Carnies and Vampires,  
or how I learned to stop worrying  
and love the alternative lifestyles  
of plants  

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CSUS
Outline for Talk

• Introduction
• Carnivorous Plants
• Parasitic Plants

Darlingtonia californica
Introduction

• Photosynthesis:

• Provide the basis for ecosystems
Introduction

Other plants obtain energy and/or nutrients in alternative ways

– Carnivorous plants
– Parasitic plants
‘This plant, commonly called Venus’ fly-trap, from the rapidity and force of its movements, is one of the most wonderful in the world.’
(Darwin, Insectivorous plants, p. 231)
People and Carnivorous Plants

• *A little history*
  – Long history of fascination, observation...and obsession
People and Carnivorous Plants

• **A little history**
  – Darwin (1875) *Insectivorous Plants*
    • plants did trap insects
    • digestion occurred
    • benefited from capture
  – Francis Darwin (1878) showed insect addition promoted flowering and seed set
What are Carnivorous Plants?

• *Definition*: Plants that have adaptations for animal capture and digestion and the absorption of nutrients

*Sarracenia leucophylla*
Diversity

• ~600 species/sub-species of carnivorous plants.

• *Utricularia* is largest genus (~200 species)
Environmental conditions

Carnivorous plants found in habitats:

• Low nutrient, acidic soil
• Bright sunlight
• Waterlogged
• Fire

Pine savannah in the Florida panhandle
Physiology and Morphology

• Nutrient needs:
  – Nitrogen
  – Phosphorus
  – Micro-nutrients
Physiology and Morphology

• Digestion:
  – passive (by symbionts)
  – enzymes

• Attractants
  – Nectar glands
  – Color
  – Volatile chemicals

• Modified leaves for capturing animals
  – Pitchers
  – Sticky traps
  – Spring traps
  – Bladder traps
Physiology and Morphology

- Differences in reliance on captured insects
- Variation in nitrogen contribution to carnivorous plants (10-87%)
- Reliance also changes through time (young to old leaves)

Ellison & Gotelli (2002)
Recent studies...Kurup et al. 2013

- Fluorescent prey traps (UV light)
- Proposed to attract arthropod prey and mutualists
- Arthropods and small mammals can see this light- act as guides
Recent studies...Greenwood et al. 2011

- Mutualisms
- *Nepenthes* in Bornea
- Nectar secretions on lid
- Mammals defecate in pitcher
- Also seen in other PP with bats
Distributions and hotspots

• Found on almost every continent
  – Americas (most genera, 8/14)
  – Asia
  – Australia
  – Africa
  – Europe
## California Carnies

<table>
<thead>
<tr>
<th>Species</th>
<th>Common name</th>
<th>Capture</th>
<th>Habitat</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Darlingtonia californica</em></td>
<td>cobra lily</td>
<td>Pitcher</td>
<td>Bogs, fens</td>
<td>CA, OR</td>
</tr>
<tr>
<td><em>Drosera rotundifolia</em></td>
<td>roundleaf sundew</td>
<td>Sticky</td>
<td>Bogs, fens</td>
<td>North America</td>
</tr>
<tr>
<td><em>Drosera anglica</em></td>
<td>English sundew</td>
<td>Sticky</td>
<td>Bogs, fens</td>
<td>Circumboreal N. America, Asia, Europe</td>
</tr>
<tr>
<td><em>Pinguicula macroceras</em></td>
<td>California butterwort</td>
<td>Sticky</td>
<td>Bogs, fens</td>
<td>CA, OR, WA, ID, MT, AK</td>
</tr>
<tr>
<td><em>Utricularia gibba</em></td>
<td>humped bladderwort</td>
<td>Bladder trap</td>
<td>Aquatic</td>
<td>Global</td>
</tr>
<tr>
<td><em>Utricularia intermedia</em></td>
<td>flat-leaved bladderwort</td>
<td>Bladder trap</td>
<td>Aquatic</td>
<td>North America, Asia, Europe</td>
</tr>
<tr>
<td><em>Utricularia macrorhiza</em></td>
<td>common bladderwort</td>
<td>Bladder trap</td>
<td>Aquatic</td>
<td>North America &amp; E. Asia</td>
</tr>
</tbody>
</table>
Capture Mechanisms

