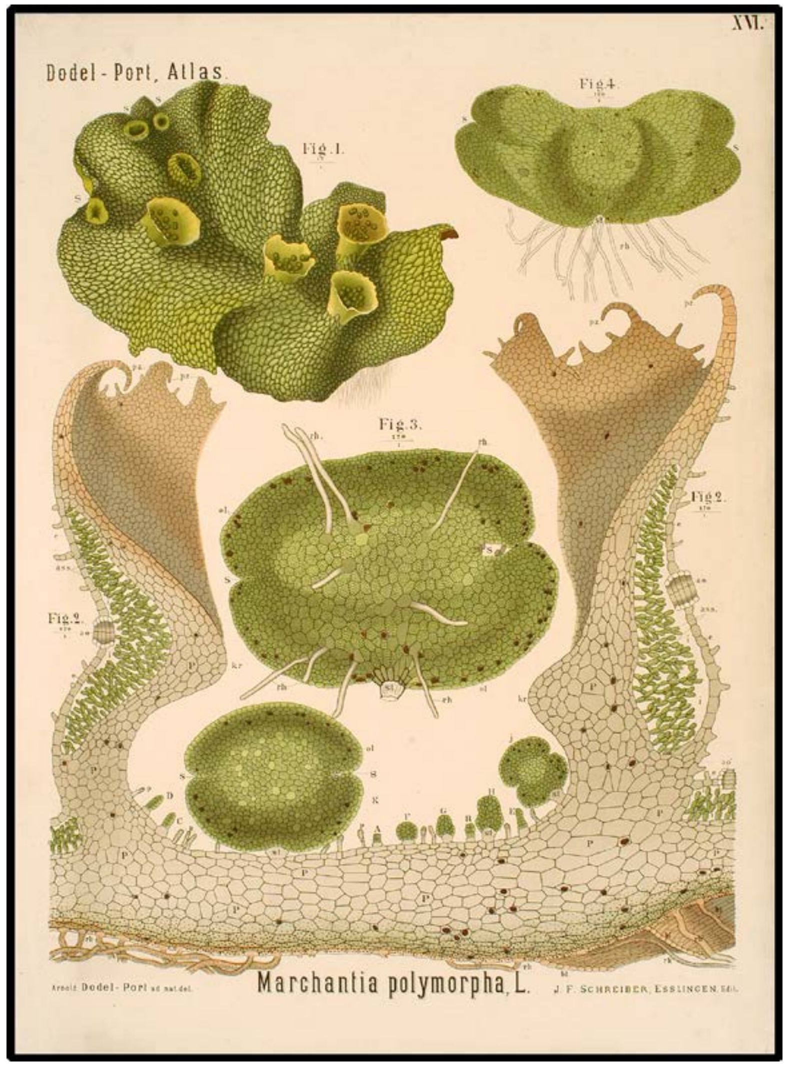
Marchantia

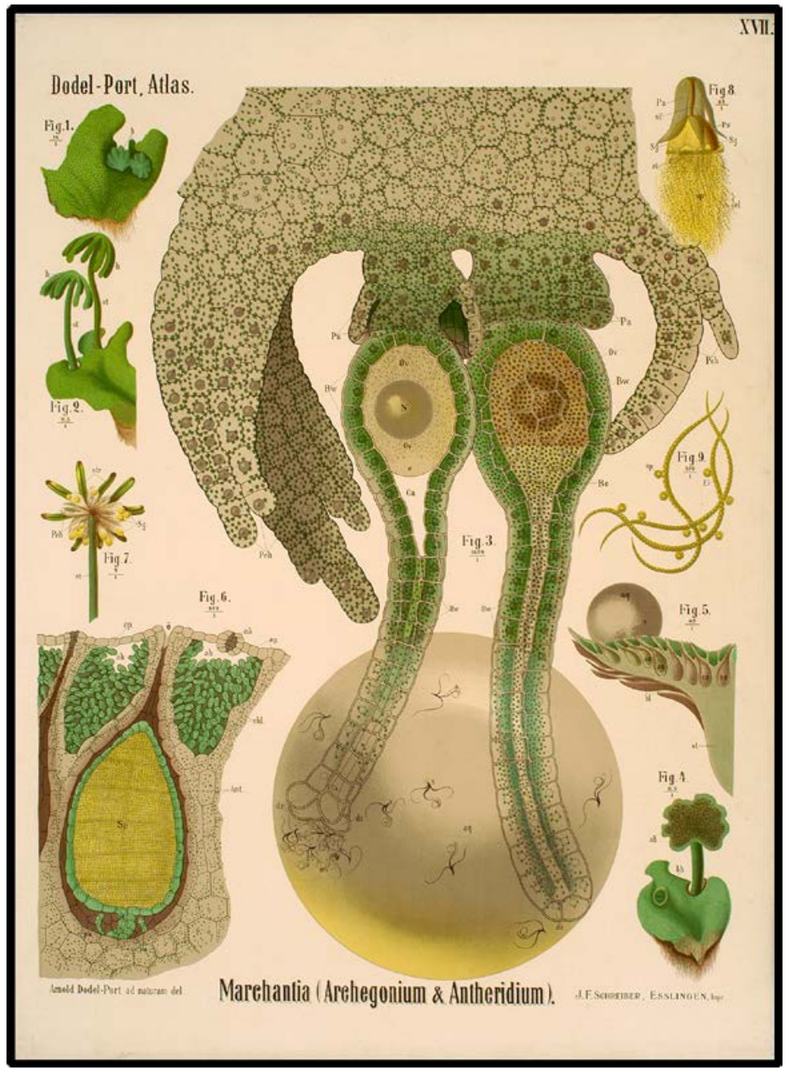
Marchantia polymorpha is the best known representative of the liverworts (or Marchantiophyta) and the species has been a subject of study for many years. These pages show copies of botanical teaching posters that feature *Marchantia polymorpha*, and are over a century old.

