Tracheophyte Phylogeny

Vascular Plants – Systematics and Characteristics

Hornworts, Mosses, Liverworts see "Bryophyte" Phylogeny Poster

sporophyte dominant
vascular tissue:
tracheids + sieve cells
sporangia many
zygote:
1st division horizontal

Lycophytes

shoots (protoxylem exarch) with lvs (lyco-/microphylls; single central, unbranched vein)
root (protoxylem endarch) dichopodial
sporangia reniform, dorsiventral and transversely dehiscent, 1 (adaxial) per leaf

- homosporous, lvs eligulate, sporangia s.t. clustered in terminal strobili — **Lycopodiales** — Lycopodiaceae
- heterosporous, lvs ligulate:
  - cormose to rhizomatous, lvs spiral, in basal rosette, microspores monolete, megaspores 50–300 — **Isoëtales** — Isoëtaceae
  - sporangia on 4-sided strobili, lvs 4-ranked, microspores trilete, megaspores 4 — **Selaginellales** — Selaginellaceae

Euphyllophytes

euphyll
leaf gaps
protoxylem exarch
roots monopodial
variously vessels
30-kb cp inversion

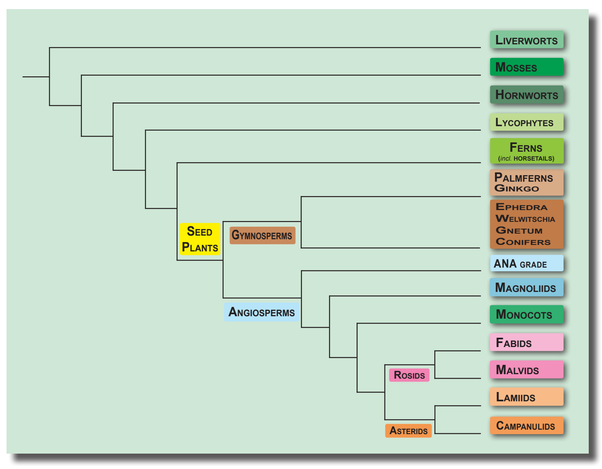
Ferns

- sporangiophores in terminal strobili, lvs whorled, fused into sheaths encircling base of internodes, stems ridged with internal hollow canals, spores with elaters 4–6, straplike — **Equisetales** — Equisetaceae

Monilophytes

sporangia in sori
sporangia primarily multi-layered: eusporangial
tapetum plasmodial
pseudoendospore +
siphonostele
stem protoxylem mesarch

- roots unbranched, root hairs absent, collateral leaf vascular bundles, gametophyte nonphotosynthetic, often subterranean, mycorrhizal
  - each leaf with fertile (sporophore) & sterile (trophophore) parts (latter inclined relative to former) — **Ophioglossales** — Ophioglossaceae
  - roots absent, lvs reduced, veins 1 or 0, sporangia 2–3, fused: synangium — **Psilotales** — Psilotaceae
  - tropical, megaphyllous, stipules +, polycyclic siphonostele, often synangia, annulus –, sporangia open by longitudinal slit or pores — **Marattiales** — Marattiaceae
  - sporangia single-layered with annulus: leptosporangial
    - annulus lateral on sporangium, opening apically — **Osmundales** — Osmundaceae
    - receptacle elongate, lvs thin, usually 1 cell layer, sori marginal — **Hymenophyllales** — Hymenophyllaceae
    - root steles with 3–5 protoxylem poles, rhizome with scales; veins anastomosing, sporangia maturation simultaneous — **Gleicheniales** — Gleicheniaceae, Matoniaceae, Dipteridaceae
    - hairs, endospore 2-layered:
      - annulus transverse, subapical, opening by longitudinal slit — **Schizaeales** — Anemiaceae, Lygodiaceae, Schizaeaceae
      - aquatic; aerenchyma +, stems dichotomizing; leaf dimorphism, heterosporous; sporocarps; annulus – — **Salviniales** — Marsileaceae, Salviniaceae
      - usually tree ferns, sori often terminal on veins — **Cyatheales** — Cyatheaceae, Cibotiaceae, Dicksoniaceae, Metaxyaceae, Thyrsopteridaceae, Loxsomataceae, Culcitaceae, Plagiogyriaceae
      - sporangial maturation mixed, annulus vertical on sporangium, interrupted by stalk and stomium — **Polypodiales** — Saccolomataceae, Cystodiaceae, Lonchitidaceae, Lindsaeaceae, Pteridaceae, Dennstaedtiaceae; Eupolypods I: Polypodiineae (*incl.* Polypodiaceae, Davalliaceae, Didymochlaenaceae, Dryopteridaceae, Hypodematiaceae, Lomariopsidaceae, Oleandraceae, Tectariaceae); Eupolypods II: Aspleniineae (*incl.* Aspleniaceae, Athyriaceae, Blechnaceae, Cystopteridaceae, Desmophlebiaceae, Diplaziopsidaceae, Hemidictyaceae, Onocleaceae, Rhachidosoraceae, Thelypteridaceae, Woodsiaceae)



Spermatophytes

eustele
secondary growth
ovules / seeds
heterosporous
pollen
pollen tube
with 2 gametes each

