# Ecology – Symbiotic Relationships

Overview of the Co-evolution and Relationships Exhibited Among Community Members

What does Symbiosis mean?

# How do **we** define *Symbiosis*?

- Symbiosis in the broadest sense is any relationship or association between two or more species (an interdependence – to some degree)
- This definition includes ***all*** types of relationships and recognize here that we are entering the realm of **community ecology** – organisms that are living close enough to influence one another

# Look at the possibilities in a matrix

| Species 1<br>Species 2 | + | 0 | - |
|---|---|---|---|
| + | Mutualism | Commensalism | Predator/Prey<br>or<br>Parasite/Host |
| 0 | Commensalism | No Effect? | Amensalism |
| - | Predator/Prey<br>or<br>Parasite/Host | Amensalism | Competition |

# This list expands on the commonly recognized relationships

- Some of these are very familiar and some are not, but we will consider them all, and when possible provide models associated with these relationships
- In this process – i.e. the interaction, the nature of the relationship dictates the level of selective pressure experienced by the symbionts
- In situations with ***strong negatives***, the intensity of the selective pressures are generally more severe for one of the participants, and often this is a case of life and death for the individual on the losing end

# But, in all of the studies of symbiosis

- We are looking at the relationships among the species in that relationship and ***change*** in response to selective features in the environment (abiotic ***and*** biotic – recall the garter snake and rough-skinned newt)
- In these relationships, we are not only evaluating change in **a** species, we are considering change in **two or more species** based upon the nature of the interaction

# When there are multiple species…

- Consider the possibilities.  What would we expect to happen?
- What happens with one species that changes or adapts over time?  (Note, this can be with regard to *any* symbiotic relationship.)  What would we expect to happen in the other species?
- This is **Co-evolution**.  Can we formally define this phenomenon?

# Co-evolution

- By the book… ***"the evolution of traits in two or more species selected by the mutual interactions controlled by those traits"***
- This involves the reciprocal interaction among the species involved, leading to the selective pressure in each of the species

