
the Strange, the Ugly,
and the Bizarre
. . . carnivores, parasites, and
mycotrophs . . .

Plant Oddities - Carnivores, Parasites & Mycotrophs

Carnivore: *Nepenthes*

Of all the plants, the most bizarre, the least understood, but yet the most interesting are those plants that have unusual modes of nutrient uptake.

Plant Oddities - Carnivores, Parasites & Mycotrophs

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Parasite: *Rafflesia*

Plant Oddities - Carnivores, Parasites & Mycotrophs

Mycotroph: *Monotropa*

Of all the plants, the most bizarre, the least understood, but yet the most interesting are those plants that have unusual modes of nutrient uptake.

Things to focus on for this topic!

1. What are these three types of plants
2. How do they live - selection
3. Systematic distribution in general
4. Systematic challenges or issues
5. Evolutionary pathways - *how did they get to what they are*

Plant Oddities - The Problems

Three factors for systematic confusion and controversy

1. the specialized roles often involve reductions or elaborations in both vegetative and floral features — DNA also is reduced or has extremely high rates of change

for example – the parasitic *Rafflesia*

Plant Oddities - The Problems

Three factors for systematic confusion and controversy

2. their connections to other plants or fungi, or trapping of animals, make these odd plants prone to horizontal gene transfer

for example – the parasitic *Mitrastema*
[work by former UW student Tom Kleist]

Plant Oddities - The Problems

Three factors for systematic confusion and controversy

3. often unrelated members of these groups converge unto the same morphology; often related members diverge in morphology

for example – carnivorous plants

Plant Oddities - The Problems

Classic example of this systematic problem is a set of three families of carnivorous plants with various types of trapping mechanisms:

How are they related? [good exam question!]

Pitcher traps

Fly paper and steel traps

Nepenthaceae - Asian pitcher plant

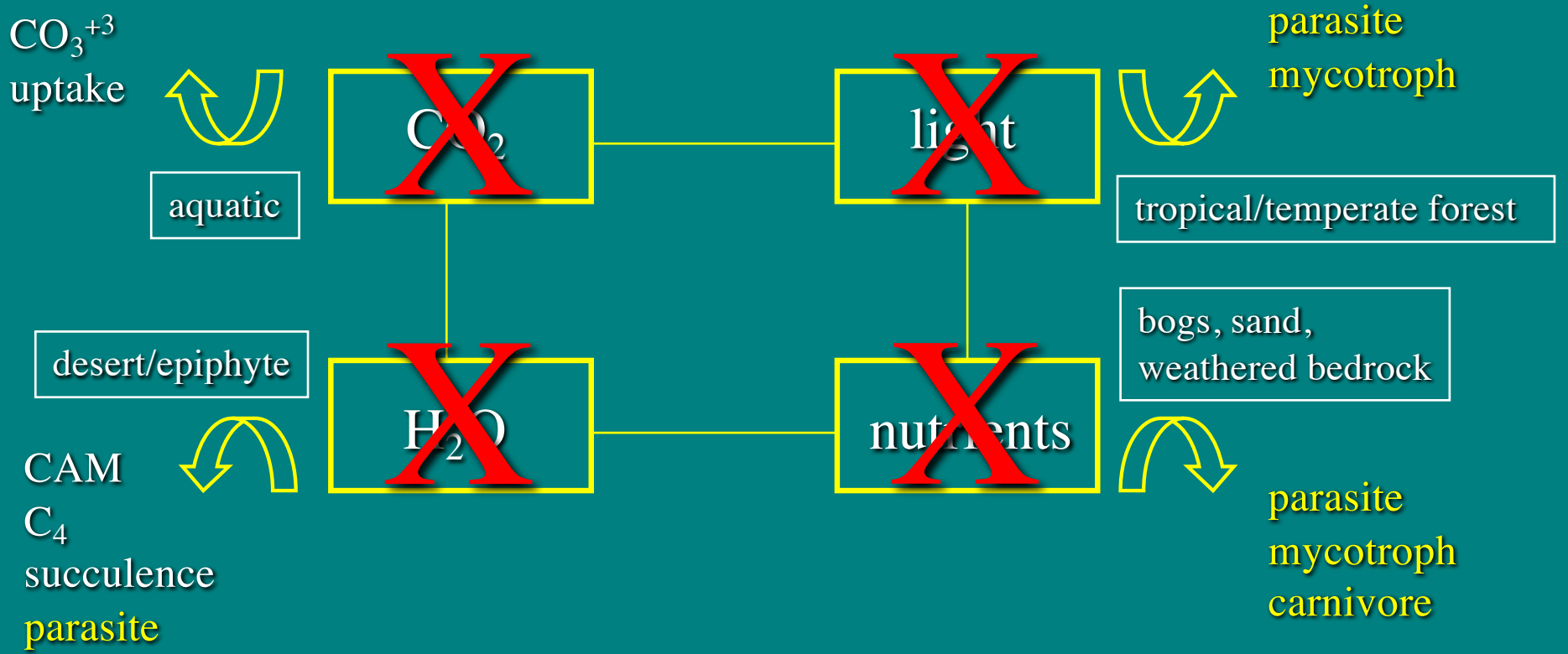
Sarraceniaceae - American pitcher plant

Droseraceae - Sundews and Venus fly trap

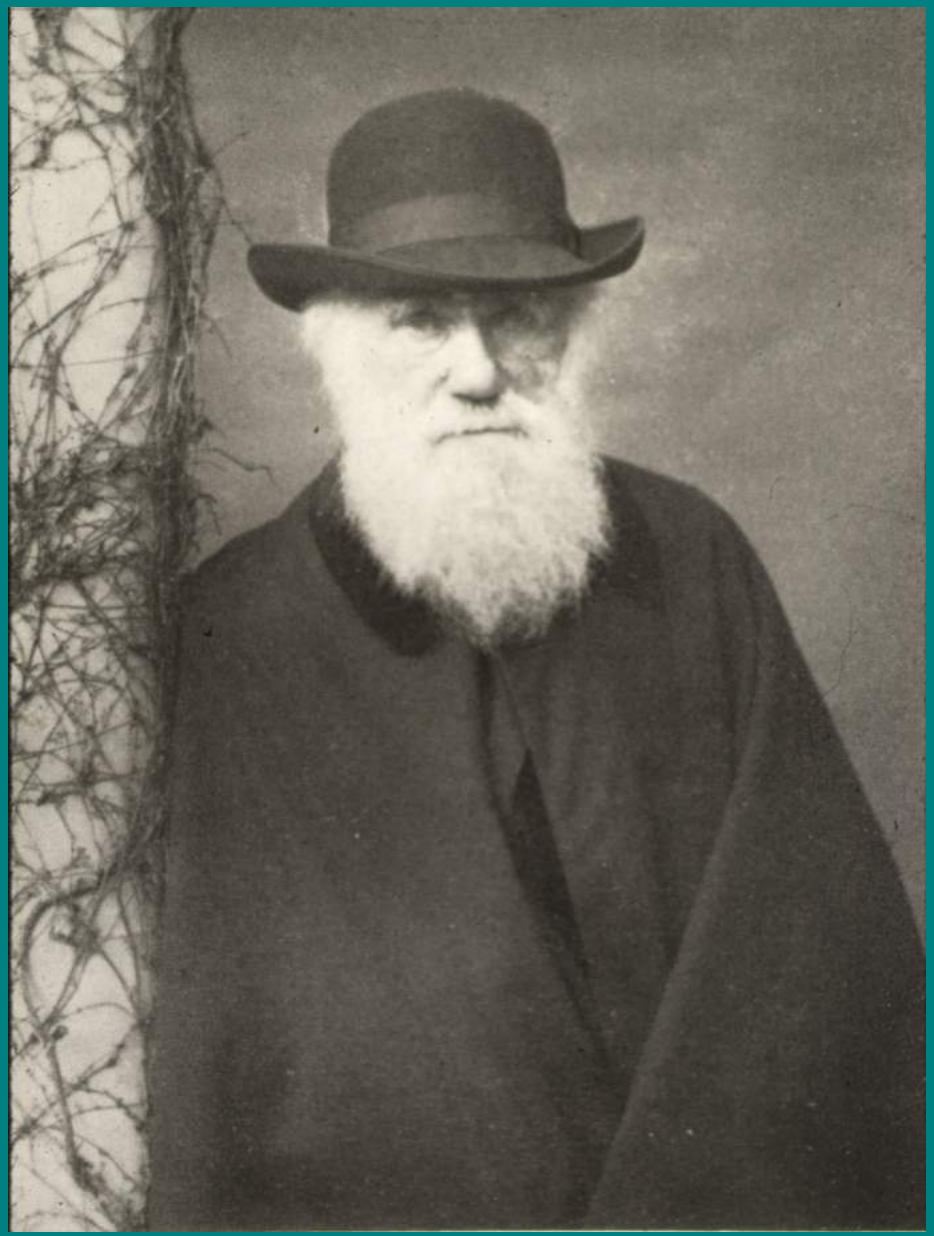
Plant Oddities - The Problems

Why do plants have these unusual life styles?

Lack of basic necessities for life on land



Carnivorous Plants



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In his book on "*Insectivorous plants*", he showed that they had adaptations to capture and digest animals.

