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# K-12 Partnership Lesson Plan

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# *Why Do Species Cooperate?*

# *A card-based simulation of the ant-acacia mutualism*

## Overview

## All species interact with other species in their community. Some types of interactions are antagonistic, where one species benefits at the expense of another- such as predators and prey, or parasites and their hosts. However, interactions between species may also be mutualistic, where both species benefit from interactions with one another. Examples of mutualisms abound in nature, such as pollination, cleaner fish, and gut bacteria.

## Interacting species are constantly co-evolving. Predators may become faster to overcome their prey, while the prey get better at dodging attacks. Likewise, in cooperative interactions, each species is under selection to obtain the most benefit from the interaction at the lowest cost. Since cheating may have immediate benefits to an organism, it is difficult to understand how mutualisms evolve and remain stable through time.

## This lesson explores the circumstances that favor the evolution of cooperation, and why two species might cooperate. By using a card game simulation, students will see how cooperation is maintained, or lost, between ants and acacia trees depending on the environment they are living in.

**Objectives**

At the conclusion of the lesson, students will be able to:

* Give examples of cooperatively co-evolved species
* Describe why species might cooperate in the wild
* Perform a simple simulation of species interaction
* Graph the outcome of a simulation

**Length of Lesson**

1 hour

**Grade Levels**

Advanced middle school or high school

**Standards covered (NGSS)**

Disciplinary Core Ideas:

* **HS-LS2-2**: use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales
* **HS-LS2-6:** evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may results in a new ecosystem
* **HS-LS2-8**: evaluate the evidence for the role of group behavior on individual and species’ chances to survive and reproduce
* (covered by extension) **HS-LS4-6**: create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity

Cross Cutting Concepts:

* Cause and effect
* Systems and system models
* Stability and change of systems

Science and Engineering Practices

* Developing and using models
* Analyzing and interpreting data
* Engaging in argument from evidence

**Materials**

* Introduction powerpoint (available at <http://kbsgk12project.kbs.msu.edu/lessons/>)
* One worksheet per student (available at <http://kbsgk12project.kbs.msu.edu/lessons/>)
* 25 each of Acacia cooperate, Acacia exploit, Ant cooperate and Ant exploit cards per pair of students. Card templates available at (available at <http://kbsgk12project.kbs.msu.edu/lessons/>) Or you can use any other types of cards with 4 distinct colors/patterns
* One rule card per student (half Acacia, half Ant) (available at <http://kbsgk12project.kbs.msu.edu/lessons/>)

**Background**

Different types of interactions occur among species in a community. Some species compete for the same resources and therefore have reduced fitness in the presence of one another. Other species may predate on, or parasitize, others and therefore benefit at the expense of those species. In commensal interactions, species benefit without affecting another. Finally, in mutualisms, each species benefits from interacting with one another.

Mutualisms are less well-studied than other types of interactions, but are no less important! In fact, they are relevant to all biological life. Mutualisms may underlie the evolution of multicelluarity. Endosymbiotic theory says that vital organelles in animal and plant cells, such as mitochondria and chloroplasts originated from symbiotic unicellular organisms. Support for this theory comes from structural and DNA similarities between chloroplasts and cyanobacteria as well as mitochondria and proteobacteria.

Furthermore, understanding mutualisms will likely help us in practical areas. For example, evidence is just beginning to emerge about the importance of gut bacteria on human health. Gut bacteria seem to play an important role in our immune system function, the acquisition of vitamins from food, and the ability to properly digest substances like lactose. It is likely that gut bacteria may affect other systems in our body, and is an exciting new frontier in medical research!

In addition, plants have important mutualisms with fungi and bacteria that live on their leaves and roots. These organisms help them acquire nitrogen from soil, improve pathogen resistance, and play a role in stress tolerance. The ability to harness such organisms could improve agricultural methods.

From an evolutionary standpoint, it is difficult to understand how mutualisms can evolve and remain stable. This is because we would expect cheaters to be favored, as they would obtain a benefit without providing anything in return. The present game uses the ant-acacia mutualism to help students intuit how and when mutualisms will evolve.

Acacia trees are prevalent across the African savannah. These acacias are often associated with ants, and the ants provide protection against herbivores (including elephants!) while the acacias provide shelter and food in the form of nectar. These ants can viciously attack herbivores that attempt to harm their home tree, often sacrificing their lives, while the acacias devote valuable resources towards making nectar and domatia (structures that house the ants). There is evidence that this mutualism may break down in the absence of elephants, since the acacias no longer need the protection from ants. The following simulation explores this idea.