Seed Plants

- dioecious, zooidogamy
  - pachycaulous; pinnate megaphylls, males with pollen cones, pollen tube simple, roots with N_2-fixing cyanobacteria — **Cycadales**
    - in ♀: whorls of individual megasporophylls at trunk apex alternate with trophophylls (no seed cones) — **Cycadaceae** — *Cycas*
    - seed cones with 2[3] seeds per megasporophyll, lignins with syringaldehydes — **Zamiaceae** — *Bowenia, Ceratozamia, Chigua, Dioon, Encephalartos, Lepidozamia, Macrozamia, Microcycas, Stangeria, Zamia*
  - pollen tube branched — **Ginkgoales**
    - stout short shoots with lvs flabelliform, dichotomously veined, deciduous, ovules 2 (basal collar); cotyledons 2 — **Ginkgoaceae** — *Ginkgo*
- ovules/seeds not enclosed by carpel, pollen tube haustorial, primarily anemophilous, primary endosperm, no bisexual strobili — **Gymnosperms**
  - xeromorphic, lvs scale-like, sheathed, shed early, stems narrow, striate, photosynthetic, seed cones: 1–3 ovules; double fertilization — **Ephedraceae** — *Ephedra*
  - **Pinales**: loss of spermatozoids, nucellar siphonogamy, lvs morphologically diverse
    - dioecious, striate pollen, binucleate sperm, cotyledons 2, "Gnetales" * vessels, porose perforation plates
      - caudex, lvs 2 (straplike) life-long basal continuous growth, venation parallel, ♀ gametophyte tubes grow towards pollen tubes — **Welwitschiaceae** — *Welwitschia*
      - ectomycorrhizal, lvs opposite, simple, broad, venation reticulate (angiosperm-like "convergence"), laticifers — **Gnetaceae** — *Gnetum*
    - Conifers
      - monoecious, resin canals; lvs linear (needles), pollen mostly 2-saccate, ovules 2, inverted, seeds winged — **Pinaceae** — *Abies, Cathaya, Cedrus, Hesperopeuce, Keteleeria, Larix, Nothotsuga, Picea, Pinus, Pseudolarix, Pseudotsuga, Tsuga*
      - monoecious or dioecious, lvs broad to acicular, pollen not saccate, seed cones large, disintegrate, cotyledons 2–4 — **Araucariaceae** — *Agathis, Araucaria, Wollemia*
      - dioecious, roots with nodules, 1 ovule/scale, cone often one seeded, receptacle and/or epimatium/carpidium fleshy, cotyledons 2 — **Podocarpaceae** — *Acmopyle, Afrocarpus, Dacrycarpus, Dacrydium, Falcatifolium, Halocarpus, Lagarostrobus, Lepidothamnus, Manoao, Microcachrys, Nageia, Parasitaxus, Pherosphaera, Phyllocladus, Podocarpus, Prumnopitys, Retrophyllum, Saxegothaea*
      - monoecious, "double needles" (cladodes), ovules 7–9 — **Sciadopityaceae** — *Sciadopitys*
      - dioecious, evergreen; pollen cones tiny, peltate microsporangiophores, 1 ovule, 1 seed/cone, arillate, cotyledons 2 — **Taxaceae** — *Amentotaxus, Austrotaxus, Cephalotaxus, Pseudotaxus, Taxus, Torreya*
      - cone scales opposite: monoecious (*Juniperus:* monoecious or dioecious), lvs mostly scale-like, pollen not saccate; ovules 1–20/scale, cotyledons many, seed cones terminal — **Cupressaceae** — *Actinostrobus, Athrotaxis, Austrocedrus, Callitris, Calocedrus, Chamaecyparis, Cryptomeria, Cunninghamia, Cupressus, Diselma, Glyptostrobus, Fitzroya, Fokienia, Juniperus, Libocedrus, Metasequoia, Neocallitropsis, Papuacedrus, Pilgerodendron, Platycladus, Sequoia, Sequoiadendron, Taiwania, Taxodium, Tetraclinis, Thuja, Thujopsis, Widdringtonia, Xanthocyparis*

bisexual flower; fruit (ovules enclosed by carpel)
loss of spermatozoids
pollen tube penetrating stigma/style/nucellus/synergid (complete siphonogamy)
vessels; pollenkitt; primarily zoophilous
double fertilization: triploid endosperm

Angiosperms see Angiosperm Phylogeny Poster

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- hypothetical tree based on molecular phylogenetic data (Dec. 2016)
- branch lengths deliberate, not expressing actual time scale
- if a character is marked as being a potential synapomorphy at a node/for a clade, this does not mean that all members of that clade possess that character
- References: Judd W et al. (2016); Simpson M (2010); Soltis DE et al. (2005/2011); Christenhusz MJM et al. (2011/2014); Schuettpelz E, Schneider H, The Pteridophyte Phylogeny Group (2016)

see also: Stevens PF (2016) APweb – www.mobot.org/MOBOT/research/APweb

* the here presented sister relationship of Pinaceae to the Gnetaceae-Ephedraceae-Welwitschiaceae clade ("Gnepine"), has remained controversial to date, placing the latter within Pinales, and thus Gnetales would not represent a separate order

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