Carnivorous Plants

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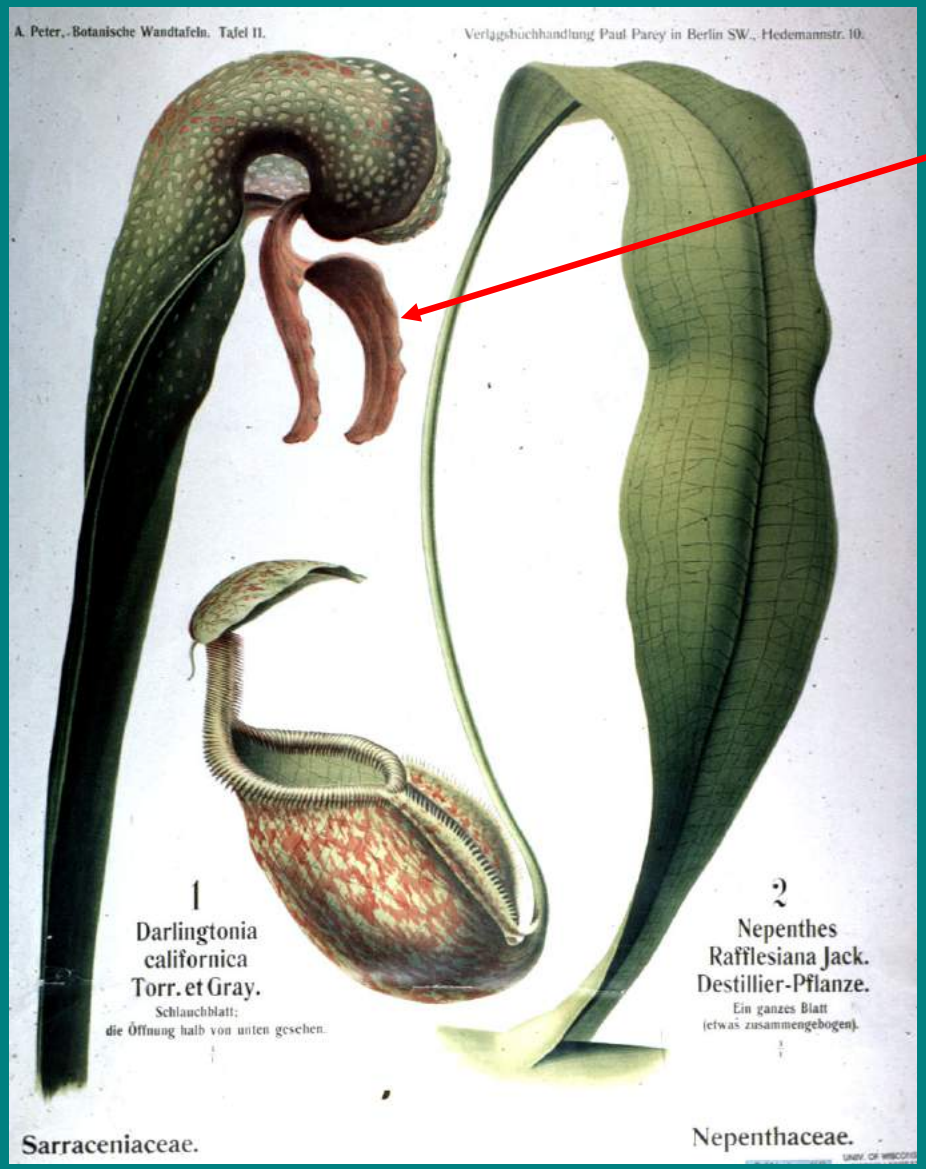
Tom Givnish, University of Wisconsin, has refined the definition of what is a carnivorous plant:

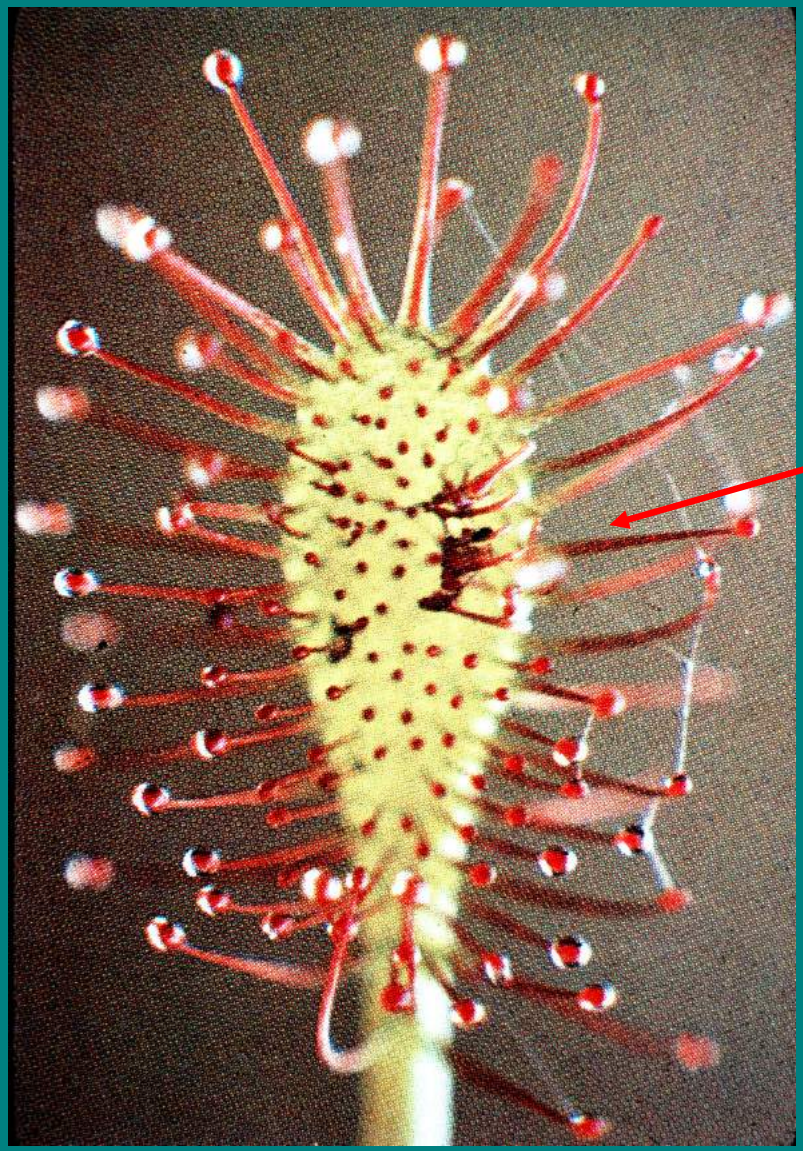
1. Adaptations to lure, capture, and digest prey
2. Ability to absorb nutrients from animals

Carnivorous Plants



Luring device of some type often involving color, movement, and smell

Carnivorous Plants



Luring device of some type often involving color, movement, and smell

Trapping device of some type (pitchers or drowning pools, steel traps, sticky leaves, etc.)

Carnivorous Plants

Luring device of some type often involving color, movement, and smell

Trapping device of some type (pitchers or drowning pools, steel traps, sticky leaves, etc.)

Ability to digest animals trapped, often with release of pronases and other enzymes into pool or on animal

Carnivorous Plants

Amino acids radioactively labeled being incorporated into the scales of *Brocchinia* (pineapple family)

Luring device of some type often involving color, movement, and smell

Trapping device of some type (pitchers or drowning pools, steel traps, sticky leaves, etc.)

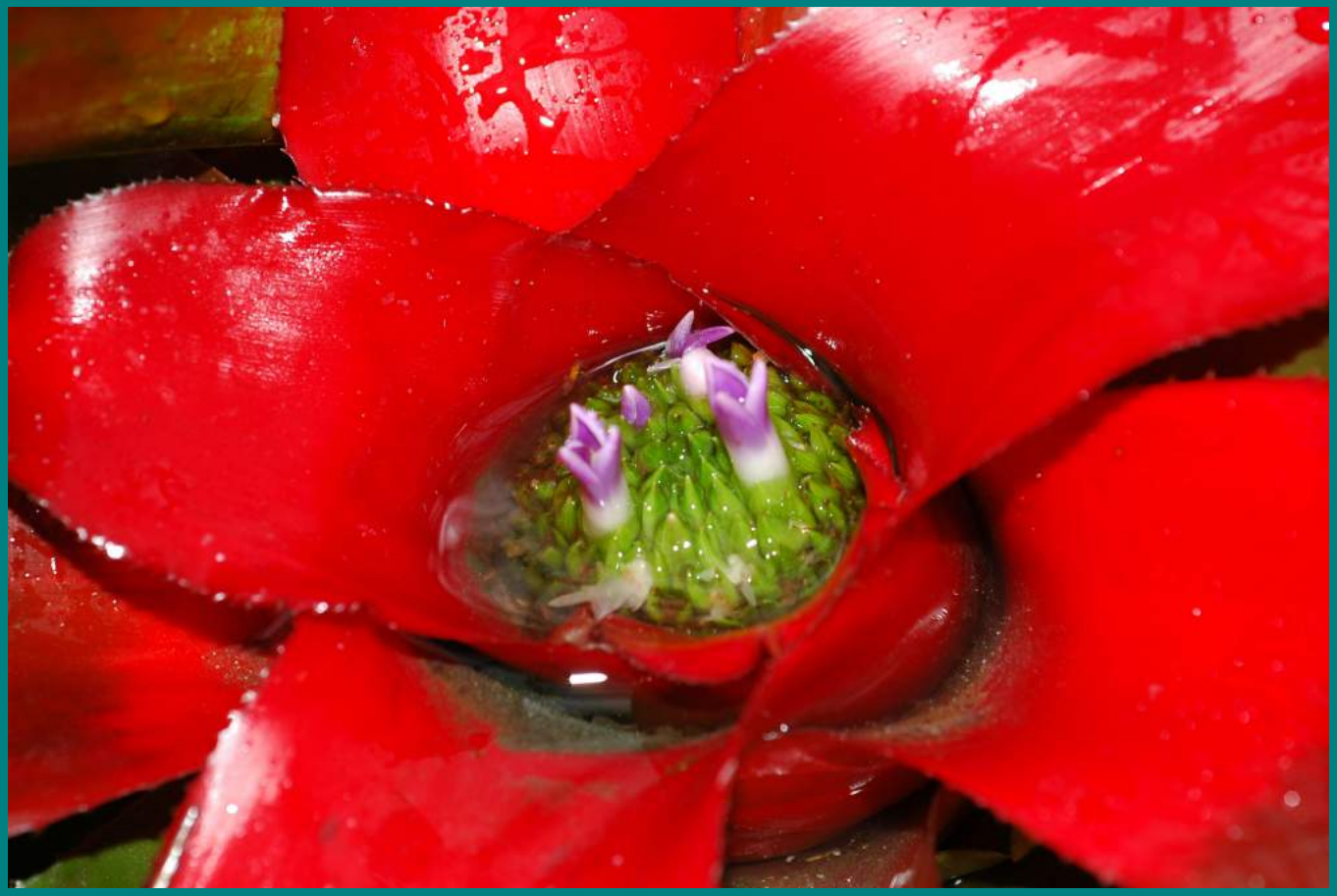
Ability to digest animals trapped, often with release of pronases and other enzymes into pool or on animal

Mechanisms to uptake amino acids once animal is digested, often with specialized hairs or scales

Carnivorous Plants

What are not carnivores?

