**Plant evolution, morphology and diversity (in English)**

**Lecturer:** Dr. Dmitry Sokoloff
**Semester:** no preference
**Day:**
**Time:** Weekly lectures of 2 hr each.
**Credits**: 2 points
**Target students**: 2nd - 3rd year undergraduate Biology/Environmental Science students, open to graduate students.
**Course Prerequisites**: General biology or General botany. **Students that have not taken any of these courses or equivalent will not be accepted.**
**Course Language**: English
**Course Name in Hebrew:** אבולוציה, מורפולוגיה ומגוון של צמחים
**Students #**: No limit.

**Background:**

Land plants , also known as embryophytes, are the dominant group of photosynthetic organisms in most terrestrial ecosystems, including all domesticated crops. The course will provide a broad outline of the evolutionary history, current and past diversity, as well as patterns of function and development of reproductive organs across all major groups of land plants. The problem of the evolutionary origin of land plants and their life cycle with alternation of generations will be discussed. The importance of fossil record and molecular phylogenetics/phylogenomics as the two primary and equally important sources of knowledge on plant evolution will be studied. The only way of integrating these two sources is through morphology (including anatomy). The morphology of each major plant group will be discussed, with an emphasis on the structure, function, and development of reproductive organs (antheridia, archegonia, sporangia, ovules, flowers). Major events in the evolution of terrestrial vegetation will be considered, including the origins of tracheophytes and bryophytes, the origin of seed plants and seed reproduction, and the origin of angiosperms.

**Course Learning Goals:**
The general goal of the course is to provide the basic knowledge on morphological and developmental aspects of land plant evolution and to highlight the key role of morphology as a bridge between molecular/experimental botany and the fossil record. Specific goals are:

1. To gain a broad understanding of the diversity of body plans and life cycles of among all major groups of land plants.
2. To develop an understanding of the extensive data accumulated through comparative morphology, anatomy, and reproductive biology, while also recognizing the significant gaps in our primary knowledge of plant diversity. The course aims to highlight the urgency of filling these gaps to prevent the extinction of many plant species and communities due to climate and land-use change.

The students have to realise that many questions of evolutionary botany do not have a single 'correct' answer so far, but instead, several competing theories and views exist

among scientists today.

**Activities**

The course will consist of frontal lectures. Each lecture will include a 10-minute written test. Starting from the second lecture, these tests will be based on the content of the previous lecture available on Moodle. Additionally, a few scientific papers related to the previous lecture will be provided. The tests will also include questions that require drawing logical conclusions from the material covered in past lectures. Attendance at the course is compulsory, with a minimum requirement of 80% attendance.

**End of the course testing:**

This will be similar to the tests provided during regular lectures, but the accent will be made on the ability of students (1) to draw correct diagrams of life cycles and morphological/anatomical structures as well as (2) providing pros and cons over two contrasting theories on certain scientific problems to highlight their unresolved status.

**Student performance in the course will be evaluated as follows:**

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| *Testing on each lecture (mean cumulative from all classes)* | 50% |
| *Final course exam* | 50% |

**Syllabus**
(slight changes may occur on certain classes topics)

| Week/ Lecture N# | Topics and tasks |
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| 1 | **Introduction to Plant Taxonomy and Evolution**<br>Plant taxonomy as a modern science. Dynamics of new species discovery. Importance of new discoveries and a need of comprehensive biological interpretation of all species. Taxonomy and phylogenetics. The fossil record and DNA-based evidence are two main sources of information on the evolution. The only way of their synthesis is through morphology (including anatomy), which is thus at the heart of the evolutionary botany. Brief history of major approaches in taxonomy and phylogenetics. |
| 2 | **The Life Cycle of the Land Plants and Their Place in the Clade of Green Plants**<br>The most important features of land plants as compared to those of their closest phylogenetic relatives, Zygnematophyceae, Coleochaetophyceae, and Charophyceae. The life cycle of land plants differs from those of their closest relatives in the regular alternation of the haploid and diploid generation. Structure, development and function of archegonia, antheridia, gametes, spores, and spore tetrads in land plants. Fertilization in land plants. Bryophytes and tracheophytes and contrasing views on their evolutionary relationships. |
| 3 | **Liverworts**<br>Basics of bryophyte structure and ecology.<br>General characteristics of liverworts as one of three groups of bryophytes.<br>Molecular-based classification of liverworts with three classes. Simple thalloid, complex thalloid, and leafy liverworts. Developmental morphology and shoots and thalli. Types of shoot branching in liverworts. Life cycle of liverworts. Structure and arrangement of antheridia and archegonia. Structures surrounding archegonia and the developing sporophyte. Structure of the sporophyte. Spores and elaters. |
| 4 | **Mosses and Hornworts**<br>General characteristics of mosses, the largest division of bryophytes. Morphological and anatomical structure of the gametophyte (protonema and gametophore) and sporophyte. Diversity of capsule opening types in mosses and classification of mosses. Peristome as the most important evolutionary acquisition of the largest clade of mosses. Two major peristome types. Mosses and liverworts as members of the setaphyte clade. |