- Pitchers
  - Passive capture
  - Downward hairs
  - Areolae (windows- false exits)
  - Water

Nepenthes ampullaria
Cephalotus follicularis
Phytotelmata

Small bodies of water held by plants, including leaves, flowers, stems, and trunks

– Pitcher-plant

– Treehole
Sarracenia purpurea

- Range: Florida to Canada
- Leaves collect rainfall
- Habitat for a variety of aquatic species
Capture Mechanisms

- Sticky (flypaper)
  - stalked glands
  - mucinuous droplets with digestive enzymes
  - slow movement inward

Drosera

Byblis

Pinguicula
Capture Mechanisms

• Spring traps
  – Modified bivalved leaves with trigger spines, nectary and digestive glands
  – Closure initiated by prey stimulation of trigger spines
Capture Mechanisms

• Bladder traps
  – Small aquatic traps
  – Vacuum exists within
  – Triggered by prey
Conservation

• Habitat destruction
  – Wetland draining
  – Habitat conversion

• Collection and trade
Conclusions

- Carnivorous plants are unique for many reasons: morphology, physiology, ecology, evolution
- Great diversity in each characteristics: morphology, physiology, ecology, evolution
- Conservation efforts require 2-prong approach: reduce collection and habitat destruction
“... its supplies ready-made from the sap of its host. In this parasitic state it has no need for organs of nutrition of its own, and Nature therefore takes them away. Henceforth, to the botanist, the adult Dodder presents the degraded spectacle of a plant without a root, without a twig, without a leaf, and having a stem so useless as to be inadequate ...”

— Natural Law in the Spiritual World
Henry Drummond 1883
Parasitic plants

• Receive food from other plants or fungi
• Considered a pest (noxious weed)
• Have + and - effects
Parasitic plant diversity

- >4000 worldwide
- ~100 in California
Parasitic Plants

- Root parasites
- Stem parasites
- Holoparasites
- Hemiparasites
Not so black and white.....

<table>
<thead>
<tr>
<th>Hemiparasite</th>
<th>Holoparasite</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Facultative</strong></td>
<td><strong>Obligate</strong></td>
</tr>
<tr>
<td>Santalales (r, s; 149/2101–2114)</td>
<td>Cuscuta (s; 1/145)</td>
</tr>
<tr>
<td></td>
<td>Lennoaceae (r; 2/5)</td>
</tr>
<tr>
<td></td>
<td>Mitrastemonaceae (r; 1/2)</td>
</tr>
<tr>
<td></td>
<td>Balanophoraceae (r; 17/43–44)</td>
</tr>
<tr>
<td></td>
<td>Rafflesiaceae (e; 3/19)</td>
</tr>
<tr>
<td></td>
<td>Apodanthaceae (e; 3/23)</td>
</tr>
<tr>
<td></td>
<td>Cytinaceae (r; 2/7–11)</td>
</tr>
<tr>
<td></td>
<td>Cynomoriaceae (r; 1/2)</td>
</tr>
<tr>
<td></td>
<td>Hydnoraceae (r; 2/15–18)</td>
</tr>
<tr>
<td>Krameriaceae (r; 1/18)</td>
<td></td>
</tr>
</tbody>
</table>
...and wait there’s more....

- Mycoheterotrophs
- Parasitize mycorrhizal fungi
  - Mutualism with plants
- Indirectly receive energy and nutrients from plant