Plants which may accidentally kill (drown in this case) animals and even be able to utilize their amino acids; leaf "pitcher" in this case is simply an adaptation to collect water as an epiphyte.



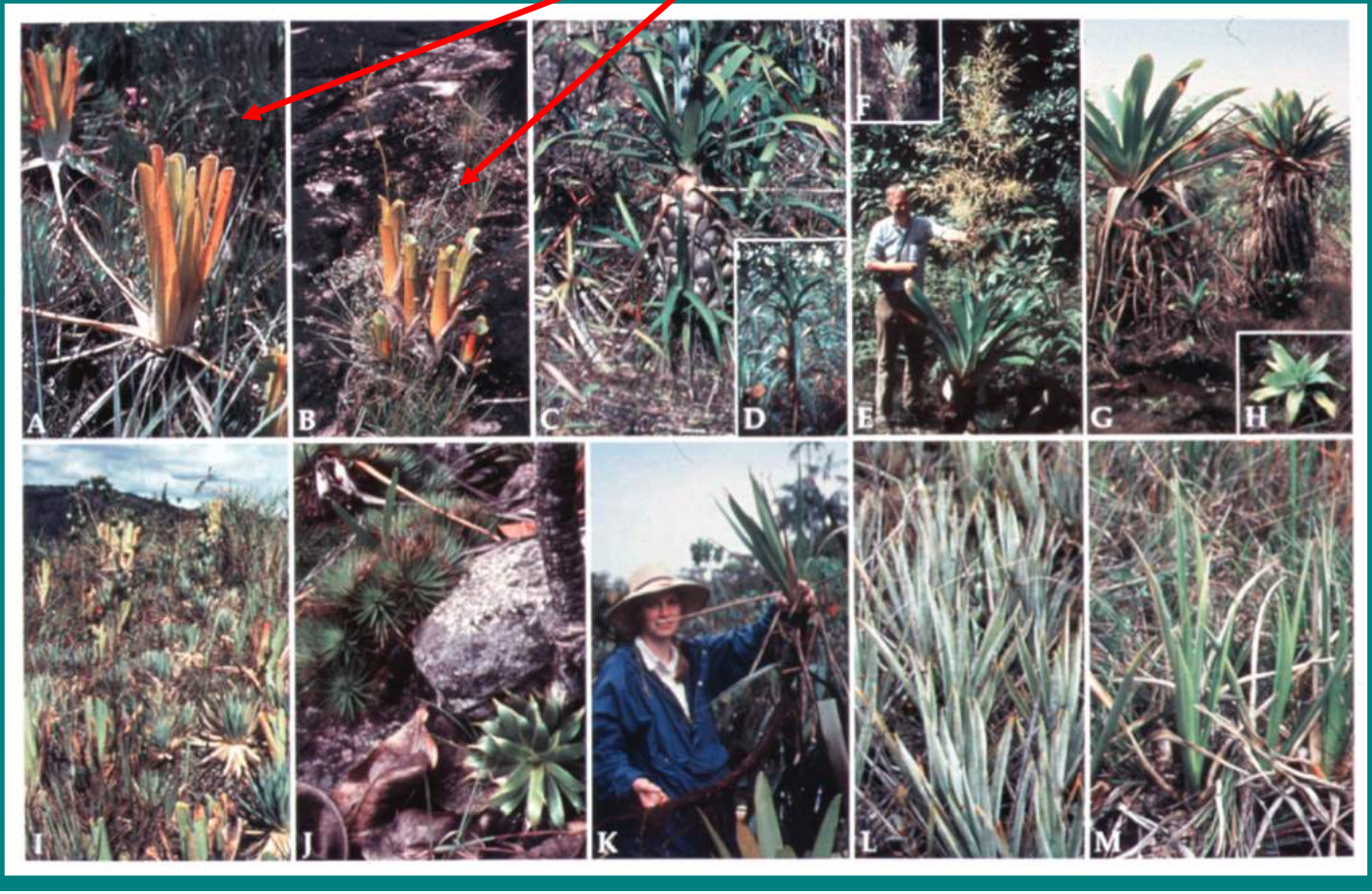
Billbergia
Bromeliaceae

Carnivorous Plants

What are not carnivores?

So it is not surprising that carnivores show up in groups that have "pre-adaptations" to the carnivory life style.

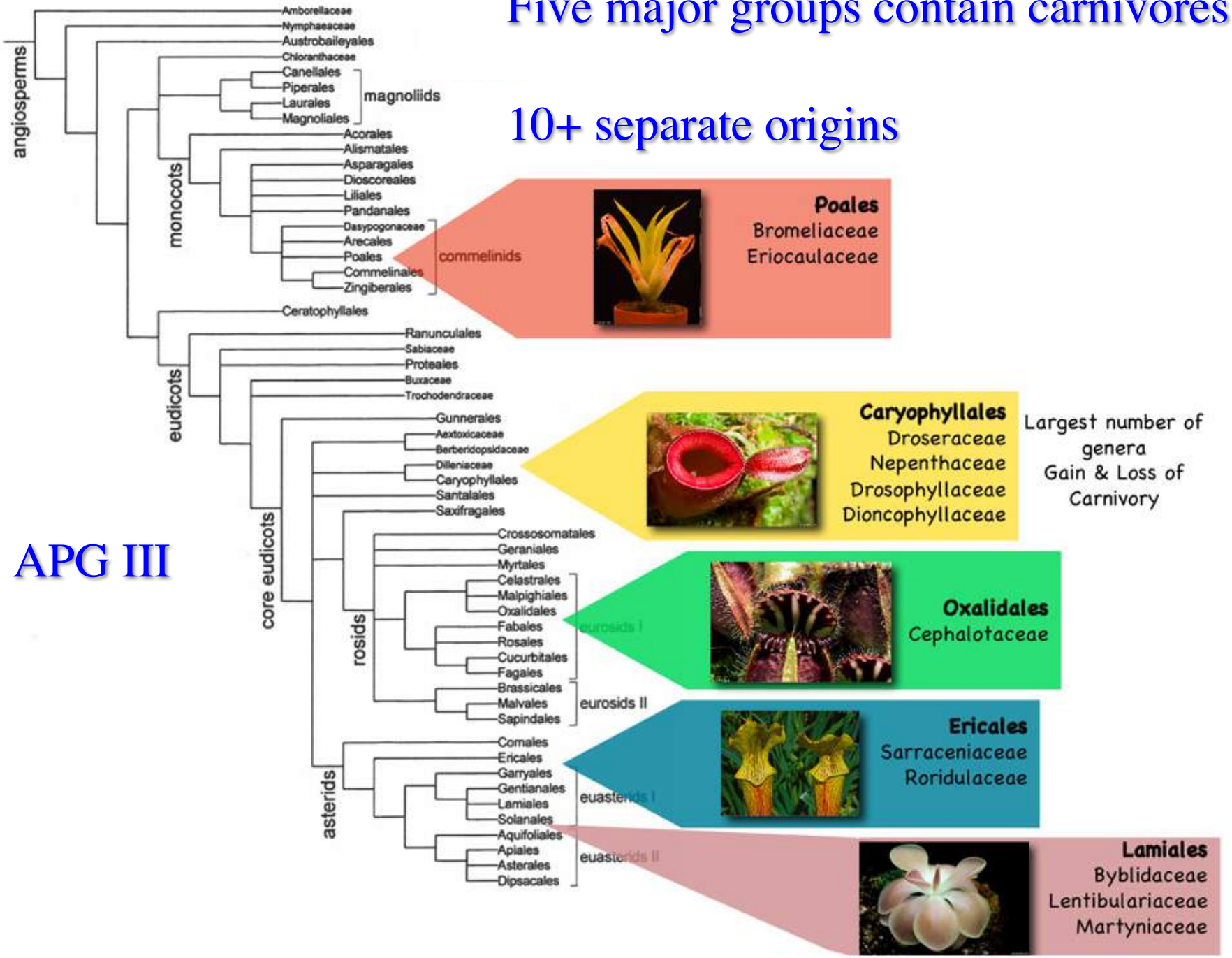
Shown here are two species of *Brocchinia* that are carnivores in the pineapple family.



They are closely related to other species in the genus that impound water or are ant-fed, but not carnivorous.

Five major groups contain carnivores:

