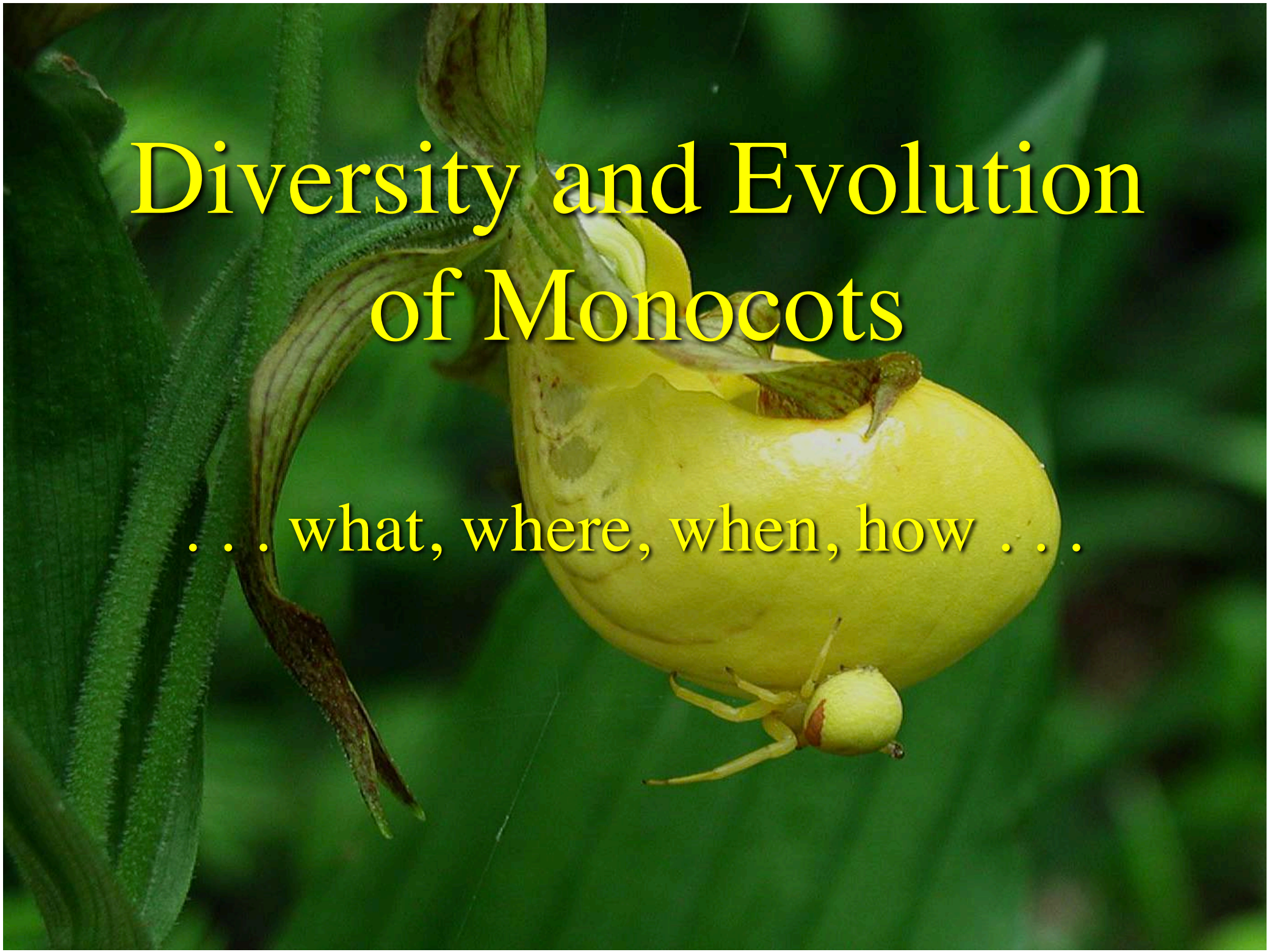
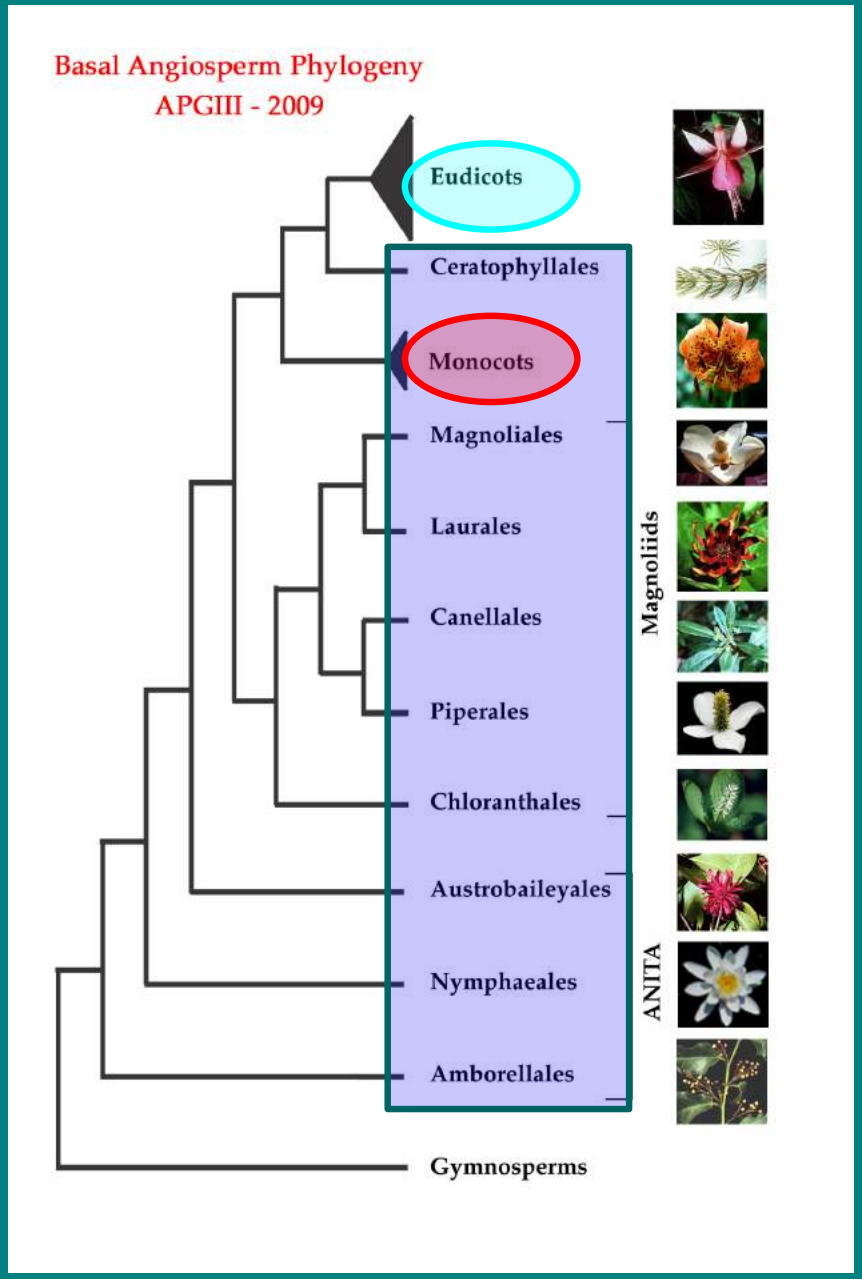


Diversity and Evolution of Monocots

. . . what, where, when, how . . .

Monocots!



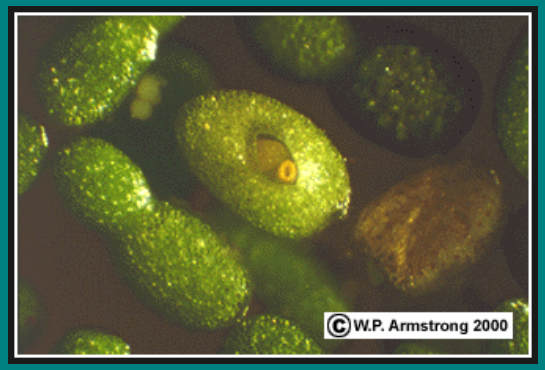
We will finish our survey of angiosperms by examining the monocots - a lineage of basal angiosperms

Basal angiosperm lineage, but is appearing to be closer to eudicots than most other basal angiosperms

Monocots!

- Large group: ~ 60,000 species!
- Old lineage: ~134 mya
- Great diversity: habit, habitat, pollination, morphology
- Adaptive radiations:

  (orchids–21,950 spp; grasses–10,035 spp)
- Smallest & largest seeds: orchids; *Lodoicea maldivica*
- Largest inflorescences (titan arum, palms, bromeliads)
- Smallest fruit, flower & flowering plant (*Wolfia*)



Tremendous economic importance



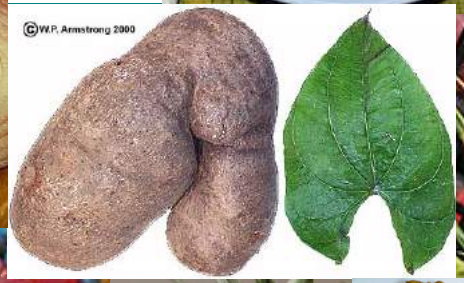




















Diversity in ecology

- "Trees", grasses, rosettes, vines, epiphytes…
- Carnivores, mycotrophs…
- Habitats: dry, wet, aquatic…
- Pollination: water, wind, zoophily

Diversity of aquatic habits

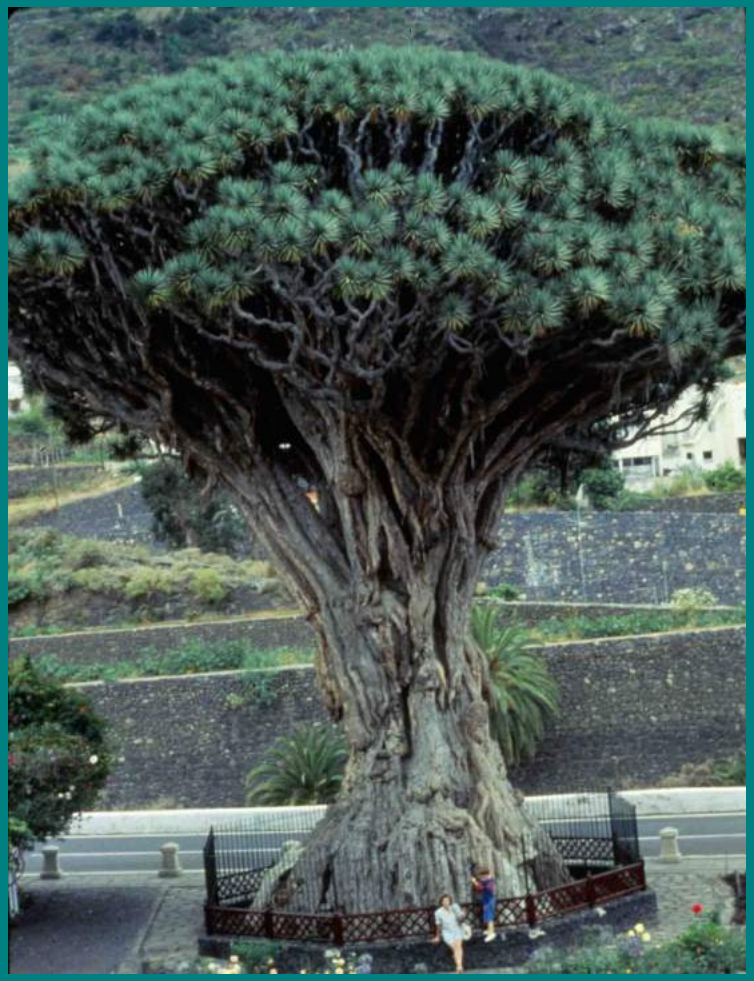
Emergent, floating, or submerged aquatic group of monocots

These are the first diverging monocots

Monocot "trees"

No vascular cambium activity ⇒ no true secondary growth (wood)

Anomalous secondary growth ⇒ "trees"



Dragon tree – a lily relative

Woody palm

Monocot leaves

- Parallel venation (or derived forms) vs. pinnate or reticulate venation as in most dicots
- (more on this later)

