Digging Through Layers of Soil Science

Grades 7–8

INSIDE

What's Inside

Eww! What's

Probably dirt.

Did you know that "dirt" is essential to feeding the world? And actually, scientists prefer the word "soil" when talking about healthy, rich matter that provides plants with nutrients. It's an amazing resource that's essential to our survival and that of nearly every organism on Earth. Our planet is mostly made of rock with an iron-nickel core. Plants and animals, including us, occupy a thin area on its surface. Our existence is possible because of a thin layer of soil that comes between the planet's rocky interior and us.

Soils are different everywhere, and they are natural expressions of the environment in which they form. Scientists recognize five main factors that influence soil formation: 1) parent material, 2) climate, 3) living organisms, 4) topography, and 5) time. Of course, in addition to these five factors, human activity also can influence soil formation.

Parent material

Parent material refers to both the organic and mineral material in which soil formation takes place. Materials from living or once living organisms can be called organic, like dead plant material, worms, and decomposing insects. Mineral can include weathered rock, ash from volcanos, and sediments deposited by wind and water. Nonliving materials, such as clay, rocks, or sand are inorganic materials. Soil formation will happen more quickly in materials that allow water to move through it.

Climate

Climate influences the amount of water available for weathering the parent material and the temperature at which it occurs. A warm, moist climate fosters plant growth and speeds up decomposition; both of which contribute to faster soil formation.

s that under your nails?

Living Organisms

Plants supply soil with organic material and help prevent erosion. Deep-rooted plants have a greater impact on soil formation than shallow-rooted plants because they create larger channels for water movement. Insects, earthworms, fungi, and bacteria are important because they help decompose organic material releasing plant nutrients.

Topography

The three dimensional shape of the land influences water movement. As a result, the water movement influences the speed of soil formation. Since water flows downward due to gravity, soils on slopes are prone to erosion. Areas that are very wet or very dry may not be as fertile as more balanced areas. Since very wet or very dry areas make plant growth difficult, soil forms slower.

Time

The weathering of rock slowly produces soils. It can take centuries to produce fertile topsoil. Constant exposure to wind and rain cause the rocky crust to break slowly down into smaller particles. As rainwater seeps into cracks, temperature extremes cause the water to freeze. The rock expands, contracts, and fractures. Organisms that live on and in the soil help these weathering actions along.

Pop Quiz

1. Fill in the blank:The five main factors that influence soil formation include 1) parent material, 2) _____, 3) living organisms, 4) topography, and 5) _____.

2. A _____ fosters plant growth and speeds up decomposition, both of which contribute to faster soil formation.

   a. moderate climate
   b. dry, windy climate
   c. warm, moist climate
   d. cold, tundra climate

3. Which of the following does not help decompose organic material releasing plant nutrients?

   a. Nematodes
   b. Insects
   c. Earthworms
   d. Fungi

4. Based on context clues in the article, what does topography mean?

_____
_____
_____

5. In your own words, explain the role that time has in soil formation.

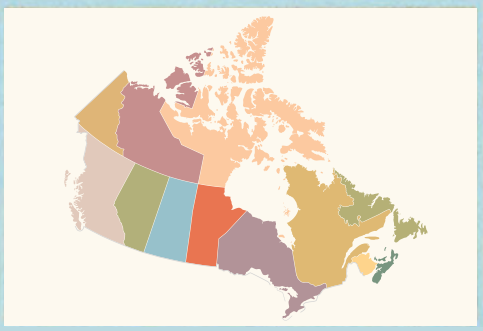
_____
_____
_____

Fun Soil Facts

One tablespoon of soil has more organisms in it than there are people on earth.

Earthworm populations consume 2 tons of dry matter per acre per year, partly digesting and mixing it with soil.

It takes anywhere between 200 to 500 years to make one inch of topsoil.



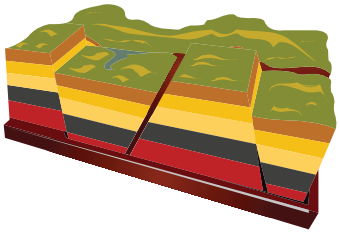
Scientists have found thousands of different types of soil only in Canada. Click Here

Ref: Soil Classification Working Group, 2001. Soils of Canada, Agriculture & Agri-Food Canada, Research Branch. Scale: 1/6 500 000 map. Cartography by B. Lacelle

Soil Horizons

The process of soil formation is gradual. It produces a series of horizontal layers. In a typical area, a soil might have three or four horizons, or layers. Horizons can be told apart by physical characteristics of color and texture. As mentioned previously, the formation of soil horizons is influenced by a number of factors, such as air, water, sunlight, and plant material. The weathering of the parent material occurs first at the surface and then works its way downward. This means that the uppermost layers can change the most, while the deepest layers are the most similar to the original parent material. To visualize the soil horizons, scientists dig a hole several meters thick to expose the layers. The edible activity on the next page will help you learn about each layer; there is a description of each layer listed with each material.

SOIL HORIZONS:



Bedrock is made of rock from the compressed layers of soil above it. Plant roots do not reach this layer.

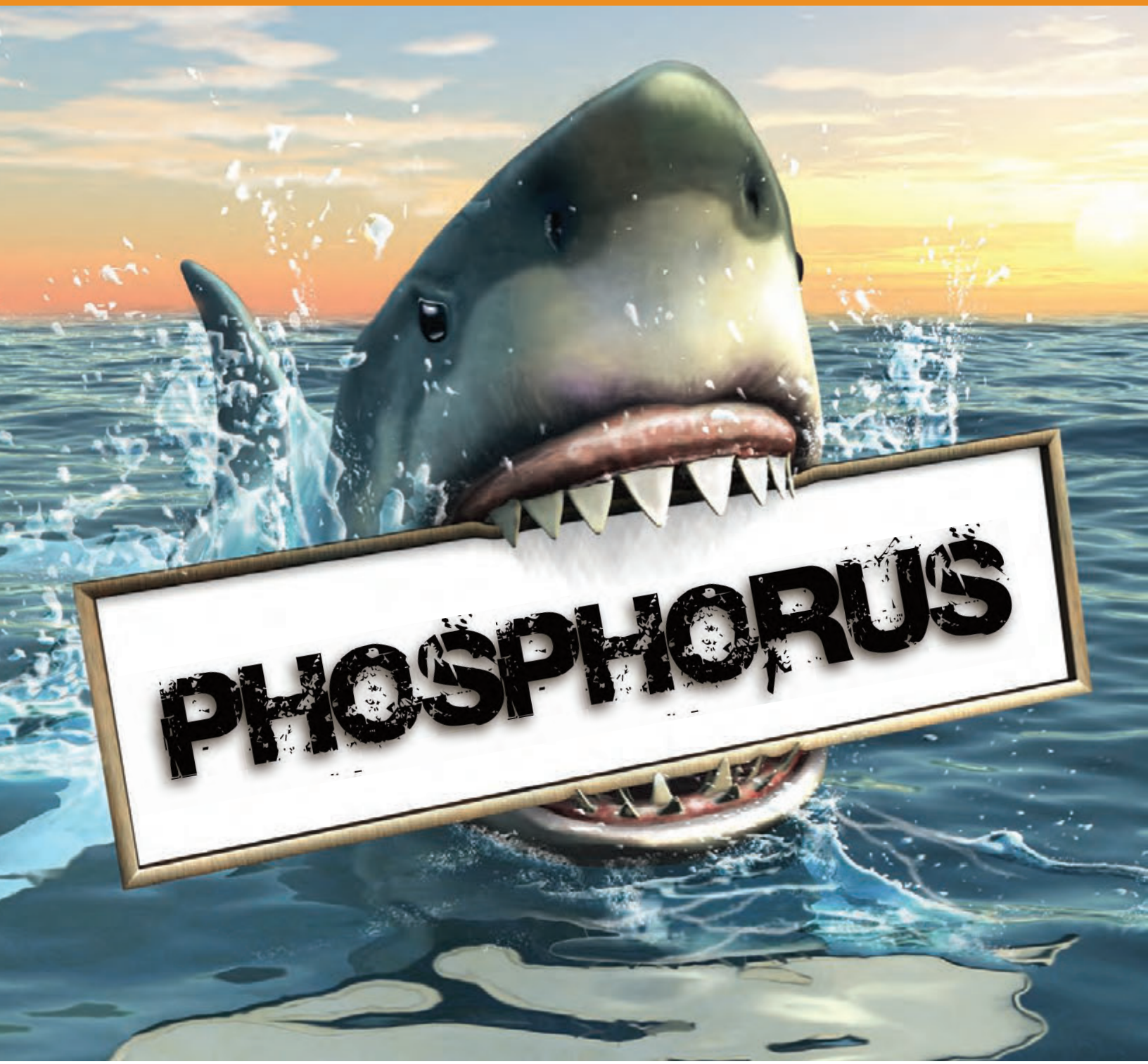
A layer of **parent material** exists between bedrock and subsoil and can contain rocks. Organisms don't thrive here and chances of plant roots entering it are low. This can be found 1.5 meters below our feet, but it varies on location.

