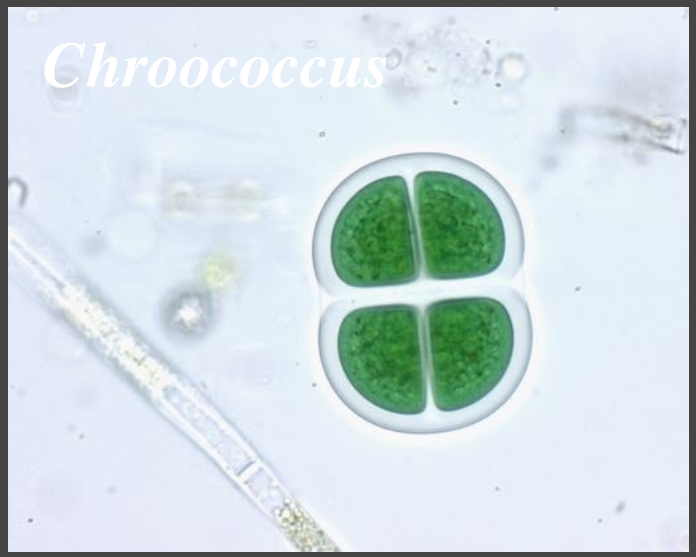
Examples:

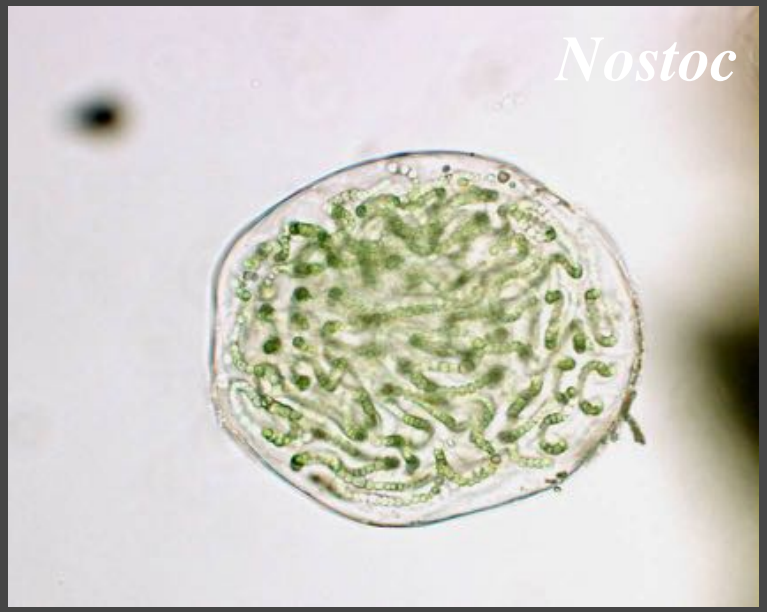
- *Gloeocapsa* (Chroococcales)

- *Chroococcus* (Chroococcales)

- *Nostoc* (Nostocales)







Morphological types of terrestrial blue-green algae: 3 **- Unbranched uniseriate filaments**

Examples:

- *Oscillatoria* (Oscillatoriales)

- *Lyngbya* (Oscillatoriales)

- *Leptolyngbya* (Oscillatoriales)

- *Phormidium* (Oscillatoriales)

- *Microcoleus* (Oscillatoriales)

- *Plectonema* (Oscillatoriales)

Morphological types of terrestrial blue-green algae: 4 - **Branched uniseriate filaments**

