BT Corn Resistance Game

This game demonstrates how the use of pesticides can lead to resistance in the pest population. In this case we’re using genetically modified BT corn, which produces its own pesticide against rootworms. It is designed to complement the final Powerpoint lecture section in Pig Bang Theory: the implications of ignoring evolution.

Materials Needed:

* Cards to represent BT and non-BT corn, we used playing cards with blue and red backs. Four per color, per person
* Small tokens in two colors to represent resistant and non-resistant worm populations. We used two varieties of dried beans. Four per color, per person
* Six-sided dice, one per person
* Copy of rules for each person

Game Set-up:

1. Arrange students so that everyone has at least one neighbor, preferably in a grid so everyone has several neighbors
2. Give each student four cards of each color, four tokens of each color, and one die. Have them fill in which colors are which on their rule sheet
3. Tell students to imagine they are farmers, and each has room to plant four fields worth of corn. They are going to grow corn for several summers (rounds), and try to grow more corn than all their classmates. Plan to do at least three rounds with your class, or you may not see resistance build up. Before the game can start, they each need to set up their field
4. Instruct students to select all four of their non-BT corn cards, and explain that this is the corn they have always planted. It is normal, traditional corn, and it yields 30 bushels/acre. Have them place the cards in front of them, to represent what they grew last year. Ask them to determine how much corn they grew last year (30\*4 = 120 bushels total).
5. Have each student get four tokens that represent the non-resistant worms and place them in the middle of their fields. Explain that these are normal corn rootworms. They live all over your farm, and always eat a bit of your crop. The worms, however, do not live in a *specific* place on your farmland, they can easily move from place to place, so they don’t need to be tied to a specific card. A typical farm setup might look like this:
6. Finally, tell the students that their seed company has just called, and is now selling both traditional corn seed, and a new BT corn. This new BT corn creates its own pesticide, which can kill rootworms, and increases yield to 40 bushels/acre as long as there are no rootworms around that are resistant to the pesticide.
7. For the first round all the students should perform their actions at the same time, so everyone understands the rules, then they can play the next two rounds on their own

Game Steps/Rules (with explanations):

1. **Planting:** Each student should decide how many fields of corn they want to plant, and with which type of corn. Each student can plant a maximum of four fields per round, with any combination of traditional and BT corn
2. **Checking for resistance:** All populations have variation for their traits, even if we can’t always see that variation. Since each student already has worms living in their field, there is a chance each season that some of those worms are already resistant to BT corn, but it was impossible to tell until some BT corn was planted. For each field of BT corn planted, students should roll a die. If they roll a four, five or six, one of their rootworms is actually resistant, and it’s token should be replaced with a resistant token. Students roll based on the number of BT cornfields, **regardless** of how many non-resistant rootworms they have. For instance, if a student has three resistant worms and only a single non-resistant worm, and then plants three BT corn fields, they must roll three times, and any of those rolls can make the non-resistant worm resistant. The only time a player with BT fields does NOT have to roll is if all of their worms are already resistant. If a player has played **ONLY** BT corn, and still has non-resistant corn worms at the end of this step, there is nowhere for those non-resistant worms to live, and they die. The player does his/her scoring based on whatever worms are left. As long as a player has **at least one** traditional corn field, all non-resistant worms can take refuge there.
3. **Scoring:** Traditional cornfields always yield 30 bushels/acre. BT cornfields have variable yield depending on whether any worms can eat them. For each resistant worm at a students’ farm, each BT cornfield yields 2 fewer bushels/acre. This means that for each traditional corn field, students should give themselves 30 points, for each BT corn field, students should give themselves 40 minus the number of resistant worms times two. So if a student plants three BT and one traditional field, and has two resistant worms their score for this round is:

Score = traditional + BT- (2x2) + BT- (2x2)+ BT- (2x2)

Score = 30 + 36 + 36 + 36

NOTE: If the students have only resistant worms in their fields, the yield of BT crops drops to that of non BT crops or 30 bushels/acre. Therefore, if the student has one traditional field, 3 BT fields, and ONLY resistant worms on their farm, they will get 30\*4 corn for that year.