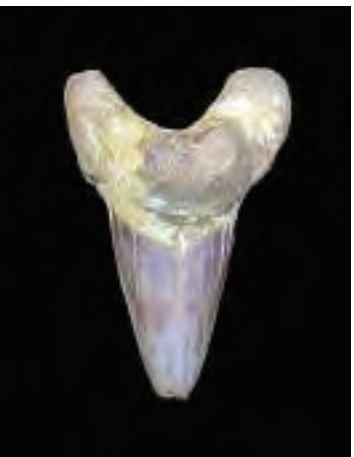
Subsoil contains some nutrients but is also rich in clay. Subsoil can be found 1 - 1.2 meters below our feet.

Topsoil is rich in nutrients, such as nitrogen, phosphorus and potassium. Topsoil is essential for plant growth. Topsoil can be as deep as 1 meter.

PHOTO: HOLGERK

Phosphorus (P) helps plants catch the sun's energy.





It's the ultimate form of recycling: much of the world's fertilizers come from remnants of ancient sea life. Phosphate, for example, is mined from ore deposits that are rich in fossilized sea remains, like this shark's tooth. Phosphate is mined from the ground and converted into a form that plants, including apple trees, can use. Phosphorus is essential to plants because it is the backbone of DNA, the genetic blueprint contained in every living cell. Who would have thought that apples, which are high in phosphate, have a connection to sea creatures from more than 20 million years ago?

* TRY THIS!

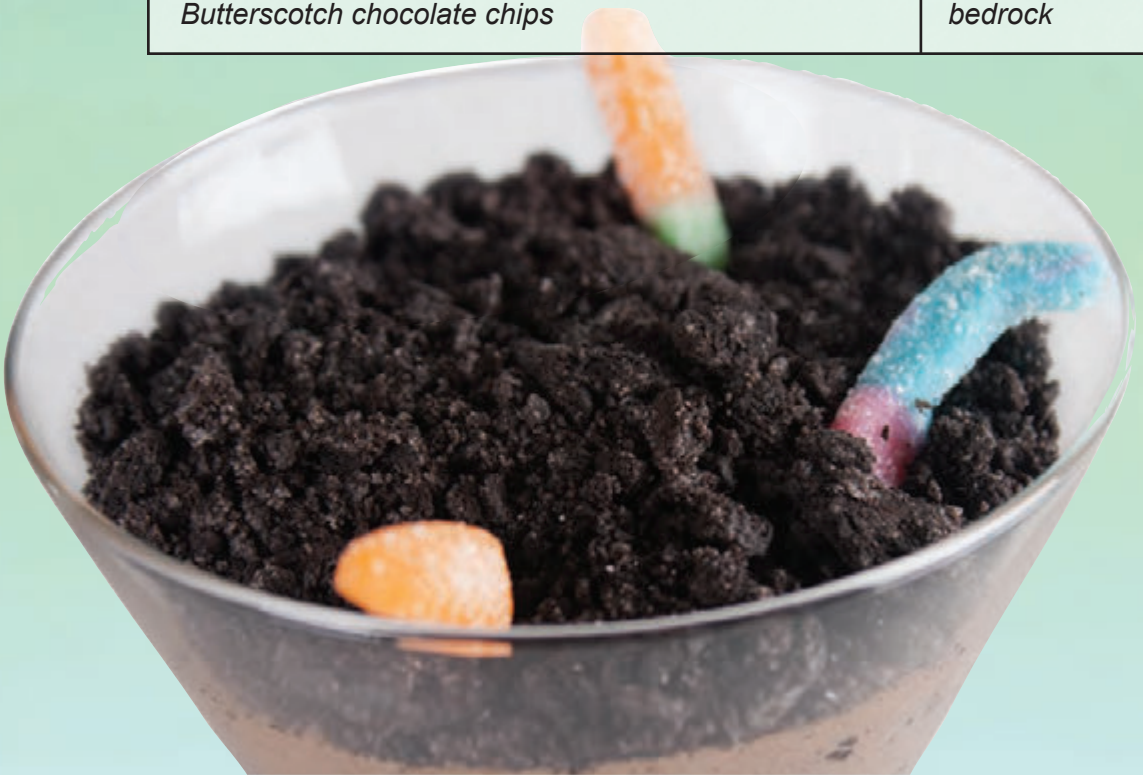
Edible Soil

Gather the following materials:

- **Small clear cups and spoons**
- **Gummy worms**
- **Green coconut (colored with green food coloring)**
- **Chocolate pudding**
- **Sprinkles—preferably a mixed variety with three colors**
- **Crushed Oreos**
- **Roughly chopped graham crackers**
- **Butterscotch chocolate chips or round tan cereal**

While considering what you know about soil horizons, fill a clear cup with the ingredients listed, and write explanations in the blank table for what each ingredient represents. For example, butterscotch chocolate chips could represent bedrock, because it is usually a light tan color and is made of rock from the compressed layers of soil above it. After you add topsoil, don't forget to 'plant grass and fertilize!'