# Remember the Rough-skin Newt and the Garter Snake?

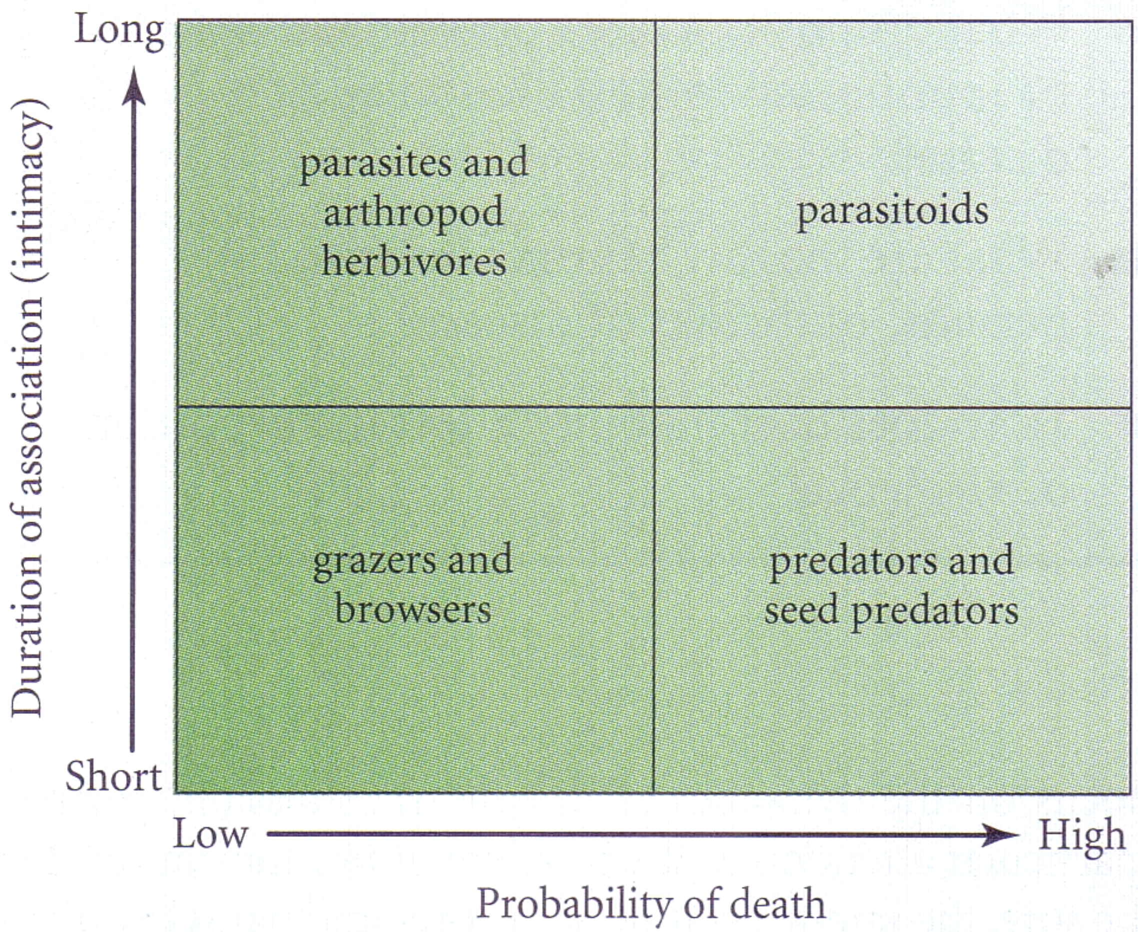

# Think about this in terms of Competition Among Species

- Here we are looking at a negative (-/-) situation for both (all) of the participants
- In any competitive relationship, there is either extinction of one of the competitors or coexistence
- In these analyses, the superior competitor will typically **win the game** (with some room for stochastic events – and remember our metapopulation model) but it is not that simple!

# What about coexistence?

- In this case, there are a variety of potential outcomes.  This includes resource partitioning and character displacement or niche shift if one species is doing the changing
- The nature of the selective force is ***resource acquisition*** – be it food, water, nesting sites, shelter, etc.

