Evolutionary ecology
Interaction web

**Interactions include:**
- Consumer-prey
- Competition
- Mutualisms
- Physical environment
Kinds of interactions

A. With physical environment

B. Species interactions
   1) Direct
      i. One-way interactions
      ii. Reciprocal interactions—can lead to coevolution
   2) Indirect
Reciprocal interaction
Direct vs. indirect interactions
Evolutionary Ecology—mostly considers:

1. how interactions (among species and between species and their physical environment) shape species through selection and adaptation;

2. consequences of the resulting evolutionary processes on populations, communities and ecosystems.
Example 1
Endothermy in fishes

Influence of environment on species characteristics
The diagram illustrates the relationship between the rate of a physiological process and an environmental variable (Water Temperature), showing an optimum at mid-range values.
## Table 1. Mitochondrial volume of oxidative muscle cells.

<table>
<thead>
<tr>
<th>Cell type</th>
<th>Mitochondrial volume as % of cell volume</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pigeon pectoralis</td>
<td>29%</td>
<td>James and Meek, 1979</td>
</tr>
<tr>
<td>Trout red muscle</td>
<td>31%</td>
<td>Johnston and Moon, 1981</td>
</tr>
<tr>
<td>Antarctic fish red muscle</td>
<td>30%</td>
<td>Londraville and Sidell, 1990</td>
</tr>
<tr>
<td>Cicada tymbal muscle</td>
<td>33%</td>
<td>Josephson and Young, 1985</td>
</tr>
<tr>
<td>Finch cardiac muscle</td>
<td>34%</td>
<td>Bossen et al., 1978</td>
</tr>
<tr>
<td>Mackerel red muscle</td>
<td>36%</td>
<td>Bone, 1978</td>
</tr>
<tr>
<td>Insect flight muscle</td>
<td>44%</td>
<td>Elder, 1975</td>
</tr>
<tr>
<td>Anchovy red muscle</td>
<td>45%</td>
<td>Johnston and Moon, 1981</td>
</tr>
<tr>
<td>Billfish heater cells</td>
<td>63%</td>
<td>Block, 1991</td>
</tr>
</tbody>
</table>
Hot Tuna are Faster & More Powerful

T. albacares

Power (W) vs Frequency (Hz)

Temperature: 30°C, 25°C, 20°C, 15°C

Inset: Thermal Imaging of Tuna Muscles
Tunas Have High Oxidative Cell Metabolism
Scombroid fishes—tunas and billfishes

- **Gasterochisma melampus**
- **Scomber scomber**
- **Trichiurus lepturus**
- **Acanthocybium solanderi**
- **Scomberomorus cavalla**
- **Thunnus thynnus**
- **Thunnus albacares**
- **Scomberomorus maculatus**
- **Xiphius gladius**
- **Makaira nigricans**
- **Istiophorus platypterus**
- **Tetrapturus albidus**
- **Tetrapturus audax**
- **Makaira indica**
- **Tetrapturus angustirostris**
- **Scombrolabrax**
- **Ruvettus pretiosus**
Tropical predatory fishes

- Billfish, tunas, sharks
- Clear, warm water
- Premium on performance of brain, vision
- Evolution of endothermy
- Rapid growth; short life spans
Example 2

Color and speciation in African cichlids

Species interactions
**A**

\[ \frac{1}{y} = 0.15 + (-0.0002x), \quad r^2 = 0.76, \quad F = 35.42, \quad P = 0.0001 \]

**B**

1. \( \frac{1}{y} = 1.07 + (-0.002x), \quad r^2 = 0.82, \quad F = 51.44, \quad P = 0.000002 \)
2. \( \frac{1}{y} = 1.16 + (-0.002x), \quad r^2 = 0.85, \quad F = 61.92, \quad P = 0.000001 \)
3. \( \frac{1}{y} = 0.82 + (-0.001x), \quad r^2 = 0.48, \quad F = 10.08, \quad P = 0.009 \)
4. \( \frac{1}{y} = 1.31 + (-0.002x), \quad r^2 = 0.84, \quad F = 56.74, \quad P = 0.000001 \)
Loss of species

- Agriculture—nutrients and run-off
- Reduced water clarity
- Reduced color discrimination in cichlids
- Loss of bright colors, increased interbreeding, reduction in species
Coevolution

-/-  competitive
+/-  antagonistic
+/+  mutualistic
+/o  commensalistic
Examples 3 and 4—coevolution in antagonists

**Consumer** (Parasite)  

**Prey** (Host)  

- **Resistance**  
- **Defense**  

+  

-
Example 3—nest parasites, coevolution in hosts and parasites
Robin  
Pied wagtail  
Dunnock  
Reed warbler  
Meadow pipit  
Great reed warbler
Example 4—food chain length and plant/herbivore coevolution