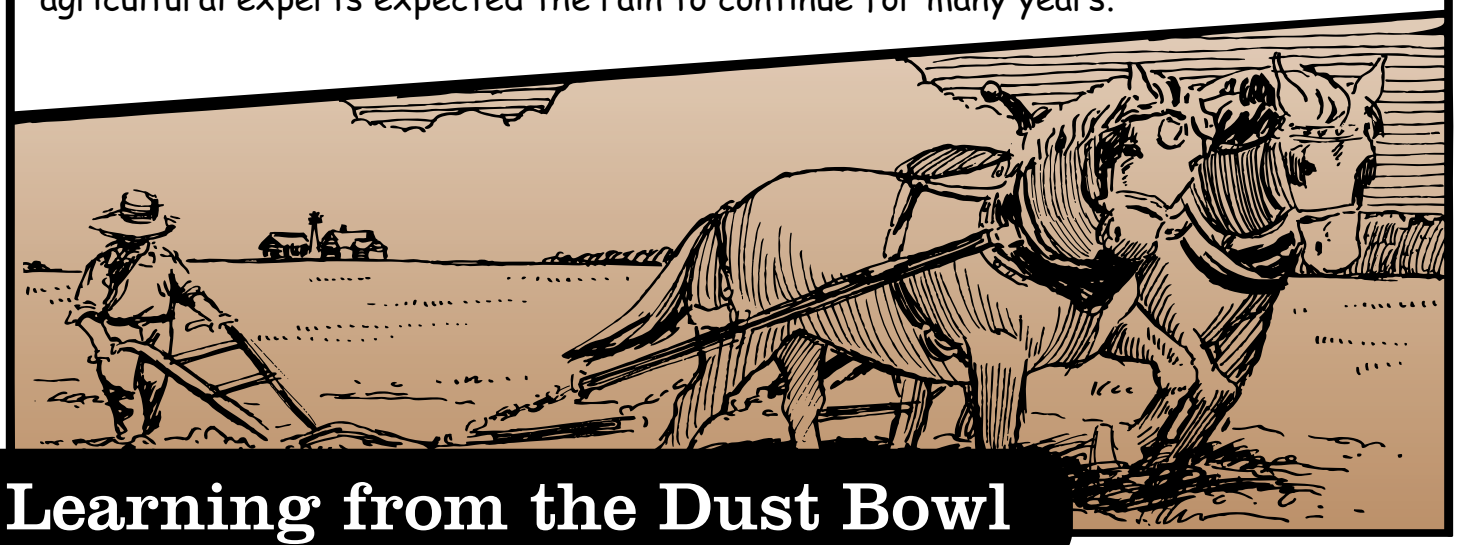
INGREDIENT:	REPRESENTS:
Gummy worms	
Green coconut (colored with green food coloring)	
Chocolate pudding	
Sprinkles—preferably a mixed variety with three colors	
Crushed Oreos	
Roughly chopped graham crackers	
Butterscotch chocolate chips	*bedrock*



WORD BANK

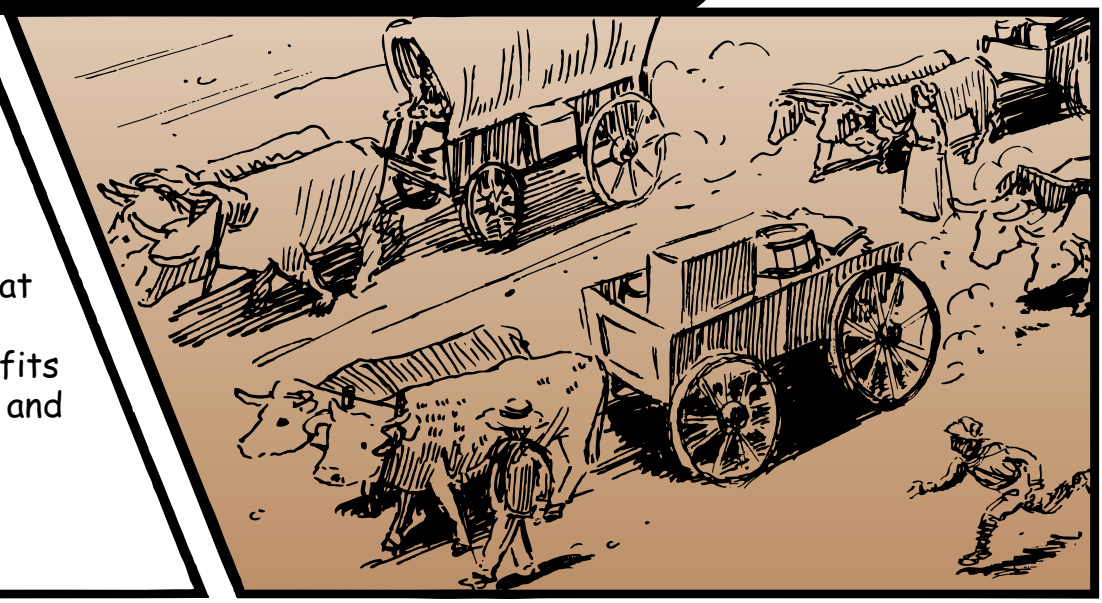
- Parent material
- Worms
- Bedrock
- Subsoil
- Grass and plants
- Fertilizer
- Top soil