10+ separate origins



APG III

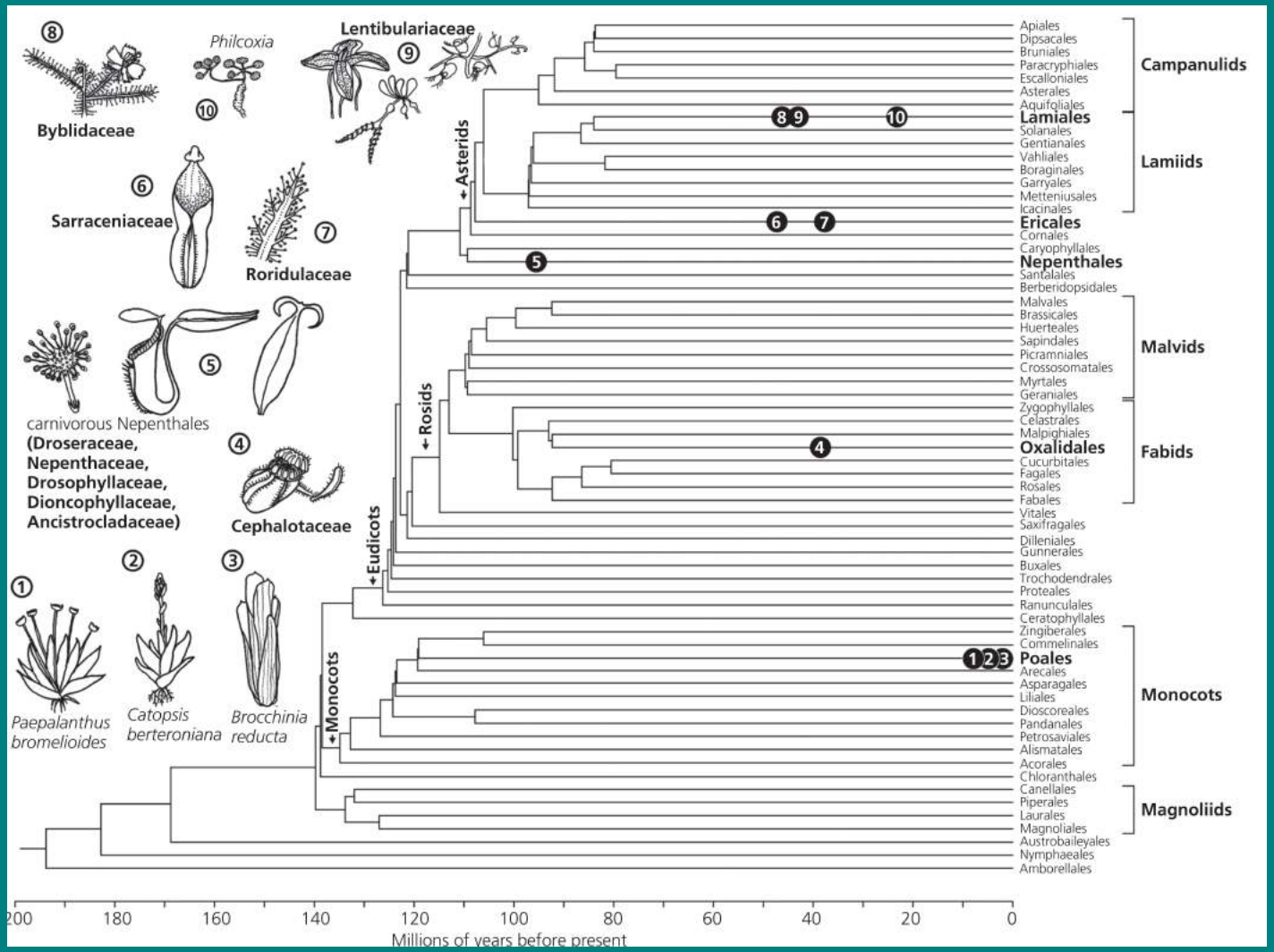
Carnivorous Plants

CHAPTER 3

Evolution of carnivory in angiosperms

Andreas Fleischmann, Jan Schlauer, Stephen A. Smith, and Thomas J. Givnish

2018



Carnivorous Plants

Carnivorous plants are centered in 3 nutrient poor bedrocks around the world.

Southeastern United States coastal plain: the ancient erosional product of the Appalachian uprise and with boggy peatlands

Carnivorous Plants

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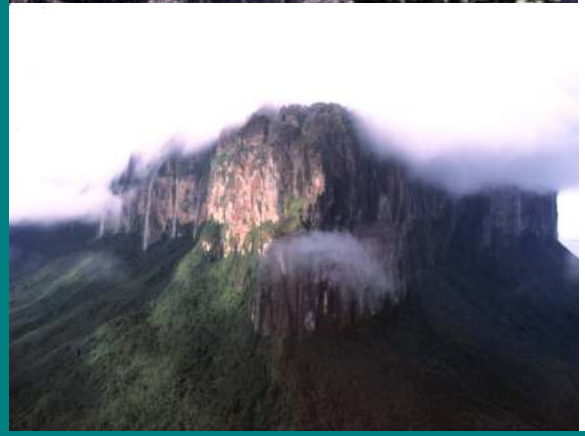
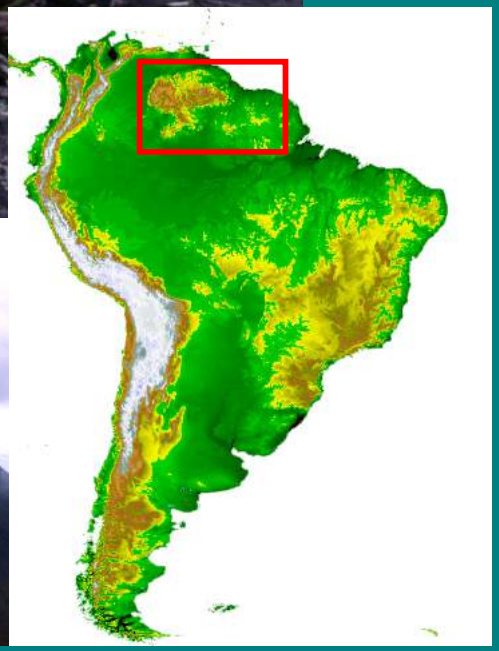
Southeastern United States coastal plain: the ancient erosional product of the Appalachian uprise and with boggy peatlands

Western/Southern Australia - a Precambrian bedrock, highly leached, and nutrient poor

Carnivorous Plants

Carnivorous plants are centered in 3 nutrient poor bedrocks around the world.





Southeastern United States coastal plain: the ancient erosional product of the Appalachian uprise and with boggy peatlands

Western/Southern Australia - a Precambrian bedrock, highly leached, and nutrient poor

Guayana Highlands of southern Venezuela and adjacent areas of Brazil and Colombia - the higher elevation "tepuis" are rain drenched and extremely nutrient poor

Carnivorous Plants

Passive traps – no movement

pitfall

- Sarraceniaceae - American pitcher plants
- Nepenthaceae - Asian pitcher plants
- Bromeliaceae - “pineapple” pitchers
- Cephalotaceae - Australian pitcher plant

lobster pot

flypaper

Carnivorous Plants

Passive traps - pitfall

Heliamphora
Sarraceniaceae

Woody pitcher plants restricted to tepuis of South America

Carnivorous Plants

Passive traps - pitfall

Sarracenia
Sarraceniaceae

pitcher plants restricted to coastal plains of SE U.S.A. with *S. purpurea* (above) distributed to the north

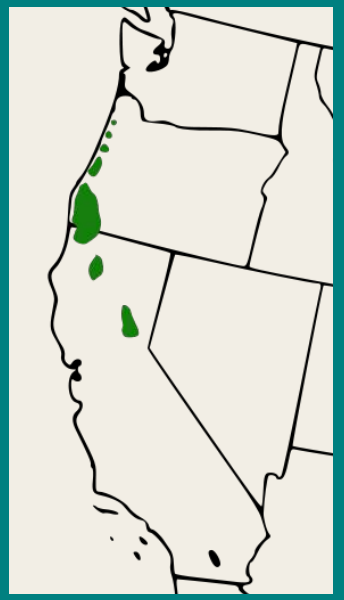
Carnivorous Plants

Passive traps - pitfall

Pitcher plants often have an alluring leaf flap, then downward projecting hairs, then a slippery slope of wax, and finally a drowning pool. Codine like compounds stupefy the insects before digestive enzymes are released.

Carnivorous Plants

Passive traps - pitfall



Darlingtonia (Sarraceniaceae) - the Cobra lily restricted to northern California and Oregon

Insects are attracted by sight of the "cobra" tongue and nectar produced there. Once in the pitcher, the insects slip into the drowning pool.

Carnivorous Plants

Passive traps - pitfall

Nepenthes (Nepenthaceae) is a large genus of pitcher plants in Asia and a few in African rainforests

Carnivorous Plants

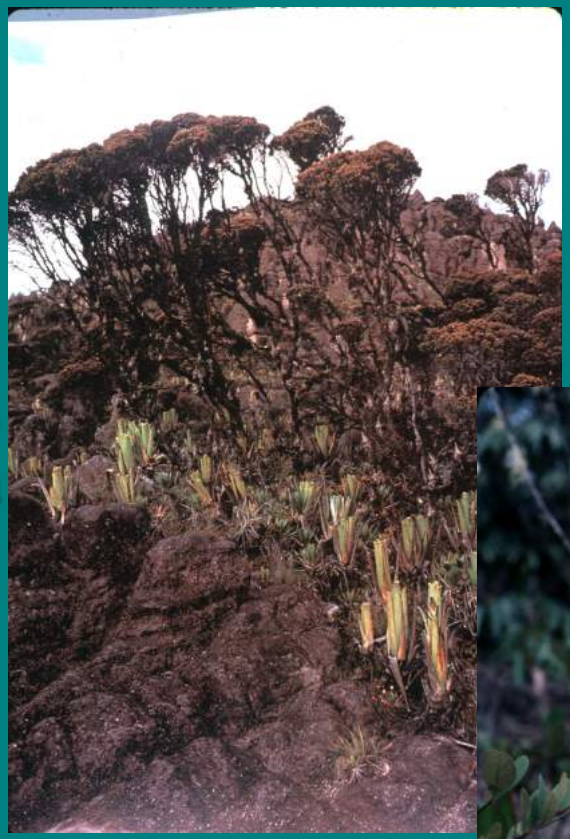
Passive traps - pitfall

Nepenthes (Nepenthaceae) is a large genus of pitcher plants in Asia and a few in African rainforests

The pitcher is a modified leaf drip tip, a common feature in rainforest leaves

Carnivorous Plants

Passive traps - pitfall



Brocchinia is one of two genera of Bromeliaceae, the pineapple family, that are carnivorous. It is the only example of a genus with both carnivorous and non-carnivorous species.

Catopsis is the only other carnivorous member of the Bromeliaceae

Carnivorous Plants

Passive traps - pitfall

Brocchinia reducta is restricted to the nutrient poor summits of the tepuis. When grown in the greenhouse with nitrogen added, the leaves green up and the pitcher opens up.

Carnivorous Plants

Passive traps - pitfall

Cephalotus - the Australian pitcher - is so unusual looking that its systematic placement was unknown until recent DNA evidence placed it near the family Oxalidaceae or sorrels.

Oxalis

Carnivorous Plants

Passive traps

pitfall

Sarraceniaceae - American pitcher plants
Nepenthaceae - Asian pitcher plants
Bromeliaceae - "pineapple" pitchers
Cephalotaceae - Australian pitcher plant

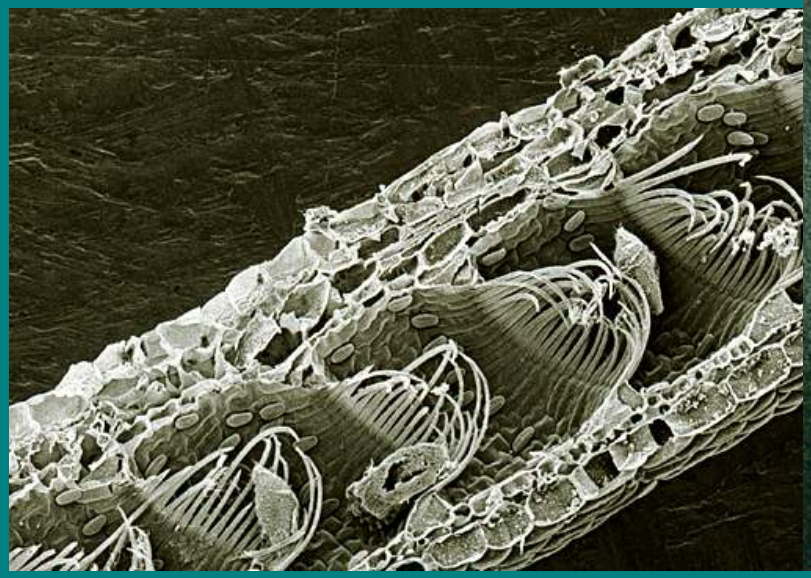
lobster pot

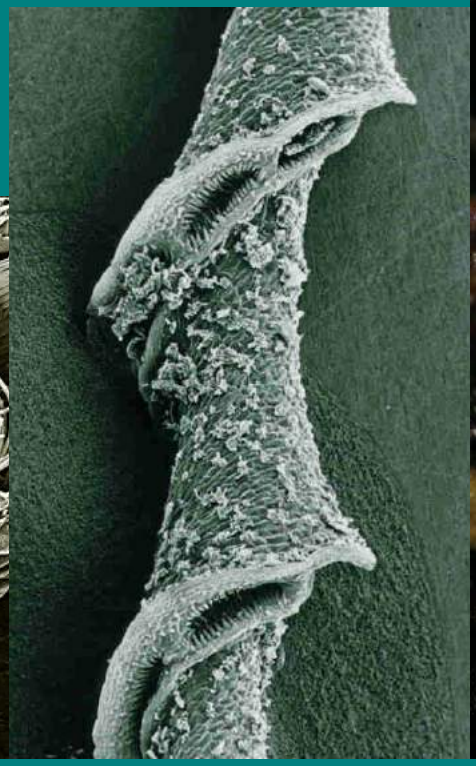
Sarraceniaceae (*Sarracenia psittacina*)
Lentibulariaceae (*Genlisea*)

Carnivorous Plants

Passive traps - lobster pot

Genlisea - the corkscrew - semiaquatic carnivore of protozoa from Brazil, Africa, Madagascar. Modified leaves form a corkscrew which attract paramecium which get directed via hairs towards a digestion area





Carnivorous Plants

Passive traps

pitfall

- Sarraceniaceae - American pitcher plants
- Nepenthaceae - Asian pitcher plants
- Bromeliaceae - "pineapple" pitchers
- Cephalotaceae - Australian pitcher plant

lobster pot

- Sarraceniaceae (*S. psittacina*)
- Lentibulariaceae (*Genlisea*)

flypaper

- Byblidaceae - rainbow plant
- Droseraceae (*Drosophyllum*)
- Dioncophyllaceae
- Roridulaceae
- Plataginaceae

Carnivorous Plants

Passive traps - fly paper

Byblis (Byblidaceae) - the rainbow plant - has modified leaves with sticky hairs. Light hitting the glandular hairs causes a rainbow effect which seems to attract insects.

However, no movement by either the leaves or hairs show and the mode of carnivory is thus considered passive.

Recently placed in Lamiales but once thought to be a Rosid.

Carnivorous Plants

Passive traps - fly paper

Roridula (Roridulaceae) - single species restricted to South Africa; now placed in Ericales

Carnivorous Plants

Active traps – with movement!

flypaper

Lentibulariaceae (*Pinguicula*) – butterwort
Droseraceae (*Drosera*) - sundews

Carnivorous Plants

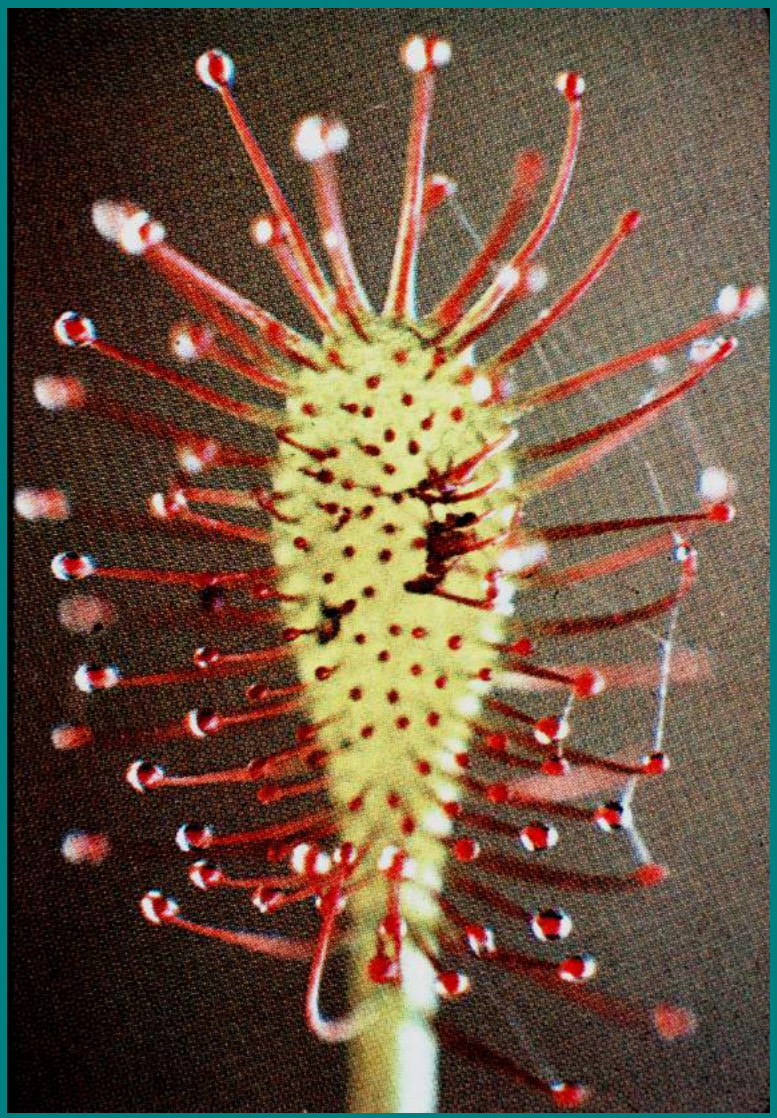
Active traps - flypaper

Pinguicula (butterwort) has modified leaves with sticky buttery top surfaces. Leaves curl to assist in capture.

Carnivorous Plants

Active traps - flypaper

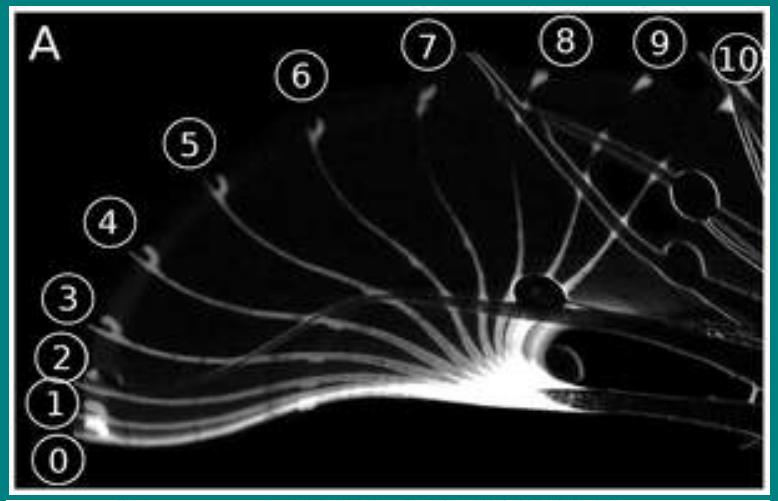
Drosera (sundews) have modified leaves with sticky tentacles. These are alluring, sticky, and move to further trap the insects.

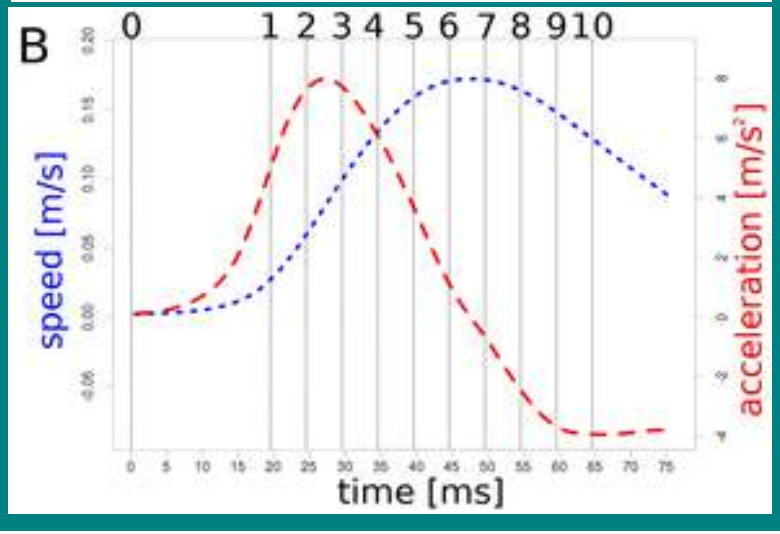


Carnivorous Plants

Active traps – flypaper with a catapult!

