Lecture summary:
- Definitions.
- Examples.
  - Symbiotic and non-symbiotic.
  - Crops.
  - Fruit dispersal.
  - Gut mutualists.
  - Mycorrhizae.

2. Processes: Mutualism
- Mutualism is an interaction in which both partners benefit.
- Symbiosis just means "living together" in close association (excluding parasitism).
- Mutualism is a special kind of symbiosis, but mutualists don’t have to be symbionts to benefit each other:
  - So mutualisms can be either symbiotic or non-symbiotic.

3. Processes: Mutualism
- Most of the world’s biomass is made of mutualists:
  - most plants, coral reefs, pollinators.
  - "- individuals in a population of each mutualist species grow, survive and reproduce at higher rates when in presence of individuals of the other species”
- Note: it is not a “cosy” relationship - each species acts completely selfishly.
4. Processes: Mutualism

• (1) Nonsymbiotic mutualisms:
  – Cleaner fish.
  – Ants tending aphids.
  – Pollinator-flower interactions.
• (2) Symbiotic mutualisms:
  – Fungus-alga associations in lichens (Fig. 13.21).
  – Fungus-plant associations in mycorrhizae.
  – Animal-alga associations such as the flatworm *Convoluta roscoffensis*.

5. Examples of nonsymbiotic mutualisms:

• Bull’s horn acacia and *Pseudomyrmex* ants *(Figs. 13.2 & 13.3)*
• Shrimps and gobid fish *(Fig. 13.3)*
• Clown fish & anemones *(Amphiprion percula)*
• Cleaner fish & customers.
• Honey guide and ratel.
• Defense mutualisms like Müllerian mimicry in heliconid butterflies *(Jim Mallet web page)*
• Group defense.

6. Agricultural/domestic mutualists:

  – Are domestic crops and domestic animals examples of mutualisms with man?
  – Is your dog or cat a mutualist?
  – If there are many more of a species than there would have been without the association it must be a mutualism!
  – “Farming” also occurs in termites and ants where they “tend” aphids or butterfly larvae or fungus gardens *(Fig. 13.8) (leafcutter ants)*.
7. Fruit dispersal and pollination:

- Fruit dispersal is mostly a generalist phenomenon (Fig. 13.7)
- Pollination
  - Charles Darwin was fascinated by pollination:
    - He described the specialized floral structure of the Madagascar star orchid in 1859 with nectar tubes approx. 30 cm long.
    - He suggested that a pollinator must exist with an appropriately long proboscis and 40 years later a hawkmoth with a 25cm proboscis was found
  - Floral diversity & pollinators (Fig. 8.5, Howe & Westley, 1988)
  - Fig wasp mutualism (Fig. 7.7, Howe & Westley, 1988)

8. Symbiotic mutualisms:

- Degrees of symbiotic association (Fig. 13.10)
  - Such a range of association dependence implies that closer associations might benefit the interactants.
  - Greater stability for the symbiont or the opportunity to control environmental conditions through the association.

9. Gut mutualists:

- Gut inhabitants in plant-feeding vertebrates and invertebrates:
  - Problem is coping with cellulose - a very hard to digest polysaccharide.
  - Many animals have solved the problem by hosting bacterial microcosms in their guts.
  - Ruminants (deer, cattle & antelope) have a 4-chambered stomach
    - Rumen harbors a complete ecological community of protozoa and bacteria that compete, predare and cooperate through mutualisms, all based on the complex plant molecules that the host ruminant cannot digest (Fig. 13.11).
  - Termites are "insect deer" with their own microflora that digest cellulose (Figs 13.11 & 13.14 of termite gut flora).
  - Aphids also have tightly associated symbiotic mutualists (Fig. 13.12)
10. Mycorrhizae:

- Sheathing ectomycorrhizae & vesicular arbuscular (VA) endomycorrhizae are found in the majority of plant species (Figs 13.15 & 13.17) and they clearly benefit plants (Fig. 13.18) by providing P, N & Ca.
  - Ectomycorrhizae occur as a sheath most often on the roots of trees and can be cultured in isolation from their hosts and require soluble carbohydrates as their carbon resource from the host (not cellulose like free-living fungi).
  - VA endomycorrhizae are extremely widespread and penetrate host cells which makes them very difficult to culture.

11. Nitrogen fixation:

- Bacteria associated with the roots of some plants can fix atmospheric nitrogen and make it available to the plant (Fig. 13.19)

- This benefits the plant and influences the outcome of other ecological processes (Fig. 13.21)

12. Postscript on mutualisms:

- The ultimate symbiotic mutualism may be evolution of the eukaryotic cell.
- “Tit-for-tat”: Axelrod & Hamilton have demonstrated theoretically the increased stability generated from cooperation.
- Sex may have evolved through parasitism that led to cooperation and mutualism because of mutual benefit.
Figure 13.21
(3rd ed.):
Lichens:
(a) even distribution of algal cells through fungal hyphae,
(b) algae confined to central fungal cells,
(c) specialized cephalodium with cyanobacteria

Figure 13.2:
Bull’s horn acacia:
Protein-rich Beltian bodies on leaflets (top).
Hollow thorns used by ants (bottom).

Figure 13.3: Ant protection of leaves against herbivores
Figure 13.3 (3rd ed.) : Blind, burrowing shrimp with goby mutualist.

Amphiprion percula with anemone

Müllerian mimics among Heliconius butterflies in South America
Leaf cutter ants and their fungus garden

Figure 13.5 (3rd ed.): frequency of fungus garden licking by attine ants.

Figure 13.7 (3rd ed.): Bird & mammal fruit feeding in Malaysia
Figure 8.5: Divergence in phlox family (Polemoniaceae) according to pollinator guild (Howe & Westley, 1988).

Figure 7.7: (Howe & Westley, 1988)
Fig (Ficus) syconium with wingless male and winged female fig wasps (Blastophaga).

Figure 13.10 (3rd ed.):
Variation in the nature of symbiotic associations
Figure 13.11 (3rd ed.) : Microbial digestion in sheep rumen (see Fig. 13.10 4th ed.)

Animal food

- 100 g of NH₃
- Methane and 
  

Figure 13.11: Termite gut with endospore-forming bacteria (E), spirochaetes (S) & protozoa.

Figure 13.14 (3rd ed.): Symbiotic spirochaete & protozoa from termite intestine.
Figure 13.12: Congruent phylogenies of aphids and their endosymbionts

Figure 13.15: Sheathing mycorrhiza on pine root

Figure 13.17 (3rd ed.):
Vesicular arbuscular mycorrhiza
Figure 13.18: Influence of mycorrhiza on phosphate content of leek shoots.

Figure 13.19: Rhizobium root nodule development

Figure 13.21: Effects of Rhizobium and nitrogen on competition between soybeans (G) and a grass (P).