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| | General characteristics of hornworts. Differences from other groups of higher plants: liverworts, mosses and vascular plants and features common to hornworts and any one of these groups. Structure and hornwort stomata and contrasting views on their function. Symbiosis of hornworts with cyanobacteria and fungi. |
| 5 | **The Enigma of the Origin and Evolution of the Land Plant Life Cycle**<br>Comparative characteristics of bryophytes and tracheophytes (vascular plants). Viewpoints on the evolution of the life cycle of land plants. Silurian and Devonian fossil land plants. The significance of fossils from Rhynie. Morphological and anatomical structure of sporophytes of *Aglaophyton*, *Horneophyton*, and *Rhynia*. Ideas about their evolutionary relationaships. Gametophytes of plants from Rhynie. The problem of the absence of any bryophyte fossils in Rhynie and possible evolutionary implications. |
| 6 | **Lycopsids**<br>Lycopsids and euphyllophytes as two major caldes of extant tracheophytes. Contrasting scenrios of the evolutionary origins of leaves.<br>General characteristics of lycopsids. Extinct telomic members of lycopsids.<br>Leafy homosporous lycopsids. Their early fossil record. Contrasting evolutionary interpretations of *Asteroxylon*. Extant homosporous lycopsids. Morphological and anatomical characteristics and features of the biology of sporophytes and gametophytes. Structure abd development of lycopsid roots suggest their independent origins from those of euphyllophytes. The concept of heterospory. General features of the life cycles of heterosporous vascular plants. Heterosporous Lycopods. Morphological and anatomical structure of sporophytes. Structure and possible function of the leaf ligule. Male and female gametophytes. Fossil heterosporous lycopsids, including organisms with no close functional parallels in extant ecosystems. |
| 7 | **Free Sporing Tracheophytes (Ferns and Horsetails)**<br>The clade of monilophytes revealed unsing molecular phylogenetics and lacking obvious synapomorphies. Horsetails. General characteristics of extant members of *Equisetum*. Structure of shoots, roots, strobili, sporangia, spores and gametophytes. The unique spores of *Equisetum*: functional and developmental aspects. The most important fossil relatives of horsetails. Major groups of leptosporangiate and eusporangiate ferns. Structural and ecological features of sporophytes and gametophytes. Leptosporangium as an important synapomorphy of the largest group of ferns, its structure and development. Patterns of sporangium opening. Hormonal regulation of sex expression in gametophytes of homosporous leptosporangiate ferns. Heterosporous ferns and their ecological |

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| | specificity. |
| 8 | **The Origin and Early Evolution of Seed Plants. Cycads.**<br>The origin of seed plants. Functional, developmental, and ecological implications. Progymnosperms. The origin of the bifacial cambium. Gymnosperms and arcogymnosperms. Evolutionary origins of the ovule and seed reproduction. Prepollen and pollen. Features of the reproductive biology of the earliest ovule-bearing plants. Seed ferns as a level of development of seed plants.<br>General characteristics of extant cycads. Morphological and anatomical structure of the vegetative and reproductive organs of the sporophyte. Structure and development of female and male gametophytes, sexual process, structure of the seed. Ecological features of cycads, adaptations to entomophily. Are extant cycad species living fossils? |
| 9 | ***Ginkgo* and Conifers**<br>*Ginkgo biloba* as the only modern representative of once diverse and ecologically important evolutionary lineage. Similarities and differences with cycads in the morphological and anatomical structure and reproductive biology. The origins of siphonogamy in the evolution of seed plants. General characteristics of conifers and their major groups. The morphological nature of the seed scale: the importance of comparative morphology and fossil record. Life cycle of conifers using pine as an example. Basics of conifer ecology. |
| 10 | **Gnetales: the Mysterious Clade of Seed Plants**<br>*Ephedra*, *Gnetum* and *Welwitschia*, plants with contrasing ecology, habit, and external morphology form the gymnosperm order Gnetales. Important similarities with flowering plants (angiosperms) and conifers. Phylogenetic placement of Gnetales and the problem of long branch attraction. |
| 11 | **Introduction to Angiosperms**<br>Flowering plants, or angiosperms, are the largest and most important group of land plants for humans. Ecological and morphological diversity of angiosperms. The most important features defining angiosperms as a group. What is a flower and how can it be defined? Diversity of flowers. Perianth and its types. Androecium. Typical structure of the stamen of angiosperms. Diversity of pollen grains of angiosperms and the taxonomic significance of palynological features. The concept of carpel. Ascidiate and plicate carpels. Diversity of angiosperm gynoecia, its functional and evolutionary interpretations. The concept of congenital and postgenital fusion in plant development using gynoecium as an example. Flowers with superior, inferior and semi-inferior ovaries. |

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| 12 | **Fundamentals of reproductive biology of angiosperms**<br>The structure of the ovule and female gametophyte (embryo sac) of angiosperms. Double fertilization and endosperm formation, embryo and seed coat development. Hypotheses on the evolutionary origins of the embryo sac and double fertilization of angiosperms. Basics of pollination biology in angiosperms. Diversity of fruits of angiosperms. Patterns of fruit and seed dispersal. |
| 13 | **The Origin, Evolution, and Classification of Angiosperms**<br>The problem of the origin of angiosperms. The most important points of view on the origin of the flower. The importance of molecular phylogenetics, paleobotany and developmental genetics. Angiosperm Phylogeny Group classification of angiosperm families. General characteristics of monocotyledons and the origin of monocots. |