Drosera glanduligera (S Australia) has two kinds of tentacles



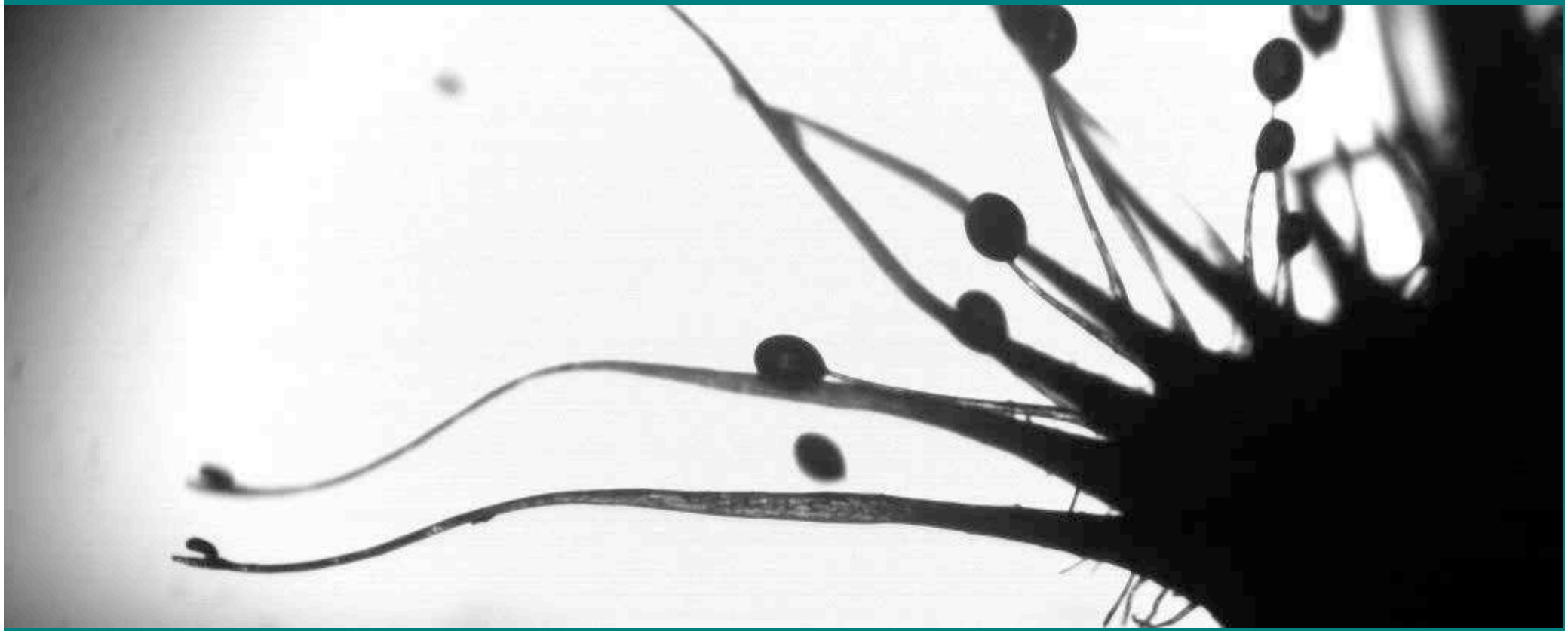


snap tentacles & glue tentacles

"snap" is as fast as the Venus flytrap


Echtzeit / Real time

Snap tentacle at 1/80th speed



Carnivorous Plants

Active traps

flypaper

Lentibulariaceae (*Pinguicula*) – butterwort
Droseraceae (*Drosera*) – sundews

steel trap

Droseraceae (*Dionaea*) - Venus fly trap
Droseraceae (*Aldrovanda*) - water wheel

Carnivorous Plants

Active traps - steel trap

Dionaea (Venus fly trap) has modified leaves acting as steel traps. Two trigger hairs must be touched to snap trap shut. One species, endangered, restricted to the Carolina bogs.

Carnivorous Plants

Active traps - steel trap

Aldrovanda - water wheel - old world rootless aquatic; the whorls of leaves are lobed as in the venus fly trap with small trigger hairs allowing the fastest known plant movement known (0.01-0.02 sec)

Carnivorous Plants

Active traps

flypaper

- Lentibulariaceae (*Pinguicula*) – butterwort
- Droseraceae (*Drosera*) - sundews

steel trap

- Droseraceae (*Dionaea*) - Venus fly trap
- Droseraceae (*Aldrovanda*) - water wheel

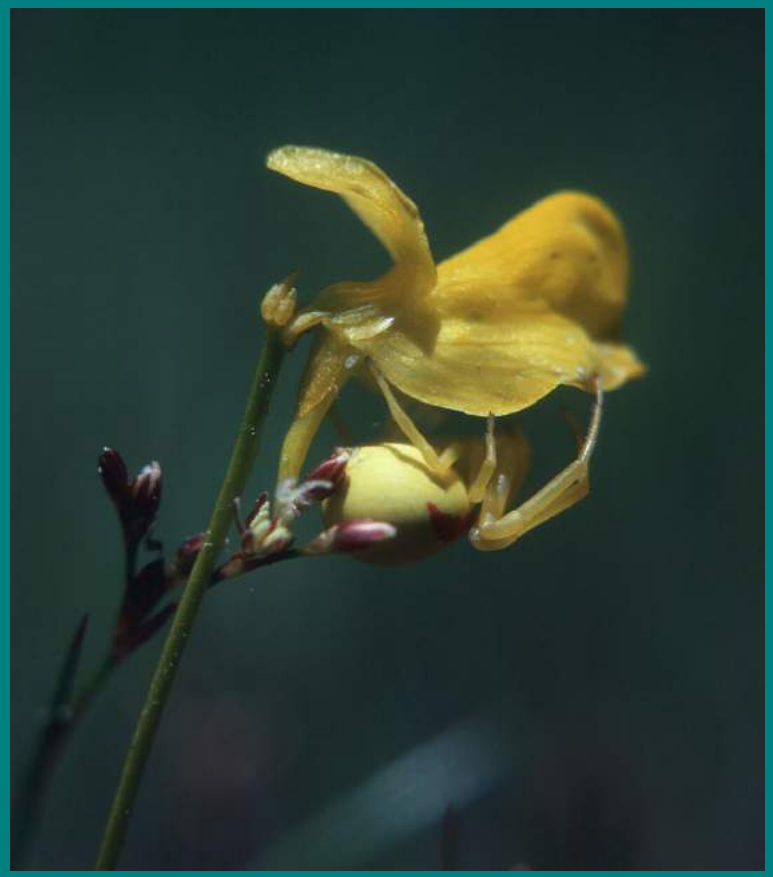
mouse trap

- Lentibulariaceae (*Utricularia*) - bladderwort

Carnivorous Plants

Active traps - mouse trap

Utricularia (bladderwort) along with *Pinguicula* (a flypaper trap) belong to the Lentibulariaceae.



Utricularia cornuta
Beaked bladderwort

Carnivorous Plants

Active traps - mouse trap

However, *Utricularia* (bladderwort) has modified underwater structures (bladders) with a trap door that when triggered sucks in aquatic organisms.

bladder

trap door with trigger hairs

Parasitic Plants

Parasites are plants that gain some or all of their carbon, nutrient and water from other living plants (off roots, stems, or leaves).

Cuscuta - dodder

Dodder parasitism first noted by Theophrastus around 300 BC

Presents numerous difficulties for systematists

- reduced vegetative features
- convergent vegetative features
- weird flowers often
- plastid DNA loss
- nuclear DNA evolves fast
- horizontal gene transfer with host

Parasitic Plants

Parasites are plants that gain some or all of their carbon, nutrient and water from other living plants (off roots, stems, or leaves).

Cuscuta - dodder

Holoparasites - Non photosynthetic (non-green) plants that are obligate parasites

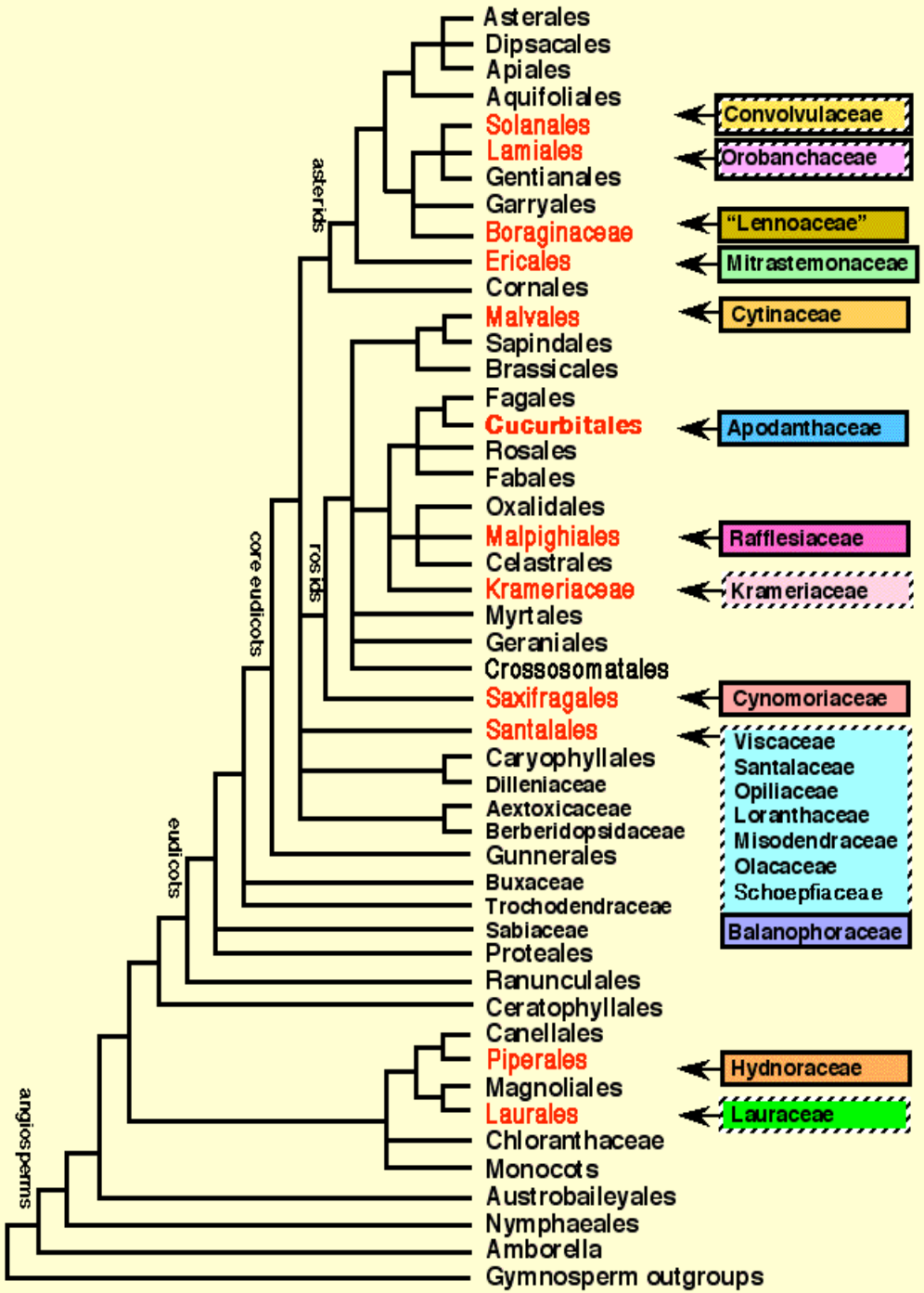
Hemiparasites - Photosynthetic (green) plants that are facultative parasites

Comandra - toadflax

Parasitic Plants

Parasites are plants that gain some or all of their carbon, nutrient and water from other living plants (off roots, stems, or leaves).

