Portrait of a model organism

Arabidopsis thaliana

cellular organisms - Eukaryota - Viridiplantae - Streptophyta - Streptophytina - Embryophyta - Tracheophyta - Euphyllophyta - Spermatophyta - Magnoliophyta - eudicotyledons - core eudicotyledons - rosids - eurosids II - Brassicales - Brassicaceae - Arabidopsis - Arabidopsis thaliana

Arabidopsis thaliana is a small flowering plant that is widely used as a model organism in plant biology. Arabidopsis is a member of the mustard (Brassicaceae) family, which includes cultivated species such as cabbage and radish. Arabidopsis is not of major agronomic significance, but it offers important advantages for basic research in genetics and molecular biology.

History of Arabidopsis thaliana as a research organism.

"Arabidopsis thaliana was discovered by Johannes Thal (hence, thaliana) in the Harz mountains in the sixteenth century, though he called it Pilosella siliquosa (and it has gone through a number of name changes since). The earliest report of a mutant (that I know of) was in 1873 (by A. Braun). F. Laibach first summarized the potential of Arabidopsis thaliana as a model organism for genetics in 1943 - he did some work on it much earlier though, publishing its correct chromosome number in 1907. The first collection of induced mutants was made by Laibach's student E. Reinholz. Her thesis was submitted in 1945, the work published in 1947. Langridge played an important role in establishing the properties and utility of the organism for laboratory studies in the 1950s, as did Rédei and others (such as J.H. van der Veen in the Netherlands, J. Veleminsky in Czechoslovakia and G. Röbbelen in Germany) in the 1960s. One of Rédei's many important contributions was to write scholarly reviews on Arabidopsis, a particularly thorough one is in Bibliographica Genetica vol 20, No. 2, 1970, pp. 1- 151. He wrote a more easily found one in Ann. Rev. Genet. (1975) vol. 9,111-127. Both go through some of the early history of the use of Arabidopsis in the laboratory, though the longer 1970 one has all the details."
--from Elliot Meyerowitz, 1998

Arabidopsis Ecotypes and Geographic Distribution

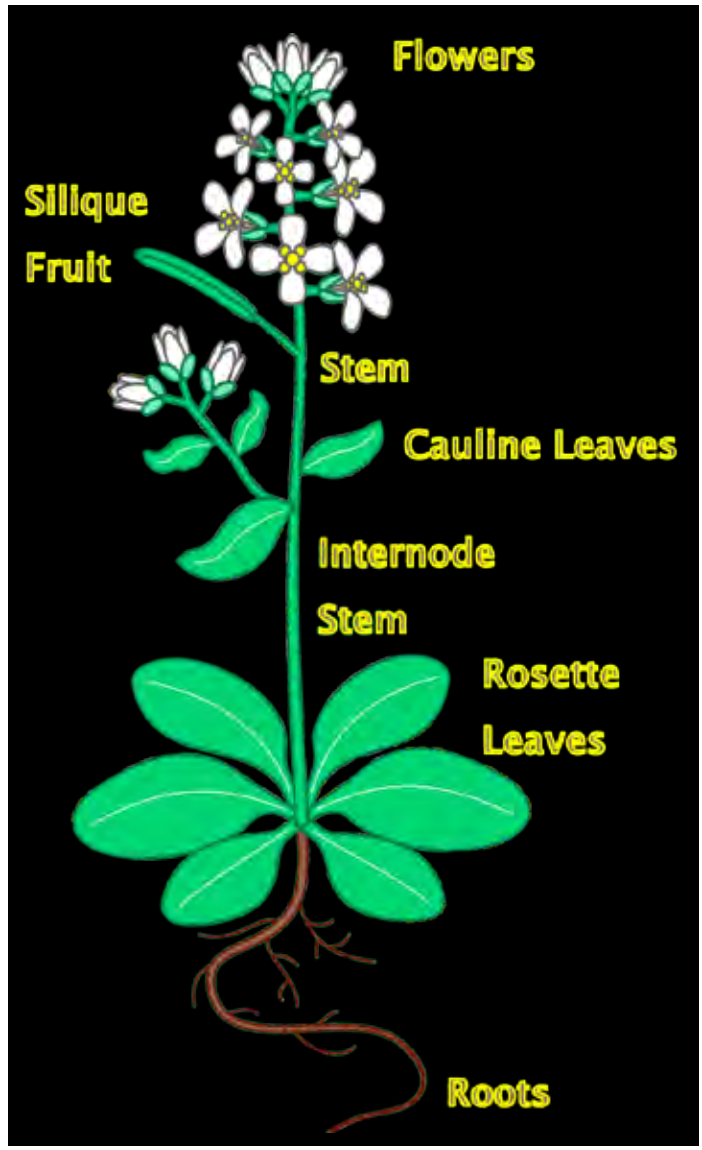
Over 750 natural accessions of Arabidopsis thaliana have been collected from around the world and are available from the two major seed stock centers, ABRC and NASC. These accessions are quite variable in terms of form and development (e.g. leaf shape,hairiness) and physiology (e.g. flowering time, disease resistance). Researchers around the world are using these differences in natural accessions to uncover the complex genetic interactions such as those underlying plant responses to environment and evolution of morphological traits. While many collections of natural accessions may not meet a strict definition of an ecotype, they are commonly referred to as ecotypes in the scientific literature.