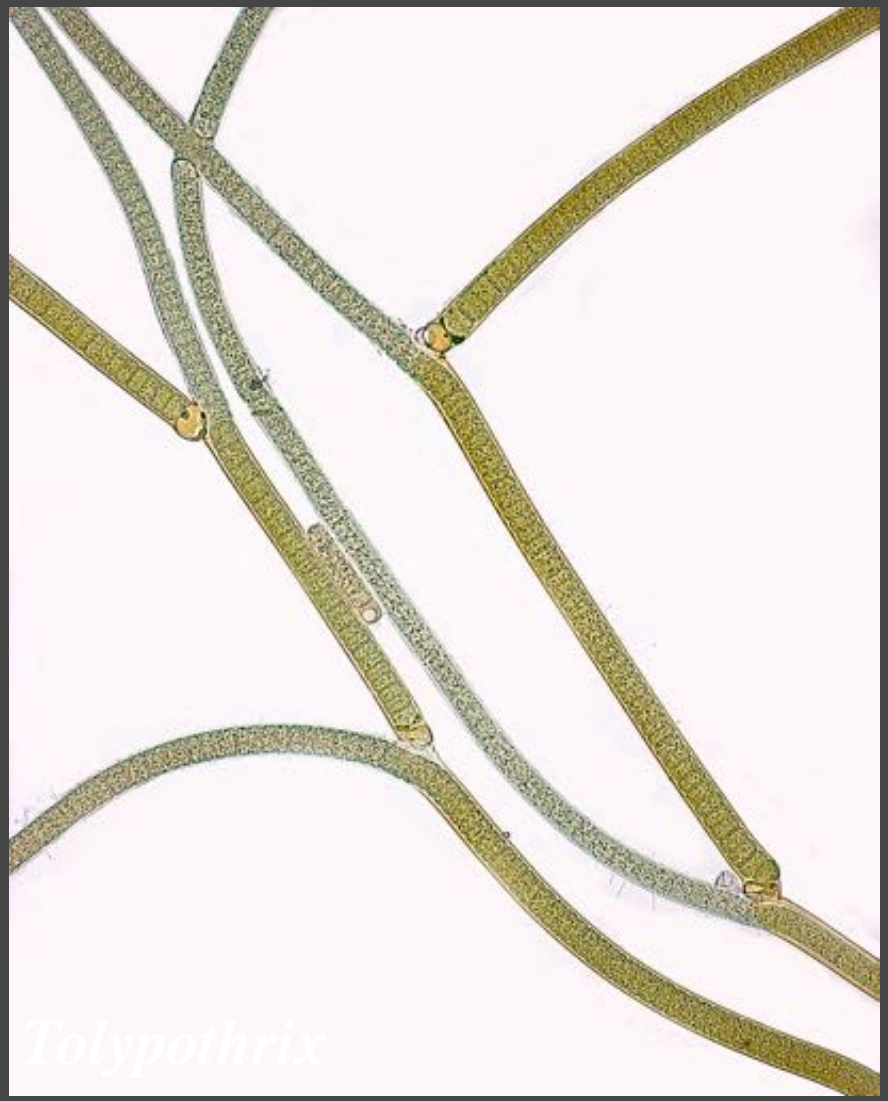
Examples:

- *Tolypothrix* (Nostocales)

- *Scytonema* (Nostocales)

- *Calothrix* (Nostocales)

- *Schizothrix* (Oscillatoriales)



Morphological types of terrestrial blue-green algae: 5 **- Pluriseriate corticated filaments**

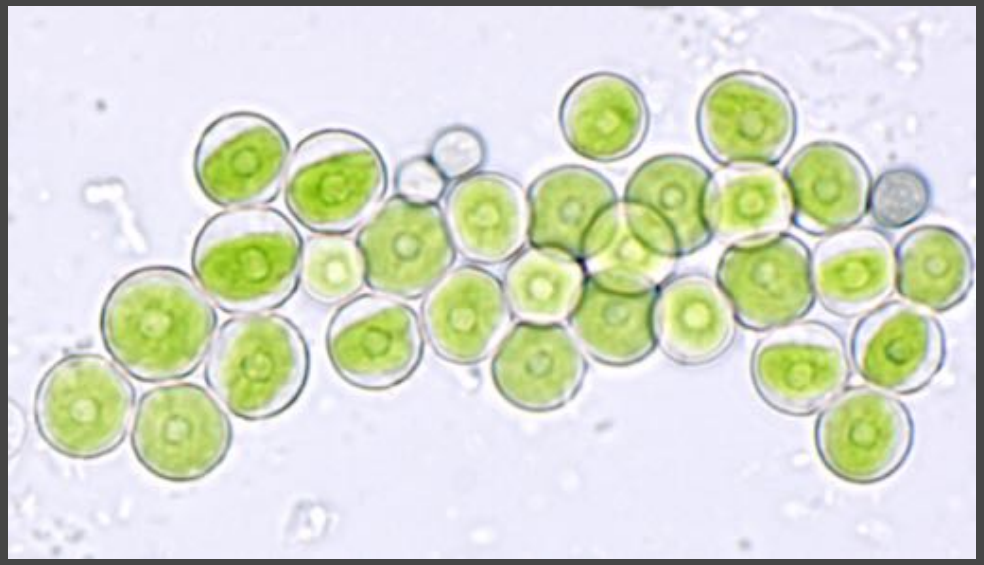
Examples:

- *Stigonema* (Stigonematales)

Morphological Convergence

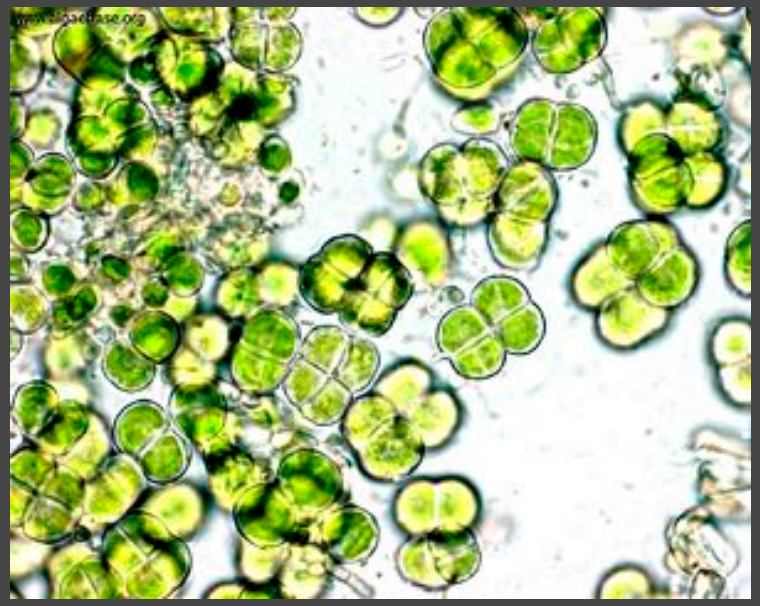
- Three main types of thallus morphology are found in subaerial algae:
  - Unicellular
  - Sarcinoid (regular packets formed by a small number of cells)
  - Uniseriate filaments

- The unicellular morphology is the most widespread in terms of number of species



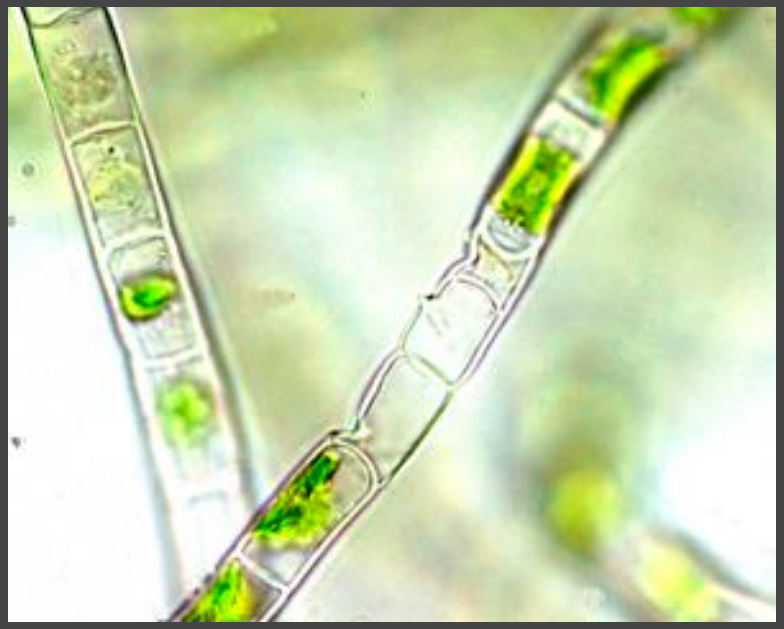
- Found in genera belonging to different lineages: *Chlorella, Spongiochrysis, Trebouxia*