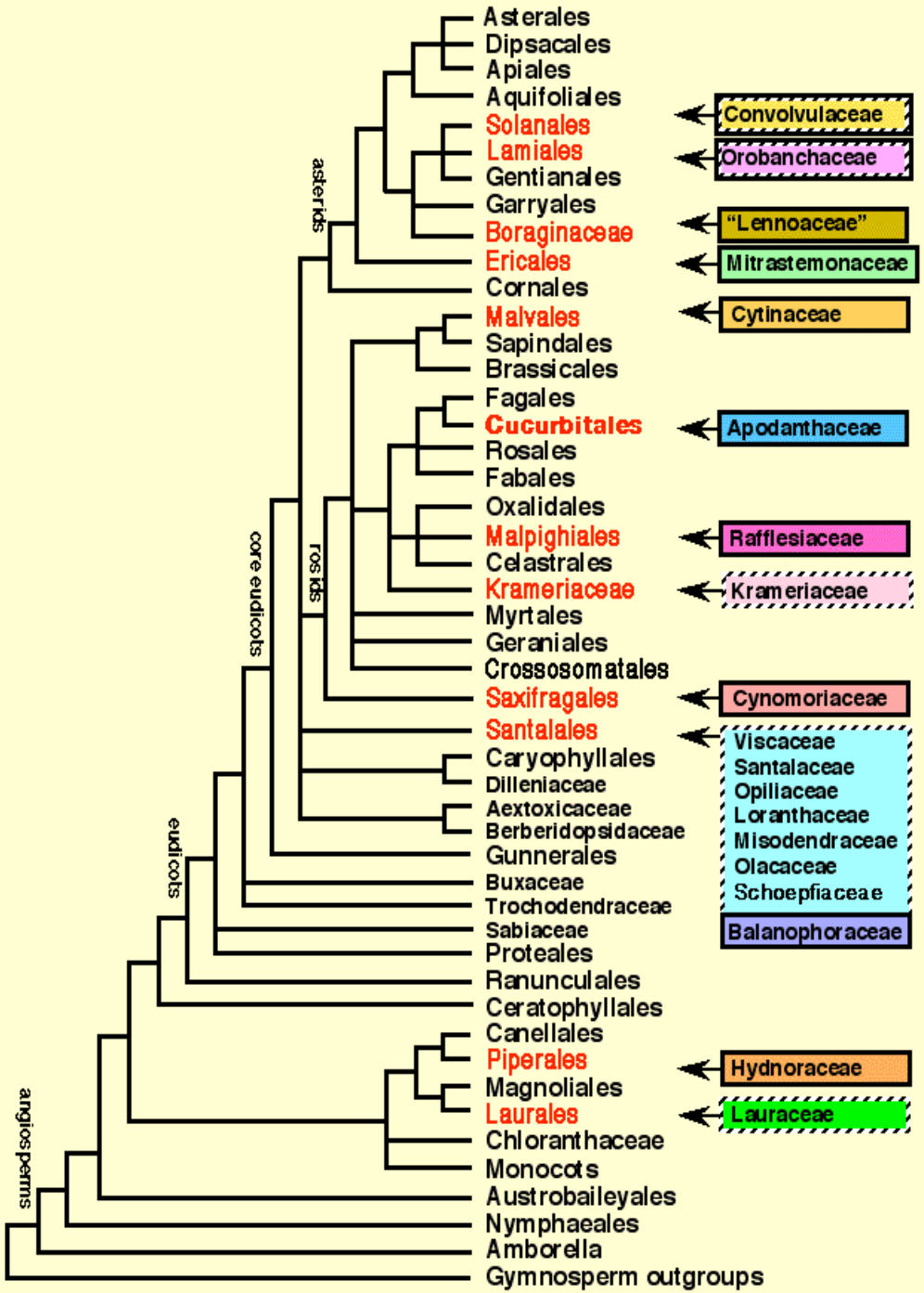
Haustoria form connection of parasite (*Epifagus* - beechdrops) and host (*Fagus* – beech)



At least 13 origins of parasites have occurred in angiosperms

. . . but some are so reduced and bizarre (even their DNA is strange) that we do not know where they should be classified entirely

http://www.parasiticplants.siu.edu/index.html



At least 13 origins of parasites have occurred in angiosperms

. . . but some are so reduced and bizarre (even their DNA is strange) that we do not know where they should be classified entirely

for example - "Rafflesiales"

1. Rafflesiaceae
2. Hydnoraceae
3. Mitrastemonaceae

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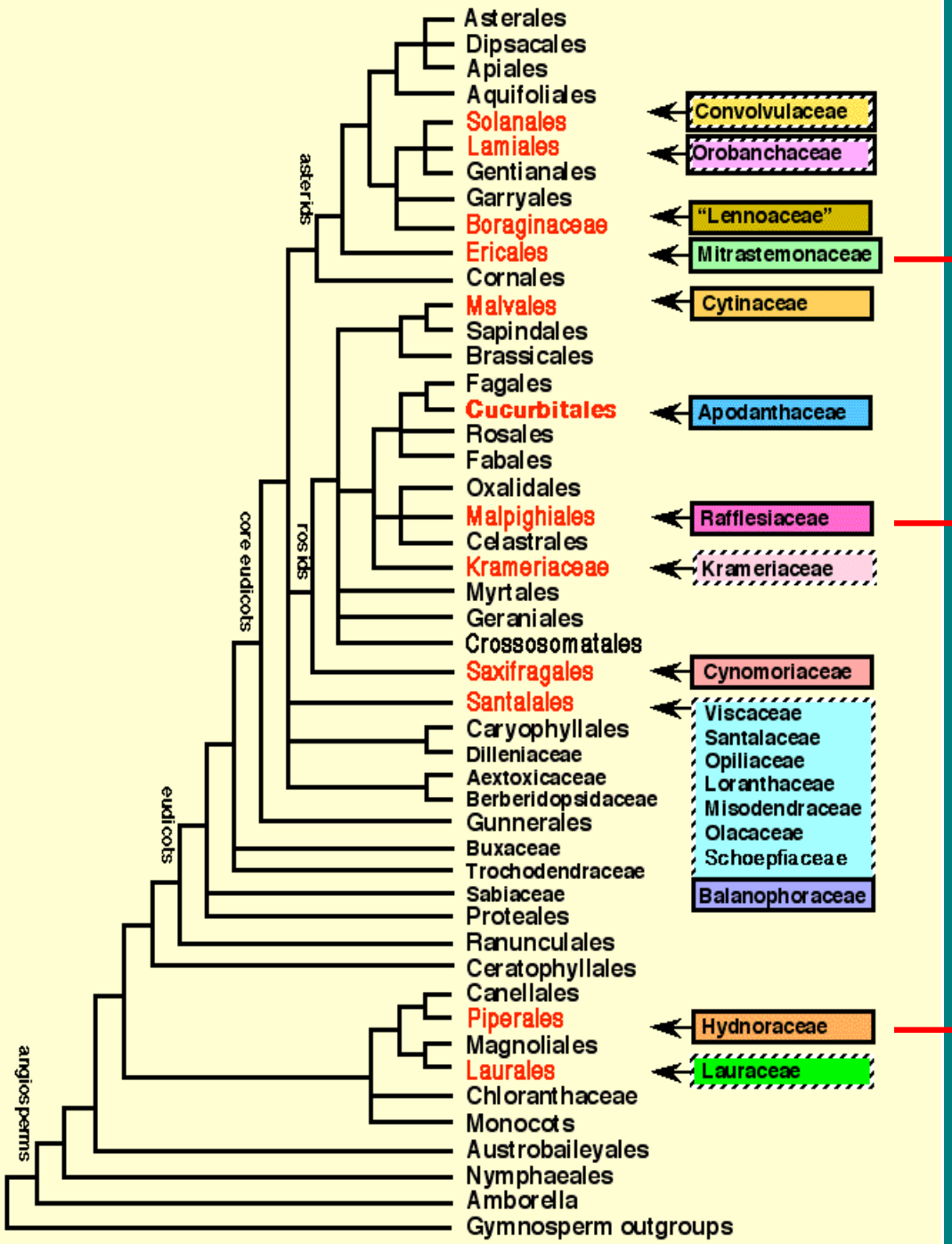