# Now, think about this for +/-



# Interspecific Relationships

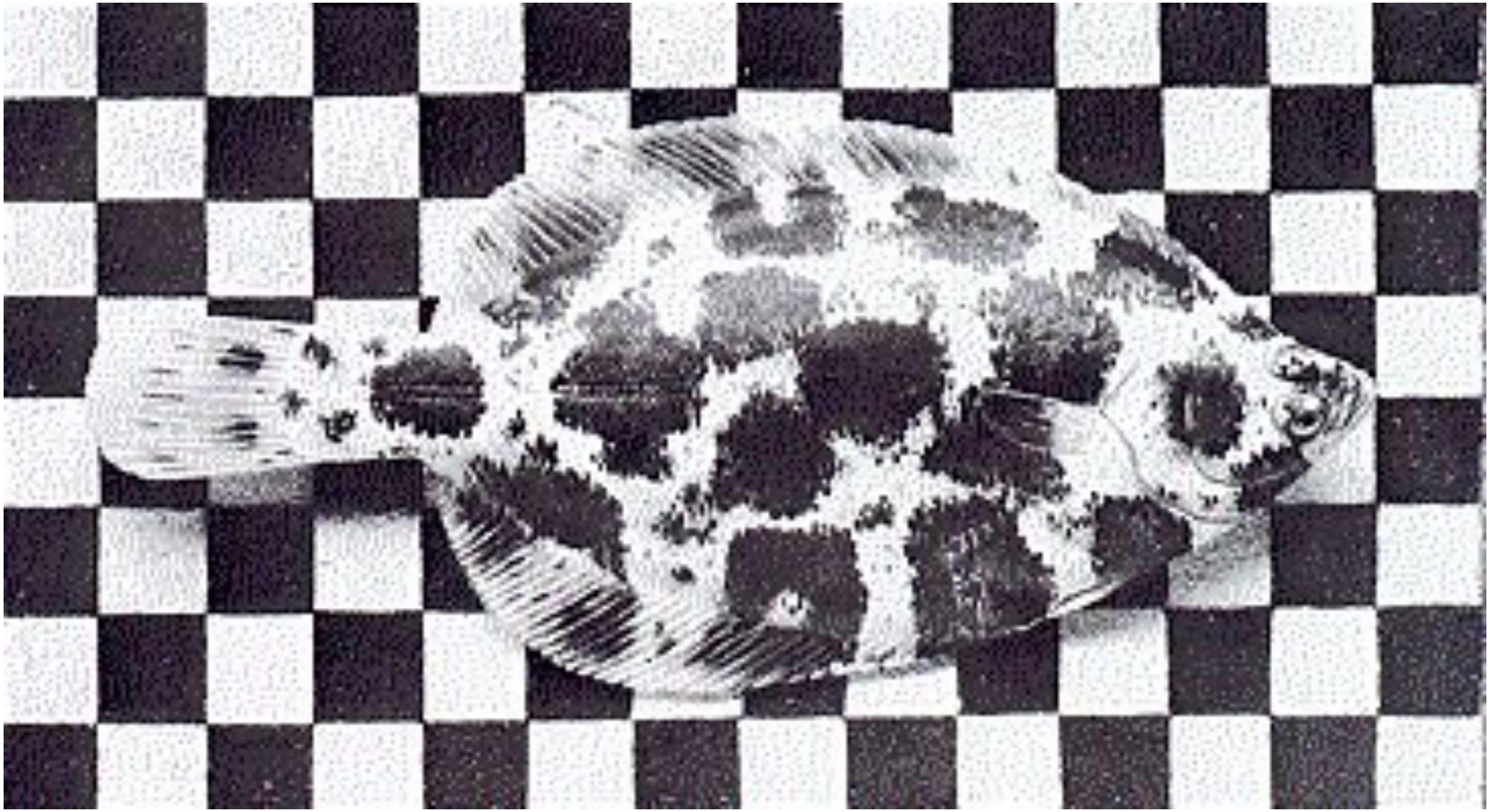
- Interactions among species, or at least populations of species provides selective pressures for the survival of these entities
- That is, we are looking at major selective forces, and in the case of **+/-** relationships, the abilities of the participants define survival of the individuals in each of the respective populations

# Look at this from the potentially negatively impacted individuals

- What are the reactions of the “prey” in response to losses to predators?
- We can address adaptations on basically **three levels; morphologically, physiologically and behaviorally** (just like we observed with regard to physiological regulation)
- The negatively impacted individuals typically pay the ultimate price, or at the very least a decrease in fitness associated with this interaction (and the pressures here may be intense)

# Predator Avoidance Mechanisms

- Certainly, defense mechanisms include behavioral, morphological and physiological mechanisms
- Behavioral Mechanisms – examples?
- Physiological – examples?
- Morphological – examples?  What is the role of mimicry?
- What about responses by the predators?




Benjamin
Cummings

# Do the same thing for the species on the "+" side of the equation

- Look at the potential physiological, behavioral and morphological adaptive programs
- Revisit the concept of co-evolution. What was our working definition?
- It makes absolute sense from the perspective of natural selection and survival of those that can, and death for those that cannot

# We are observing co-evolution

- Antagonistic relationships can clearly demonstrate co-evolutionary trends (e.g. the "arms races")
- But, the same is true for complimentary relationships where there are benefits to all or one of the participants involved
- The reasons are still selfish – the more benefit an individual gains from an interaction, the better it is for the individual

# So far…

- We have considered the “+/-” and the “-/-” types of relationships.  The negative aspects associated with these interactions have been identified as important components in the structuring of communities
- Remember the various types of interactions that can be identified in our matrix