- Even-number
  - Plants
  - Strong interaction
  - Herbivores

- Odd-numbered
  - Plants
  - Weak interaction
  - Herbivores
The players

Sea otters

Sea urchins

Macroalgae
In situ grazing

![Graph showing percent loss per 24 hours with bars for Experimental and Control conditions. The graph shows a comparison between Otters Abundant and Otters Absent scenarios.]
Approach: North Pacific/Australasian comparison

Kelp Forest of the World

Mann 1972
Plant/herbivore coevolution

Carnivores

Herbivores

Plants

Australasia

Northeast Pacific
Northeast Pacific Ocean
N = 27 Species

Australasia
N = 39 Species
<table>
<thead>
<tr>
<th>California Herbivores</th>
<th>New Zealand Herbivores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tegula funebralis</td>
</tr>
<tr>
<td><strong>Phlorotannins from % Dry Wt.</strong></td>
<td></td>
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<tr>
<td><strong>New Zealand Algae</strong></td>
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<tr>
<td><em>Ecklonia radiata</em></td>
<td>5</td>
</tr>
<tr>
<td>13.4</td>
<td>**</td>
</tr>
<tr>
<td><em>Carpophyllum maschalocarpum</em></td>
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<td>13.4</td>
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<tr>
<td><strong>North American Algae</strong></td>
<td></td>
</tr>
<tr>
<td><em>Agarum cribrosum</em></td>
<td>5</td>
</tr>
<tr>
<td>13.4</td>
<td>*</td>
</tr>
<tr>
<td><em>Dictyoneurum califomicum</em></td>
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</tr>
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<td>**</td>
</tr>
</tbody>
</table>

Steinberg, Estes & Winter, *PNAS*, 1995
Example 5

Indirect effects:

Sea otters on kelp (previous)

Led to

- Steller’s sea cow
- Body size in abalones
Steller’s sea cow

- A dugongid sirenia—radiated into North Pacific with onset of recent Glacial Age and polar cooling in the North Pacific.

- An obligate kelp feeder—dentition used for feeding on marine angiosperms lost entirely.

- Patterns driven by the radiation and proliferation of the kelps.
Sea otter → Limit grazing urchins → Poorly defended (high quality) kelp

Radiation of hydrodamaline Sirenians (Steller sea cows) In the North Pacific
Abalones--why interesting?

- Good fossil record
- Variation in maximum size among species
Fossil and extant abalones

▲ = Cretaceous
■ = Paleogene
● = Neogene
♦ = Pleistocene

Numerals represent extant species
Maximum size vs. habitat

The diagram compares the maximum shell length frequency distribution between tropical (n=27) and temperate (N=26) habitats.
Japan
NE Pacific
Australia
New Zealand
Indo-Pacific
East Africa
Mediterranean
South African

W Atlantic-Caribbean
W Africa
Japan
Tropical E Pacific
NE Pacific

Shell length (mm)
Sea otter → Limit grazing urchins → Poorly defended (high quality) kelp → Evolution of large body size in abalones
Spatio-temporal patterns in co-evolution
A Greya Moth about to Lay Eggs In, and Pollinate, a Woodland Star (Lithophragma) Flower

Source: John N Thompson
Flower-moth interactions

**Moth:**
- Deposits eggs in floral ovary
- Pollinate flower but moth larvae feed on developing seeds

**Plant:**
- Benefits from pollination (mutualism) but incurs cost from seed loss (antagonism)

By comparing plant reproductive success between floral capsules with and without moth eggs, it is possible to determine if the interaction is **commensal**, **antagonistic**, or **mutualistic**
Assessing Whether Woodland Star Plants Depend on *Greya* moths

Source: John N Thompson
Thompson and Cunningham 2002 Nature
Thompson and Fernandez 2006 Ecology
Geographic Mosaic of Coevolution: Coevolution as an Ongoing Ecological Process

- Geographic selection mosaics (GxE)
- Coevolutionary hotspots and coldspots
- Trait remixing

Source: John N Thompson
THE EVOLUTION EXPLOSION

HOW HUMANS CAUSE RAPID EVOLUTIONARY CHANGE

STEPHEN R. PALUMBI
Trophy Hunting
Fisheries

Often target the larger fish in a population
Silversides

David Conover, SUNY Stony Brook
Smaller individuals selectively removed

Larger individuals selectively removed

Growth rate (mm/d)

Generation
Cod in the Gulf of Maine

Monhegan 1880s
Cod Size Over Past 4500 years

Atlantic cod body length (cm)

Years Before Present
New synthesis of evolutionary ecology
Fig. 1 (A) Dynamics for evolutionary and ecological traits in G. fortis.
Fig. 2 (A) Population numbers for the five ungulate species in Ezard et al.’s (18) study.
Fig. 4 Experimental approach used in ongoing study of eco-evolutionary dynamics in Caribbean lizards.

A. Small lizard perches on ground, rocks, and low in vegetation, diminishing arthropods there.

B. Population size of small lizard reduced, and survivors escape into higher, thinner vegetation.

C. Small lizard adapts by evolving shorter limbs for higher, thinner vegetation, diminishing arthropods there and increasing its population size.