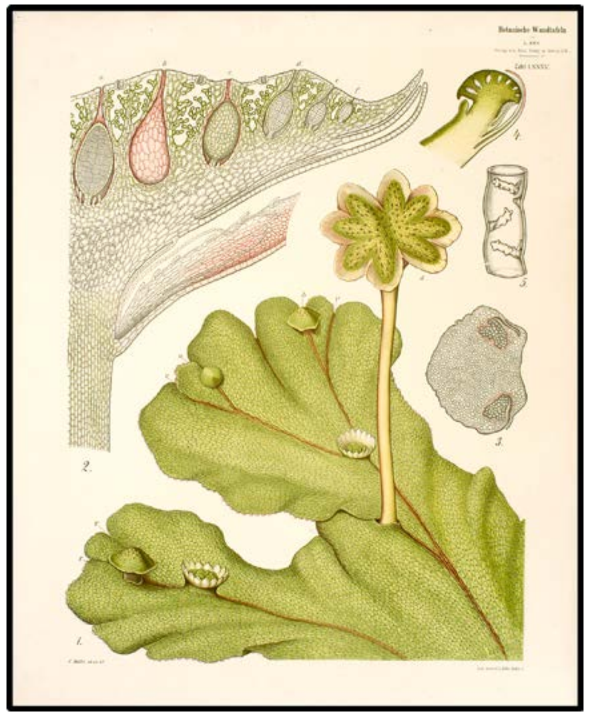
The liverworts are evolutionary relics. They are a sister clade to modern flowering plants that may have diverged almost 500M years ago. They appear to retain features of the earliest land plants including a profound morphological and genomic simplicity.