### Activities of the session

1. Introduction to cooperative evolution – see powerpoint
2. Introduction to the Ant and Acacia system – see powerpoint or resources for further info
3. Ant and Acacia simulation game
	1. Group students into pairs and explain that one person is the Acacia and one is the Ant. Each student has their own worksheet and each pair receives 25 Exploit and 25 Cooperate cards as well as rule cards. In the first round, students will perform the simulation WITH elephants (the Acacia must use the proper rule card).
	2. Students begin by starting with equal numbers of exploit and cooperate cards and shuffling. With their pile face down, they each turn over the top card (as in war). Follow the instructions on the rule cards to determine whether their card is discarded or remains in the “gene pool” and reproduces.
	3. When students use up all their cards, they count up the number of exploit and cooperate cards they have left and enter this number into the table on the worksheet.
	4. Students repeat this for 10 rounds. They then graph their results.
	5. Students then perform the simulation in an environment WITHOUT elephants. The rules for the Acacia will change somewhat. Discuss why the outcome for the Acacia is now different.
	6. Students repeat this process and graph their results.
4. Finish worksheet
5. Discussion and Questions

**Resources**

 News Resources

* <http://www.scientificamerican.com/article/of-ants-elephants-and-acacias/>

Primary articles

* Palmer TM et al. 2008. Breakdown of an ant-plant mutualism follows the loss of large herbivores from an African savanna. *Science* 319:192-195.
* Stanton ML & Palmer TM. 2011. The high cost of mutualism: effects of four species of East African ant symbionts on their myrmecophyte host tree. *Ecology* 92:1073-1082.

**Extensions and Modifications**

Using the populations of Acacia and Ants that each pair ends with, have the students predict what will happen in these populations given different scenarios. For instance:

* If elephants return to the area
* If ants can migrate between groups (pairs of players)
* If other herbivores replace the elephants

Remind students to consider what variation is left in their populations. If ALL of the Ants or Acacia in their group are of one type, then no amount of interaction will cause the other type to occur. It must be reintroduced through migration.

You can also have your students come up with their own scenarios, and design rule cards for similar simulations to test their predictions.

**Assessment**

Give students examples of new species pairs that cooperate and some details about their ecosystem. For each pair, have students explain what circumstances are favoring cooperation: what each organism is getting/providing and an example of something that could disturb that system and cause a loss of cooperation. Suggestions (with answers):

1. Clownfish and Sea Anemone: Clownfish have a protective slime coat that keeps them from being stung by the anemone, so they can eat all of the small invertebrates that try to harm the anemone. The clownfish rarely leaves this shelter, and even defecates there.
	1. The clownfish protects the anemone from harmful invertebrates that the anemone can’t sting, and also gives the anemone nutrients by defecating. The anemone stings any other fish that might try to steal the clownfishs’ home, and wards off predators. If there were no clownfish predators, the clownfish wouldn’t need protection from the anemone.
2. Algae and Fungus: Lichens are fungi that have cyanobacteria living in and on them. They typically live on rocks and trees rather than decaying things like most fungi. Cyanobacteria are a kind of algae; they can do photosynthesis, but will easily dry out or get eaten. Fungi cannot do photosynthesis, but are very good at gathering moisture and nutrients from the environment.
	1. The algae does photosynthesis and provides both itself and the fungus with energy, it gets protection from the fungus. In return for energy, the fungus also gathers enough water and nutrients for both organisms. If the fungus grew on something that was decaying, it could get it’s own energy and wouldn’t need the algae.
3. Pompeii worms and bacteria: Hydrothermal vents are breaks in the ocean floor that would be like geysers or hot springs if they were on land; they spray very, very hot water, very very quickly. This water has lots of nutrients dissolved in it that were trapped under the surface. Pompeii worms attach themselves to hydrothermal vents deep in the ocean, where the water around the vent is 176 °F, much hotter than any other multi-cellular animal can survive in. Each worm is covered with a thick coating of thermophile bacteria, which are bacteria that are happy to live in temperatures up to 252 °F.
	1. The worms can only live near the vents because the thermophile bacteria protect them from the intense heat. In return, the bacteria have an anchor point near the vent so they can get nutrients, otherwise the pressure of the vents would blow them away. If the vent temperature went down, the worms wouldn’t need the bacteria anymore.