Monocot flower: common theme

3-merous
Tepals are common

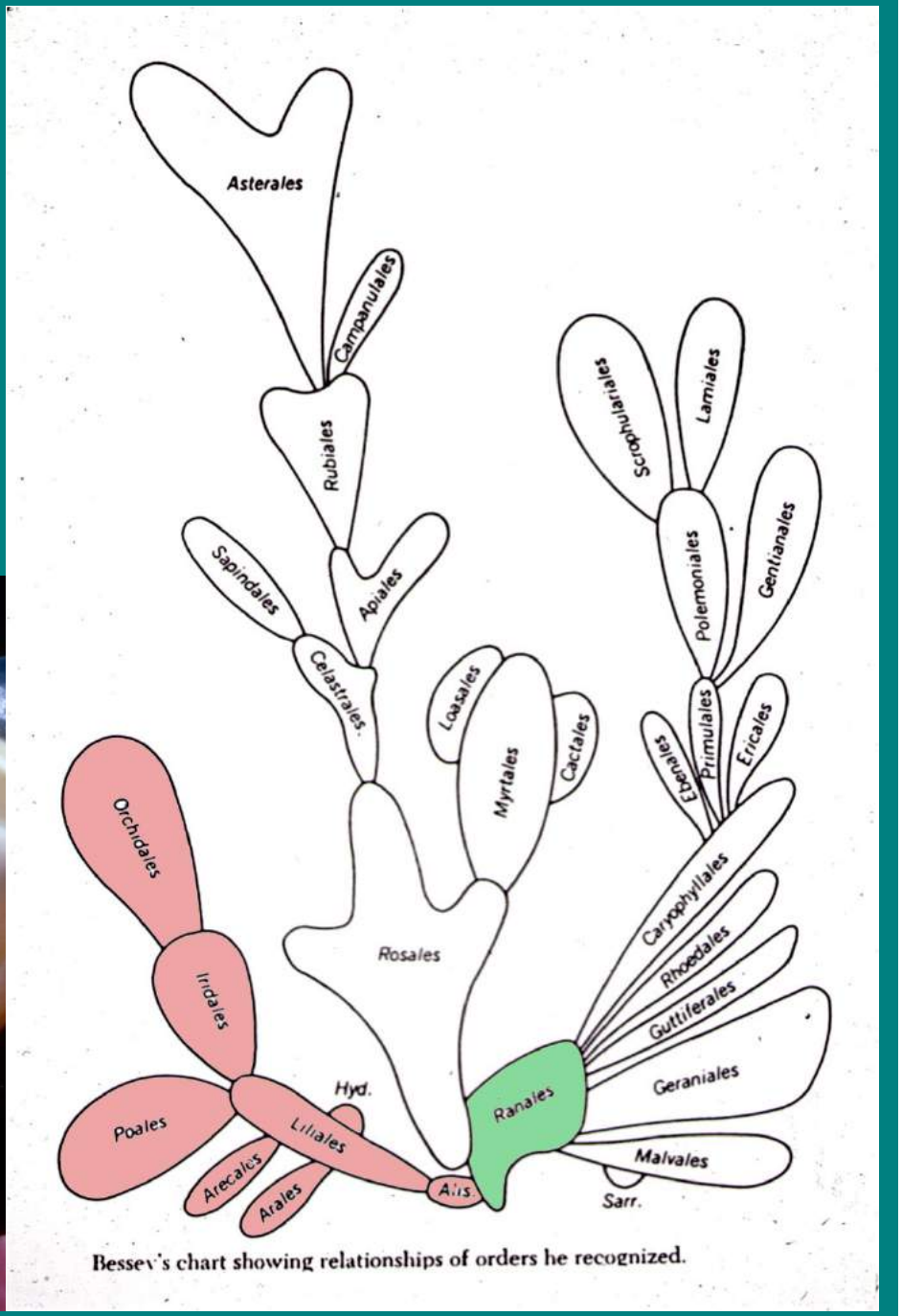
Diversity in pollination

Striking modifications & bracts:

grasses, pulpits, orchids, spadices & more!

Monocot Origins

Monocots have usually been considered as derived out of basal angiosperms - Ranales in the Bessey system or subclass Magnoliidae with Cronquist



Bessey's chart showing relationships of orders he recognized.

Monocot Origins

Crown group radiation: ~135+ mya [based on DNA evidence]

Pollen & leaf: possible early Aptian (Early Cretaceous), 113-125 mya

Oldest unambiguously assigned fossil: Araceae, 110-120 mya

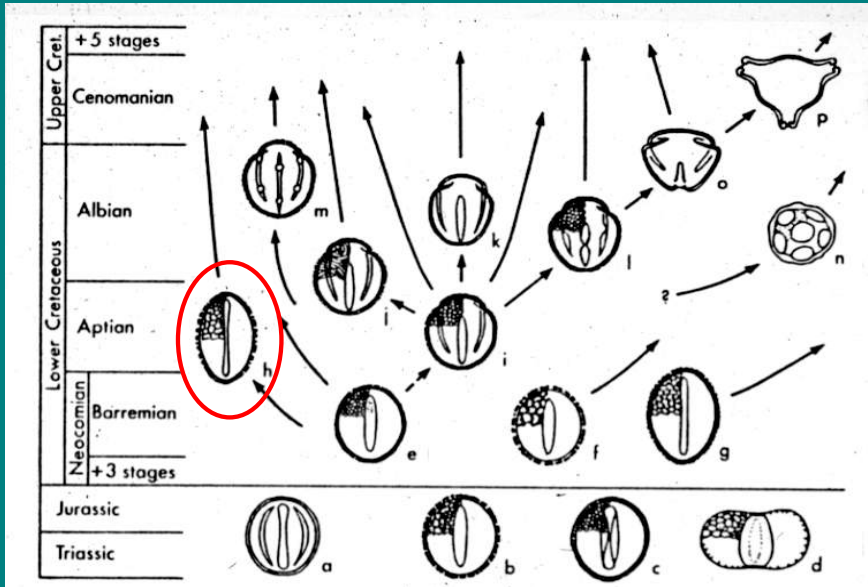


Figure 1 Time distribution and presumed relationships of principal Early Cretaceous and Cenomanian angiosperm pollen types (*e–p*), and selected pre-Cretaceous pollen types (*a–d*). *a: Eucommiidites; b:* Triassic reticulate-columellar monosulcate of Cornet (30); *c:* cycad-type alveolar monosulcate; *d:* saccate alveolar pollen of Caytoniaceae and Corystospermaceae; *e: Clavatipollenites; f: Retimonocolpites; g: Stellatopollis; h: Liliacidites,* a possible monocot; *i:* reticulate tricolpate; *j:* striate tricolpate; *k:* smooth tricolpate; *l:* grain with tricolporate tendency; *m:* tricolpodiorate; *n:* polyporate; *o:* smooth, oblate-triangular tricolporate; *p:* early member of triporate Normapolles complex.

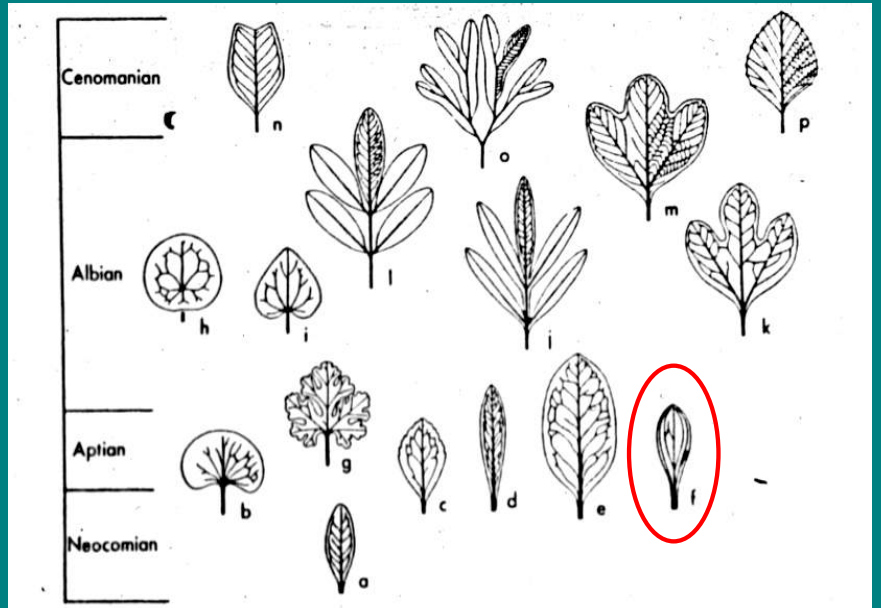
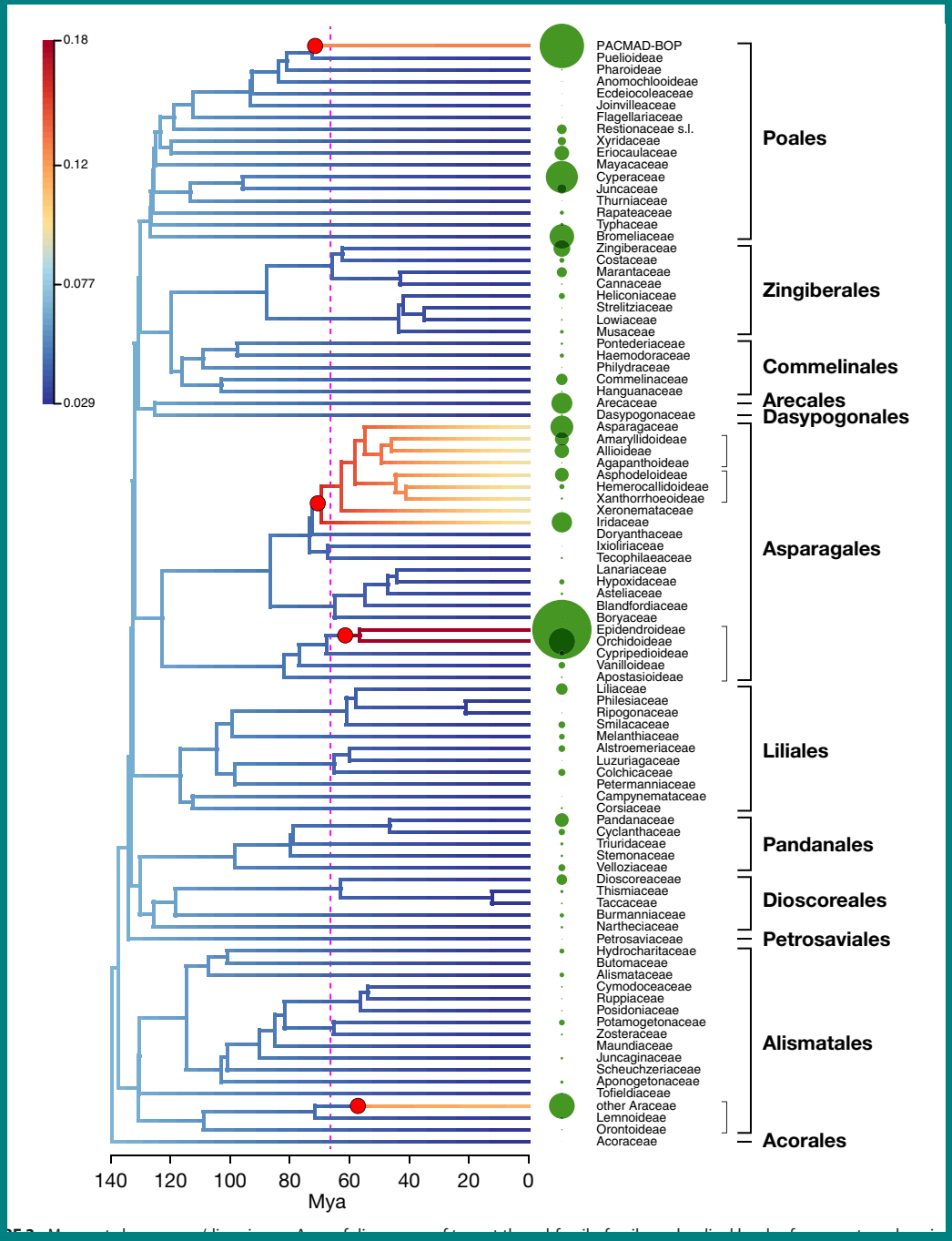


Figure 2 Principal Early Cretaceous and Cenomanian angiosperm leaf types. *a:* small, pinnately veined leaf of Vakhrameev (143); *b:* reniform; *c:* serrate; *d:* oblanceolate; *e: Ficophyllum; f: Acaciaephyllum,* a possible monocot; *g:* lobate reniform; *h:* peltate, actinodromous; *i:* ovate cordate; *j:* pinnatifid *Sapindopsis; k:* early plantanoid; *l:* compound *Sapindopsis; m:* later plantanoid, with rigidly organized fine venation; *n: Liriophyllum; o:* dichotomously compound; *p:* secondarily simple platanoid derivative.