# Look at the possibilities in a matrix

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# Co-evolution in action

- We need to look at these from the perspective of the selection pressures faced by both of the species – ***each*** is attempting to maximize their survival and reproductive output
- Consider this from the standpoint of the negatively influenced species.  Adaptations that will maximize your survival will be of a selective advantage in the population and spread throughout the population of that species by natural selection

# However, on the positive side…

- There are really two considerations for this issue
- On one hand, the more resources an individual is able to obtain, the greater the potential reproductive output
- But, if you are “too” good at what you do, what happens to the prey or host species?
- Just like a good parasite should not kill its host, a predator that is too good will eat itself to extinction if the prey species is unable to respond to these challenges

# But the positives gained may be a function of the benefits provided

- Mutualistic relationships reflect specializations based upon the interdependence between the interacting species
- That is, the reciprocity observed in many of these interactions is based upon very specific relationships and responses
- This is not the case in predator/prey and competitive relationships, although, there is some speculation that even the +/+ relationships evolved from some +/- system

# This specificity may also yield…

- Different species interacting in different geographic regions
- Beyond the metapopulation patches, when a widely distributed species maintains close relationships with other specific species, the species that is interacting may change from one location to the next
- These symbiotic homologs are important for the survival of one or both species

# Break Time

# Let us look at the "+/+" interactions

- In these relationships, both or all of the interacting species are gaining some level of benefit from the interaction
- This is commonly known as mutualism
- We can identify three basic types
  - Trophic
  - Defensive
  - Dispersive

# The Trophic type involves food

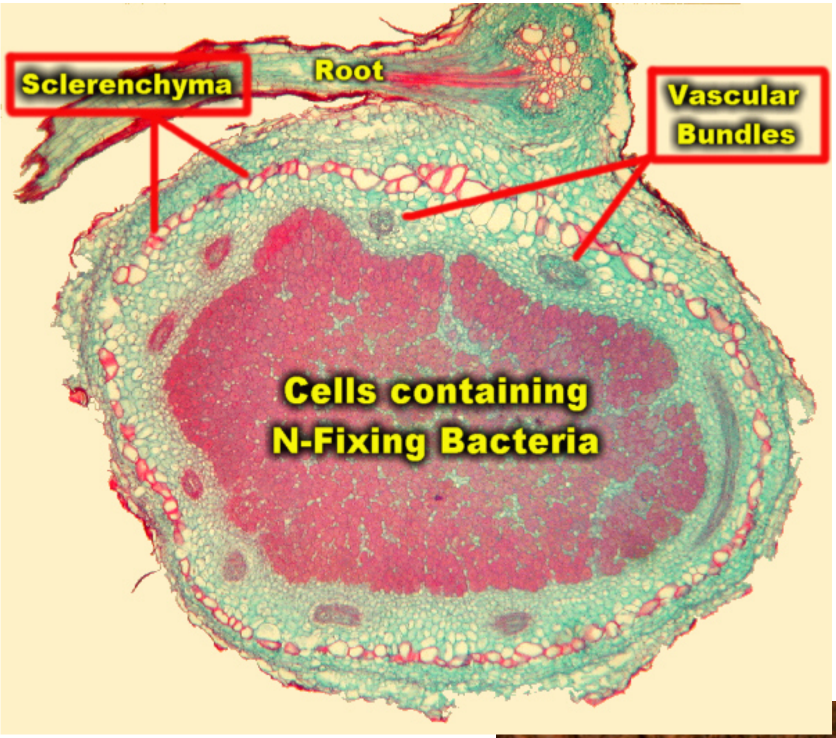
- Definition of this form of mutualism is based upon the mutual provision of nutrients for each other
- That is, both species gain in a trophic sense from this interaction
- This often entails more than just a facultative relationship – it means the ability to survive

