Plant Oddities - the Carnivores, Parasites & Saprotrophs

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.

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Parasite: *Rafflesia*

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Saprotroph: *Monotropa*

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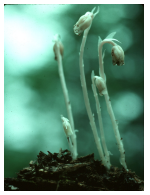


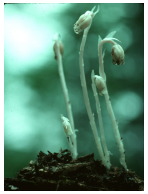
At the state, federal, and international levels, many of these plants are extremely rare, threatened, or endangered. Many are protected internationally from collection by CITES.

Plant Oddities - the Carnivores, Parasites & Saprotrophs

Three aspects of these plants present problems.

1. The biology of how they trap animals, recognize and penetrate other plants, and how they interact with fungi is often little understood.

2. The basic anatomical and morphological structures of both vegetative and floral parts of these plants are often so modified that basic structure (homology) is little understood.

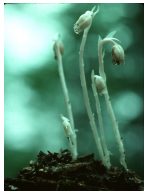


3. Systematic relationships of these plants (how to classify these organisms) are often poorly known and controversial.

Plant Oddities - the Carnivores, Parasites & Saprotrophs

Two factors for this systematic confusion

- the specialized roles often involve reductions in both vegetative and floral features
- often unrelated members of these groups converge unto the same morphology; often related members diverge in morphology



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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

Pitcher traps

Sarraceniaceae - American pitcher plant

Fly paper and steel traps

Droseraceae - Sundews and Venus fly trap

How are these three families classified?

All possible combinations of the three have been proposed!

The most influential classification system was that proposed by Arthur Cronquist who placed all three families in one order - the Nepenthales

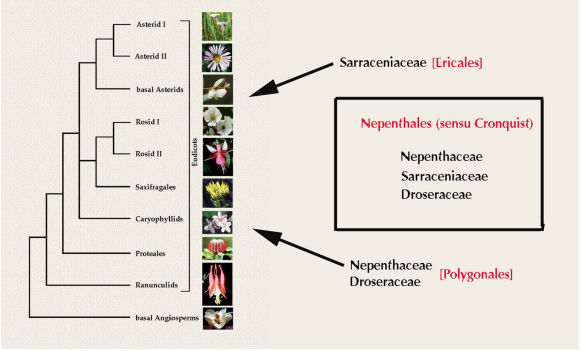
Nepenthales (sensu Cronquist)

Nepenthaceae
Sarraceniaceae
Droseraceae

How are these three families classified?

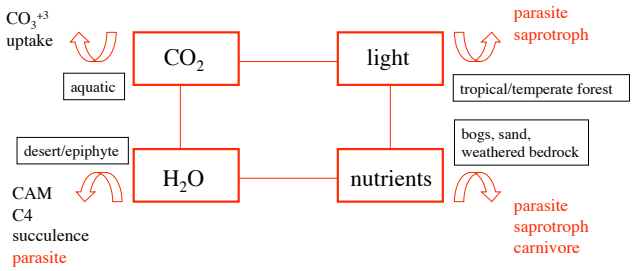
DNA sequence data indicates something quite different!

The Asian and American pitcher plant families quite unrelated; the Asian pitcher plants placed with sundew family and American pitcher plants with Ericaceae

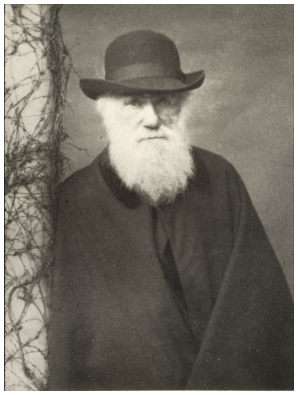


Plant Oddities - the Carnivores, Parasites & Saprotrophs

Why do plants have these unusual life styles? Lack of basic necessity for life on land.



the Carnivores



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.

the Carnivores

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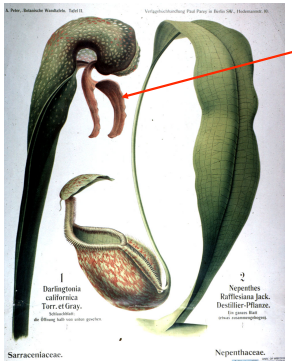
Tom Givnish, University of Wisconsin, has refined the definition of what is a carnivorous plant:

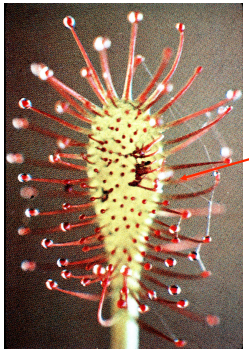
- Adaptations to lure, capture, and digest prey
- Ability to absorb nutrients from animals

the Carnivores



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

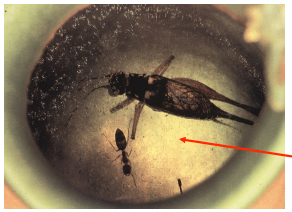
the Carnivores



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.)

the Carnivores



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 trap, often with release of pronases and other enzymes into pool or on animal

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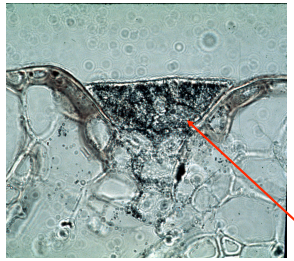


Amino acids radioactively labeled being incorporated into the scales of *Brocchinia* (pineapple family)

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 trap, 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

the Carnivores

What are **not** carnivores?

Plants who 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.

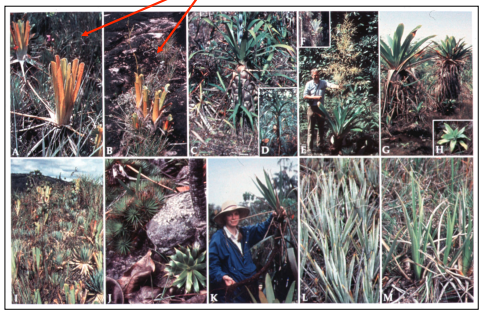
Billbergia
Bromeliaceae

the Carnivores

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 (A and B) 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.

the Carnivores

Carnivorous plants are found in 19 genera, all but 2 are dicots. They are classified into 9 groups, although many groups individually exhibit several kinds of carnivory modes.

Systematic Distribution Of 19 Genera Of Carnivores Based On DNA Evidence

1. Bromeliaceae: Liliopsida , Commelinidae (Brocchinia, Catopsis)
2. Droseraceae: Caryophyllidae (Aldrovanda, Dionaea, Drosera, Drossophyllum)
3. Nepenthaceae: Caryophyllidae (Nepenthes)
4. Dioncophyllaceae: ?Caryophyllidae (Triphyophyllum)
5. Cephalotaceae: Rosidae (Cephalotus)
6. Sarraceniaceae: "lower asterids" (Heliamphora, Sarracenia, Darlingtonia)
7. Roridulaceae: "lower asterids" (Roridula)
8. Lentibulariacae: Asteridae, Lamiales (Utricularia, Pinguicula, Biovularia, Genlisea, Polypompholyx)
9. Byblidaceae: Asteridae, Lamiales (Byblis)

the Carnivores

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

the Carnivores

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

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

the Carnivores

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

Western 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

the Carnivores

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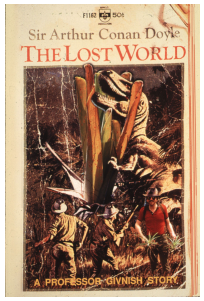


The tepui region was made famous by Sir Conan Doyle as the "Lost World" of "Jurassic" and "Arachniphobia" fame

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

Western 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

Types of Carnivores

Passive traps

pitfall

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

Types of Carnivores

Passive traps - pitfall

Heliamphora
Sarraceniaceae

Woody pitcher plants restricted to tepuis of South America

Types of Carnivores

Passive traps - pitfall

Sarracenia
Sarraceniaceae

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

Types of Carnivores

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.

Types of Carnivores

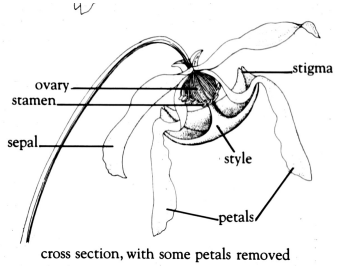
Passive traps - pitfall

Sarracenia purpurea
Sarraceniaceae

Pitcher plants have unusual drooping 5-merous flowers with peltate style and 5 stigmatic lobes and many stamens