Monocot Origins

- cpDNA genome phylogeny (Givnish et al. 2018)
- rapid radiation at base
- four large burst in species diversification



Monocot leaf evolution

Classic idea of pre-monocot characteristics – Cronquist's view:

1. Herbs
2. Aquatic
3. Perianth not specialized
4. Uni-apperturate pollen
5. Apocarpy
6. Laminar placentation

Nymphaeales
Only non-monocot order with all these characteristics

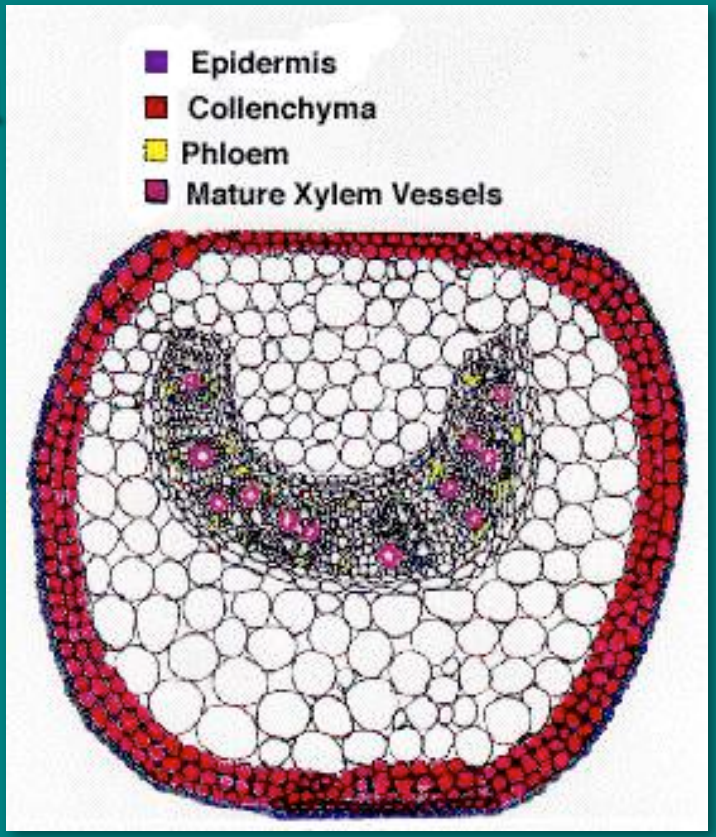
Monocot leaf evolution



- monocot leaf morphology due to aquatic ancestry

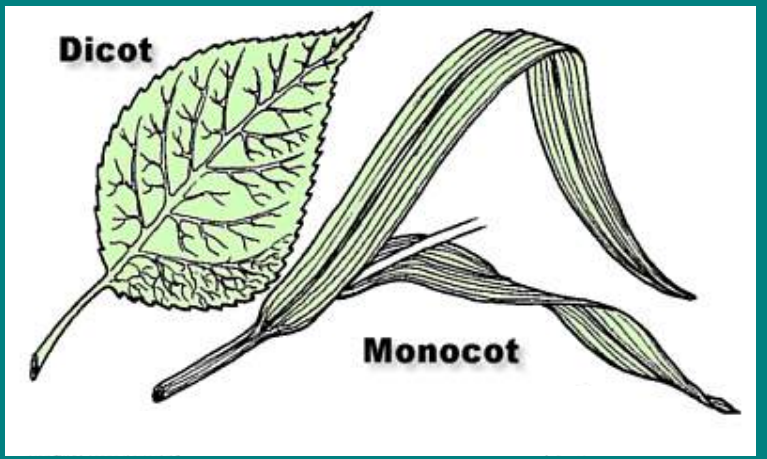
- aquatic → terrestrial → aquatic pathways

Monocot leaf evolution



celery (left) and tomato (right) asterid petioles showing parallel vascular traces

- monocot leaf is derived from an expanded bladeless petiole



Monocot leaf evolution

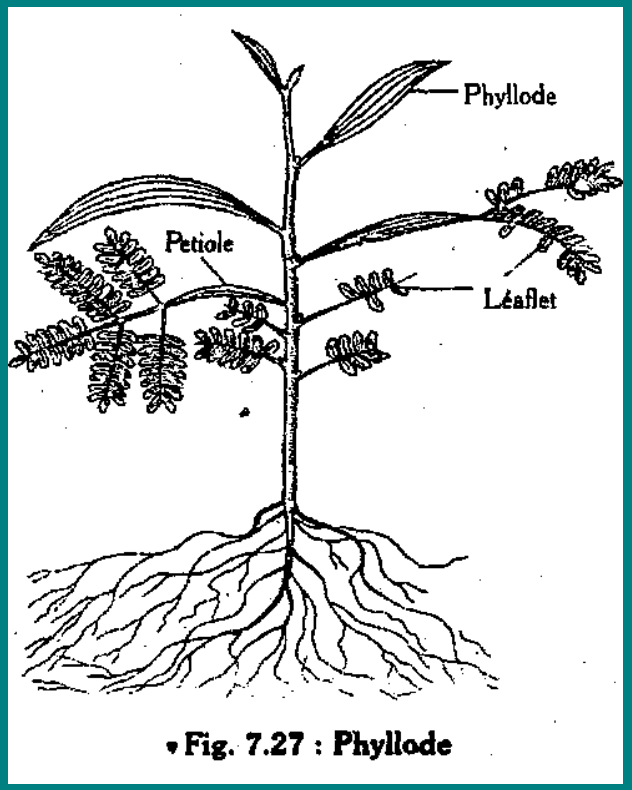
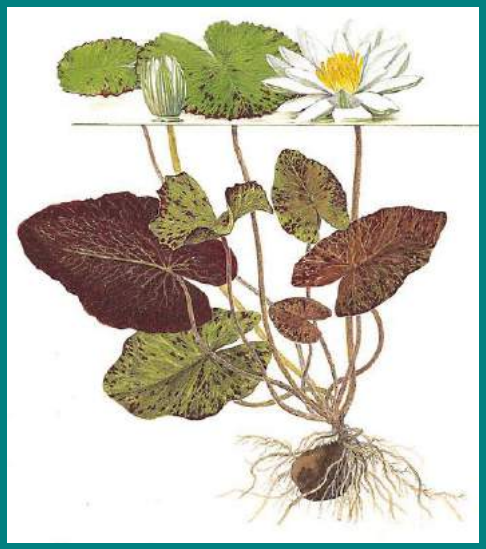


Fig. 7.27 : Phyllode

Phyllode theory: original monocot lacked a true leaf; only expanded petiole

Phyllodes: expanded blade-less petioles best seen in arid adapted woody legumes such as *Acacia*

Monocot leaf evolution



in aquatic habitat

loss of blade & expansion of tissue between parallel veins of petiole

variable expansion of tissue between parallel veins

Acorus
sweet flag

cross veins & 'reticulated' blades

Monocot leaf evolution

in aquatic habitat

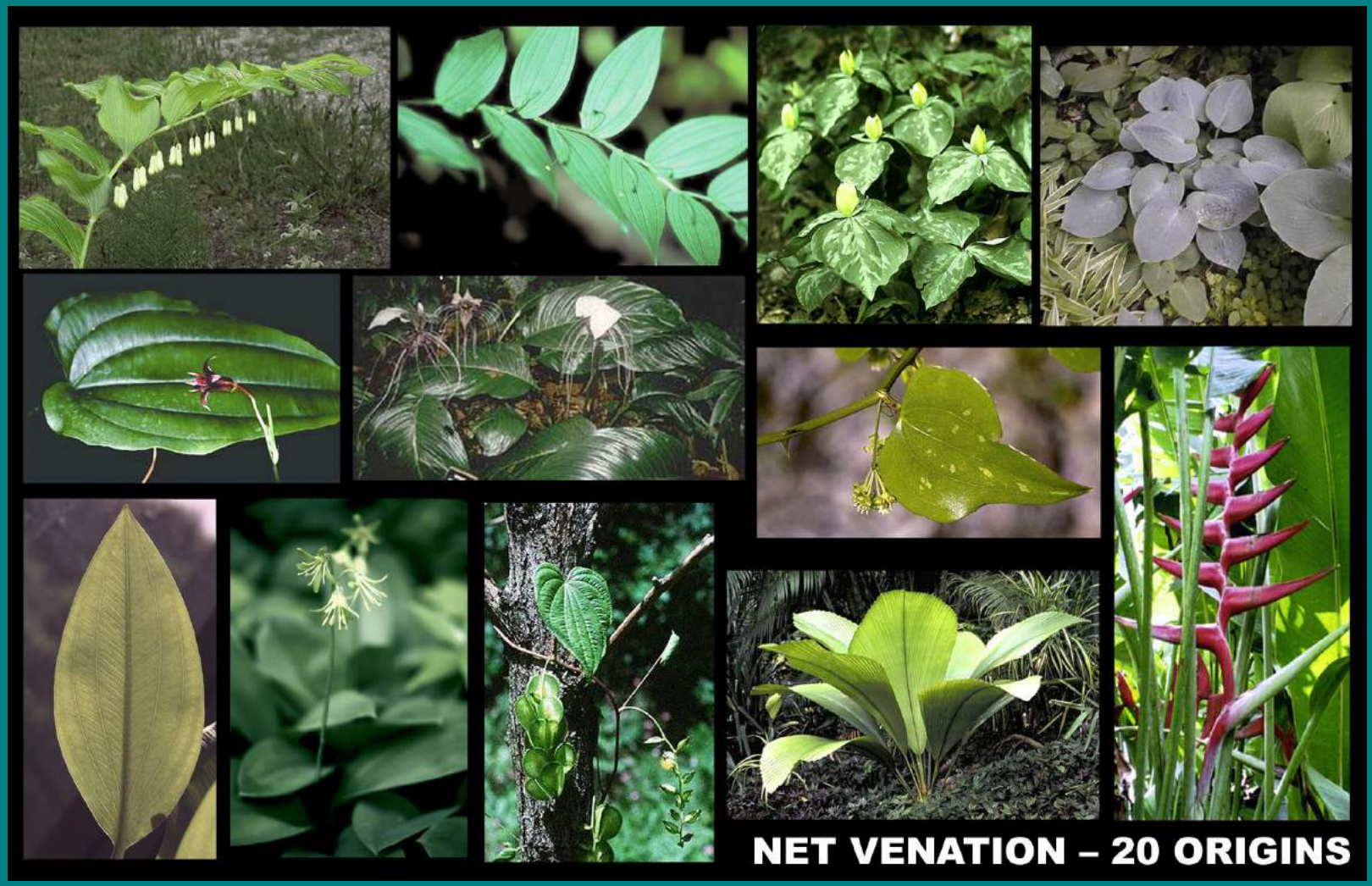
loss of blade & expansion of tissue between parallel veins of petiole

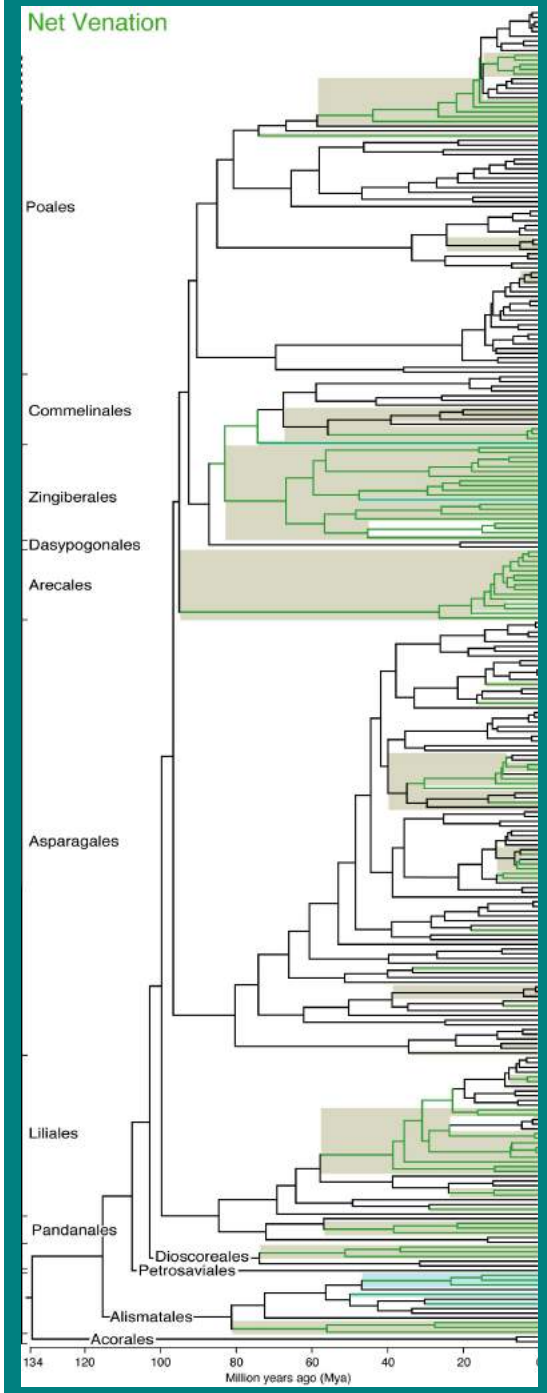
variable divergence of parallel veins to leaf edge