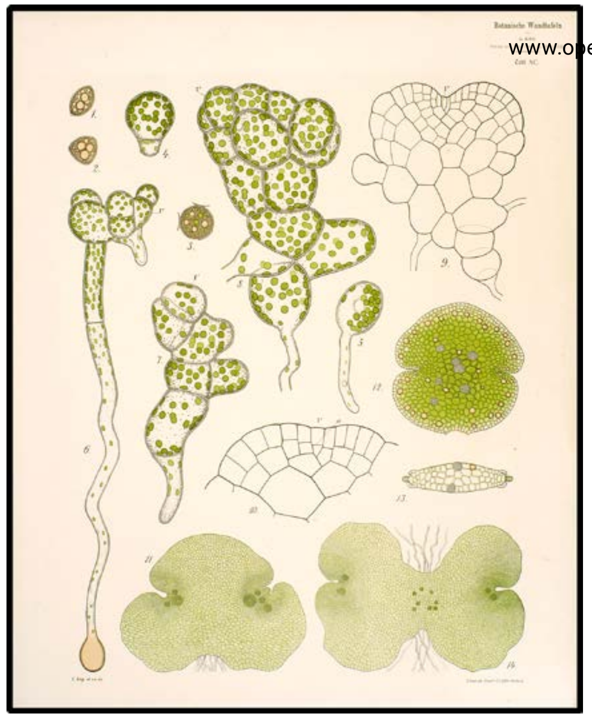
The liverworts have alternate haploid and diploid generations. Like other Bryophytes, the gametophyte or haploid generation is dominant phase of the life cycle. *M. polymorpha* has a global distribution and is often found as a weed in horticulture. M. polymorpha plants are easy to grow. They show distinctly weed-like properties, growing vigorously on soil or artificial media. The plants produce vegetative propagules. These form vegetatively inside conical splash cups. Superficial cells on the inside of a cup undergo cell proliferation to form a group of cells carried on a short stalk, the cells continue to proliferate in regular fashion to form a bi-lobed gemma. This is eventually detached from the stalk, and can be dispersed from the cup, typically by water splash. The propagules are robust and long-lived, even tolerating desiccation. Gemmae can be used for simple vegetative propagation and amplification of plantlets during experiments.

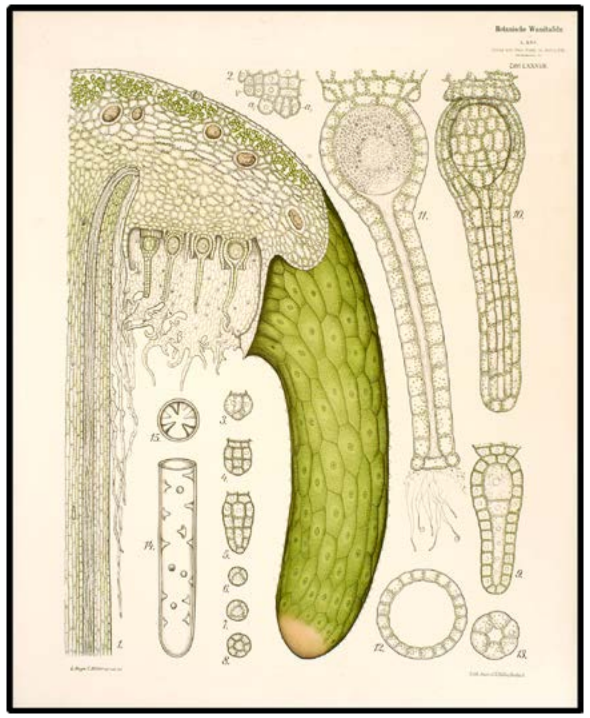
Liverworts have less efficient systems for water transport and retention than higher plants, and to compensate, show marked tolerance to desiccation. Many similar lower plants demonstrate a striking tolerance of extreme stresses, a trait that would be valuable in a crop system. Liverworts have been a largely neglected area of plant biology, but show promise as new experimental systems after recent developments in transformation methods and genome characterisation. The relative simplicity of genetic networks in liverworts, combined with the growing set of genetic manipulation, culture and microscopy techniques, are set to make these lower plants major new systems for analysis and engineering.