PNG image of world wide distribution (1993, from Jonothan Clarke).This figure was produced by Jonathan Clarke for his Ph.D. (1993) thesis with Caroline Dean at Norwich, U.K. This map was based on, i.e., re-drawn, from an original by George Redei (1969).

World map showing the geographical distribution (longitude, latitude, elevation) of more than 30 Arabidopsis ecotypes. This image was kindly provided to us by the University of Toronto and is also available as interactive map on their website http://www.bar.utoronto.ca/

Habitat and morphology

Arabidopsis is native to Europe, Asia, and northwestern Africa. It also appears to be native in tropical afroalpine ecosystems. It is an annual (rarely biennial) plant, usually growing to 20–25 cm tall. The leaves form a rosette at the base of the plant, with a few leaves also on the flowering stem. The basal leaves are green to slightly purplish in color, 1.5–5 cm long and 2–10 mm broad, with an entire to coarsely serrated margin; the stem leaves are smaller and unstalked, usually with an entire margin. Leaves are covered with small, unicellular hairs (called trichomes). The flowers are 3 mm in diameter, arranged in a corymb; their structure is that of the typical Brassicaceae. The fruit is a siliqua 5–20 mm long, containing 20–30 seeds. Roots are simple in structure, with a single primary root that grows vertically downwards, later producing smaller lateral roots. These roots form interactions with rhizosphere bacteria such as Bacillus megaterium. Arabidopsis can complete its entire life cycle in six weeks. The central stem that produces flowers grows after about three weeks, and the flowers naturally self-pollinate. In the lab, arabidopsis may be grown in Petri plates, pots, or hydroponics, under fluorescent lights or in a greenhouse.



History of Arabidopsis research

A double flower mutant of arabidopsis, first documented in 1873.

The first mutant in arabidopsis was documented in 1873 by Alexander Braun, describing a double flower phenotype (the mutated gene was likely Agamous, cloned and characterized in 1990). However, not until 1943 did Friedrich Laibach (who had published the chromosome number in 1907) propose arabidopsis as a model organism. His student, Erna Reinholz, published her thesis on arabidopsis in 1945, describing the first collection of arabidopsis mutants that they generated using X-ray mutagenesis. Laibach continued his important contributions to arabidopsis research by collecting a large number of ecotypes. With the help of Albert Kranz, these were organised into the current ecotype collection of 750 natural accessions of *A. thaliana* from around the world.

In the 1950s and 1960s, John Langridge and George Rédei played an important role in establishing Arabidopsis as a useful organism for biological laboratory experiments. Rédei wrote several scholarly reviews instrumental in introducing the model to the scientific community. The star of the arabidopsis research community dates to a newsletter called Arabidopsis Information Service (AIS), established in 1964.

The first International Arabidopsis Conference was held in 1965, in Göttingen, Germany.

In the 1980s, arabidopsis started to become widely used in plant research laboratories around the world. It was one of several candidates that included maize, petunia and tobacco. The latter two were attractive, since they were easily transformable with the then current technologies, while maize was a well-established genetic model for plant biology. The breakthrough year for arabidopsis as the preferred model plant came in 1986, when T-DNA-mediated transformation was first published, and this coincided with the first gene to be cloned and published in Arabidopsis.

Some important facts about *A. thaliana*

Approximately 115 Mb of the 125 Mb genome has been sequenced and annotated (Nature, 408:796-815; 2000).