**Orchidaceae**

**Ericaceae**

**Pterosaviaceae**
....and wait there’s more....

- Hyperparasites or epiparasites
- Parasitize parasties!
- Example: *Phoradendron scabberimum*
<table>
<thead>
<tr>
<th>Feature</th>
<th>Mimulus guttatus</th>
<th>Triphysaria versicolor</th>
<th>Striga hermonthica</th>
<th>Orobanche aegyptiaca</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrition</td>
<td>Autotrophic</td>
<td>Hemiparasite</td>
<td>Hemiparasite</td>
<td>Holoparasite</td>
</tr>
<tr>
<td>Dependence on host</td>
<td>Free living</td>
<td>Facultative</td>
<td>Obligate</td>
<td>Obligate</td>
</tr>
<tr>
<td>Genome size (Mb/1C)</td>
<td>430</td>
<td>1975</td>
<td>1672</td>
<td>3900</td>
</tr>
<tr>
<td>Chromosome number (2N)</td>
<td>28</td>
<td>22</td>
<td>38</td>
<td>24</td>
</tr>
<tr>
<td>Hosts with abundant sequence</td>
<td>N/A</td>
<td>Arabidopsis, Medicago,</td>
<td>Maize, rice, sorghum</td>
<td>Arabidopsis, tobacco,</td>
</tr>
<tr>
<td>information (model hosts)</td>
<td></td>
<td>tomato</td>
<td></td>
<td>tomato</td>
</tr>
</tbody>
</table>

Westwood et al. (2010)
PP Genetics
(Vogel et al. 2018 Nature)

• Recent whole-genome duplication

• Genes lost:
  – High photosynthetic activity
  – Nutrient uptake processes from the soil

• Evidence for horizontal gene transfer by way of genomic DNA integration from the parasite’s hosts was found
General Characteristics

• Tend to be generalists (host preference)
• ....but prefer hosts
  – high in nitrogen
  – accessible vascular system
  – low defense
• Haustoria
Haustoria

- **Function:**
  - Host attachment
  - Invasion
  - Physiological redirection of host resources into the parasite
Effects on hosts.....

Fig. 1 Change in abundance of two competing pickleweeds, *Arthrocnemum subterminale* and *Salicornia virginica*, at their ecotone following parasitism by the shoot parasite *Cuscuta salina* in a Californian salt marsh. Where *Cuscuta* is absent (open bars), *Arthrocnemum* may decline under competition from the expanding *Salicornia*. Because *Cuscuta*, however, preferentially parasitises *Salicornia* over *Arthrocnemum*, the presence of *Cuscuta* (closed bars) results in a decline in *Salicornia* and hence allows *Arthrocnemum* to expand. This action effectively stops *Salicornia* from invading into the *Arthrocnemum* zone (reproduced with permission from Callaway & Pennings, 1998).
Responses to hosts.....

Fig. 3 Uptake of host alkaloids can benefit parasitic plants. (a) Herbivore damage (mainly from moth larvae) on the root hemiparasite Castilleja indivisa when parasitic on either bitter (high alkaloid content) or sweet (low alkaloid content) lupine hosts. Uptake of lupine alkaloids clearly reduces herbivory of the parasite. (b) Pollinator visits to the Castilleja when parasitic on either bitter or sweet lupines. Uptake of alkaloids from bitter lupines increases pollinator visits (mainly by hummingbirds) to the Castilleja – possibly because the less herbivore-damaged Castilleja provide greater nectar rewards (redrawn with permission from Adler, 2000).

- Botanical parasitism of an insect by a parasitic plant
- “the first observation of a parasitic plant attacking the insect-induced galls of multiple gall-forming species and provide evidence that this interaction negatively affects gall former fitness”
Cuscuta howelliana

• Boggs Lake Dodder
• Vernal pool endemic
• Tend to attack two plants
• How do they effect the plant community in vernal pools?
Removal Experiment

• Andrea Graffis, MS Thesis
• Beale AFB
• Paired plots in VP:
  – Removed *Cuscuta*
  – Intact *Cuscuta*
Keystone Species

A. With sea otters, kelp forest food web

B. Without sea otters, urchin barren food web
Keystone Species

(-)

Dominant Competitors

(+) (-)

Species Diversity
Results

• Cover decreases
  – Host species
    • *Eryngium castrense* and
    • *Navarretia leucocephala*
  
• Biodiversity increases (native and exotic!)

• Overall community changes

Graffis and Kneitel (2015)
Conclusions

- Similar to carnivorous plants, parasitic plants are diverse in their adaptations and habitats.
- Have a diversity of effects on populations and communities.
THANK YOU!
QUESTIONS?