Types of Carnivores

Passive traps - pitfall

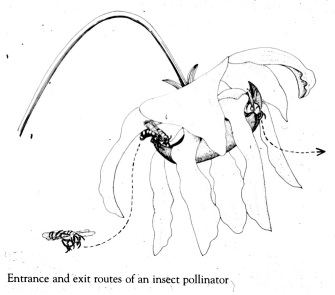


cross section, with some petals removed

Flowers have an unusual pollination syndrome geared for outcrossing

Types of Carnivores

Passive traps - pitfall


Entrance and exit routes of an insect pollinator

Flowers have an unusual pollination syndrome geared for outcrossing

Types of Carnivores

Passive traps - pitfall

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

Types of Carnivores

Passive traps - pitfall

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

Types of Carnivores

Passive traps - pitfall

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

Types of Carnivores

Passive traps - pitfall

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

Types of Carnivores

Passive traps - pitfall

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

Like many pitcher plants, *Nepenthes* exudes nectar and a sweet smell

Types of Carnivores

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

Types of Carnivores

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.

Types of Carnivores

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

Types of Carnivores

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*)

Types of Carnivores

Passive traps

pitfall

Sarraceniaceae - American pitcher plants
Nepenthaceae - Asian pitcher plants
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Cephalotaceae - Australian pitcher plant

lobster pot

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

flypaper

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

Types of Carnivores

Passive traps - flypaper

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.

Types of Carnivores

Active traps

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

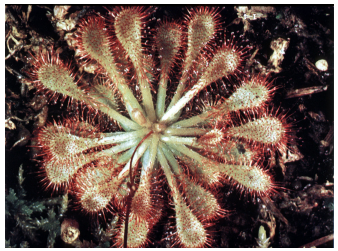
steel trap
- Droseraceae (*Dionaea*) - Venus fly trap
- Droseraceae (*Aldrovanda*) - water wheel

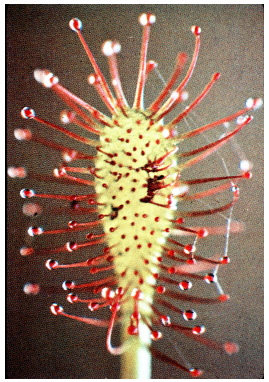
mouse trap
- Lentibulariaceae (*Utricularia*) - bladderwort

Types of Carnivores

Active traps - flypaper

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





Types of Carnivores

Active traps - flypaper

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

Types of Carnivores

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.

Types of Carnivores

Active traps - steel trap

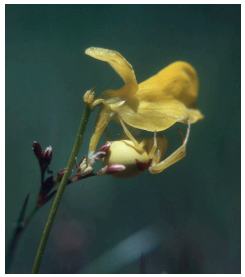
The Venus fly trap has been the inspiration of some great films.

Film kiosk at University of Wisconsin in 1975

Types of Carnivores

Active traps - mouse trap

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



Utricularia cornuta
Beaked bladderwort

Types of Carnivores

Active traps - mouse trap

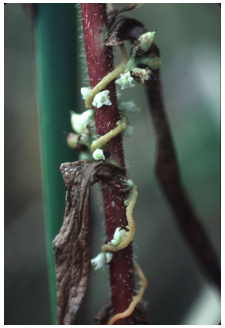
However, *Utricularia* (bladderwort) has modified underwater structures (bladders) with a trap door that when triggered sucks in aquatic organisms.

bladder

trap door with trigger hairs

the Parasites

Parasites are plants that gain some or all of their carbon, nutrient and water needs 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

the Parasites

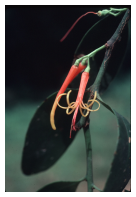
There are at least 8 groups of parasites, but some are so reduced and bizarre (even their DNA is strange) that we do not know where they should be classified.

1. Podocarpus ustus (Podocarpaceae, gymnosperm)
2. Cassytha (Lauraceae, Magnoliidae)
3. order Santalales (8 families, Rosidae) including:
   a. Loranthaceae (mistletoes)
   b. Santalaceae (sandalwood)
   c. Balanophoraceae (fungi mimics)
4. order Rafflesiales (3 families, Rosidae):
   a. Rafflesiaceae
   b. Hydnoraceae
   c. Mitrastemonaceae
5. Krameriaceae (?order Polygalales, Rosidae)
6. Cuscuta (Convolvulaceae, order Solanales, Asteridae)
7. Lennoaceae (3 genera, order Lamiales, Asteridae)
8. Scrophulariaceae & Orobanchaceae (order Lamiales, Asteridae)

the Parasites

Order Santalales - Loranthaceae (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.

