Signalling

36-149 The Tree of Life

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Plan

- Autumn Leaves and beyond
- More Adaptive Arguments

Why Do Autumn Leaves Change Color?

A few facts to note:

- Leaf senescence and abscission are already adaptations and they are linked to but distinct from coloration (e.g., some trees lose leaves while green).
- Large variation in coloration even among trees of the same species
- New pigments are produced during autumn, not just byproducts of chlorophyll degradation. This is costly.

Why Do Autumn Leaves Change Color? (cont'd)

- The Advertising Hypothesis: alert seed spreaders to improve spread of seeds.
- The Signaling Hypothesis: coloration serves as an honest signal of defensive committment against colonizing insect parasites.
- The Photoprotection Hypothesis: preventing free-radical formation, improve nutrient recovery from leaves during leaf senesence.
- The Defense Indicator Hypothesis: the chemical processes giving rise to toxins and (non-green) leaf pigments share several initial stages. So, the bright colors serve as a cue for insects to avoid those plants that are likely to produce substantial toxins.
- The Camouflage Hypothesis: differently colored plant parts make herbivorous insects more vunerable to predation because multiple backgroudns reslt in less-efficient camouflage.
- Nonadaptive byproduct of leaf senescence (chlorophyll degrades, bringing out leaf colors).

Stotting Gazelles, Peacock Feathers, . . .

Stotting Gazelles, Peacock Feathers, Noisy Nestlings, and Fancy Clothes.

We can view all of these behaviors as a way to convey a message from one sender to one or more receivers.

In each case above: Who is the signaler? Who is the receiver? What is the message?

What all of these examples also share is that the signal is *costly* to send.

In each case above: What is the cost?

When Honesty *Is* The Best Policy

The underlying problem:

1. Two individuals have access to different information.
2. If they could share this information honestly, both would gain.
3. But their interests conflict, giving each an incentive to deceive the other.

Under what conditions can they ensure honest communication?

A basic case when sharing information benefits both sides:

1. If signals are costly to produce/send, and
2. if dishonest signals are more costly than honest signals, and
3. if the added cost of dishonesty is large enough, then

communication will occur and be reliable.

Costly Signaling

What's the mechanism here?

How is the cost expressed?

What makes dishonest communication costly enough to avoid faking?

What determines the signal?

Signalling and Autumn Leaves

Hypothesis: coloration serves as an honest signal of defensive committment against colonizing insect parasites.

Brown and Hamilton found:

1. Bright autumn colors are costly to produce. This is especially true for bright red pigments (anthocyanins) which are produced anew (unlike yellows which are present during the summer) in the fall.
2. Aphids appear to avoid trees with bright red and yellow leaves when selecting overwintering colonies in the fall.
3. Tree species with bright coloration face a greater variety of specialist aphid parasites than do species without that coloration.

What are the predictions of these hypotheses? Are they consistent with observations?

Photoprotection and Autumn Leaves

The Photoprotection Hypothesis: autumn pigments prevent free-radical formation and improve nutrient recovery from leaves during leaf senesence.

Relevant facts:

- Aphids like yellow but seem to prefer whitish yellow that is consistent with unhealthy leaves.
- Some tropical trees change bright red just before shedding their leaves. Not so much temperature as timing?
- Sunscreen? Yet anthrocyanins do not absorb UV as well as some of their chemical precursors in the leaf do.
- Photoinhibition: bright light overloads chlorophyll system and slows down the process

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Photoprotection and Autumn Leaves (cont'd)

More relevant facts:

- Older leaves need more protection from photoinhibition, especially when it's cold.
- Aging leaves have an important job: recover nutrients (esp. nitrogen and phosphorus) and send it to overwintering parts of the plant. This takes a lot of energy, but is also vital to the trees survival during winter. Maintaining metabolic efficiency in those closing days is vital to recovering as many nutrients as possible.
- Another form of protection: Anthocyanins as potent antioxidants.

What are the predictions of these hypotheses? Are they consistent with observations?

If these pigments are so useful, why don't all leaves turn red?

Must we choose only one explanation?

Defense Indicator and Autumn Leaves (cont'd)

The Defense Indicator Hypothesis: the chemical processes giving rise to toxins and (non-green) leaf pigments share several initial stages. So, the bright colors serve as a cue for insects to avoid those plants that are likely to produce substantial toxins.

A few relevant points:

- Pigments (anthocyanins and caretenoids) and important toxins share a common biosynthesis pathway, production of pigments also provides improved defenses against herbivores.
- Gene expression data shows that leaf anthocyanin production increases in response to various stresses, such as temperature or tissue damage.
- Anthocyanins and caretenoids have multiple protective functions for the plants, as we've seen.
- Generation of pigments in response to multiple stresses primes the defensive system; it's able to respond more strongly and quickly.
- Field experiments: many species of trees do better *after* having received strong doses of UV-B radiation.