- Sarcinoid: packets that are formed by multiple cells



- Characteristic of one of the most common alga in the world; i.e., Desmococcus

- Uniseriate filaments



- Found in relatively very limited number of species

ECOLOGICAL TYPES OF TERRESTRIAL ALGAE

- SOIL ALGAE: algae associated with soil
- SUBAERIAL ALGAE: algae above the soil level:
  - - LITHOPHYTIC ALGAE: algae associated with stone
  - - SNOW ALGAE: algae associated with ice and snow
  - - EPIPHYTIC ALGAE: algae growing on plants
  - - EPIZOOIC ALGAE: algae growing on animals

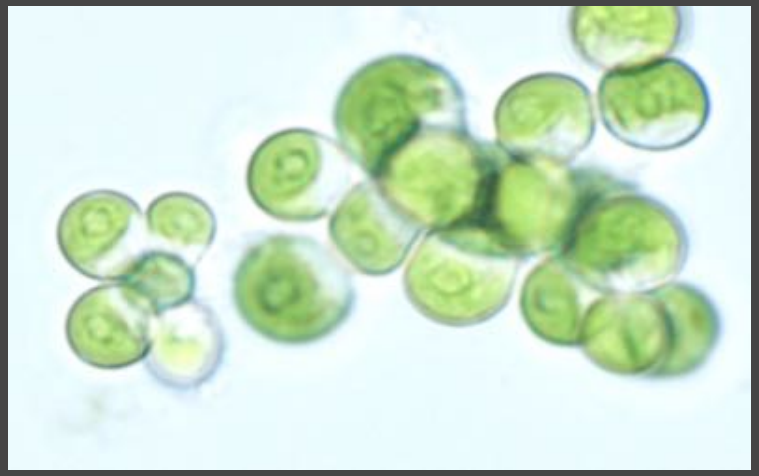
SOIL ALGAE

The soil is the best studied terrestrial algal habitat. Many tens of species of algae can be found in the soil

Algae occur on every type of soil, either arid and humid. When they are abundant, they can produce a green layer on the surface of the soil, but most frequently they occur in very small amounts and can be detected only by growth in culture

GREEN ALGAE IN THE SOIL

- Green algae dominate in acidic soils, but are also common in neutral and alkaline environments.
- Small, unicellular green algae are the most common forms.
- Several species of green algae have been found only on soils.



***Chlorella* sp.**

BLUE-GREEN ALGAE IN THE SOIL

Blue-green algae, especially filamentous forms, are common in neutral and alkaline soils.

Ecologically important, because:

1) They enrich the soil in nutrients by fixing nitrogen from the air

2) Several species of blue-green algae form crusts that limit the erosion, increase the storage of rainwater and reduce the water loss by evaporation; they provide organic matter that contributes to the formation of the soil

Nostoc commune

SUBAERIAL ALGAE

Subaerial, aerial or aerophilous algae: inhabiting any object in the air above the soil, litter or water surface, divided into:

- *Epilithic or lithophilous*: on rock, stone or cement surfaces
- Snow Algae
- *Epiphytic*: on vegetation, further subdivided into:

  -*Epiphyllous*: on leaves

  -*Epiphellous or corticolous*: on bark, stems or trunks

LITHOPHYTIC ALGAE

1) EPILITHIC: Colonize the external exposed surface of rock

2) HYPOLITHIC: live under pebbles and small stones lying on the soil

3) ENDOLITHIC: colonize the interior of rock; three types:

- CHASMOENDOLITHIC: colonize cracks open to the rock surface

- CRYPTOENDOLITHIC: colonize structural cavities within porous rock

- EUENDOLITHIC: penetrate actively into the rock forming tunnels that conform with the shape of the thallus

EPILITHIC ALGAE

Prasiola calophylla

Haematococcus pluvialis in bird bath

Any type of stone can be colonized by epilithic algae

Limestone and sandstone usually host a more diverse algal flora than granite

A wet climate favors the growth of epilithic algae

Blue-green algae are usually the first colonizers. They are able to survive on surfaces that are too dry for green algae

Epilithic algae grow on stone monuments, where they may be a considerable practical problem

Trentepohlia umbrina on limestone

EPILITHIC ALGAE ON MONUMENTS

Epilithic algae grow on the surface of stone and can promote the solution of stones such as limestone. Several species of terrestrial algae are reported to produce organic acids that dissolve alkaline stones.

