What is so important about phosphorus?

Active Listening Questions:
- Why might understanding the role of phosphorus in living systems be important to society?
- Based on the clip, which scientific fields do you think are involved in understanding the phosphorus cycle?

**WHAT:** As agroecologist Tim Crews explains in this clip from the 2009 public presentation “Agriculture After Norman Borlaug,” phosphorus (P) is an essential nutrient for life. For instance, P is one of the primary elements of DNA, which means that all known organisms—plants, animals, and even amoebas—need phosphorus. Although humans generally get enough of it in our diets, the demand for P by plants is very high relative to the supply of it in soils. Thus, in many instances around the world, the availability of P restrains how much can grow in a given area. For this reason, P is considered by ecologists to be a limiting nutrient.

**How:** The model presented by Dr. Crews is a qualitative depiction of the phosphorus cycle, meaning that it characterizes processes conceptually but not quantitatively. A model like this is a simplification of a much more complex system. Components of the model are derived from observations, though, due to the enormity of landscapes, inferences and generalizations must be drawn from limited observations. As a result, models are not exact replicas of the real world but rather imperfect, though useful, representations.

**WHY:** Confidence in our understanding of the importance of P comes from centuries of previous work by scientists. P was first discovered to be important component of bone in 1771. Later, reproducible observations found P to be an important element of every living thing. Such knowledge, combined with the basic principle of conservation of mass, which states that matter is never lost within a system allows scientists like Dr. Crews apply this principle to the phosphorus cycle and qualitatively and quantitatively track the flow of phosphorus in and between systems.

**So What:** Making sense of the role of phosphorus in living systems contributes to our understanding of the natural world and our understanding of managed agricultural systems. As will be explored in further clips, humans have greatly benefited from knowledge of the role of phosphorus in living systems because it has enabled us to alter phosphorus cycles in order to boost productivity, resulting in higher rates of food production. However, this has also resulted in unintended consequences, raising significant concerns about the sustainability of such practices.

**Bio:** Tim Crews is the Director of Research and Research Ecologist at The Land Institute. Dr. Crews is interested in the ecology of agriculture. Specifically, his research focuses on how prairie ecosystems maintain soil fertility and how these insights can be applied to the need for fertilizer inputs.
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**TAKING THE REINS**

**Discussion Questions:**
Discuss with a friend or record your thoughts in a journal.

- Why does Dr. Crews say that phosphorus is essential to life?
- Most plants draw their nutrients (such as phosphorus) from the soil. As a living thing, you are also dependent upon nutrients. Where do you get essential nutrients from, and why, biologically speaking, are you not able to get nutrients directly from the soil?

**Quiz Questions:**

**Quiz 1.** There are about 13 nutrients that plants get from minerals dissolved from rock in the soil. Which of the following is commonly the least abundant relative to plants' demand for it?

a) Potassium  
b) Phosphorus  
c) Sulfur  
d) Calcium  
e) Nickel

**Quiz 2.** Phosphorus is an important nutrient for which of the following reasons:

a.) It's the “backbone” of DNA.  
b.) The demand for it is highest relative to its abundance in Earth's crust.  
c.) Humans struggle to get enough of it in their diet.  
d.) A & B Only  
e.) All of the above.

**Quiz 3.** For the most part, how do natural “pools” of phosphorus develop in soils?

a.) Precipitation events such as rain and snow  
b.) Weathering of rock over time and deposits from dust  
c.) Natural soils do not contain phosphorus. It's only an amendment that humans have added as a fertilizer.  
d.) From phosphorus-fixing plants

**Glossary Term:**
**Limiting Nutrient**
An element or compound that a living thing needs for growth or survival, but which is not readily available in the quantity needed relative to other necessary nutrients. During growth, the available pool of this component will be the first to be used up, causing growth to stop, thereby limiting it.
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Go Beyond: Limited Ingredients
Complete this activity and record answers and thoughts your science journal or discuss with a friend.

Dr. Crews and other scientists describe phosphorus as a limiting nutrient. A limiting nutrient is an element or compound that a living thing needs for growth or survival, but which is not readily available in the quantity needed relative to other necessary nutrients. In this sense, nutrients are like the ingredients needed in a baking project where the final product (like cookies) represents successful plant growth.

Step 1:

Imagine a baking project (or conduct your own baking experiment in real life). If the warm, delicious cookies represent a healthy plant, then the ingredients used to make the cookie represent nutrients needed for growth.

Imagine you want to make cookies and in your pantry and fridge you have the following components:

- 2 cups butter · 3 teaspoons of baking soda
- 1/2 cup white sugar · 1 teaspoon of salt
- 3/4 cup brown sugar · 3 tablespoons vanilla
- 3 eggs · 5 cups flour
- 1 cup chocolate chips

The ingredients in your home are like the different available nutrients in the soil. Just as you have more brown sugar than white sugar, there are some nutrients in the soil that are more common than others. This does not necessarily mean they are the most important nutrients.

You have decided to bake 24 cookies. To make 24 cookies you need:

- 1 cup butter 1/4 teaspoon of baking soda
- 1/2 cup white sugar 1/8 teaspoon of salt
- 1 cup brown sugar 1 teaspoon vanilla
- 2 eggs 2 cups flour
- 1/2 cup chocolate chips

Looking at the ingredients you have and the ingredients you need, will you able to make a full batch of 24 cookies? What is the ingredient that you do not have enough of?
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Go Beyond: Limited Ingredients--continued

The ingredient of which there is not enough to make a full batch is the “limiting ingredient.” Note that the limiting ingredient is not the same as the ingredient you have the least of: what makes it limiting is the amount you have in relation to the amount that you need. The same is true of the limiting nutrient in soil: it may be more common that other elements, but if it is needed in higher quantities than those other elements, then the amount of that nutrient in the soil will limit how many or how much plants can grow.

Just like the ingredients in cookie baking, amounts of nutrients available in a given plot of soil may change. If this happens, the nutrient limiting plant growth may change as well.

Step 2:
Although you have plenty of other ingredients, you cannot make a full batch of cookies without the needed amount of any of the ingredients. Likewise, plants can only grow as much as the least available nutrient will allow. Even though a plant might need a higher total amount of nitrogen than phosphorus, if there is lots of nitrogen and little or no phosphorus, the plant will be unable to grow.

You figured out that your limiting ingredient will not allow you to bake a full batch of cookies, so you bake a 1/2 batch of cookies instead. Calculate how much you have left of each ingredient after baking. Imagine you then go to the store and purchase 6 cups each of white and brown sugar but no other new ingredients. If you want to bake another batch of cookies, what will your limiting ingredient be now? Can you make a full batch this time or only a half batch?

Discussion/Journal Activity:
Just like the ingredients in cookie baking, amounts of nutrients available in a given plot of soil may change. If this happens, the nutrient limiting plant growth may change as well.

- What are some natural and the human activities that might change availability of a certain nutrient in the soil?

- Which type of activity--human or natural--do you think has had a larger impact on nutrient availability in the last 100 years?

Further Reading: