Plant-Animal Interactions

Focus on Herbivory

Positive Interactions

- Pollination
- Seed dispersal
- Nutrient enhancement
- Indirect: removal of competitors

Negative Interactions

- Damage (trampling)
- Herbivory
- Seed predation

Herbivory

- Consumption of all or part of a living plant by a consumer

What to take away today

- Plant-animal interactions clearly important in the evolution of plants
- Impacts are at individual, population and community levels-evolution happens
- Impacts also depend on plant/animal context and patterns of allocation in plants
- Herbivory can influence community composition
- Inducible defenses can ‘cascade’ into food webs (plants can influence animal community)

Why is herbivory important to study?

- Typically the initial link in local food webs (i.e., the basis of energy and material flow within a system)
Adaptive Characteristics of Plants to Herbivory

1. **Physical**: hairs, hooks, spines

2. **Chemical**: Selective (affects some more than others), Toxic (alkaloids, amino acids) or Indigestible (tannins, lignins), can be Dose Specific (body mass), or detoxified in some cases

3. **Mimicry**: mistletoes in Australia mimic hosts, avoiding specific butterfly herbivores  
   Hosts: Eucalyptus, Acacia, Casurina

4. **Other animals**, like Ant-Acacias, Cecropia-ants, and a large variety of other similar associations degree of specialization variable

Examples of physical defense

Variety of consumers is great

- Bacteria, fungi, viruses (pathogens or phytophagous microbes)
- Small insects like aphids, scale, caterpillars
- Small mammals, rats, rabbits
- Large vertebrates like deer, elk, bison (in small groups or individuals vs herds)

Selective pressures vary depending on form of selection

- Parasitism (including pathogens) (chronic and sometimes debilitating)
- Browsing and Grazing (depends on frequency, amount, and whether it’s differential (i.e. has other consequences)
- Predation (means death to individuals and can play a strong selective role)
Impact on Plants

- Herbivory can be (as a net impact)
  - negative
  - neutral
  - positive
- Depends on life history stage, frequency, magnitude, opportunity for response, plant and animal context

Effect on plant performance depends on...

- type of tissue removed (roots vs buds vs leaves)
- plant age
- amount, timing, and pattern (early in the growing season, late in the season)
- frequency (repeated loss of apical meristems - problem for oak seedlings at Hastings)
- compensation (does PS increase afterwards, does leaf area increase)

Plant-herbivore interactions are actually quite complicated

- Defensive compounds are widespread among plant species
- Individual plants have an array of defenses
- Most plants have inducible defenses
- Variation in the environment affects effective defense of many plant species

Magnitude or frequency of herbivory: an example

- *Trifolium* and Slugs
- Cyanogenic and acyanogenic forms of clover
- Selection by mollusks (differential herbivory) increases abundance of cyanogenic forms
- Acyanogenic forms grow faster and can competitively exclude or limit cyanogenic forms

Mollusk density

<table>
<thead>
<tr>
<th>Mollusk Density</th>
<th>Cyanogenic</th>
<th>Acyanogenic</th>
</tr>
</thead>
<tbody>
<tr>
<td>High to very high</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Low</td>
<td>20</td>
<td>16</td>
</tr>
<tr>
<td>Very low</td>
<td>30</td>
<td>27</td>
</tr>
</tbody>
</table>


Growth of mollusks on different diets
Plant-herbivore interactions are actually quite complicated

- Geographic variation selects for different types or degrees of defense
- Plant diversity and feeding specialization by herbivore species reflect their intimate evolutionary history
- Plant-herbivore interactions can have long-term, complex ecosystem level consequences

The genus *Asclepias* is quite variable in their plant defenses. Considerable variation in morphology, hairiness, latex production, cardenolide production and other chemicals.

But, in another study, monarchs selected the most toxic species.

<table>
<thead>
<tr>
<th>Inspect. species</th>
<th>N</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td><em>A. fascicularis</em></td>
<td>15</td>
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<td>0</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td><em>A. speciosa</em></td>
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<td>14</td>
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<tr>
<td><em>A. incarnata</em></td>
<td>12</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>17</td>
</tr>
<tr>
<td><em>A. curassavica</em></td>
<td>11</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td><em>A. curassavica</em></td>
<td>10</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>13</td>
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<td>28</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>66</td>
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</tbody>
</table>

The cardenolide concentration of *A. curassavica* leaves was 904 μg cardenolide/0.1 g dry leaf, and that of *A. incarnata* 24 μg cardenolide/0.1 g dry leaf. Thus, *A. curassavica* at this location had, on average, 56 times more cardenolide than *A. incarnata*.

Most know about Monarch butterflies and *Asclepias* species (milkweeds) with mimicry of Monarchs by Viceroyos.

However, milkweed populations are complicated, geographically variable, and butterflies do not always mature on some species.

Many herbivores respond to this variation differentially. Monarchs differentially choose species with low-medium cardenolide concentrations, glabrous leaves, and low latex production if given a choice.

Monarch larvae also have behavioral responses, such as cutting latex flow near the base of the leaf before eating tissue.
Impact on Communities

- selectivity of herbivores can shift DOMINANCE and COMPOSITION
- e.g., rabbit exclosures in Britain and herb exclosures in Kenya - previously rare species become dominant, richness declines

Herbivory impacts can cascade along food webs

- Plants interact directly with herbivores, but also indirectly with predators of herbivores
- Plants can also respond to different types of herbivore attacks with inducible chemical defenses
- Consider, the original wild cabbage (Brassica oleracea ssp. oleracea) from which kale, collards, cabbage, broccoli, cauliflower, and other crops were developed (native to the coasts of north Africa and Europe).

General Theories of Plant Defense:

- Biochemical Coevolution
- Plant Apparency
- Resource Availability (allocaional tradeoffs)
- Many others

A number of different hypotheses about the complexity of plant-herbivore interactions.
1. Biochemical Coevolution
   (Ehrlich and Raven, 1964)
   - Plant evolves toxin
   - Some insects evolve to detoxify
   - Plants evolve new toxin
   - Subset continue to detoxify
   - Continuation of reciprocal evolution leads to phylogenetic specialization

   Coevolution predicts concordance between the phylogeny of both herbivores and food plants

   Relationships between plants and their herbivores
   Some highly specialized interactions between plants and their herbivores both quite old and quite new.
   **Suggests:**
   1) specialization does not necessarily lead to extinction
   2) specialization is a common evolutionary dynamic state capable of change, sometimes rapid change, rather than an evolutionarily static dead end

2. Plant Apparencty
   (Feeney and others, 1970's)
   - easily found plants vs difficult to locate plants
   - plants experience different selective pressures
   - defense correlates to longevity or ‘value’ of tissue
   - Apparent: quantitative digestibility reducers
   - Unapparent: qualitative toxins

### Qualitative vs Quantitative Defense

<table>
<thead>
<tr>
<th>Chemical Type</th>
<th>Woody</th>
<th>Herbaceous</th>
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<tbody>
<tr>
<td></td>
<td>(Type)</td>
<td>(Type)</td>
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<tr>
<td>Digestibility Enforces:</td>
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<td></td>
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<tr>
<td>Qualitative Defense</td>
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<td>Dicots</td>
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<td>Monocots</td>
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<tr>
<td>Properties</td>
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<td>Qualitative Defense</td>
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</tbody>
</table>

**Source:** After Hooper (1976).
*Phenolics indicate digestibility reducing toxins.
### 3. Resource Availability (allocational tradeoffs)

...together, the balance between them determines:

- 1) high or low investment in defenses
- 2) defenses mobile or not
- 3) defenses C-based (tannins, lignins) or N-based (alkaloids, amino acids)

### Relationship of investment in plant growth and defense (from resource availability theory).

High growth rate means defense decreases realized growth rates by allocating away from growth

Low growth rate means defense increases realized growth rates by protecting photosynthetic tissues

### Mobile vs Immobile Defenses

`trade-off between cost and leaf lifespan`

point at which leaf lifespan makes immobile defenses cost-effective
Summary

• Variety of positive and negative interactions between plants and animals
• Herbivory can have a diversity of impacts:
  – Depends on scale of question
  – Focus of life history stage?
  – Focus on population?
  – Focus on community?

Summary 2

• Plants show strong adaptations to herbivory
• Many general theories of plant defense, three focused on in text:
  – Biochemical coevolution
  – Plant apparency
  – Resource availability (allocational tradeoffs)