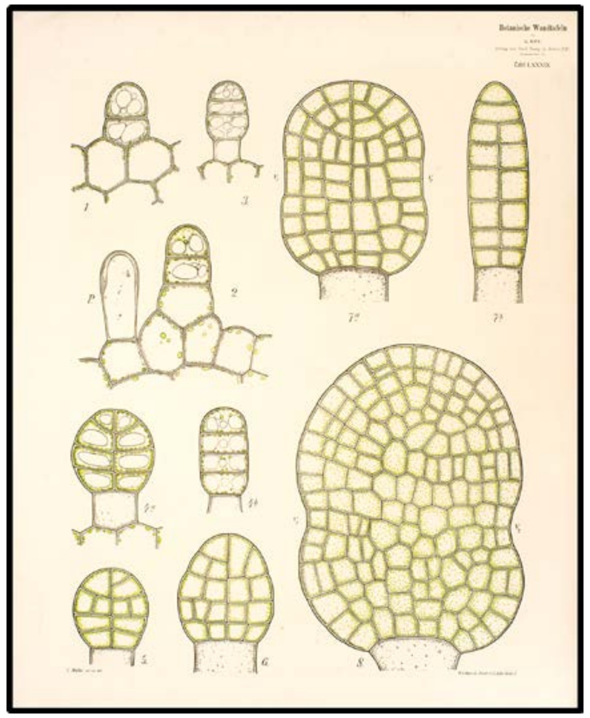


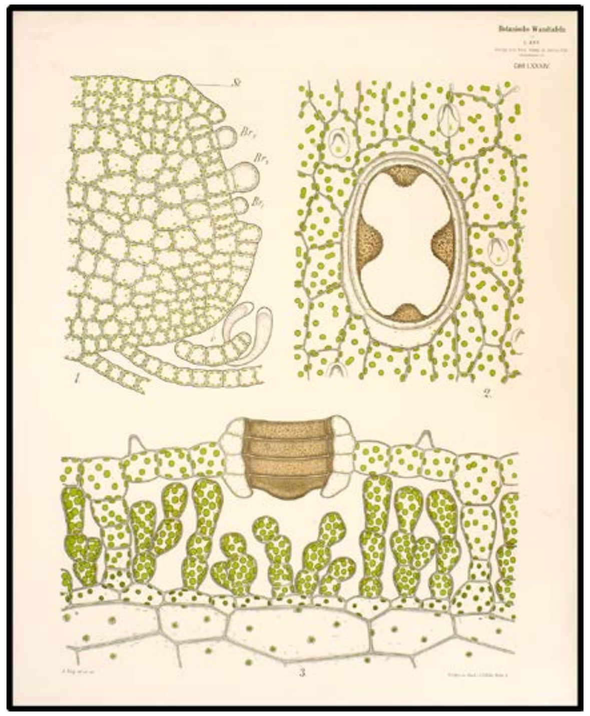










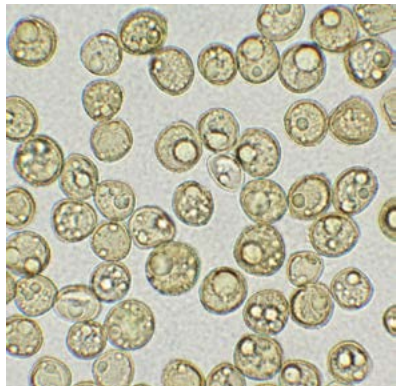


Marchantia Simple & Fast.

Simple morphology
Marchantia polymorpha is the best-studied species of liverwort. Liverworts form a sister clade to modern flowering plants, thought to have emerged around 480M years ago.

Male and female plants
Marchantia plants are haploid with a simple prostrate forms. Male (right) and female (left) plants produce distinctive gamete-bearing structures.

Sexual reproduction
Fertilisation results in the production of a short-live diploid phase (sporophyte), which terminates in the production of yellow sporangia.



Millions of spores
Each sporangium contains 100,000's of spores, which can he stored cryogenically and used for propagation.

Spore germination
Spores germinate rapidly when transferred to suitable media, and the entire process of early development is exposed, and can be visualised directly.

Tiny plants in culture
Germinating spores give rise to plantlets with recognisable body plans and anatomical features within a few days,

(images: Jim Haseloff)