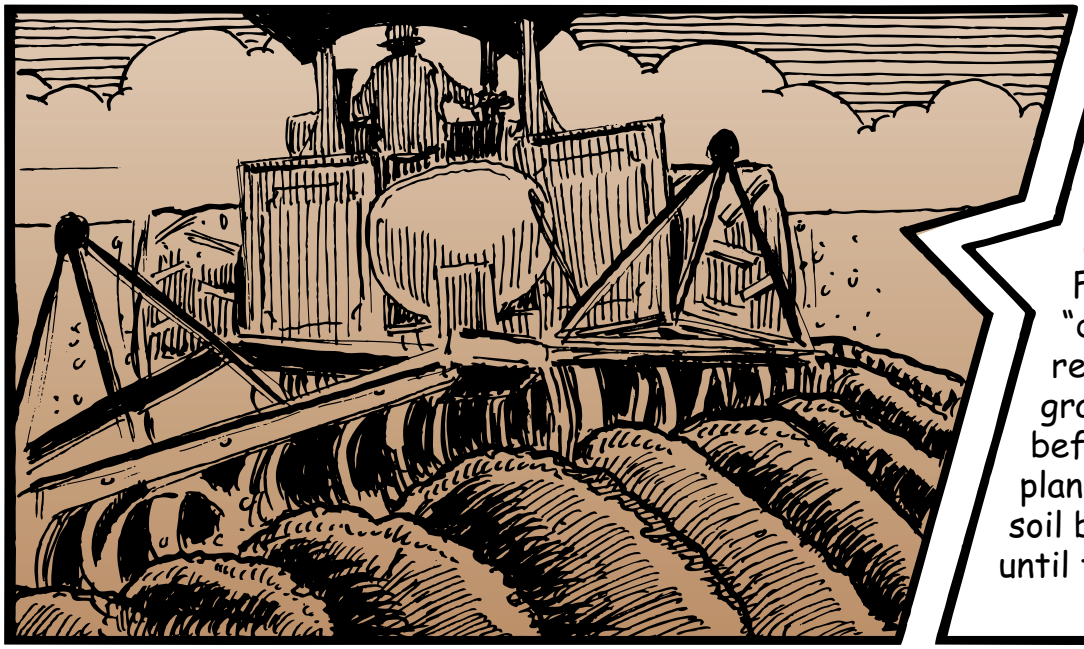
During the late 1800s, an unusual amount of rain fell on the Great Plains. Farmers and agricultural experts expected the rain to continue for many years.



Learning from the Dust Bowl

The moist, productive soil encouraged people to settle in the Great Plains and begin farming. As demand for wheat increased, farmers increased their profits by cultivating more and more land.





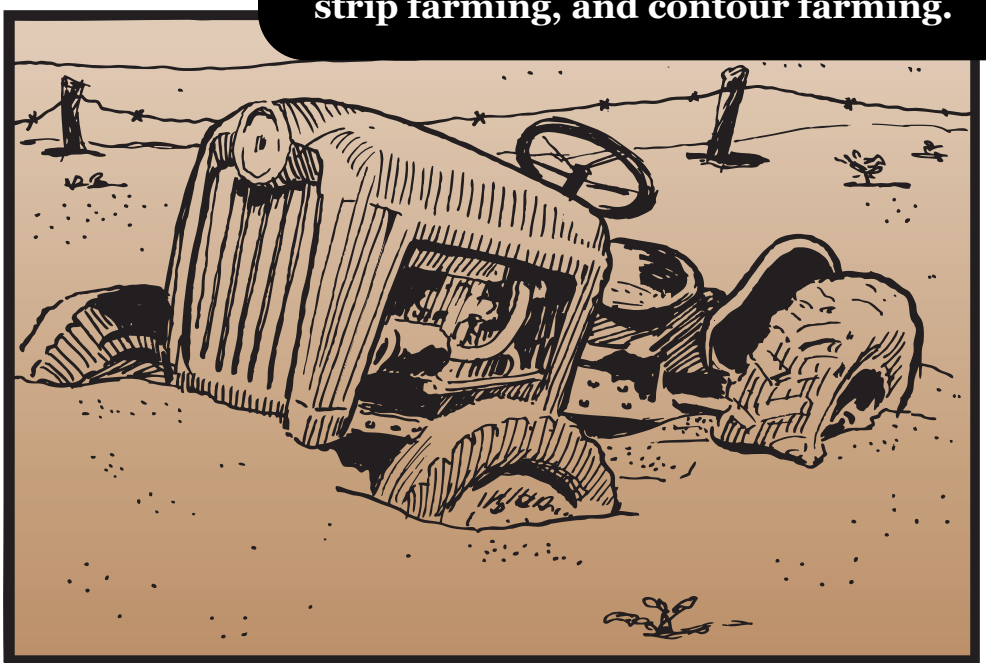
Mechanized equipment allowed for more efficient farming over an ever-expanding area. Farmers practiced "deep plowing" that removed native grasses in the fields before they began planting. This left the soil barren for months until the next planting.