Extensive genetic and physical maps of all 5 chromosomes are available.

The life cycle is short--about 6 weeks from germination to seed maturation.

Seed production is prolific and the plant is easily cultivated in restricted space.

Transformation is efficient utilizing Agrobacterium tumefaciens.

A large number of mutant lines and genomic resources is available.

A. thaliana is studied by a multinational research community in academia, government and industry.

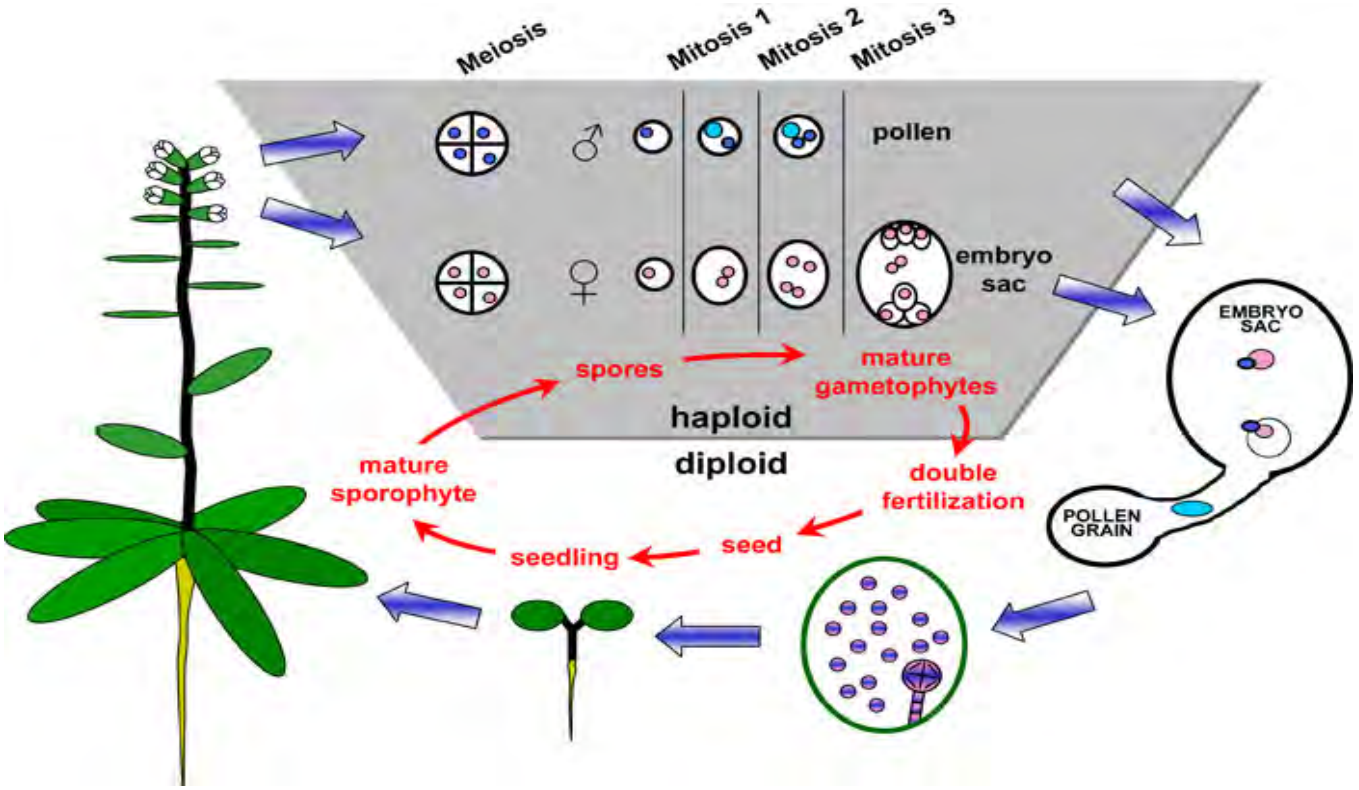
Such advantages have made Arabidopsis a model organism for studies of the cellular and molecular biology of flowering plants. The Arabidopsis Information Resource (TAIR) collects and makes available the information arising from these efforts.

Characterized ecotypes and mutant lines of arabidopsis serve as experimental material in laboratory studies. The most commonly used background lines are Ler, or Landsberg erecta, and Col, or Columbia.