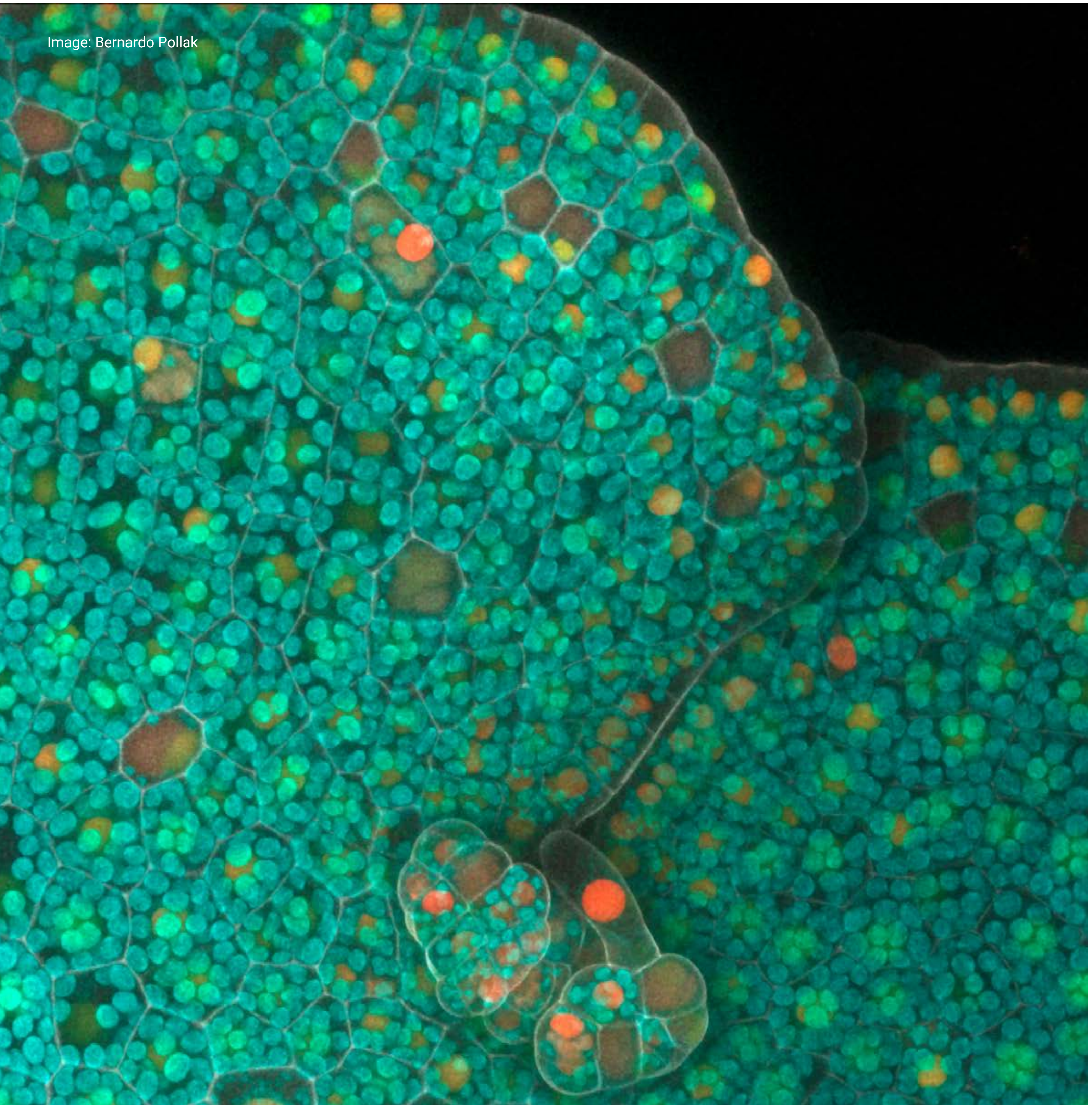
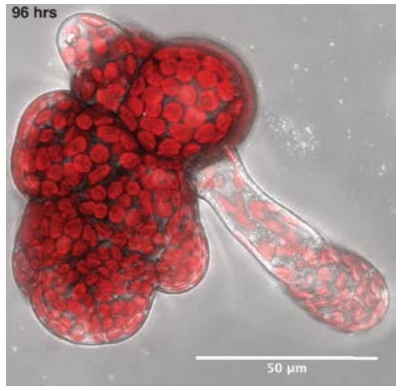


Image: Bernardo Pollak

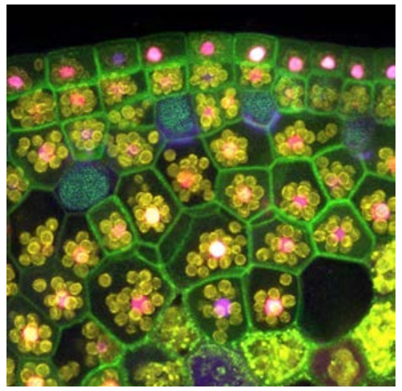
Visualising the plant

Marchantia plants can be easily transformed with fluorescent protein gene markers, and directly visualised using advanced fluorescence microscopy techniques. The example above shows cells in the meristematic notch of a Marchantia plant labelled with a nuclear-localised red fluorescent protein. The early stages of development in Marchantia are open and unobscured by surrounding tissues. This allows easy and direct observation of formative processes during morphogenesis.