'parallel-pinnate' venation of palms and bananas

Monocot leaf evolution

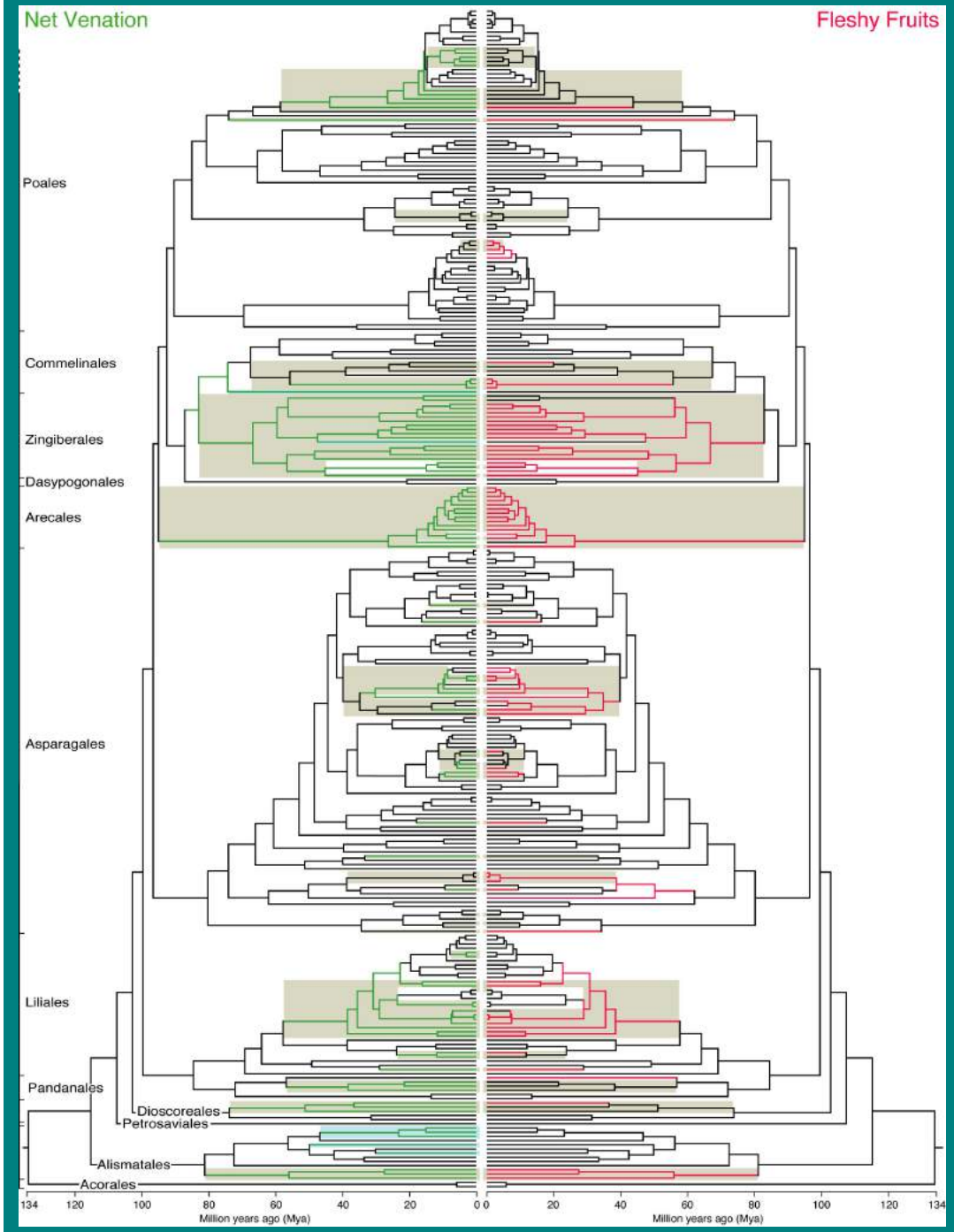
functional ecological arguments for evolution of broad leaves and fleshy fruits of monocots in shady understory conditions (T. Givnish, 1984, 1999, 2002)





Concerted convergence

Occurrences of net venation are overlain on this monocot phylogeny



Concerted convergence

Occurrences of net venation and fleshy fruits are overlain on this monocot phylogeny

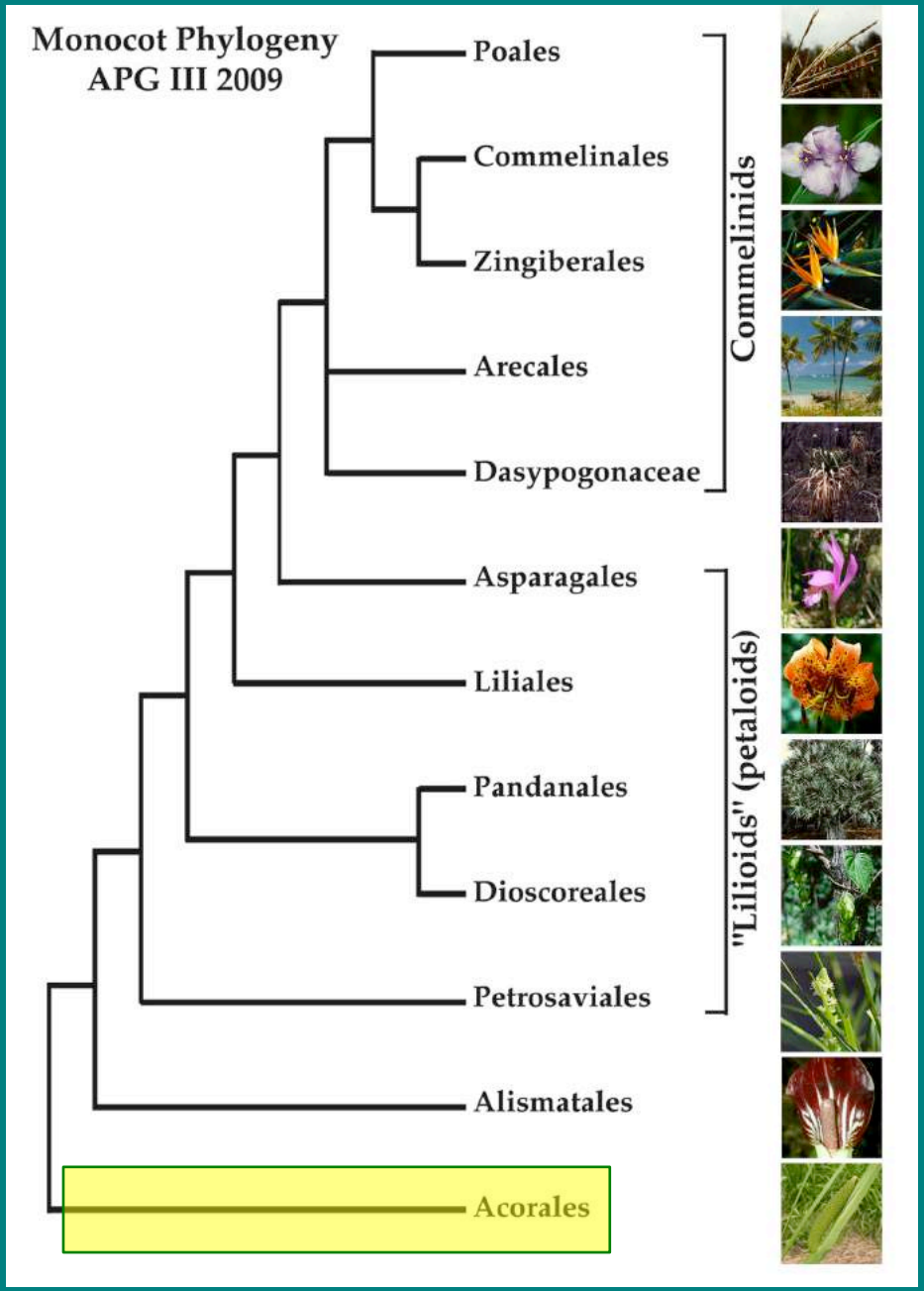
Both features:

- arise multiple times
- are correlated with each other
- arise in understory clades

Survey of monocots

4 main groups:

- Acorales - sister to all monocots
- Alismatales
  - inc. Aroids - jack in the pulpit
- "Lilioids" (lilies, orchids, yams):
  - non-monophyletic
  - petaloid
- Commelinids
  - Arecales – palms
  - Commelinales – spiderwort
  - Zingiberales –banana
  - Poales
    - pineapple
    - grasses & sedges



Acorales (*Acoraceae - sweet flag)

- Emergent aquatic plants with ethereal oils and no raphides

2 species:

Acorus calamus, Old World

A. americanus, New World

Both species in Wisconsin

Acorus
sweet flag

*Acoraceae - sweetflag

Flat filaments

P^{6} A^{6} $\underline{G}^{(3)}$ $^{\infty}$ seeds

- Inflorescence with 'spathe' and spadix
- Flowers bisexual

Acorus americanus - sweet flag

*Acoraceae - sweetflag

Flat filaments

P^{6} A^{6} $\underline{G}^{(3)}$ $^{\infty}$ seeds

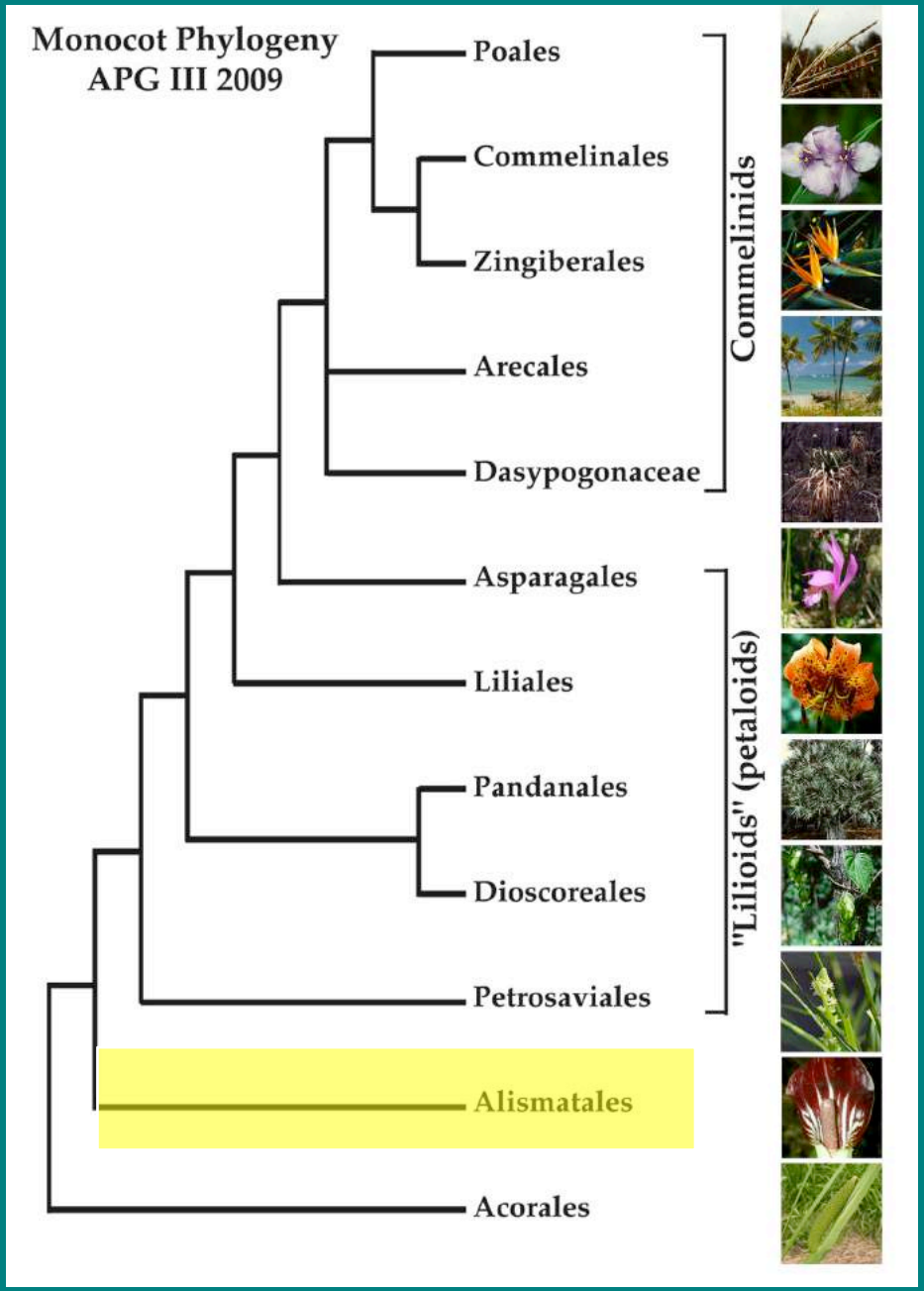
- Inflorescence with ‘spathe’ and spadix
- Flowers bisexual

