

Quick guide

Physcomitrella patens

Ralf Reski¹ and David J. Cove²

What is *Physcomitrella patens*?

A moss which is proving to be a useful new model plant species, one that is increasingly being used in experimental studies.

What place have mosses in the wider scheme of things?

They are plants, though rather different from the seed plants which usually come to mind when we think of plants — the flowering plants, such as the weed *Arabidopsis*, or conifers, such as the Christmas tree. Mosses do not have flowers, vascular tissue or seeds; they are thus grouped into a different subdivision of plants — of which there are four in total — from the flowering plants. Mosses and liverworts used to be placed in the same phylum, but they are now generally regarded as being sufficiently different to be placed in two distinct phyla: Bryophyta and Hepatophyta, respectively. Mosses have evolved with little change from the first land plants, and include about 24,000 different living species.

A tiny plant, upside-down... All plants develop from single cells. In seed plants, these zygotes develop into embryos which become encapsulated in seeds for dispersal. Mosses produce spores not seeds. What makes the difference? Plants show an alteration of two generations: one, the gametophyte, is haploid and produces sex organs and gametes — sperm and egg cells generated by mitosis. As in animals, sperm fertilize egg cells to produce diploid zygotes which subsequently grow into embryos. These embryos produce the diploid sporophyte generation, which produces haploid spores by meiosis.

Spores give rise to the next gametophyte generation. In seed

plants, the gametophytes are reduced to a few cells which only specialized botanists can find; the dominating generation is the diploid sporophyte. In bryophytes, including mosses, the dominating generation is the haploid gametophyte and the sporophyte is a reduced structure, which is completely dependent on the gametophyte (Figure 1).

So, very early in land plant evolution, a major decision was made: whether to grow in the diploid sporophyte stage, as in seed plants, or in the haploid gametophyte stage, as in the mosses. This is probably one of the reasons why mosses are too small to be used as Christmas trees.

So why the interest in *Physcomitrella patens*?

The haploidy of the predominant gametophyte generation in mosses provides technical advantages. In haploid organisms, we do not need to be concerned with genetic dominance, as we cannot have heterozygous haploid tissue. As a consequence, a loss-of-function mutation in a gene cannot be compensated by a functional allele on the homologous chromosome, as there is no homologous chromosome in a haploid cell. Thus, altering or destroying a gene in a haploid organism directly leads to an altered phenotype, making forward and reverse genetic approaches more straightforward in haploid moss than in diploid seed plants.

A major additional asset of mosses came from the discovery that, in the moss *Physcomitrella patens*, recombination occurs between DNA introduced into cells by transfection and homologous sequences in its nuclear DNA. This occurs as efficiently as in yeast — five orders of magnitude (!) more efficiently than in any other plant species that has been tested. Since then, this technique has been used to study gene–function relationships in single gene knockout mosses. Additionally, homologous recombination has been used to generate tagged, saturated *Physcomitrella* mutant

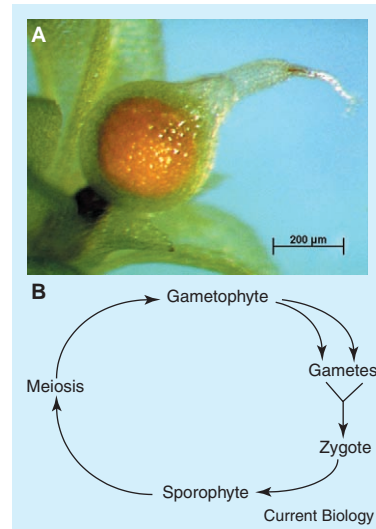


Figure 1. (A) A *Physcomitrella* sporophyte developing on a leafy gametophyte. (B) The life cycle of a moss (see text for details). The photo in (A) was taken by Manuel Mildner.

collections as the basis for genome-wide studies of plant gene functions.

A special offer from moss? The last common ancestor of mosses and seed plants lived about 450 million years ago. Mosses have not changed much since then, and, consequently, they offer the chance to learn more about plant evolution and diversity. Are there differences between gametophytic and sporophytic gene regulation? How do single cells decide to differentiate into new tissues? Are basic mechanisms of regulatory networks and cross-talk conserved between mosses and seed plants? Can novel genes or metabolites be identified from moss?

Mosses offer a variety of metabolites that are not known from seed plants. Some of them, like very long-chain polyunsaturated fatty acids, are of significant commercial value in improving the human diet and consequently the relevant moss genes are being transferred into seed plants to alter their fatty acid composition into a moss-like one. Moss can be grown efficiently in large-scale bioreactors to produce foreign proteins, including human proteins. Inactivating, by homologous recombination, the

genes for the enzymes that mediate plant-specific protein glycosylation alters the modification patterns of moss proteins to a human-like pattern; a milestone in the production of biopharmaceuticals in plants.

The best has yet to come

Sequence information from the *Physcomitrella* transcriptome is rapidly increasing and presently covers more than 95% of the estimated 25,000 protein-encoding moss genes. Mosses have conserved, ancient biochemical pathways; unlike seed plants they show no real codon-bias; on average, they have fewer representative members per protein family; and they have more than 5,000 genes with no clear homolog in seed plants. This impressive set of novel genes is attracting more and more scientists.

However, to fully understand — and exploit — land plant diversity, the full genome sequence of *Physcomitrella* is needed. The genome size is 511 Mb on 27 chromosomes, so sequencing the complete genome is not too daunting a mission these days. An international sequencing consortium will be launched at the next international moss meeting in Freiburg, Germany (www.plant-biotech.net/moss2004). Support from the broader community, however, is greatly appreciated.

Where can I find out more?

- Cove, D.J. (2000). The moss, *Physcomitrella patens*. *J. Plant Growth Reg.* 19, 275–283.
- Reski, R. (1998). Development, genetics and molecular biology of mosses. *Bot. Acta* 111, 1–15.
- Schaefer, D.G. (2002). A new moss genetics: targeted mutagenesis in *Physcomitrella patens*. *Ann. Rev. Plant Biol.* 53, 477–501.

Useful moss links:

- <http://www.moss.leeds.ac.uk>
<http://moss.nibb.ac.jp/>
<http://www.biology.wustl.edu/faculty/quatrano.html>
<http://www2.unil.ch/lpc/docs/pp.htm>
<http://www.plant-biotech.net>
<http://www.cosmoss.org>

¹Plant Biotechnology, University of Freiburg, Schaezlestr. 1, 79104 Freiburg, Germany

²Centre for Plant Sciences, University of Leeds, Leeds LS2 9JT, UK