When the weather was wet, deep plowing worked well. However, in 1930 an extended drought began and crops failed. The dry soil was over-plowed into fine particles that were easily blown away by the near-constant winds.

High winds carried massive amounts of topsoil eastward. Dust was carried all the way to Chicago and eventually Cleveland, Boston, and New York City.

LEARN MORE: Research crop rotation, strip farming, and contour farming.

The cruel lesson of the Dust Bowl is that topsoil is a precious resource that must be protected. Challenges associated with maintaining healthy soils include nutrient depletion, erosion, and water runoff. Different farming practices now address these challenges, like crop rotation, strip farming, and contour farming.



Nutrients for Plants

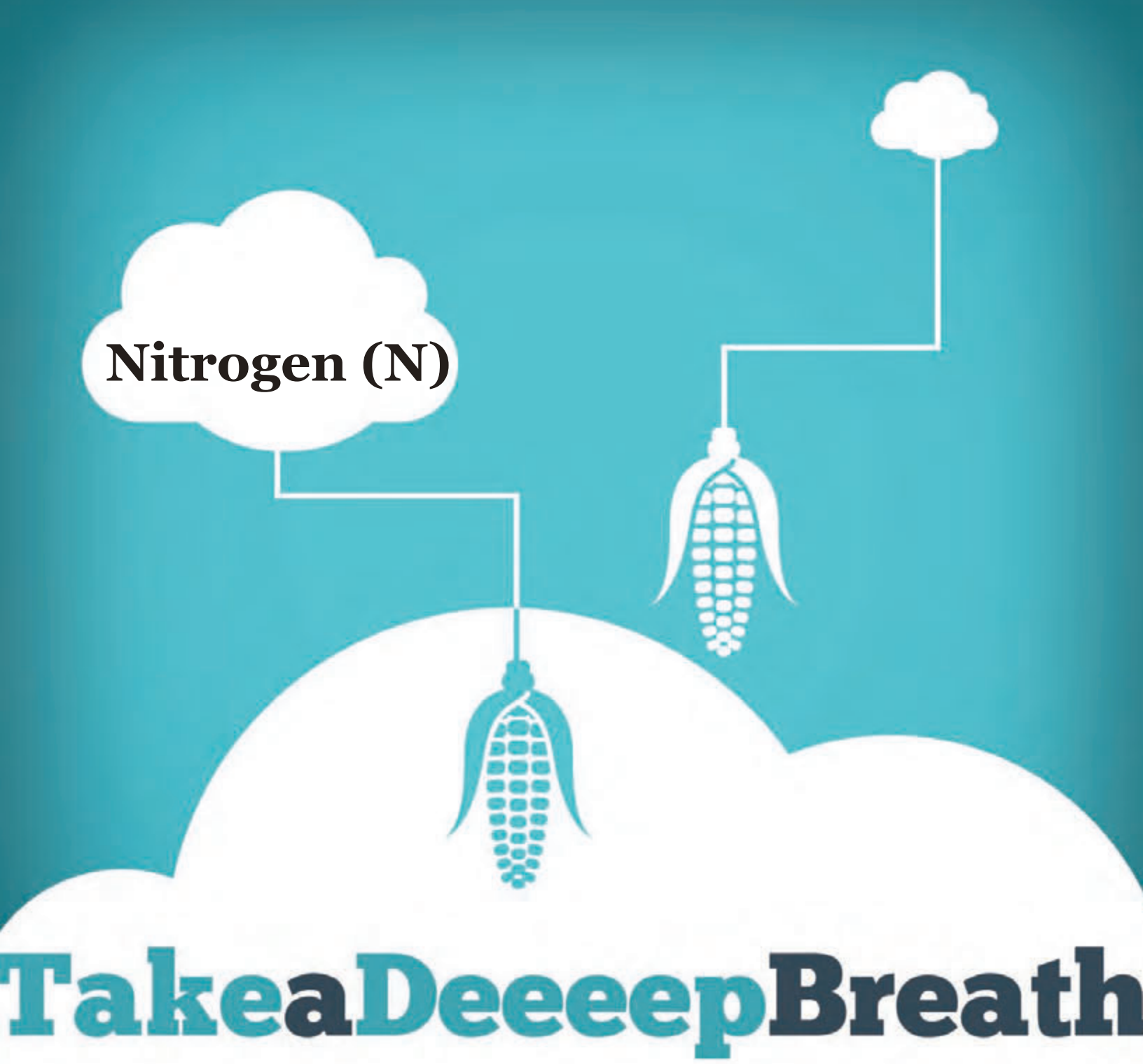
A nutrient deficiency results if not enough of a nutrient is available to keep the plant healthy.

