The Ecological Cost of Dinner

LESLIE REINHERZ: Hello. I'm Leslie Reinherz. I teach biology at Canton High School in Canton, Massachusetts. But today, I'm at Plimoth Plantation. And here, we're going to be learning about food energy, where it comes from, what it's used for, and how it flows through our environment. We will then use our understanding of energy flow in the environment, along with some other environmental considerations, in order to examine the actual ecological cost of the food that we eat.

Before you begin this lesson, you should be familiar with food webs and food chains. You should also be familiar with the reactions of photosynthesis and cellular respiration. Plimoth Plantation, in Plymouth, Massachusetts, in the United States of America, is where some of our early settlers, the pilgrims, celebrated the first Thanksgiving with the Wampanoag Indians in 1621.

PILGRIMS: Hey, ho, nobody at home. Meat, nor drink, nor money have I none.

LESLIE REINHERZ: It was a three-day feast, with a lavish spread of food energy.

KATHLEEN WALL: Turnips, we have here. Carrots, we have here. These are really--

LESLIE REINHERZ: Kathleen Wall, Colonial Foodways Culinarian at Plimoth Plantation, is talking with me about the food that was consumed at the first Thanksgiving meal.

KATHLEEN WALL: Our modern Thanksgiving, we think of turkey and all the trimmings, so mashed potatoes, and stuffing, and gravy, and cranberry sauce. In 1621, turkey would not have been the only bird on the table. They talk about wild fowl. And so that included ducks and geese and the turkeys themselves that they took in wild. I mean even passenger pigeons.

There was venison on the table that the native people brought. So that's something else from out of the woods. The geese might have been stuffed with chestnuts that came from local trees. But there also would have been side dishes from the things the English grew in their gardens from seed they brought from England, like turnips and cabbages.

LESLIE REINHERZ: Let's start exploring food energy by assembling a Thanksgiving food web. Your instruction sheet shows the elements of an ecological community in 17th century New England. Cut them out and arrange them to show the feeding relationships within the community. Since we'll be talking about energy flow, be sure to label the feeding levels of the organisms as producers, primary consumers, or secondary consumers and draw arrows from one organism to another, showing the direction in which food energy is flowing.

Welcome back. Let's take a look at our Thanksgiving food web.

Plants like the oak tree, the corn, and the berry bush produce their own food by photosynthesis. So they are producers in our food web, on the lowest feeding level. They get their energy directly from the Sun.

Dear and geese get their food energy by consuming plant parts, like acorns and raspberry leaves. So they are primary consumers on the next level.

[SINGING]

The pilgrim and Wampanoag eat corn, berries, and other plant-based food. So they, too, are primary consumers. But they have more than one role in our food web. When they meat from the goose or the deer, they are secondary consumers.

Wherever you find living things, you find a flow of food energy, from the Sun, to producers, to consumers. Now, have you ever thought about why all of that energy is moving around? What do plants and animals do with it?

Your worksheet asks you to list plant and animal activities that need energy, both at the level of the cell and the level of the whole organism. Use your list to decide whether plants or animals are the biggest energy users.

Hello again. I hope you've come up with a long list of ways to use food energy. All activity in living things requires energy.

When plants, like berry bushes and corn, photosynthesize, they make glucose. But they don't just store it so that animals can have food to eat. They use most of it themselves.

First, they convert their own glucose to ATP. Then, they use the ATP to do jobs, like making pollen for reproduction, repairing damage to leaves and stalks, and pulling nutrients from the soil into roots.

[YELL]

Animals, including humans, depend on ATP for the same sorts of activities and more, dividing cells for growth and for repair, moving muscles, making nerves fire, and generating heat.

KATHLEEN WALL: For the people in the colonies, even different than back in Europe, they had no oxen to turn their fields. So they're doing all of that by hand. Most of your calories were spent planting. So you had your garden. You had your fields.

They're gathering out from the wood. They're shooting animals. They're fishing. So everything you put on your table, someone has put effort in to get it there.

LESLIE REINHERZ: You might say that the pilgrims and Wampanoags were on a quest for ATP. Life would simply not be possible without energy in this form.

Speaking of forms of energy, let's look at how energy changes its form as it moves through the food web. It starts out in the form of photons, which are bundles of light energy, cast onto our planet every day by the Sun. And it ends up as ATP, inside of cells. How does it change forms in between?

For the next activity, you're going to trace the path of energy as it moves through our Thanksgiving food web. The goal is to document the changes in form as energy moves from the Sun, to the human guests at the Thanksgiving dinner table. Use the diagrams of photosynthesis and cellular respiration and the question sheet as guides.

I hope you've seen that energy doesn't really ever sit still. From the Sun, you get light energy. Producers like the berry bush convert light energy into chemical energy.