Acorus americanus - sweet flag

Alismatales

4 main groups:

- Acorales - sister to all monocots
- Alismatales
  - inc. Aroids - jack in the pulpit
- "Lilioids" (lilies, orchids, yams)
  - non-monophyletic
  - petaloid
- Commelinids
  - Arecales – palms
  - Commelinales – spiderwort
  - Zingiberales –banana
  - Poales
    - pineapple
    - grasses & sedges



Alismatales - aquatics

Recurring themes:

Aquatic ⇒ brackish ⇒ marine habitats

Insect ⇒ water pollination

Alismatales - aquatics

Emergent, floating, or submerged aquatic group of monocots

Alismatales - aquatics

Showy flowers, insect-pollinated

Associated with the aquatic habit is the trend from insect-pollinated, showy flowers to water-pollinated, reduced flowers . . .

and increasing effort to vegetative rather than sexual reproduction

Reduced unisexual flowers, water-pollinated

Alismatales - aquatics

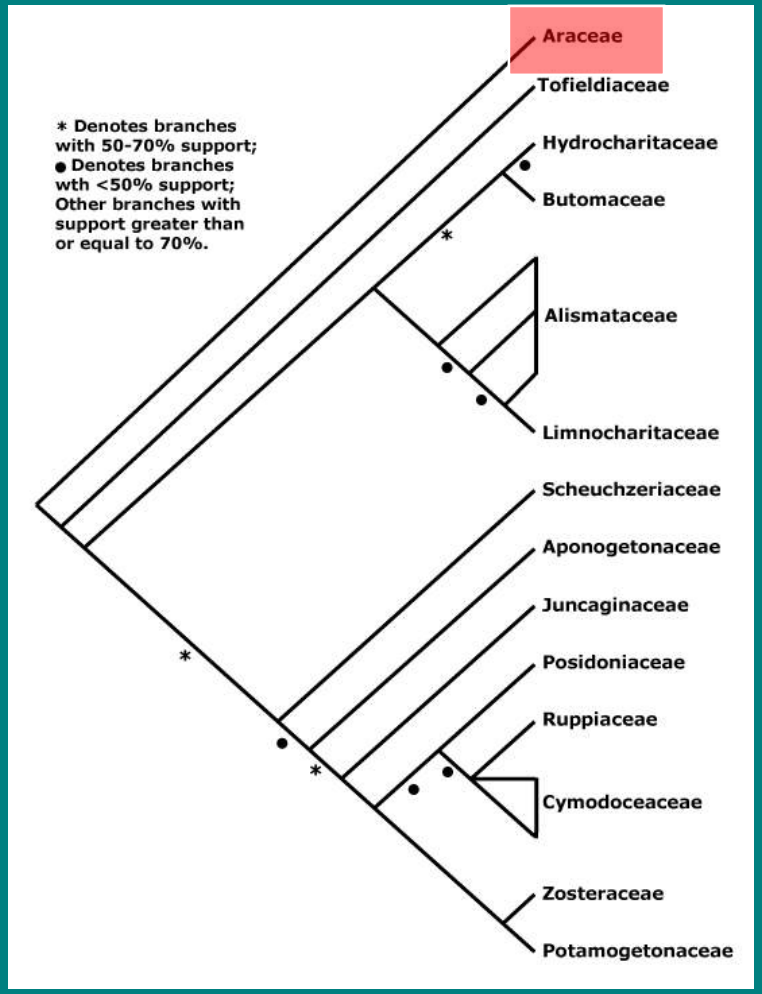
Showy flowers, insect-pollinated

72% of Alismatales are unisexual - monoecious or dioecious

132 species are hydrophilous (*how many origins?*) – answer later

Reduced unisexual flowers, water-pollinated

*Araceae - aroids



104 genera
2,550 species

- Sister family to other Alismatales
- Tropical (to temperate)
- epiphytes, herbs, aquatic

*Araceae - aroids

- raphides in vacuoles with mucilage
- Ca-oxalate (endo-osmosis)

- defining characteristic is the inflorescence of spathe and spadix
- spathe (or bract) is common in monocots

*Araceae - aroids

Symplocarpus foetidus - skunk cabbage

Inflorescence a fleshy spadix, surrounded by bract called the spathe

CA 0 CO 0 A 6- G (2-3)

Flowers unisexual or perfect
Fruits berries clustered on spadix

Arisaema triphyllum - jack-in-the pulpit

*Araceae - aroids

L:female
R:male

Arisaema triphyllum - jack-in-the pulpit
[or jill-in-the-pulpit ?]

*Araceae - aroids

Symplocarpus foetidus - skunk cabbage

Cabbage-like leaves emerge later in the spring

Foetid smelling spathe and spadix emerges early in spring or late winter; attracts carrion flies by heating up and volatizing off the odor

*Araceae - aroids

Symplocarpus foetidus - skunk cabbage

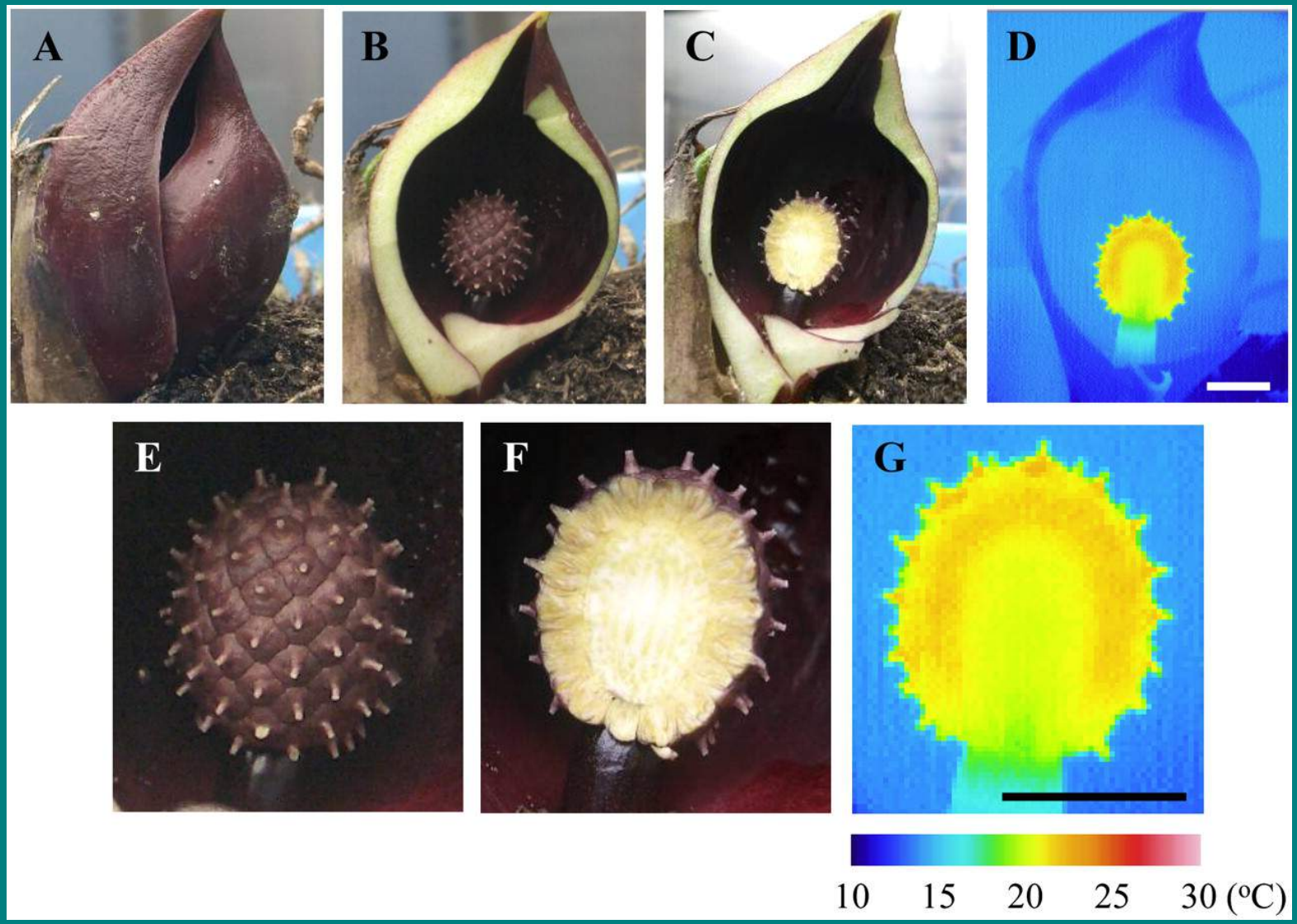
flesh flies – *Sarcophagidae*

sapromyophily pollination

carrion flies – *Calliphoridae*

gnats - *Mycetophilidae*

Endogenous heating of skunk cabbage (*S. renifolius*) spadix



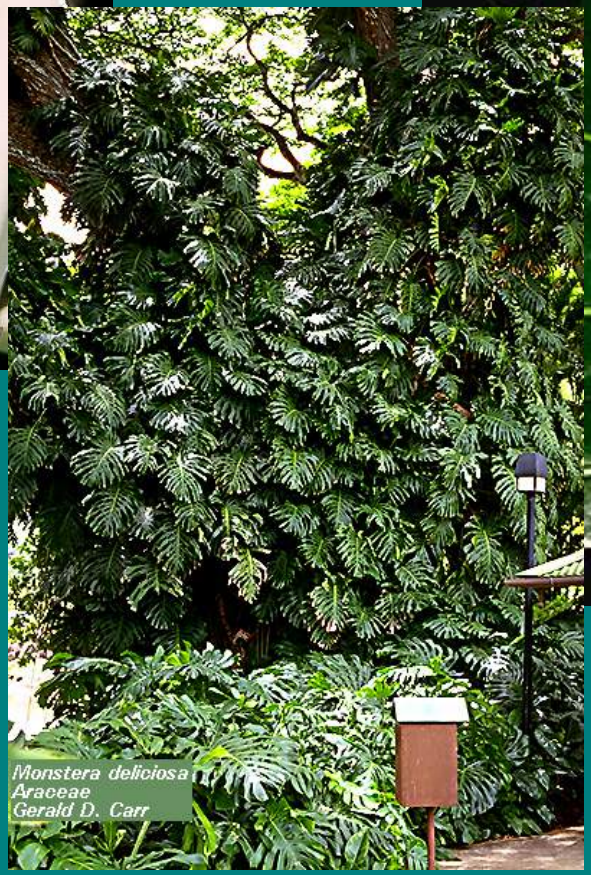
Onda Y. et.al. Plant Physiol. 2008:146:636-645

*Araceae - aroids

Calla palustris - water arum

Only emergent aquatic member of the family in Great Lakes

*Araceae - aroids



Monstera - tropical aroid

*Araceae - aroids

Zantedeschia
arum lily

funeral plants!