the Parasites

Order Santalales - Santalaceae (sandalwood family)

Santalanum - sandalwood

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

the Parasites

Order Santalales - Santalaceae (sandalwood family)

Comandra
toadflax

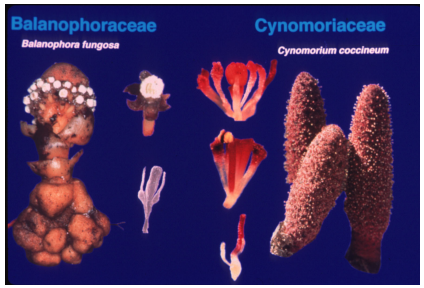
Geocaulon
earthstem

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

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

the Parasites

Order Santalales - Balanphoraceae and other fungal mimics



Species so reduced and so fungus-like, that many have only recently been recognized as flowering plants.

Restricted to dark, wet tropical forest floors.

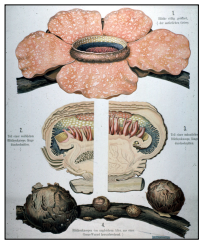
the Parasites

Order Rafflesiales - Rafflesiaceae [order is yet to be placed in classification]

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

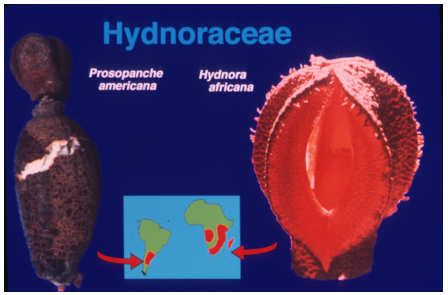
Rafflesia

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



the Parasites

Order Rafflesiales - Hydnoraceae [order is yet to be placed in classification]



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

the Parasites

Cuscuta - the dodders (Cuscutaceae)

The family is totally holo-parasitic and comprises only *Cuscuta*, the dodders.

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

the Parasites

Cuscuta - the dodders (Cuscutaceae)

Convolvulus - morning glory

Dodder vegetative and floral features are similar to that of the twining morning glory family which is not parasitic.

DNA evidence shows that *Cuscuta* is placed in the middle of the Convolvulaceae family. It is essentially a twining morning glory that is non-green and parasitic.

the Parasites

Scrophulariaceae and Orobanchaceae (order Lamiales)

The snapdragon (Scrophulariaceae) and the broomrape (Orobanchaceae) families have long been considered to be closely related within the mint order (Lamiales) - along with the carnivorous Lentibulariaceae (butterwort, bladderworts).

Indian paintbrush
Scrophulariaceae

Broomrape
Orobanchaceae

the Parasites

Scrophulariaceae (order Lamiales)

Castilleja

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

Pedicularis

Aureolaria

the Parasites

Orobanchaceae (order Lamiales)

Orobanche

The broomrape family contains only holo-parasites (e.g., broomrape, beech-drops, and squaw-root) - many with species-specific host relationships.

Epifagus

Conopholis

the Parasites

Scrophulariaceae and Orobanchaceae (order Lamiales)

DNA evidence now shows that the hemi-parasites of Scrophulariaceae should be classified with the holo-parasites of Orobanchaceae, and not with other members of the Scrophulariaceae which are not parasitic.

Indian paintbrush
Scrophulariaceae

Closely related !

Broomrape
Orobanchaceae

the Saprotrophs

The saprotrophs are non-green plants that form **haustoria** (stem/root-fungal) connections with fungi. The fungi provide water, nutrients, and carbon source for the plants. This relationship is often referred to as a parasitic-fungal life style. Most common in low nutrient, acidic, low-light forests.

Voyria
Gentianaceae

2 tropical forest saprotrophs

Triuris
Triuridaceae

the Saprotrophs

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

Coralorhiza
Coral-root
Orchidaceae

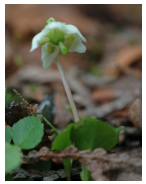
Monotropa
Indian pipe
Monotropaceae/
Ericaceae

the Saprotrophs

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 saprotrophs.

Mycorrhizal dependency

Bear-berry
Ericaceae



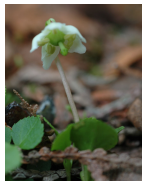
Shinleaf
Pyrolaceae

Pinesap
Monotropaceae

the Saprotrophs

DNA evidence now shows that both the Pyrolaceae and Monotropaceae are independently placed 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