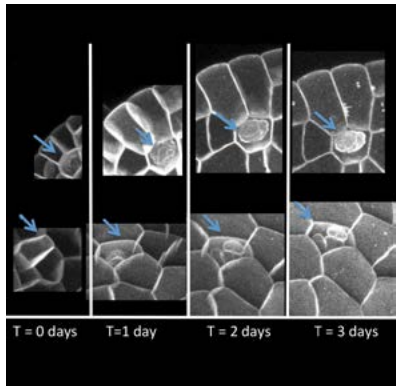
Chloroplast development

Chloroplast development can be sampled and visualised in a synchronised cohort of germinating spores (image: Bernardo Pollak).



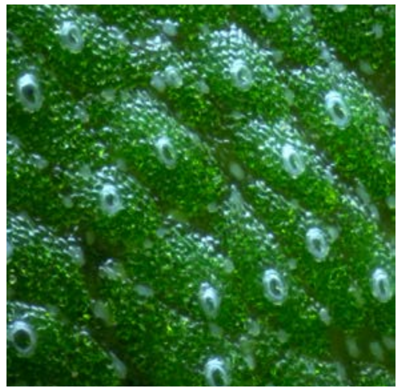
Microscopy

High resolution microscopy techniques allow the non invasive imaging of subcellular features and dynamics in intact plants (image: Fernan Federici).



Oil cells

Marchantia produces oil cells, which are devoted to the production of secondary compounds. The differentiation of these cells can be directly visualised *in situ* (image: Nuri Purswani).



Modular architecture

Cell proliferation, patterning and differentiation results in the formation of repeated air chamber structures across the surface of the plant.

Simple root system

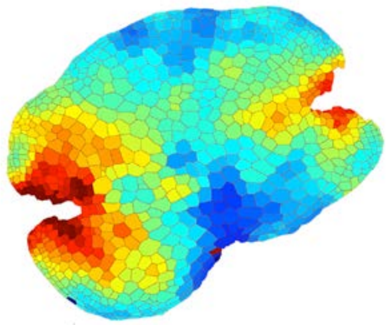
Marchantia lacks a proper root system, instead elongated rhizoid cells perform this role. Specification of rhizoids shows similarity to that of root hairs in higher plants.

Clonal propagation

Marchantia form cup-like organs that spontaneously produce clonal propagules called gemmae.

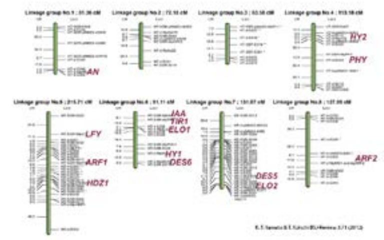
Asexual propagules

Gemmae have a regular size and morphology, and can be harvested and germinated for simple observation of engineered growth and development (image: Jim Haseloff)



Quantitative imaging

The dynamics of cellular growth and development can be quantitatively measured and parameterised using quantitative imaging techniques (image: Nuri Purswani).



Simple genome

The *Marchantia polymorpha* genome is relatively small (280 MB) and comprises 8 autosomes and 1 sex chromosome that make up the haploid genome.