Spathiphyllum

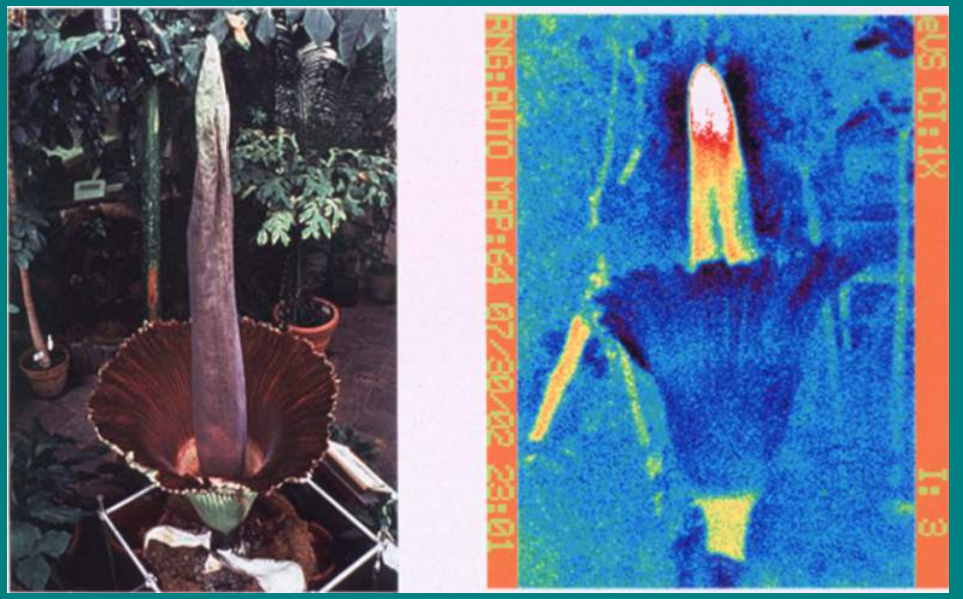
*Araceae - aroids

other strange aroids:

Amorphophallus - titan arum

Pistia - water lettuce

"Lemnaceae" - duckweeds



*Araceae (Lemnaceae - duckweeds)

Lemna minor - small duckweed

Floating or submersed aquatic *family* almost cosmopolitan in distribution; Vegetative reproduction primarily

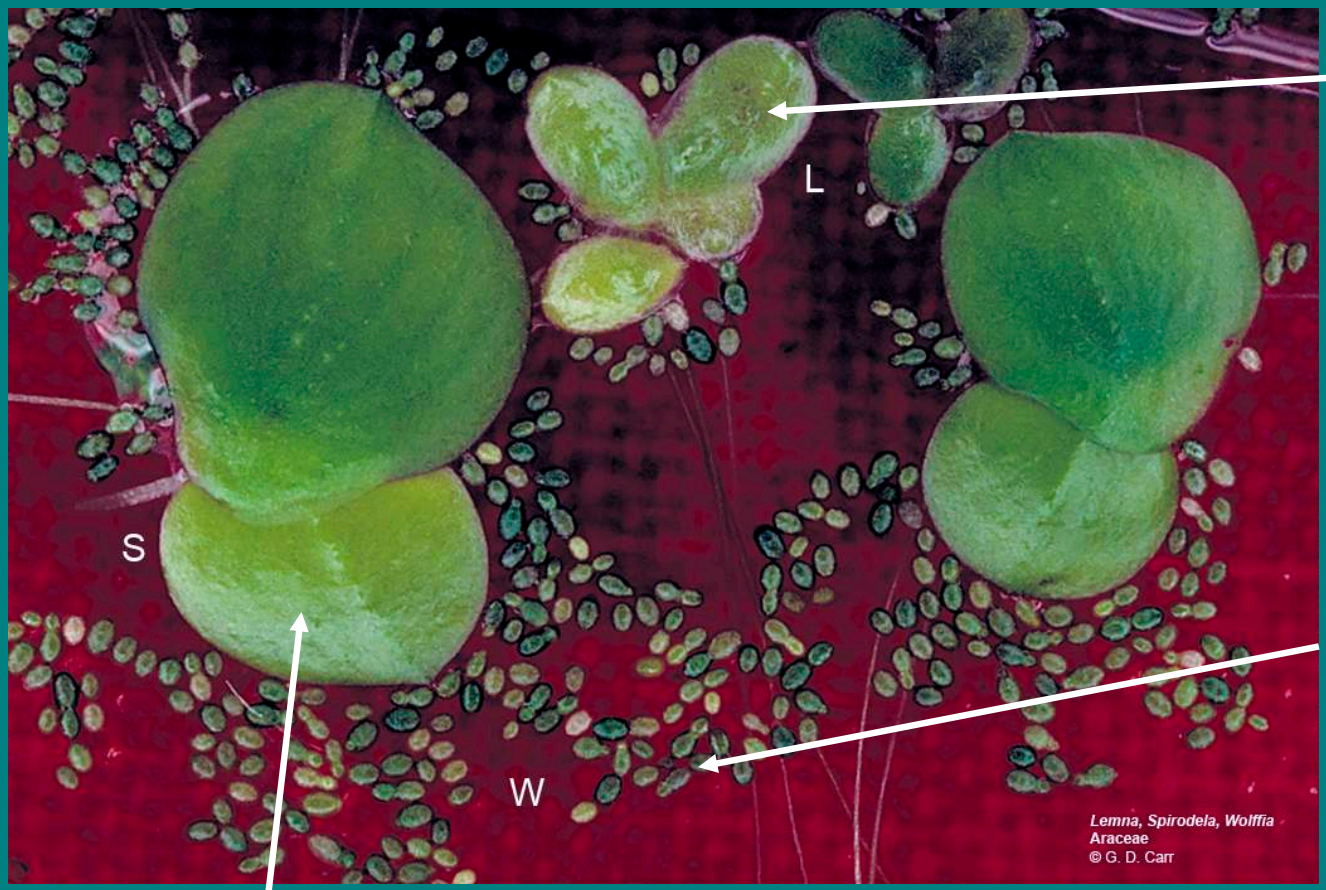
Now known to be derived from within the Araceae

Includes the smallest angiosperm, and the smallest flower

Inflorescence reduced to 1 female and 1-2 male flowers

Lemna turionifera - perennial duckweed

*Araceae (Lemnaceae - duckweeds)



Lemna

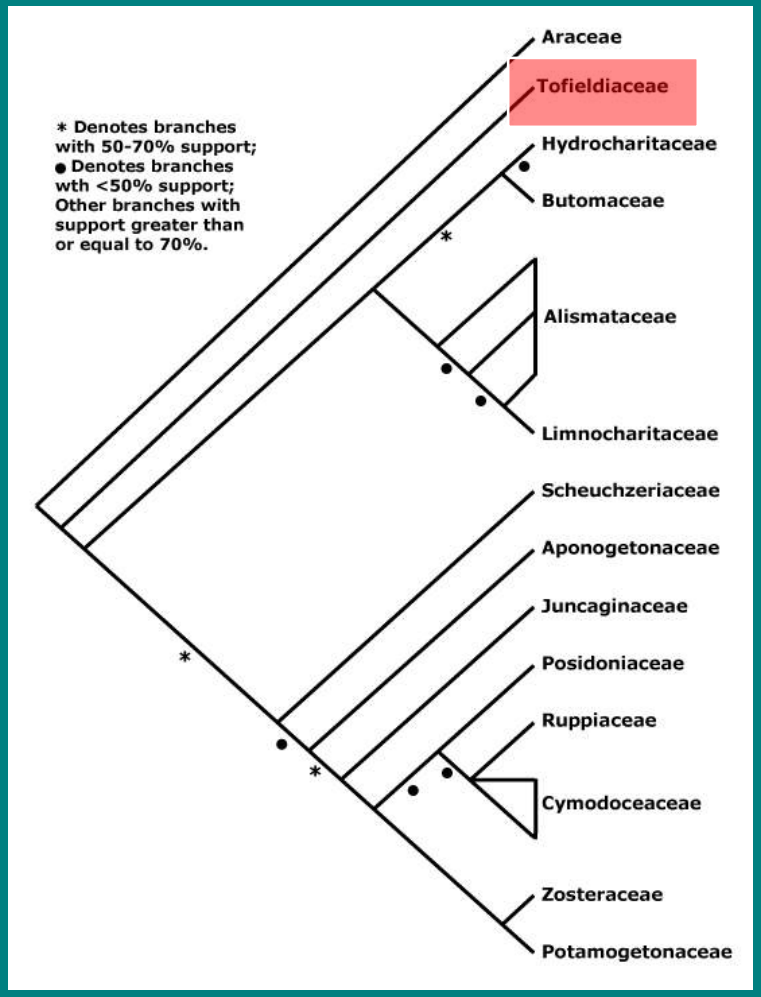
Smallest member of the family and the angiosperms:

Wolffia columbiana - water meal

Spirodela polyrhiza
great duckweed

Largest member of the family

Tofieldiaceae - asphodels




Triantha glutinosa

- Surprising inclusion!
- "Lilioid" flowers (Liliaceae s.l.)
- wet loving small herbs

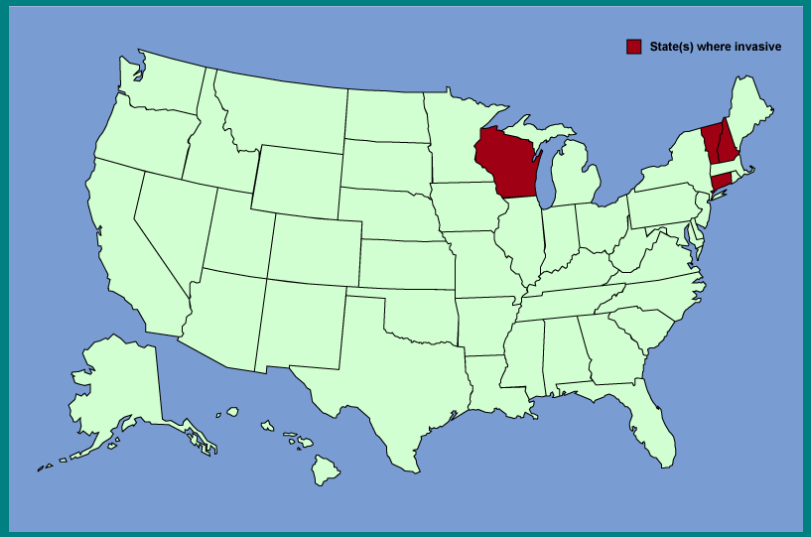
Butomaceae - flowering rush

- emergent aquatic family
- leaves show no obvious blade and petiole differentiation

Butomaceae - flowering rush

- flowers in umbels
- unsealed carpels - follicles
- introduced - invasive

CA 3 CO 3 A 9 G 6



Butomus umbellatus - flowering rush

Alismataceae - water plantain

Aquatic or wetland family, especially in north temperate regions

Leaves long petioled, often with sagittate-shaped leaves

Tubers starchy, often edible

Alismataceae - water plantain

CA 3 CO 3 A 6 - ∞ G 6 - ∞

Calyx of 3 green sepals, corolla of 3 white petals

Apocarpic in a head or ring

Perfect, monoecious, dioecious

Alismataceae - water plantain

CA 3 CO 3 A 6 - ∞ G 6 - ∞

Calyx of 3 green sepals, corolla of 3 white petals

Apocarpic in a head or ring

Achenes (head of achenes here)

Alismataceae - water plantain

Similar to *Sagittaria*, but with carpels in one ring rather than globose head

Alisma plantago-aquatica - water plantain

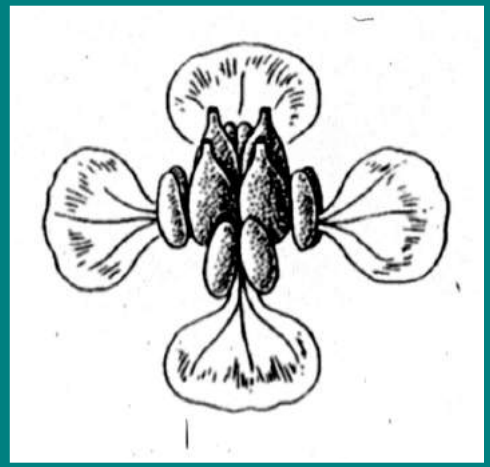
Potamogetonaceae - pondweed

Aquatic plants with dimorphic leaves,
25 species in Wisconsin
difficult to identify, hybridize, and some are troublesome weeds

Potomogeton sp. - pondweed

Potamogetonaceae - pondweed

- perianth of 4 clawed segments if present
- gynoecium typically of 4 free, 1-ovuled carpels
- fruit drupe-like