# Lichens are a good example

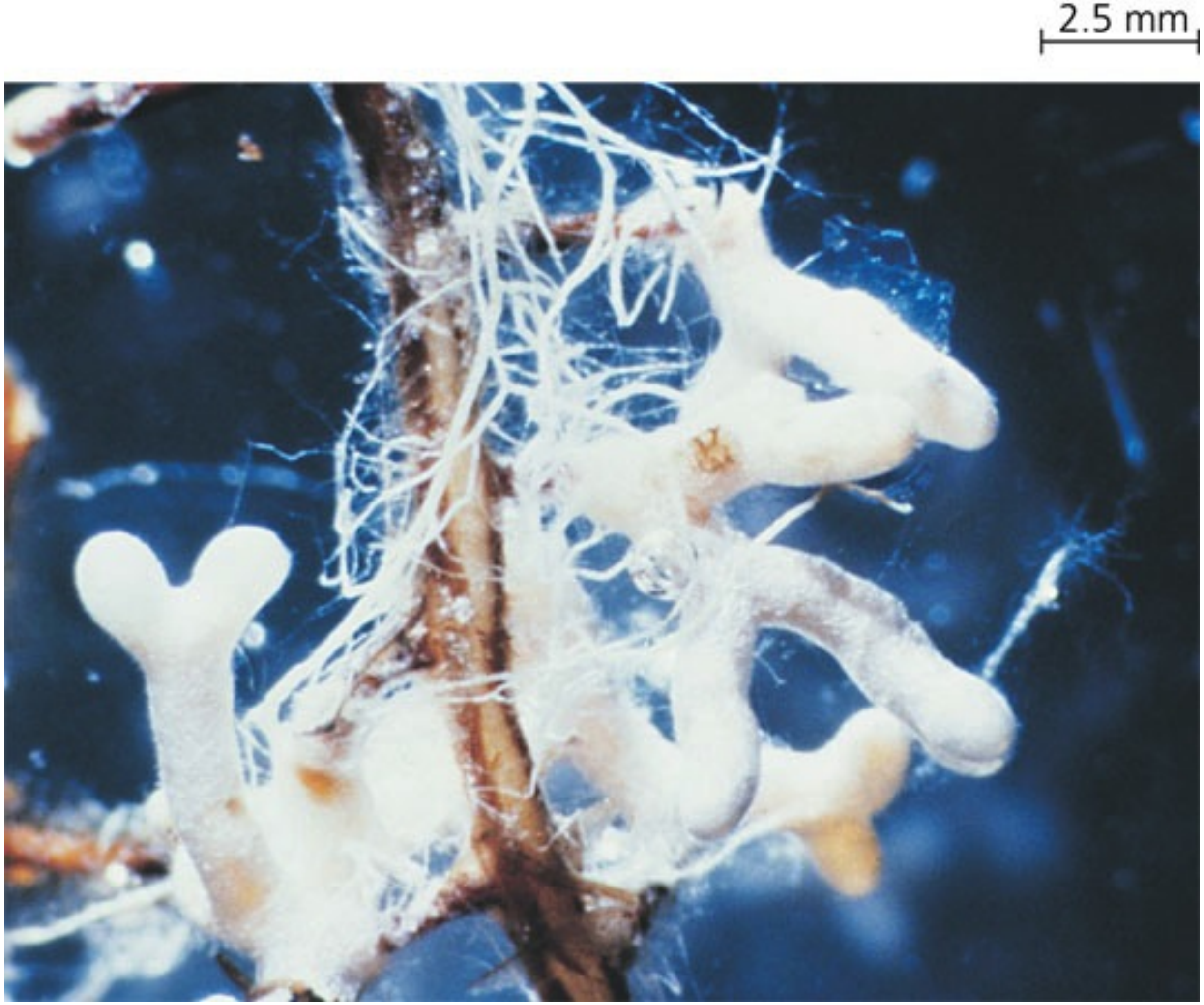
# Nitrogen fixing bacteria

**26.13 Roots of a legume (pea) with nod-ules**

# Nitrogen fixing bacteria


# The effect of Mycorrhizae



# Defensive mutualism

- This form of mutualism generally involves a situation where one member receives food for defending the other from either herbivores, predators or parasites
- The relationships here can be quite complex and the actual benefits gained clearly evolved as a selfish feeding strategy
- But here, we also have the possibility for aggressive mimicry and "cheating" with regard to the mimics


