**Game Theory and Biotic Interactions**

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**Grades:** 7th through 10th; **Group Size:** 2 per group (adjustable, many groups OK); **Approximate Time:** 45-60 min

**NC Essential Standards:**

Bio 2.1.3 Explain various ways organisms interact with each other

Bio.3.2.3 Explain how the environment can influence the expression of genetic traits

**Next Generation Science Standards:**

MS-LS2-2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

HS-LS2-8. Evaluate evidence for the role of group behavior on individual and species’ chances to survive and reproduce

**Description:** This lesson plan and activity will introduce middle school and high school students to biotic interactions between organisms more generally, and basic elements of game theory more specifically. This lesson plan includes a group activity to simulate the prisoner’s dilemma, which can be generalized to discuss cooperation and competition in natural populations. Finally, interactions between participants are used to discuss selection and stable strategies.

**Learning Objectives & Lesson Approach:**

1. Interactive activity: Students split into groups of two to learn and play a prisoner’s dilemma scenario with changing rewards.
2. Students discuss as a class their play strategies and translate these into natural scenarios. Students also complete the evaluation worksheet/homework to generalize their observations to the natural world.

**Location:** Indoor/classroom

**Materials:** digital materials (game varieties, scorekeeping sheets, and the Powerpoint lecture) can be found at:

GITHUB HERE

* Computer with Powerpoint and projector (optional, lecture can be adapted)
* Cooperate/betray cards and scorekeeping sheets

**Preparation:**

1. Download all materials from the web link listed above.
2. Print out cooperate/betray cards and scorekeeping sheets (one set of each per group)
3. Obtain some form of timer.
4. Arrange desks and chairs so that two seats, side by side, face two other seats, side by side.

**Activity:** (tested on classes of 12-30 students, adjust as necessary)

1. Start on first slide, and immediately divide class into groups of 2 (group size can be adjusted, but >3 is more difficult to manage).
2. Inform them of the game, and introduce the rules. Most game dynamics emerge spontaneously, so the less introduction, the better.
3. Leave slide 3 (scoring) on the screen and allow pairs of students to face off against another random pairing.
4. In this activity, the instructor is the referee. Give approximately 1 minute or less for each team to decide on a strategy (betray or cooperate). In subsequent rounds, 15-30 seconds to decide on a strategy is sufficient. Any behavior during this period, including talking, lying, or deal making, is allowed and should be encouraged.
5. Count to 3, and then tell students to reveal their strategy at the same time. This represents the end of a single round.
6. Allow students to record their scores, then require teams to shuffle so that each team is playing a new team.
7. Repeat steps 4-6 for 10-15 rounds. This will take approximately 15 minutes.
8. Move the powerpoint forward to add the new scoring rules.
9. Repeat steps 4-6 for 10-15 rounds. This will take another 15 minutes.
10. Almost invariably, some students will cooperate continuously, while others will betray. Some students find an optimal strategy of alternating. Deceit is common. Often, cliques of cooperators will form. These are all dynamics that can be referred to during the rest of the lecture, and can often be promoted by playing more rounds.
11. After approximately 30 rounds, allow students to tally their scores and reveal them to the class.
12. Ask students to describe their strategies. Slides 9-12 relate in-game strategies to biotic interactions as well as group behaviors in natural populations.
13. Optimal strategies have a mathematical basis. We have often had luck emphasizing the interplay between biology and mathematical simulation when discussing Nash equilibria.
14. Close with a discussion of natural populations and humans. Good examples are often animals and the introduction of trash (educator reference 1), as well as when invasive species disrupt existing evolutionarily stable strategies (educator reference 2).

**Educator References:**

* + - 1. <https://www.nrdc.org/onearth/lure-landfills-how-garbage-changes-animal-behavior>
      2. <https://oceanservice.noaa.gov/facts/invasive.html>

**Assessment:**

1. Students should be able to complete the attached homework sheet.
2. Students should be able to understand how complex social interactions can arise through simple rules (conflict over resources or mates, for example).
3. Students should be able to identify instances of social strategies in nature.
4. Students should be able to understand the role of human intervention in disrupting evolutionarily stable strategies.

**Homework:**

Describe an example of cooperation in nature.

Describe an example of competition in nature.

Describe an example of dishonest signaling in nature.

Describe an example of humans disrupting an evolutionarily stable strategy.