It goes without saying that people and plants are very different organisms. Among many other things, people are consumers, while plants are producers. Despite their many differences, both people and plants are made up of cells, and both must contain certain nutrients in order for cells to be healthy. If a person is lacking a necessary vitamin, mineral, or essential element, then they have a deficiency. For instance, a person can become anemic if a person lacks iron. If a person has too little calcium, his or her bones become brittle. Healthy eating, including fresh vegetables and fruits, helps prevent these nutrient deficiencies in humans. Similarly, soil serves as a nutrient bank for plants; it contains most of the nutrients plants need. Plants require 17 essential nutrients for healthy growth. A nutrient deficiency results if not enough of a nutrient is available to keep the plant healthy. Interestingly, plants and humans require some similar essential elements, like iron, calcium, phosphorus, and potassium.

When a plant needs more of a nutrient, it shows specific symptoms related to the deficiency. For example, if a corn plant is deficient in nitrogen then the plant will often have large yellow sections on its leaves. A farmer concerned for the health of his or her crops must use scientific tools to prevent deficiencies and, if necessary, to examine these symptoms and diagnose problems, much like a doctor does when they have a human patient with a deficiency. Soil and plant tissue tests are used to detect nutrient imbalances. Once the problem has been identified, steps are taken to correct the problem.

Plants get their essential elements from air, water, and soil. Farmers prescribe fertilizers for their soil and crops, similar to doctors prescribing vitamins for their patients. The three main nutrients plants need to be healthy are nitrogen, phosphorus, and potassium. These nutrients are needed in the highest quantity in most plants.

Explain why nutrients are essential for humans. How is this similar to plants' need for nutrients?



About 78 percent of the air we breathe is made up of nitrogen which, among other things, is a vital nutrient for growing corn and other crops. The trouble is, corn plants can't "digest" nitrogen and use it directly from the air. Fertilizers help them out by converting nitrogen from the air into nitrogen for the ground. Farmers apply the fertilizer. Corn takes up the nutrients, grows tall and provides food for us all. So next time someone asks where nitrogen fertilizer comes from, have them take a deep breath . . . then say: **"Guess what?"**

The Nitrogen Cycle

Although air is about 78 percent nitrogen, plants cannot make use of the atmospheric nitrogen gas (N_2). Instead, plants need to obtain their nitrogen by taking up the cation ammonium (NH_4^+) or the anion nitrate (NO_3^-) in the soil. These ionic forms of nitrogen are generated by the breakdown of organic material in the soil or through a process called nitrogen fixation that is carried out by soil microbes. Some crop plants (legumes, such as peas, beans, peanuts, and soybeans) live in close association with nitrogen-fixing bacteria that are found in their roots and convert atmospheric nitrogen (N_2) gas to a form that plants can use. This is called biological fixation. These types of crops have a steady source of nitrogen and do not require nitrogen-containing fertilizers.

The nitrogen cycle describes the processes by which nitrogen moves between its various chemical forms. Biological or physical processes can cause these chemical conversions. Four processes are essential to the nitrogen cycle.

Nitrogen fixation refers to the process by which atmospheric nitrogen (N_2) is converted to nitrogen–containing compounds that are usable by plants. Nitrogen fixation can be accomplished through the action of lightning or bacteria in the soil.