Image © E. Schloegl

# The Ant/Acacia Relationship

# The third type - dispersive

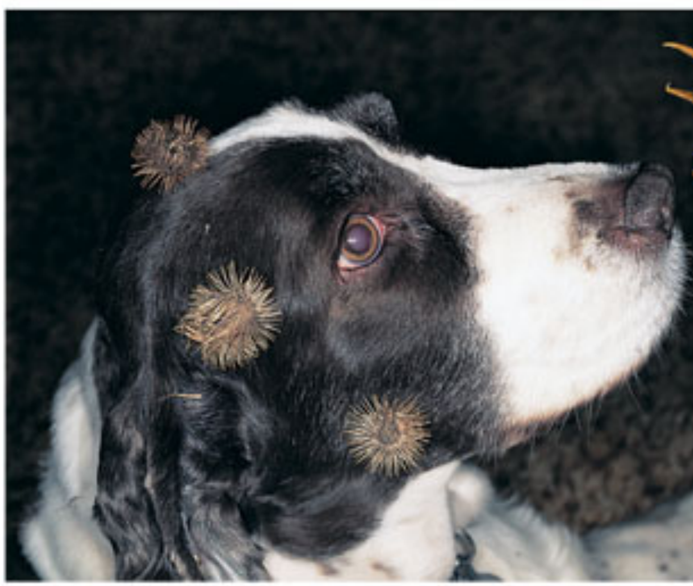
- Here, we are talking about the situation where again, one is gaining a trophic benefit, but the other is benefiting in terms of movement of some part of that organism
- We can look at this from the perspective of pollination or seed dispersal of an organism from one area to another

# Dispersal of Seeds

- The fruits act as the major source of nutrients for many species, but the reproductive success of an individual plant often depends on moving those seeds to an area of **reduced competition**
- This is not only true at the level of inter and intraspecific competition, but perhaps more importantly from related individuals (parent/ offspring considerations)
- If the individual is successful and gets the seeds dispersed to open habitat, the young will experience reduced competition and the disperser had lunch

**(a)** Wings enable maple fruits to be easily carried by the wind.

**(b)** Seeds within berries and other edible fruits are often dispersed in animal feces.



**(c)** The barbs of cockleburs facilitate seed dispersal by allowing the fruits to "hitchhike" on animals.

# Pollinator/Flowers

- This dispersive relationship often involves a great deal of specialization among the participants
- The rationale for this specialization is quite simple – the plant depends on the vector to distribute the pollen to a conspecific
- A generalist may visit many different species of flowers, wasting much of the pollen, but the specialization results in a tightly coupled mutualistic relationship that is highly dependent and beneficial to all involved

**(a) A flower pollinated by honeybees.** This honeybee is harvesting pollen and nectar (a sugary solution secreted by flower glands) from a Scottish broom flower. The flower has a tripping mechanism that arches the stamens over the bee and dusts it with pollen, some of which will rub off onto the stigma of the next flower the bee visits.

**(b) A flower pollinated by hummingbirds.** The long, thin beak and tongue of this rufous hummingbird enable the animal to probe flowers that secrete nectar deep within floral tubes. Before the hummer leaves, anthers will dust its beak and head feathers with pollen. Many flowers that are pollinated by birds are red or pink, colors to which bird eyes are especially sensitive.

**(c) A flower pollinated by nocturnal animals.** Some angiosperms, such as this cactus, depend mainly on nocturnal pollinators, including bats. Common adaptations of such plants include large, light-colored, highly fragrant flowers that nighttime pollinators can locate.

# Check out this video on Youtube:

http://www.youtube.com/watch?v=Hv4n85-SqxQ (there are 6 parts to the movie)

# Whenever there is a “+”…

- There is the potential for cheating
- That is, the benefit gained from this interaction may come at a cost (the reciprocal “+”)
- So, if you can get the benefit for free or at no cost, the system is open to cheating
- That is exactly what we see in many of these relationships
- How does selection operate on this level?