Mitrastema

Rafflesia

Hydnora

Parasitic Plants

Order Piperales - Hydnoraceae

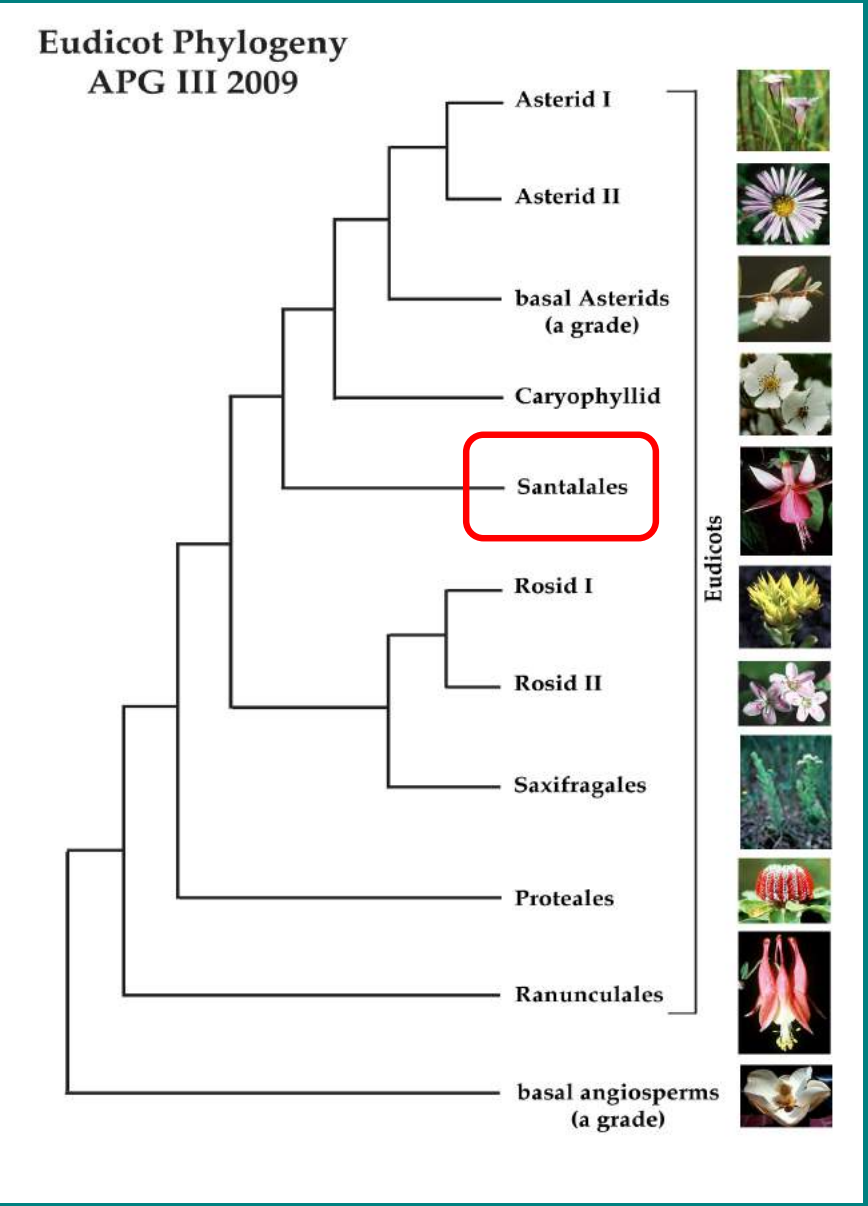
Very reduced family morphologically with a peculiar southern South America and southern African distribution. Related to Aristolochiaceae!

Hydnora

Prosopanche

Parasitic Plants

Order Santalales - Santalaceae (sandalwood)



The hemi-parasitic sandalwood family is largely Old World and often important wood sources (sandalwood, gopher wood).

Santalanum - sandalwood

Parasitic Plants

Order Santalales - Santalaceae (sandalwood)

Comandra
Bastard toadflax

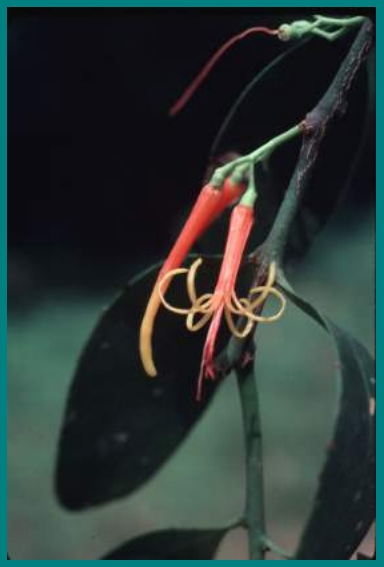
Geocaulon
earthstem

Two genera occur in the Great Lakes region. *Comandra* is known to have the greatest number of host plant species.

Parasitic Plants

Order Santalales - Loranthaceae & Viscaceae (mistletoes)

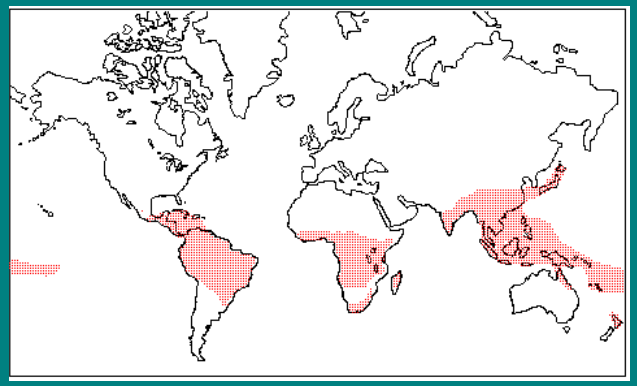
Most mistletoes are epiphytic (grow on branches of other plants). However, most epiphytes are not parasitic as they only use the host plant for support.



Mistletoes are found in both temperate and tropical climates, but most diverse in the tropics.

Parasitic Plants

Order Santalales - Balanphoraceae and other fungal mimics



Species so reduced and so fungus-like, that many only recently have been recognized as flowering plants. APGIII places them in Santalales.

Restricted to dark, wet tropical forest floors.

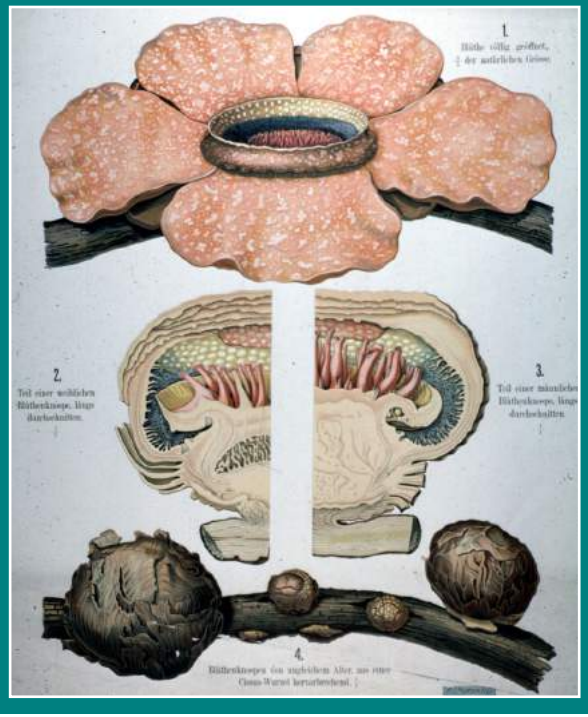
Parasitic Plants

Order Malpighiales - Rafflesiaceae

Holoparasite restricted to vines of the grape family in Paleotropics. Vegetative parts of plant is mycelia-like and within the host. Only the largest flower in world emerges from the vine.

Rafflesia

Anatomy is so bizarre, many structures seem to have no homology with floral parts.



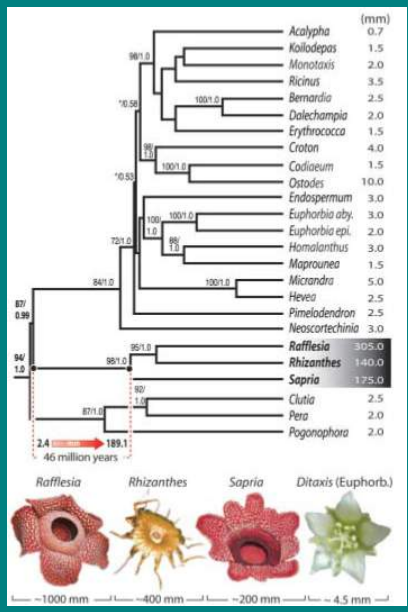
Parasitic Plants

Order Malpighiales - Rafflesiaceae

Read the short Science paper by Chuck Davis and colleagues on where Rafflesiaceae is exactly placed within the order Malpighiales and why this placement is so bizarre! [Reading #1 for lecture exam 3]

Hint: the largest flowers in the world appear to be imbedded in a family with the _____ flowers in the world

Rafflesia



Parasitic Plants

Order Solanales - *Cuscuta* (Convolvulaceae)

Cuscuta

As twining parasites, they attach to the host stems and penetrate into the vascular tissue.

Related to the twining, non-parasitic morning glories - preadaptation?

Ipomoea

Parasitic Plants

Order Lamiales - Orobanchaceae

Castilleja

The broomrape family contains both hemi-parasites (e.g., Indian paintbrush, lousewort, and false foxglove) . . .

Pedicularis

Aureolaria

Parasitic Plants

Order Lamiales - Orobanchaceae

Epifagus

The broomrape family contains both hemi-parasites (e.g., Indian paintbrush, lousewort, and false foxglove)

. . .

and holoparasites (beechdrop, broomrape, cancer-root)

Orobanche

Conopholis

the Mycotrophs

Mycotrophs (myco-heterotrophs, "saprophytes") live without photosynthesis because they have established a co-evolutionary relationship with a mycorrhizal fungus that is attached to the root of a photosynthetic, woody plant — a three way association such that nutrients (carbon) flow from host plant root, to mycorrhizal fungus to the myco-heterotroph.

Voyria
Gentianaceae

2 tropical forest mycotrophs

Triuris
Triuridaceae

the Mycotrophs

Mycotrophs are known in eight families - three Asterid and five monocot

Arachnitis (Corsiaceae)

Campylosiphon (Burmanniaceae)

Voyria (Gentianaceae)

the Mycotrophs

Not surprisingly, the most common occurrences of mycotrophs occur in the families or closely related families of those photosynthetic plants with strong mycorrhizal associations - a common feature of many plants

Corallorhiza
Coral-root
Orchidaceae

Monotropa
Indian pipe
Ericaceae

the Mycotrophs

The blueberry family (Ericaceae) has traditionally been separated from the shinleaf family (Pyrolaceae) and the Indian-pipe family (Monotropaceae) because the latter two exhibit increasing dependence on the fungal association. The Monotropaceae becoming obligate mycotrophs.

germination

Bear-berry
Ericaceae

entire life

Shinleaf
Pyrolaceae

entire life + loss of plastids

Pinesap
Monotropaceae

Mycorrhizal dependency

the Mycotrophs

DNA evidence now shows that both the Pyrolaceae and Monotropaceae are independently derived from within the Ericaceae. That is, certain members of the Ericaceae s.l. (sensu lato - or in the broad sense) are now adapted to the extreme mycorrhizal dependency.

Bear-berry
Ericaceae

Shinleaf
Pyrolaceae

Pinesap
Monotropaceae