Algal growth is frequently associated with dampness and patches may develop where, for example, rainwater is allowed to concentrate and flow down. Under warm, moist climatic conditions a complete cover of algae may develop across a stone surface in a few years.

Even when no structural damage occurs, algae cause aesthetical disfigurement to the surface colonized.

Algal growths are common on walls, sculptures, and human constructions causing concern for conservation in Italy and Greece (biodeterioration)

Cologne, Germany 1880 and now

Dispersion: Aerial transport (Aerobiology)

Air-borne algal spores and fragments (187 spp of algae and protozoa)

Animals: Spiders, beetles, birds

Rain

Hypolithic and endolithic blue-green algae are usually the only algae occurring on mountains of deserts

SNOW ALGAE

Some species of algae inhabit snow and ice; when occurring in large amounts, they can color the snow red, green, blue or yellow

Snow algae need liquid water, which occur the snow-air interface. For this reason, they are active only for a limited time (usually only a few weeks a year), in which they have to complete their life cycle

Small unicellular green algae are the most common type of snow algae

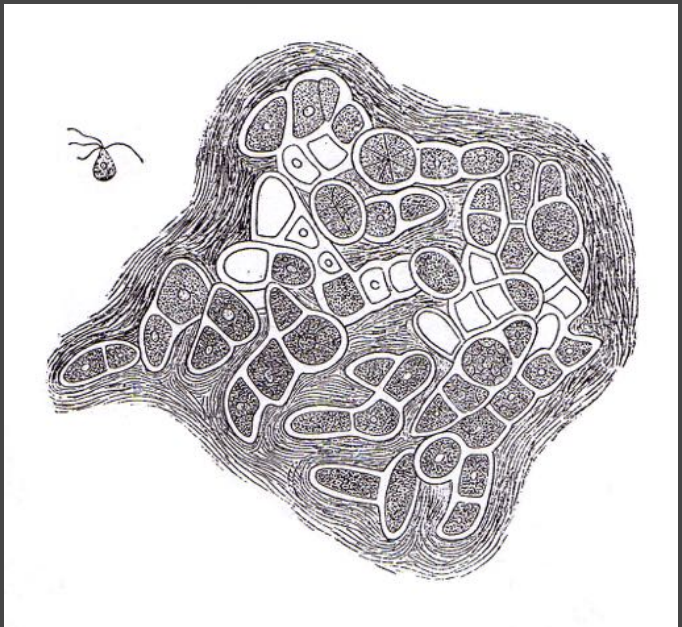
- **Epixylous**: on dead wood such as poles, posts, doors
- **Epimetallous**: on metals

The main factors are temperature and humidity

These algae are especially abundant in temperate and tropical regions where rain and atmospheric humidity are higher

Epizoic Algae: growing on animals

Some species of algae can grow on the skin or the fur of animals
Normally, they are not cause of diseases to the animal host
A rich microalgal flora has been found growing on the fur of sloths
Other animals on which alga have been found include spiders and monkeys.



Trichophilus welckeri
described from fur of
sloths in Amazonia

Epiphytic algal communities

Depending directly upon rain water or high humidity for their water supply

Subject to extreme desiccation

Some are semi-parasitic

Subaerial habitat is characterized by absence of nutrients other than those in rain and those obtained by solution of dust or material on or from the host plant tissues