In the first phase of photosynthesis, this chemical energy is held within energy-carrier molecules. In the next stage, these molecules transfer their energy to the chemical bonds of sugars, like glucose. When a deer eat the leaves of a raspberry bush, the energy in the chemical bonds of glucose gets transferred during cell respiration, first to energy carrier molecules, .and then, after going through a set of energy transfers along the electron transport chain, into molecules of ATP.

There's an interesting problem with energy transfer and it has big consequences for feeding our planet. The problem is that energy transfer is not efficient. By the time one molecule of plant sugar is converted to ATP during cell respiration, 60% of the original energy has been lost to heat.

And food energy gets lost in another big way in an ecosystem. Think back to the list of energy uses you created in your second activity. Once a deer has used its food energy to move muscles, the energy is no longer available for growth. So it can't be used to make more deer meat. And the only energy that will get transferred from a deer to a Thanksgiving guest is the energy stored in the meat of the deer.

Now, I'd like you to think about the overall flow of energy in an ecosystem. How much energy, starting from the Sun, makes its way from one feeding level to the next? I'd like you to first try to guess at how much is lost because of either inefficiencies or because it's used up for non-growth, day-to-day activities. Then I'd like you to support your guess with reasoning.

And finally, I would like for you to make a diagram that shows how much energy you think is left over, that can be transferred from one feeding level to the next. See if you can guess the percentage of energy that's either lost because of inefficiency or used up for day-to-day non-growth activities at each feeding level.

How did you do in your diagrams? Here's a classic one that ecologists use to show the transfer of energy from one feeding level to the next.

The biggest loss occurs at the start. Less than 1% of the Sun's energy gets converted to plant sugar. From there, the energy flow follows what ecologists call the 10% rule. On average, only about 10% of the plant food eaten by a primary consumer will turn into something that a secondary consumer can eat. The rest of its food energy is used for daily activities, like respiration, movement, and reproduction, or it's lost as heat.

When a secondary consumer preys on a primary consumer, only 10% of what it eats will be turned into its own flesh. Once again, the rest is used up in daily activity. About 90% of energy is never transferred from one feeding level to the next.

The 10% rule of energy availability has an impact on survival, especially when food is scarce. Imagine you and two friends are shipwrecked on an island. There's plenty of fresh water and enough firewood for cooking your meals. But the only food you have is one dairy cow and 1,000 pounds of grain.

You want to survive as long as possible. And it's not possible to plant anything. You have to choose. Are you going to eat the cow first and then eat the grain? Should you feed some of the grain to the cow, drink her milk, and eat some of the grain yourself? I'd like you to work in small groups and come up with a strategy that will maximize the number of days you can survive.

Welcome back, again. If you want to survive on the island as long as possible, you have to take into account the 10% rule. If you allow the cow to eat the grain, 90% of the energy in that grain is going to be lost, either to heat or it's going to used to fuel the activities of the cow.

The best strategy to maximize your survival is to avoid feeding the cow entirely. On dairy farms, a milking cow can eat as much as 75 pounds of feed a day. That's a month and a half of human food.

Now, you probably won't ever be left on a desert island with only a cow and some wheat. So why is this exercise so important in understanding the ecological cost of dinner? It's important because the food energy invested in putting a consumer on the table is much greater than the food energy invested in putting a producer on the table. In other words, the food energy invested in putting meat on a plate is greater than the food energy invested in putting vegetables and grains on the plate.

In fact, some ecologists actually suggest that a vegetarian diet would be better for the health of our planet. But food decisions in real life are complicated. They take into account taste preferences, cultural traditions, health, and nutrition. And in any event, we need to look at the bigger picture, something called our ecological footprint.

The ecological footprint is a measure of how much natureor natural resourceswe're using compared to how much is available. For the last activity, I'd like you to think about all the ways in which the first Thanksgiving meal differed in its ecological footprint from a typical modern-day Thanksgiving meal. Use your worksheet and your guided questions in order to help you make this comparison. There are some menus that are provided for those of you who may not be familiar with the food offerings from the first Thanksgiving or from a modern American Thanksgiving meal.

I hope you've discovered that the ecological footprint of the pilgrims and the Wampanoag was a lot smaller than ours is today. The 10% rule of energy availability still applied in the 17th century. But the difference was that there were a lot fewer people. What that means is that for the pilgrim and Wampanoag, the amount of nature that they were using was relatively small in comparison to the amount of nature that was available to them.

KATHLEEN WALL: The same men who were planters, who were planting the corn, are also the fishermen, the same men who were out hunting in the woods. So all of the fish they have on their table is local fish. All of the wild fowl they have on their table is local. So everything they need here, they just have to go and bring it in.

LESLIE REINHERZ: There's an ecological cost to processing, packaging, and transporting food. Couple that with the 10% rule of energy availability and our modern food habits have a huge impact on the environment. Some ecologists estimate that today it takes our planet one year and six months to regenerate the resources that we use in one year.