# We have yet to consider two forms

- These are Commensalism and Amensalism
- Look at these again in terms of the selective forces acting on the participant(s)
- Remember what is happening with commensalism, one species is gaining a benefit and the other or others are not influenced, at least not significantly

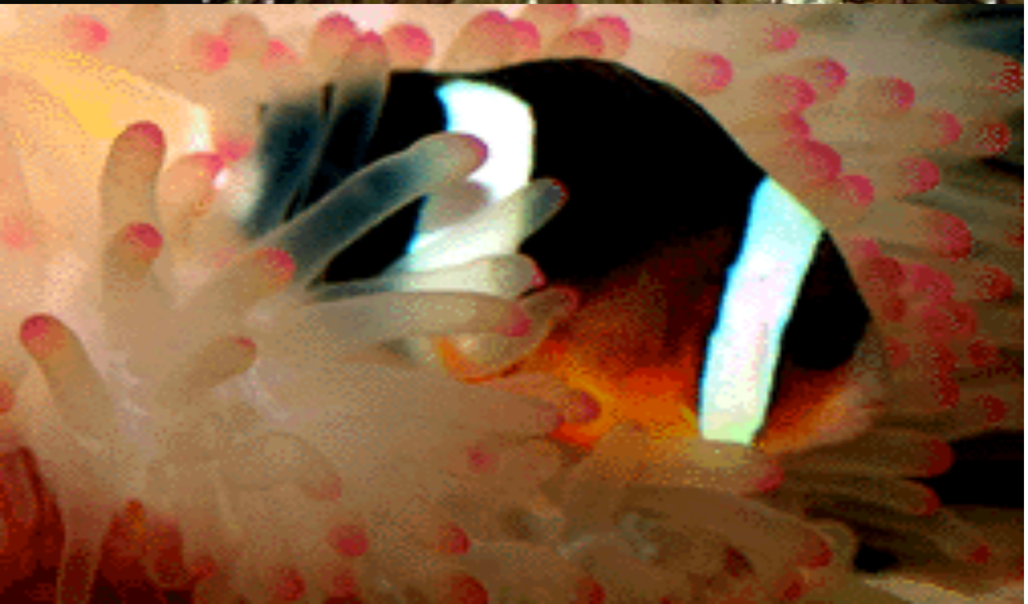
# Are there good examples?

- Well yes, actually many if you consider all of the potential benefits an organism might gather from a particular relationship
- Often this is a matter of scale, such that the activities of one species is really insignificant to the overall fitness of the other member in that relationship
- Look at a few examples

# Barnacles on a whale

# Just hitchin’ a ride, but what else?






# Now, what about Amensalism?

- These are situations where the relationship is a “0/-”
- The basis for this interaction is the presence or the normal activity patterns of a particular species may negatively impact other species
- Potential examples of amensalism?
- Note that this is sometimes a “size” thing too