1. **Mating:** In corn worms, the mutation that makes the pest resistant to BT corn is *recessive*. This means that hybrids between resistant and non-resistant corn worms are non-resistant. In this step, we randomly mate the corn worms to see what the next generation looks like. No matter how many worms the student has at the beginning of this step, they will end with four worms.
	* 1. **Starting with four worms:** Students should pick up their worms and shake them in their hands to randomize them, then, without looking, separate them into pairs. These are their mating pairs. If the worms in a pair match, the student keeps them as is, if the worms do not match (would make hybrid offspring) replace the resistant worm with a non-resistant one
		2. **Starting with 1-3 worms:** The only way to have 1-3 worms is if they are all resistant, therefore the resistant worms will procreate to fill the available space. The student should add more resistant tokens to their field until they have four worms
		3. **Starting with 0 worms:** The only way to have 0 worms is if the student had all BT crops this turn and did not have any resistant worms. Since all the worms at their farm died, worms will move in from nearby during the off-season. The student should choose a neighbor at random, and give themselves a new set of four worms that match their neighbors.
2. **Plant the next year’s crop:** Based on their current worm population, students should strategize to choose the corn varieties to plant for the next season, and start over at Step/Rule 1.

**Notes:**

* This game closely mimics the actual biology of this system, and the strategies mimic those available to real farmers
* What should happen in this game, is that students who choose to plant 25% or 50% traditional corn do the best. They are very unlikely to get 100% resistant rootworms, and so will get a larger bonus from the BT corn. Accordingly, the current EPA guidelines for farmers stipulate that 20-50% of each farm be planted with traditional corn to slow rootworm resistance. We have been successful with seeing obvious trends within three seasons/rounds. More seasons would be more effective in demonstrating how long resistance can be delayed by following the EPA guidelines.
* Some students may immediately plant all BT corn, and give themselves an entirely resistant worm population very early in the game. These students will do very well in the first season, but poorly in the long run. This is relatively common with real-life farmers, and a large reason that rootworm resistance is currently a problem. As in a real farm, it is possible for these students to knock back their resistant worms by doing a crop rotation, that is, by not planting corn for a round. This will leave their resistant worms with nothing to eat, and they will all die in Step/Rule 2. The student will score zero for this round, then get new worms in the same distribution as a random neighbor as in part C of Mating. This is not part of the general rules, because in rural areas, I try to encourage these students to come up with the solution for themselves. If your students are very unfamiliar with farming, you may want to explicitly explain this concept.
* Some students insist on placing one worm in each field, rather than in the center. These students may have trouble understanding why they can two or three or four non-resistant rootworms with only a single traditional corn crop. Be sure to explicitly talk about how worms are mobile creatures. They can move around your entire farm and eat wherever they want.

**BT Corn Resistance Game**

**Goal:** Grow the most corn!!

Traditional Corn Cards are: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and are worth 30 corn

BT Corn Cards are: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_and are worth 40 corn (unless you have resistant worms)

Normal Rootworms are: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Resistant Rootworms are: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_and reduce each of your BT fields yield by 2 corn

**Steps to play:**

1. **Planting:** Decide how many fields of corn you want to plant, and with which type of corn. You can plant a **maximum of** **four** fields per round, with any combination of traditional and BT corn.
2. **Checking for resistance:** All populations have variation for their traits, even if we can’t always see that variation. There is a chance each season that some of your worms are already resistant to BT corn, but it was impossible to tell until some BT corn was planted. For each field of BT corn you planted, roll a die. If you roll a four, five or six, one of your rootworms is actually resistant, and it’s token should be replaced with a resistant token. You should roll based on the number of BT cornfields, **regardless** of how many non-resistant rootworms you have. As long as you have **at least one** traditional cornfield, all of your non-resistant worms can take refuge there. If you played **ONLY** BT corn, and still have non-resistant corn worms at the end of this step, there is nowhere for those non-resistant worms to live, and they die. Do your scoring based on whatever worms are left. You do not have to roll if all of your worms are already resistant, or if you didn’t plant any BT corn.
3. **Scoring:** Traditional cornfields always yield 30 bushels/acre. BT cornfields have variable yield depending on whether any worms can eat them. For each resistant worm at a students’ farm, each BT cornfield yields 2 fewer bushels/acre. This means that for each traditional corn field, students should give themselves 30 points, for each BT corn field, students should give themselves 40 minus the number of resistant worms times two. So if you planted three BT and one traditional field, and have two resistant worms your score for this round is:

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