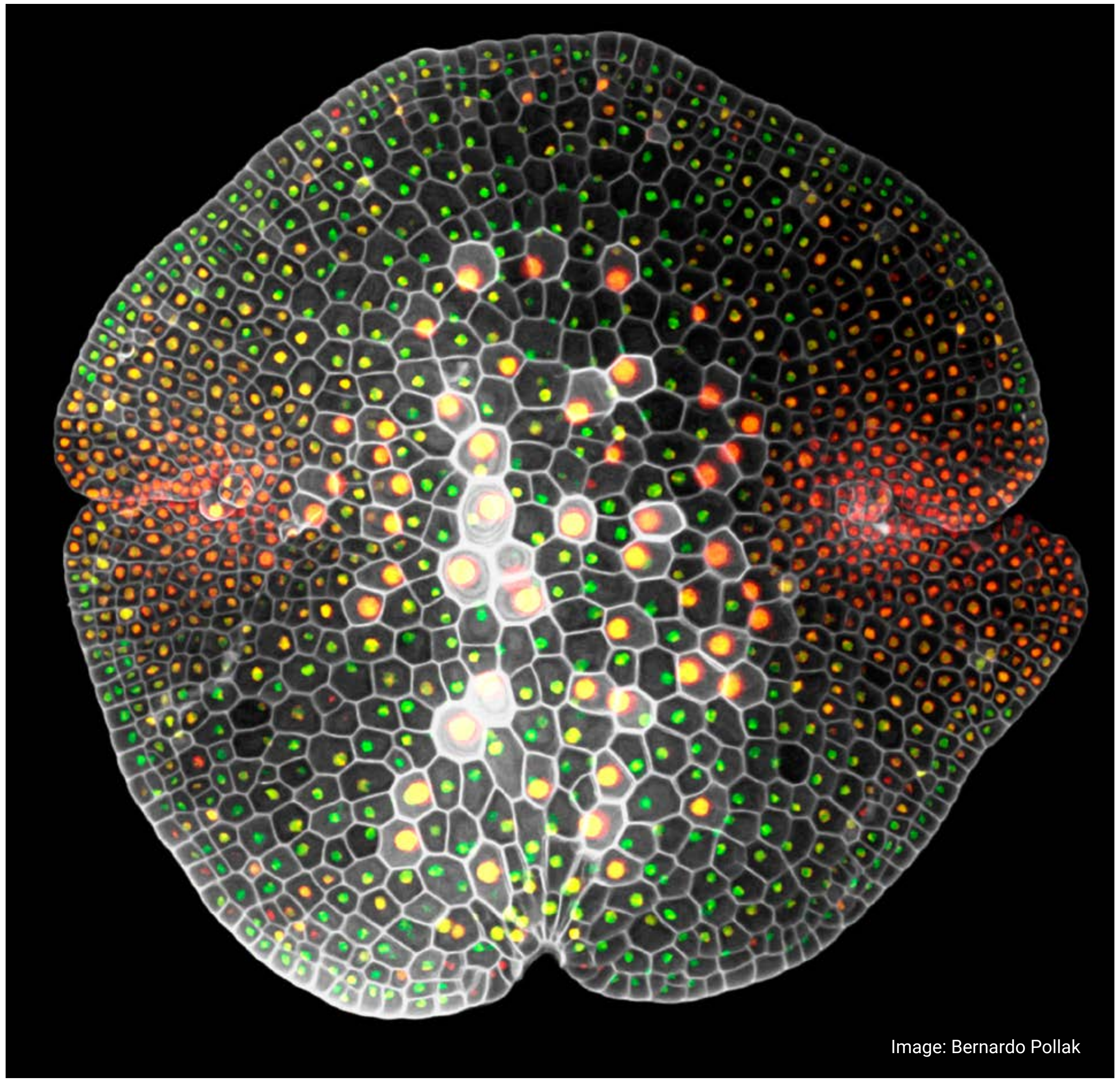


Image: Bernardo Pollak

A testbed for plant synthetic biology

Marchantia polymorpha is the best characterised liverwort. It is a thalloid liverwort, forming a body of sheet-like tissues that possess distinct upper and lower surfaces. The upper surface has a modular structure, with repeated cellular units that form simple cell complexes adapted for photosynthesis and gas exchange. Like other Bryophytes, the gametophyte or haploid generation is dominant phase of the life cycle. Marchantia has a global distribution, and is often found as a weed in horticulture. The plants grow vigorously on soil or artificial media. Marchantia plants spontaneously produce clonal vegetative propagules, or gametogenesis can be induced by exposure to far red light. Male and female plants can be sexually crossed to produce spores.

The plants are extraordinarily prolific. A single cross can produce millions of propagules in the form of single-cell spores. Spores can be harvested in huge numbers and stored indefinitely in a cold, desiccated state. Each spore can germinate to produce a new plant, and, unlike higher plants, can undergo the entire developmental sequence to produce an adult plant under direct microscopic observation.

Sequencing efforts have provided a draft of the ~280Mbp genome. Most of the major gene families present in more advanced plants are represented by a single or few orthologues in Marchantia, meaning that there is low genetic redundancy. The apparent simplicity of genetic networks in liverworts, combined with the growing set of techniques for genetic manipulation, culture and microscopy, are set to make this primitive plant a major new system for analysis and engineering.

OpenPlant has adopted Marchantia as a simple testbed for plant synthetic biology.

We have identified and sequenced a Cambridge isolate of *Marchantia polymorpha*, and are using the annotated genome to compile a novel library of DNA building blocks based on a common syntax for DNA parts and a technique for rapid assembly of DNA circuits. We aim to create an open system for reprogramming plant metabolism and form in a simple engineering testbed.

Image: Jim Haseloff