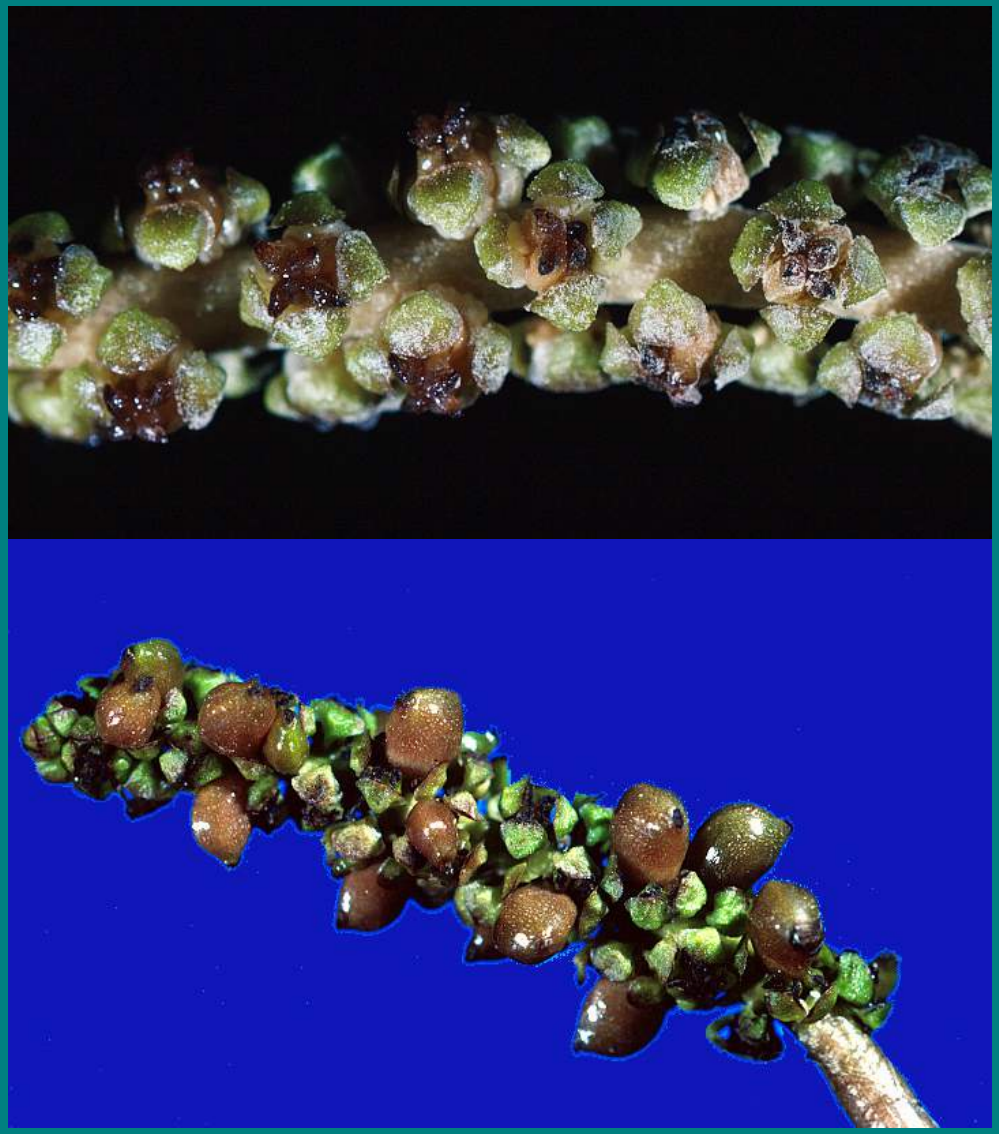


CA 0,4 CO 0 A 4 G 4

Potomogeton sp. - pondweed

Potamogetonaceae - pondweed

Potomogeton nodosus - pondweed



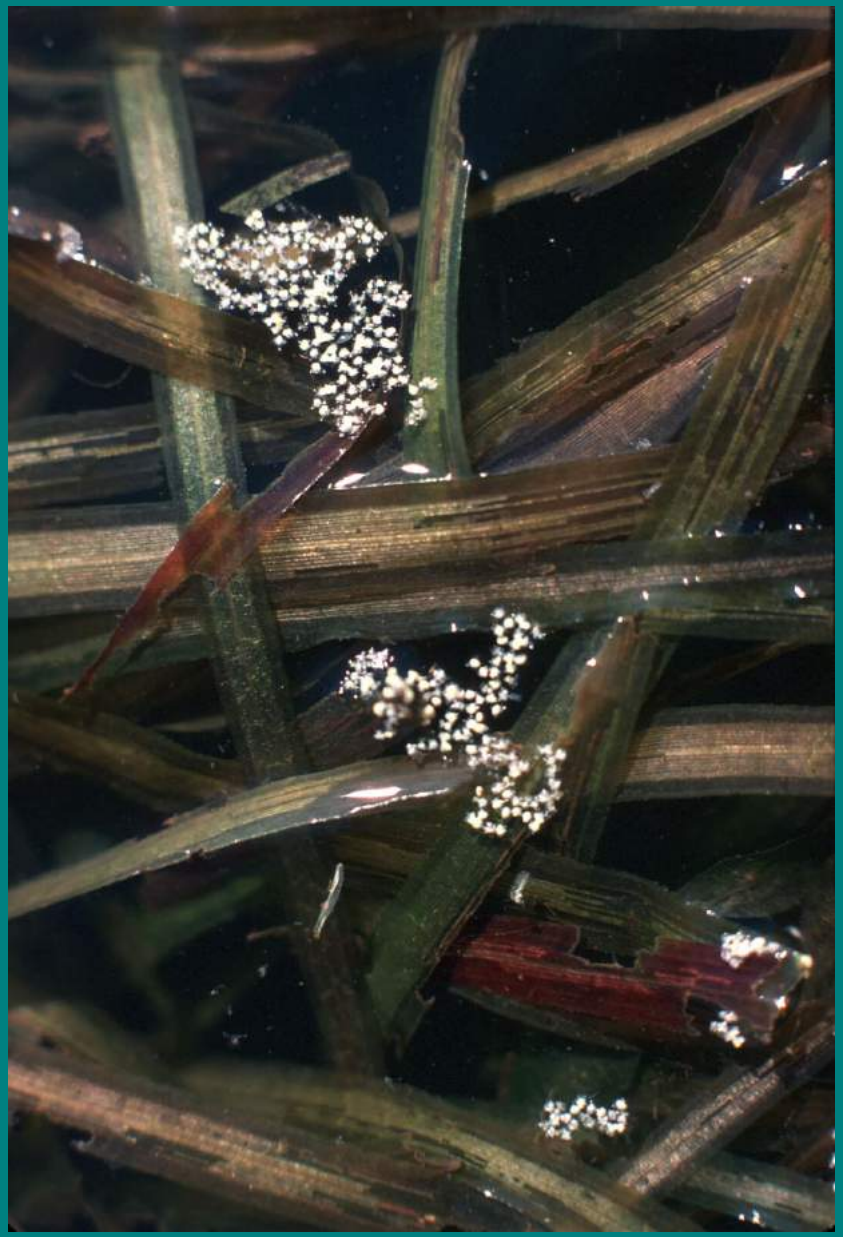
Flowers (top) and fruits (bottom)

Hydrocharitaceae - frog bit

- submersed or floating aquatic plants
- various forms of water pollination present

Elodea canadensis - waterweed

Hydrocharitaceae - frog bit



Vallisneria (tapegrasses, eelgrasses) are composed of two species, one New World, one Old World

Vallisneria americana - tapegrass (with *Hydrilla verticillata*)

Vallisneria americana - tapegrass

Hydrocharitaceae - frog bit

Vallisneria spiralis - tapegrass (OW)

Note the floating male flowers and one large female with 3 stigmatic areas on a long peduncle

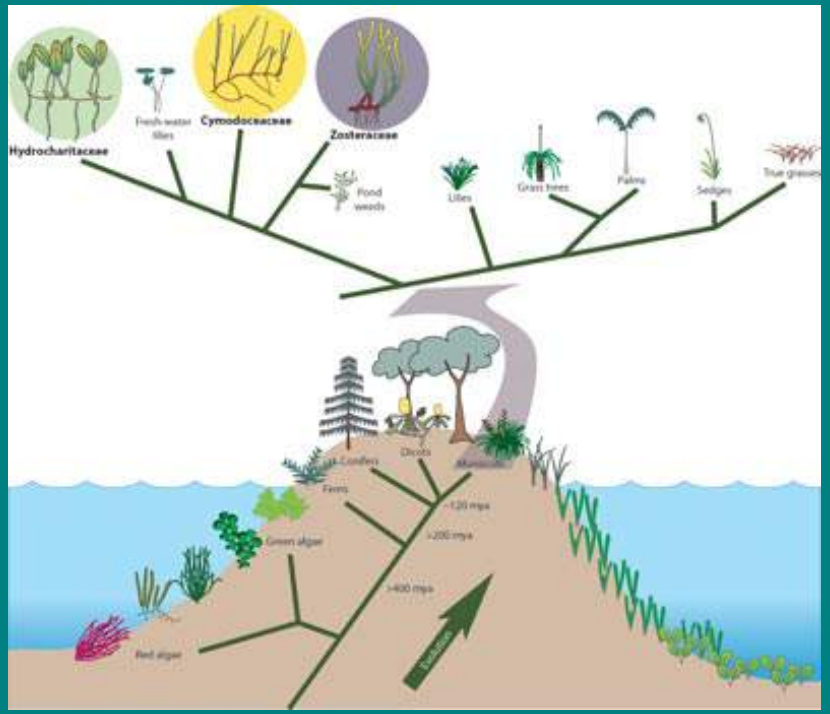
- male flowers in clusters; female flower single
- pollen water boat floats and attaches to 3 broad stigma of the female flower
- flower retracts and forms fruit under water

Vallisneria americana - tapegrass

Evolution of Sea Grasses

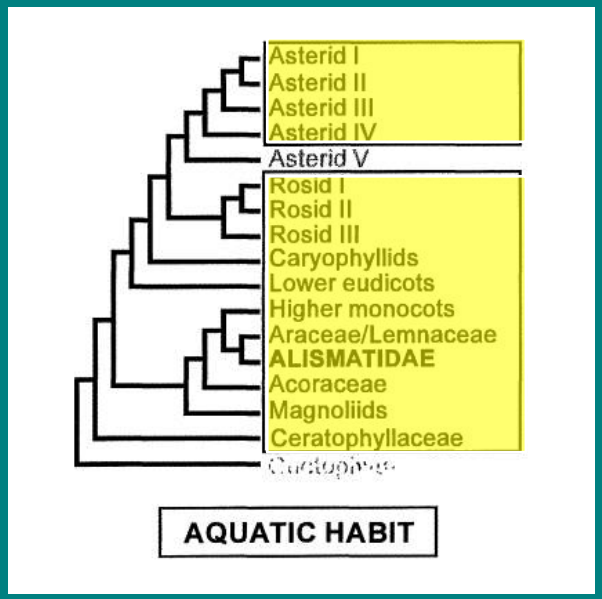
Don Les' story of plants going back to the oceans 450 million years later

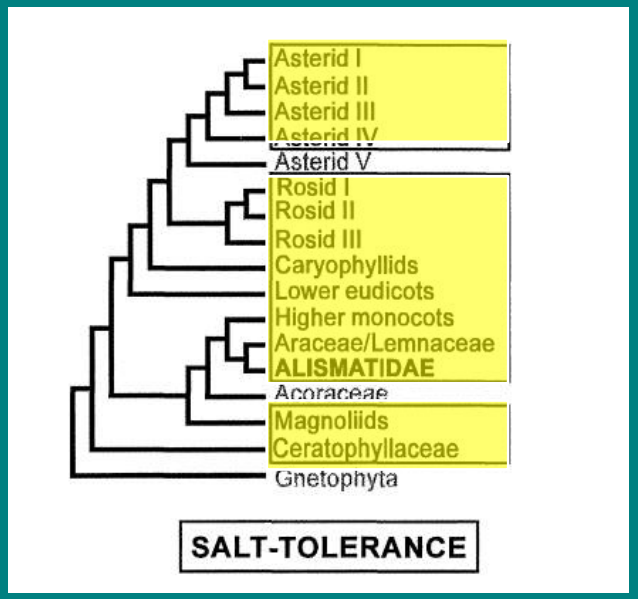
. . . another story of convergence and divergence