Other background lines less-often cited in the scientific literature are Ws, or Wassilewskija, C24, Cvi, or Cape Verde Islands, Nossen, etc. Series of mutants, named Ler-x, Col-x, have been obtained and characterized; mutant lines are generally available through stock centers, of which best known are the Nottingham Arabidopsis Stock Center-NASC and the Arabidopsis Biological Resource Center-ABRC in Ohio, USA.

The Col or Columbia ecotype was selected, as an agronomically performant line, by Rédei, within a (non-irradiated) population of seeds named Landsberg he received from Laibach. Columbia is the ecotype sequenced in the Arabidopsis Genome Initiative.

The Ler or Landsberg erecta line was selected by Rédei from within a Landsberg population on which he had performed some X-ray mutagenesis experiments. As the Ler collection of mutants is derived from this initial line, Ler-0 does not correspond to the Landsberg ecotype which is named La-0.



Life cycle of Arabidopsis thaliana

The mature plant possesses primary and secondary roots, rosette and cauline leaves, and inflorescences. Flowers are composed of sepals, petals, stamens (male reproductive organs) and carpels (female reproductive organs). After pollination, the fertilized egg develops into an embryo inside the silique. The embryo possesses two meristems, a shoot meristem (SAM) and a root meristem (RAM), where new organs and tissues are initiated during post-embryonic growth. Seeds germinate and give rise to seedlings composed of the embryonically-formed hypocotyl and cotyledons.

Use of Arabidopsis thaliana as a model organism

Botanists and biologists began to research *A. thaliana* in the early 1900s, and the first systematic collection of its mutations was performed around 1945.

It is now widely used for studying plant sciences, including genetics, evolution, population genetics, and plant development. It plays the role in plant biology that mice and fruit flies (Drosophila) play in animal biology. Although *A. thaliana* has little direct significance for agriculture, it has several traits that make it a useful model for understanding the genetic, cellular, and molecular biology of flowering plants.

The small size of its genome, and the fact that it is diploid, makes *Arabidopsis thaliana* useful for genetic mapping and sequencing — with about 157 mega base pairs and five chromosomes, arabidopsis has one of the smallest genomes among plants. It was the first plant genome to be sequenced, completed in 2000 by the Arabidopsis Genome Initiative.

The most up-to-date version of the *A. thaliana* genome is maintained by the Arabidopsis Information Resource (TAIR). Much work has been done to assign functions to its 27,000 genes and the 35,000 proteins they encode.

Post-genomic research, such as metabolomics, has also provided useful insights to the metabolism of this species and how environmental perturbation can affect metabolic processes.

The plant's small size and rapid life cycle are also advantageous for research. Having specialized as a spring ephemeral, it has been used to found several laboratory strains that take about six weeks from germination to mature seed. The small size of the plant is convenient for cultivation in a small space, and it produces many seeds. Further, the selfing nature of this plant assists genetic experiments. Also, as an individual plant can produce several thousand seeds; each of the above criteria leads to *A. thaliana* being valued as a genetic model organism.

Plant transformation in arabidopsis is routine, using *Agrobacterium tumefaciens* to transfer DNA to the plant genome. The current protocol, termed "floral-dip", involves simply dipping a flower into a solution containing Agrobacterium, the DNA of interest, and a detergent. This method avoids the need for tissue culture or plant regeneration.

The Arabidopsis gene knockout collections are a unique resource for plant biology made possible by the availability of high-throughput transformation and funding for genomics resources. The site of T-DNA insertions has been determined for over 300,000 independent transgenic lines, with the information and seeds accessible through online T-DNA databases. Through these collections, insertional mutants are available for most genes in arabidopsis.

Finally, the plant is well suited for light microscopy analysis. Young seedlings on the whole, and their roots in particular, are relatively translucent. This, together with their small size, facilitates live cell imaging using both fluorescence and confocal laser scanning microscopy. By wet mounting seedlings in water or in culture media, plants may be imaged uninvasively, obviating the need for fixation and sectioning and allowing time-lapse measurements. Fluorescent protein constructs can be introduced through transformation. The developmental stage of each cell can be inferred from its location in the plant or by using fluorescent protein markers, allowing detailed developmental analysis.

TAIR and NASC are curated sources for diverse arabidopsis genetic and molecular biology information, and also provide numerous links, for example, to databases that store the results of hundreds of genome-wide gene expression profile experiments. Seed and DNA stocks can be obtained from NASC or the Arabidopsis Biological Resource Center.