I hope this lesson has got to thinking about the actual ecological costs of the food that you eat. As the population on our planet continues to grow, ecological factors may be playing a major role in our food decisions. To get you thinking about the actual ecological factors involved in food choices, you may just want to calculate the actual cost of your next meal.

Hi. I'm Leslie Reinherz. This BLOSSOMS lesson is aimed at biology students who already have a basic understanding of the processes of photosynthesis in cell respiration, and the relationships to one another, and who have already been introduced to the basic structure of ecosystems and of food webs. One of the key objectives is to have students link these two areas of understanding so that they can see the bigger picture of energy flow through ecosystems. Another key objective is to get students thinking about the efficiency of energy transfer and the bearing it could potentially have on human decisions about what we grow, what we eat, and how much energy is required for the processing, packaging, and transportation of food.

The first segment sets the stage for students to think about how humans obtain food energy. If you are outside the United States of America and are unfamiliar with our national Thanksgiving holiday, please have a look at the reference material we provide with this lesson.

The first Thanksgiving celebration in America dates back about 400 years. So it's a useful reference for teaching about energy flow. Students will be able to compare food decisions and the efficiencies of bringing a feast to the table, centuries ago and in modern times.

The first activity is simply a warm up, to refresh the student's knowledge about food webs. The vocabulary about feeding levels will be rehearsed here and it will be used throughout the lesson. You'll want to make sure students use arrows to point in the direction of energy flow when they're arranging the organisms in their food web.

The second segment gets students thinking about why organisms need energy. The activity works well with students when they're in small groups and they can brainstorm with one another about what plants and animals do with their food energy.

Some students have the misconception that plants don't use energy. They just make glucose for consumers. In other words, photosynthesis is for plants and cell respiration is for animals. There's always someone in a group that can help such students get unstuck here.

The third segment introduces the idea that energy changes forms as it moves through an ecosystem. It's critical that students understand that energy has to transfer from one physical or chemical form to another as it moves through an ecosystem because this will lay the foundation for the following segment about the efficiency of energy transfer. The activity in this segment asks the students to document the changes in energy form as it arrives on our planet as photons, gets secured in molecules of glucose, and gets transferred to ATP molecules during cellular respiration.

There are several options for this activity, depending on the background knowledge and the capabilities of your students. So have a look at the choices of handouts. Some students will be ready to trace multiple energy transfers within the Krebs cycle and along the electron transport chain and others will not. Regardless of the level at which students approach this activity, each should leave with the understanding that as energy flows through an ecosystem, it changes form many times.

The fourth segment introduces the concept of efficiency during energy transfers. The bottom line is that lots of energy gets used up in an organism's daily activities or is lost as heat. Only a small quantity of energy is used to make an organism grow larger, build flesh, so to speak.

Students are asked to complete an activity in which they guess the percentage of energy that transfers from one feeding level to the next within an ecosystem. If they have already read about this in a textbook, they'll know that there is, on average, a 10% transfer of energy between each trophic level. But the correct answer is not the point here. What's key here is for students to appreciate the large number of energy transfers as organisms search for and consume their food and as that food is broken down at the molecular level.

The fifth segment presents the 10% rule of energy transfer and asks the students to use their understanding of this rule to solve an energy transfer challenge problem. Students have to imagine they're stranded on an island with one dairy cow and 1,000 pounds of grain. They need to make food decisions that will keep them alive as long as possible. They should come to a consensus within their group about their survival strategy because this will require the students to argue their ideas and listen to one another. What's important in this challenge problem is that students provide not just an answer, but also an explanation.

Some students may get diverted and try to solve the problem by inventing other possibilities on the island. Just remind them they have enough water. They are able to cook meals using the firewood. There are no additional sources of food available, no delivery, no rescue boats, et cetera. Have them focus on the very specific problem at hand.

The final segment introduces the concept of ecological footprint, a measure of how much nature is being used compared to how much is available. Students are asked to consider not only the efficiency of energy flow, from one feeding level to another, but also the efficiency with which humans bring food to the human dinner table.

The final activity asks them to compare a Thanksgiving feast in the time of the pilgrims, to a Thanksgiving feast in modern times. Menus for each feast are provided on the worksheets for students not familiar with a Thanksgiving meal. The idea is to get the students thinking about energy spent in the processing, packaging, and transportation of food. There are no right or wrong answers to this activity. Rather, it is an opportunity for students to begin the debate about food decisions that may play a role in their future.

Thank you for your interest in using this BLOSSOMS lesson. I hope you and your students will enjoy the activities and the challenge question. If you'd like to know more, please don't hesitate to get in touch. You can reach me by contacting the people at the MIT BLOSSOMS program.

[MUSIC PLAYING]