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.

Carnivore: Nepenthes

Parasite: Rafflesia

Mycotroph: Monotropa

Things to focus on for this topic:
1. What are these three types of plants
2. How do they live
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

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]

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

for example – carnivorous plants

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

- Nepenthaceae - Asian pitcher plant
- Sarraceniaceae - American pitcher plant
- Droseraceae - Sundews and Venus fly trap

How are they related? [good exam question!]
Plant Oddities - The Problems

Why do plants have these unusual life styles?

Lack of basic necessities for life on land

- $\text{CO}_2$ uptake
- aquatic
- desert/euphlophete
- CAM
- succulence
- parasite
- tropical/temperate forest
- bogs, sand, weathered bedrock
- parasite
- mycotroph
- carnivore

Carnivorous Plants

Charles Darwin (and his grandfather) was the first to painstakingly study carnivorous plants.

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

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.)
- 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

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.

Brocchinia
Bromeliaceae

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

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.
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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

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 - pitfall

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

Carnivorous Plants
Passive traps - pitfall

Heliamphora
Sarraceniaceae
Woody pitcher plants restricted to tepuis of South America

Sarracenia
Sarraceniaceae
Pitcher plants restricted to coastal plains of SE U.S.A. with S. purpurea (above) distributed to the north
Pitcher plants often have an alluring leaf flap, then downward projecting hairs, then a slippery slope of wax, and finally a drowning pool. Cusine like compounds stupefy the insects before digestive enzymes are released.

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.

Nepenthes 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**

*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.

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**Carnivorous Plants**

*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.

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**Carnivorous Plants**

*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.

**Carnivorous Plants**

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

**Carnivorous Plants**

*Sarraceniaceae* (*Sarracenia psittacina*)
*Lentibulariaceae* (*Genlisca*)
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.

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, neither the leaves nor hairs show any movement and the mode of carnivory is thus considered passive. Recently placed in Lamiales but once thought to be a Rosid.

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

Passive traps - fly paper

*Philcoxia* (Plataginaceae) – three species restricted to Brazilian Cerrado: one feeds on nematodes!

Carnivorous Plants

Active traps - fly paper

*Lentibulariaceae* (*Pinguicula*) – butterwort

*Droseraceae* (*Drosera*) - sundews

Active traps

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

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

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

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

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

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).

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

*Comandra* - toadflax

*Helianthus* - sunflower
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.

For example - "Rafflesiales"

1. Rafflesiaceae
2. Hydnoraceae
3. Mitrastemonaceae

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

Order Piperales - Hydnoraceae

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

Hydnora

Order Santalales - Santalaceae (sandalwood)

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

Santalum - sandalwood

Parasitic Plants

Order Santalales - Santalaceae (sandalwood)

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Parasitic Plants

Order Santalales - Santalaceae (sandalwood)

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

Comandra

Bastard toadflax

Geocaulon

earthstem

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 - Balanophoraceae 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

Rafflesia

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.

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!

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?
Parasitic Plants

Order Lamiales - Orobanchaceae

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

Parasitic Plants

Order Lamiales - Orobanchaceae

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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.

the Mycotrophs

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

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

Arachnitis (Coriaceae)
Campylosiphon (Burmanniaceae)
Voyria (Gentianaceae)

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.

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.

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

Bear-berry
Ericaceae

Shinleaf
Pyrolaceae

Pinesap
Monotropaceae

Mycorrhizal dependency

germination
entire life
entire life + loss of plastids