Tropical Rainforest

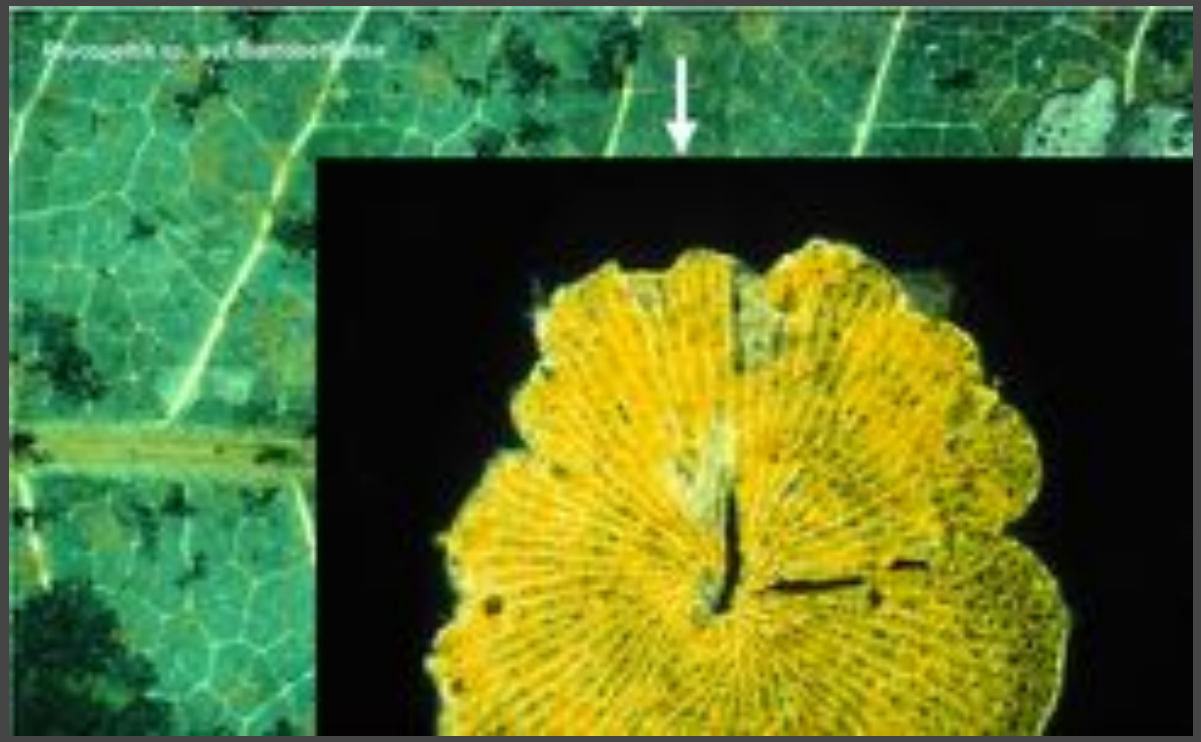
Epiphytes in the Olympic temperate rainforest, Washington

Epiphyllous communities (phyllosphere)

Composed largely by Trentepohliales genera: *Trentepohlia, Cephaleuros*, and *Phycopeltis*

Usually associated with fungal filaments to constitute loose lichen associations

Occurring in situations where the leaf surface is sufficiently moist for algal growth but not so wet as to encourage the growth of bryophytes



Corticolous communities

Composed not only by *Pleurococcus* but also *Trentepohlia*, *Chlamydomonas, Chlorella, Neochloris, Spongiochloris, Stichococcus, Oscillatoria* and *Botrydiopsis*

In NC 19 algal genera were found, Gymnosperms mostly support Chlorophyta while other trees have Cyanophyta and a few diatoms

In PR if forest is wet enough algae normally associated with underwater habitats can colonize tree stems: Diatoms at the base, Cyanophyta in the mid-zone and only Chlorophyceans in the upper zone of trees

SUMMARY

- Terrestrial algae are widespread in terrestrial environments
- They represent a very diverse group of organisms, which has been produced by multiple invasions of different evolutionary lineages from aquatic environments to the land
- Although terrestrial algae are most abundant in humid places, they can colonize any environment, including the most hostile
- When growing on human-made surfaces, they may represent a major practical nuisance and others are causing problems in economic crops
- Terrestrial algae are among the most poorly-known organisms on our planet. Their diversity has begun to be understood only recently, and it is worthy of much more attention that it has received so far

The terrestrial algae are a challenging group of algae that should continue to be studied—perhaps especially in the tropics where they are abundant and diverse, but are disappearing as fast as their habitats are disappearing


At the African Savanna


At the Amazonian forest


At the Mayan ruins

Required reading:

- Rindi, F. Mikhailyuk, R., Sluiman, H., Friedl, T. and J. Lopez-Bautista. 2011. Phylogenetic relationships inInterfilum and Klebsormidium (Klebsormidiophyceae, Streptophyta). Molecular Phylogenetics and Evolution 58:218-231

- Rindi, F., Allali, H., Lam, H., and J. Lopez-Bautista. 2010. An overview of biodiversity and biogeography of terrestrial green algae. In: Columbus, F. (ed.) Biodiversity Hotspots, Nova Science Publishers Inc., Hauppauge, NY