# For example?

- Perhaps the crushing of plants under the feet of larger forms – clearly this negatively impacts the plants or other organisms that are being crushed without influencing the other species
- Perhaps shadowing by larger species of plants preventing sufficient light penetration for photosynthetic activities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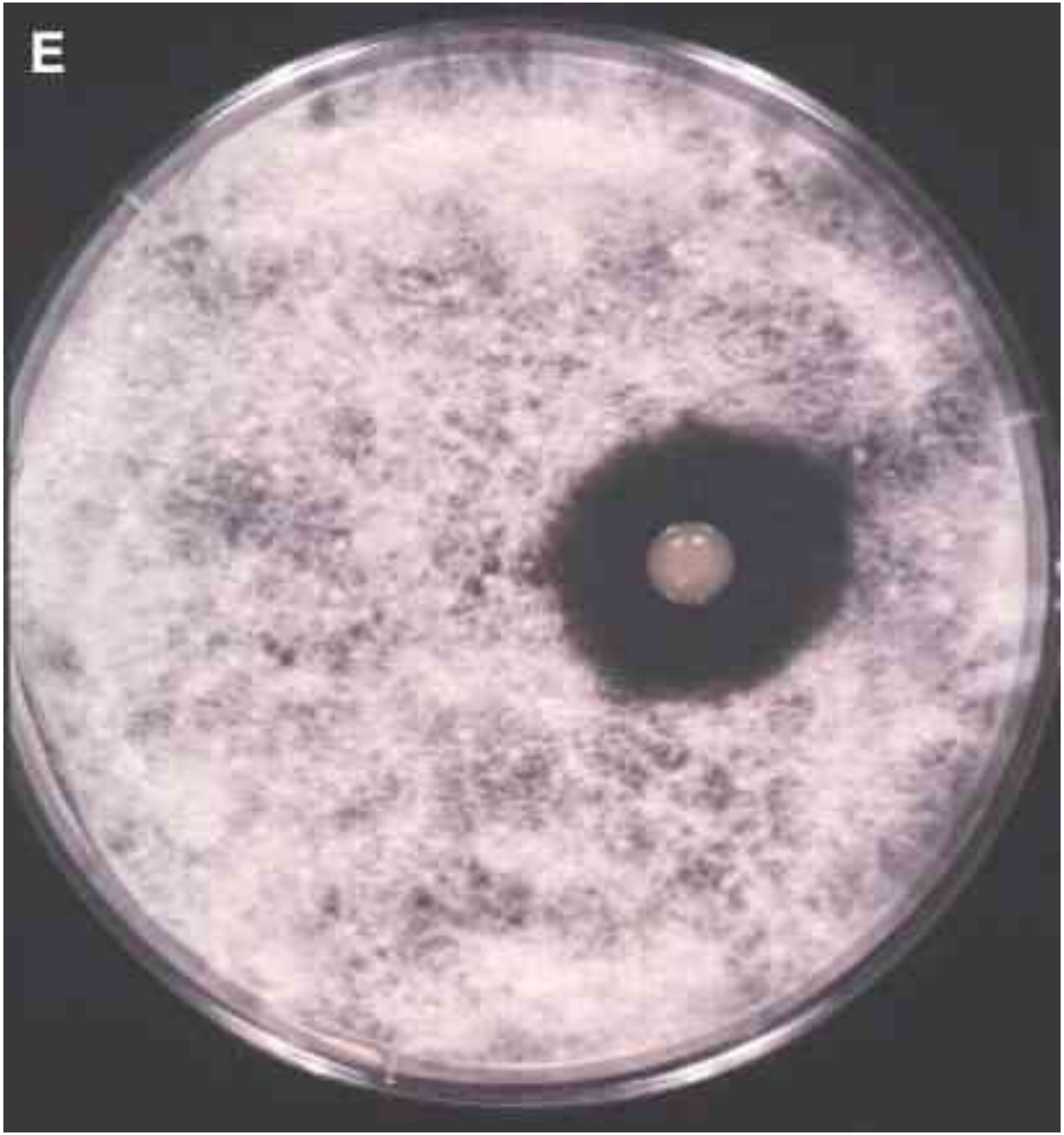
# Other possible examples

- Allelopathy is sometimes cited as an example of amensalism
- Plants are well known for the inclusion of chemical compounds in their tissues and often times this is in response to herbivores
- But these same chemicals can influence the growth of other species – this negatively impacts this other species

# Note the lack of vegetation

# Anti-bacterial or fungal compounds

- Some species are also capable of producing antibiotics
- These chemicals are naturally produced compounds that have the effect of inhibiting the growth of other organisms – a side benefit if you will
- These features are almost preadaptations that can eliminate potential competitors or parasites in the community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# Details of Relationships

- We will spend some time on the relationships that have received the most attention in a modeling sense
- These are competition and predator/prey relationships and the mathematical models provide insight into the functioning of the systems **and** the methods associated with ecological modeling studies