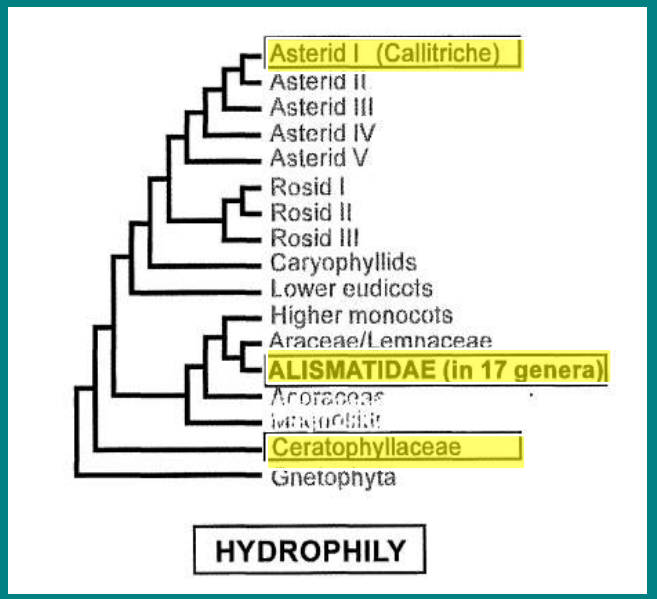


Evolution of Sea Grasses

Aquatic ⇒ Salt Tolerant ⇒ Hydrophily







Aquatic plants found in most lineages

Salt tolerance also wide-spread

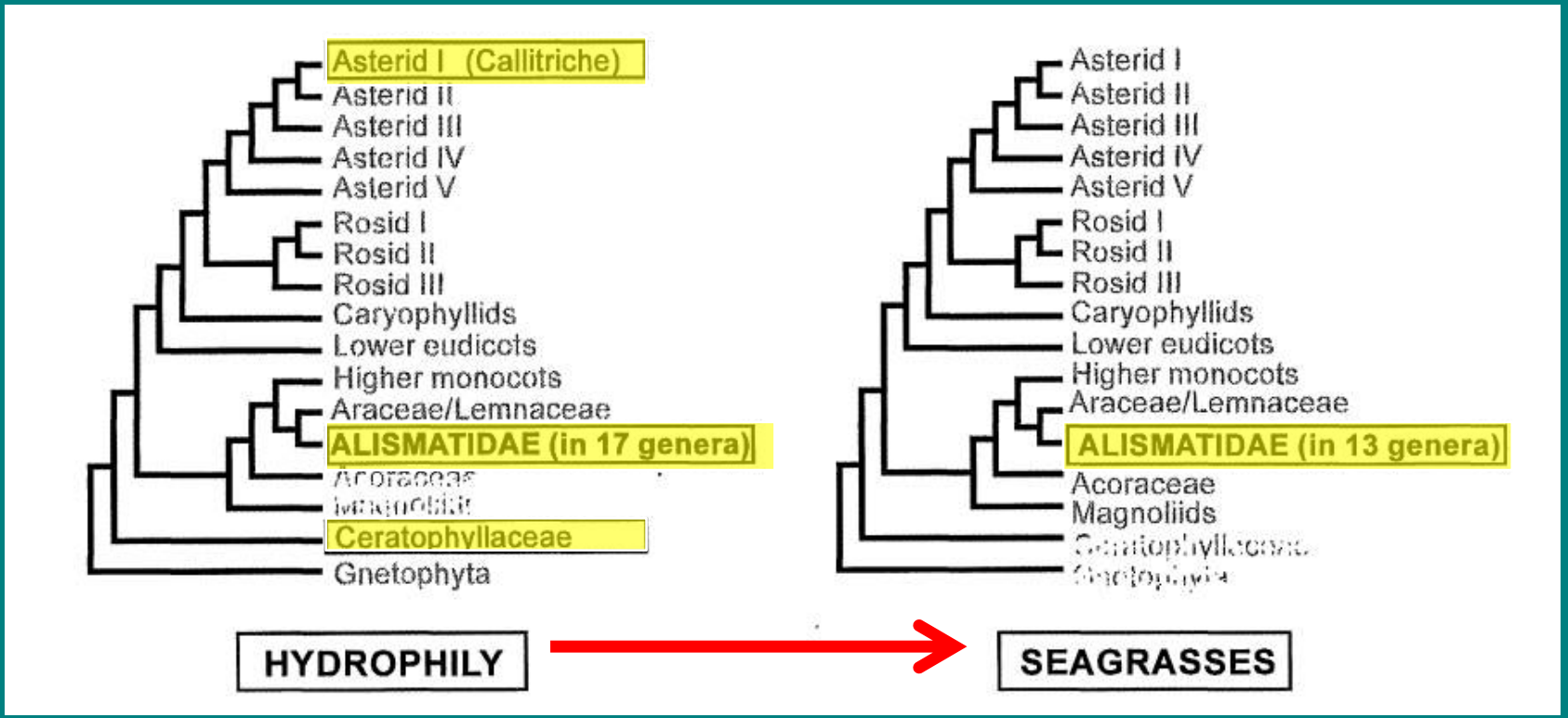
Water pollination restricted

Callitriche

Ceratophyllum

Evolution of Sea Grasses

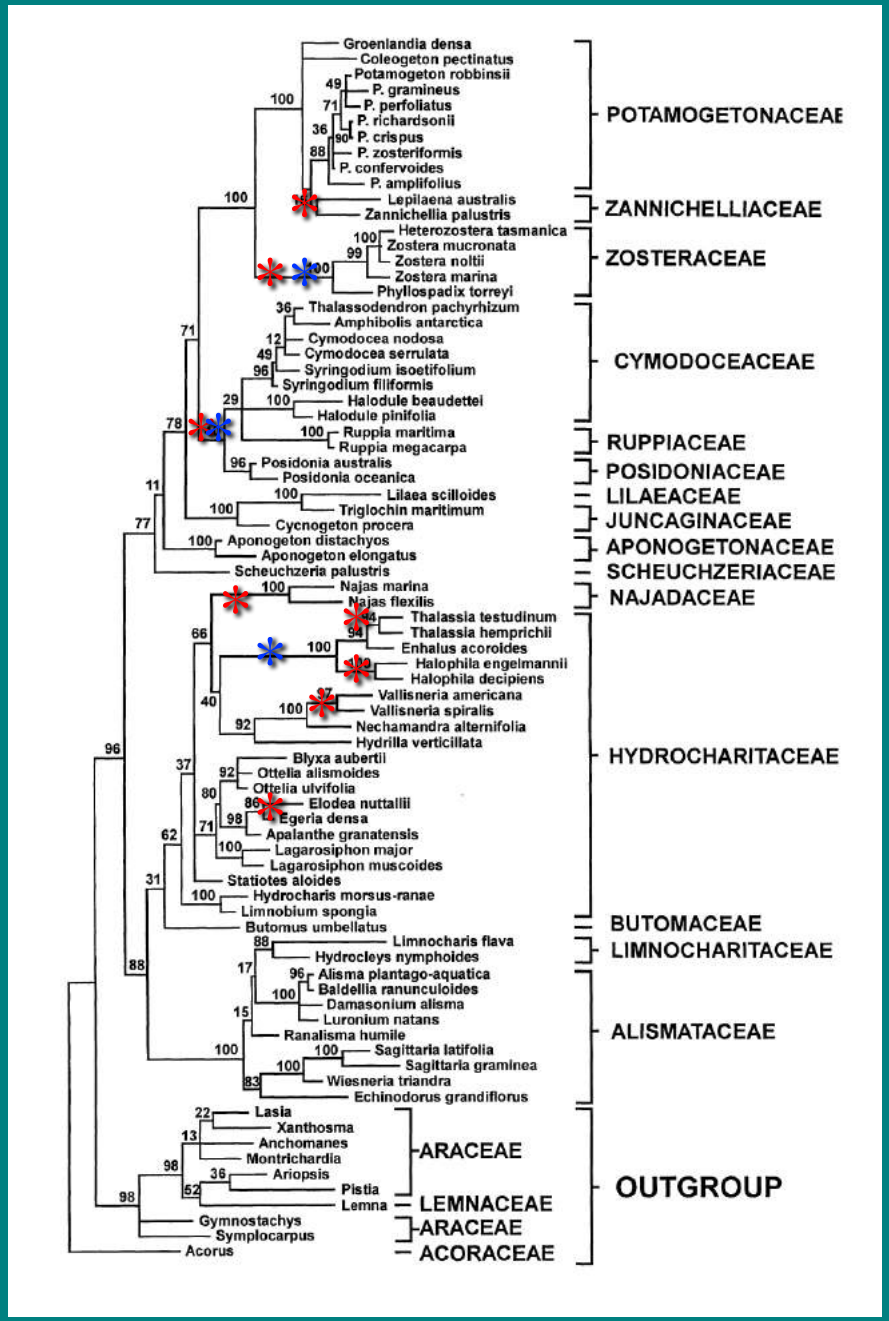
⇒ Hydrophily ⇒ Marine



Seagrasses found in only one lineage of these aquatic, salt tolerant, and water pollinated lineages (order Alismatales)

A single origin of seagrasses?

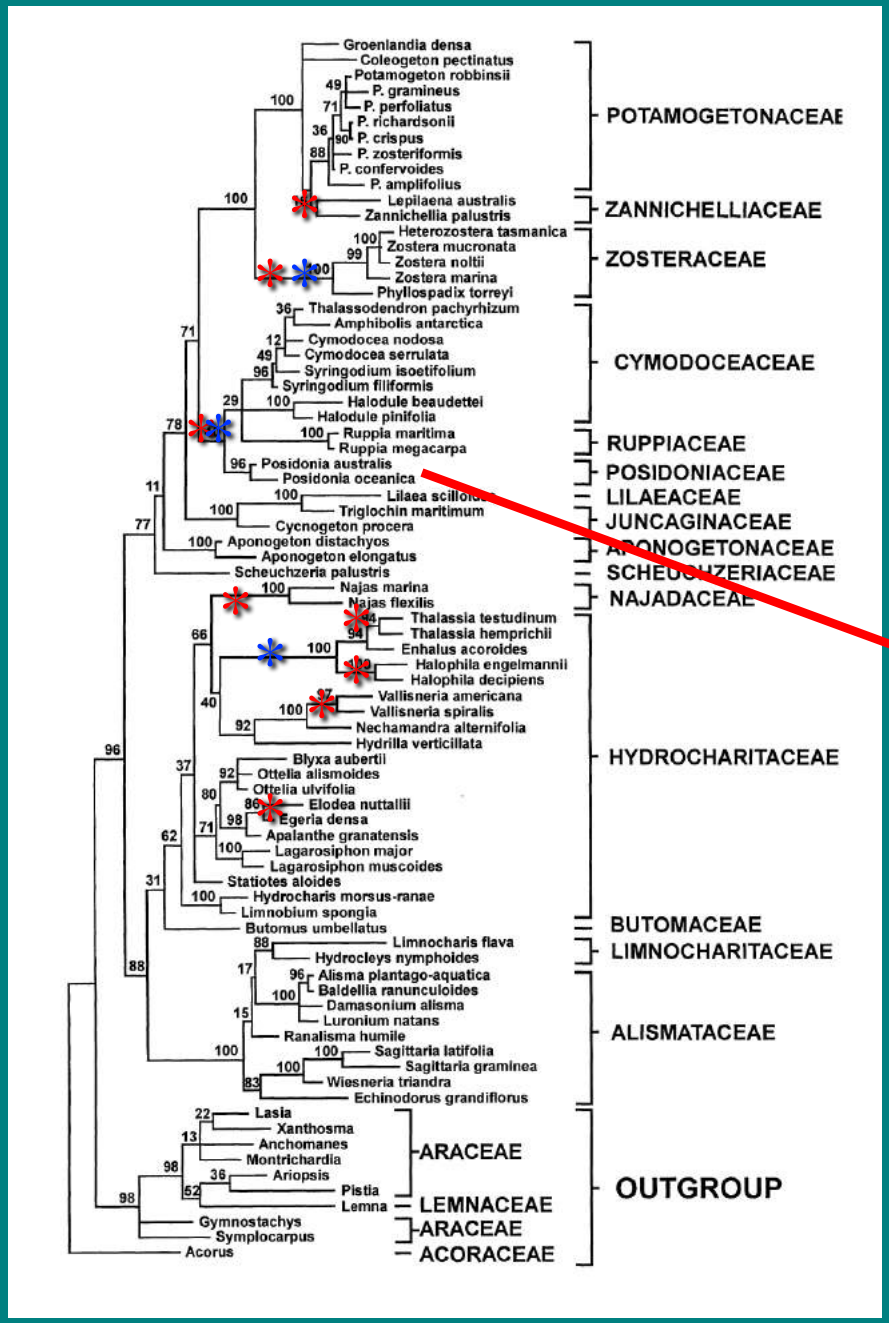
Evolution of Sea Grasses



- hydrophily originated 10 times in angiosperms
- 8 of these times independently in Alismatales!
- marine habitat originated 3 times independently in Alismatales!
- marine habitat correlated with hydrophily

DNA based tree of Alismatales with water pollination and seagrasses mapped on

Evolution of Sea Grasses



- oldest known clonal organism
  - 200,000 years old !

Posidonia oceanic L.