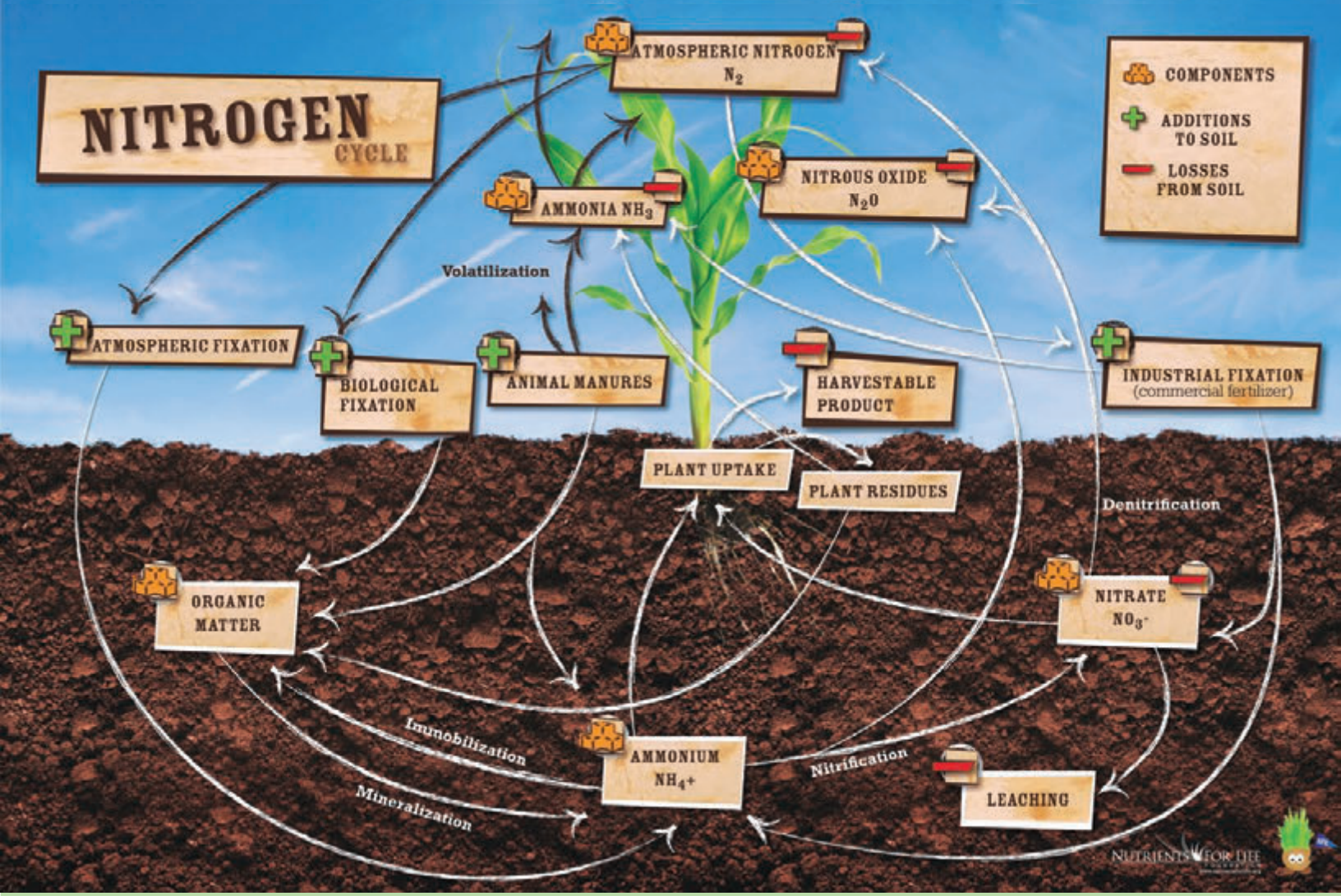
Ammonification refers to the process by which bacteria and fungi convert decomposed nitrogen-containing compounds into ammonium ions (NH_4^+).

Nitrification refers to the process by which bacteria convert ammonium ions into nitrite (NO^{2-}). Other bacteria convert nitrite to nitrate (NO^{3-}). This is important because nitrites (NO^{2-}) can reach levels that are toxic to plants.

Denitrification refers to the process by which bacteria convert nitrates (NO^{3-}) back to atmospheric nitrogen (N_2).

Let's Summarize the Nitrogen Cycle!

First, recall that plants cannot use the nitrogen in the air that is so plentiful. When plants and animals die and decompose, they add nitrogen to the soil. Bacteria in the soil convert the nitrogen into compounds that plants can use. Plants take in these nitrogen-containing compounds through their roots and use them to grow. Animals and people eat the plants, use the nitrogen, and return it to the soil when they die and decompose.



WORD SCRAMBLE

BAICOILOGL XAOFIINT

RICNOGNAI RAALEMTI

ROINIICITANTEFD

TRNIETA

MIAMANO

MAOPSIETRCH GEONIRTN

EMUEGL

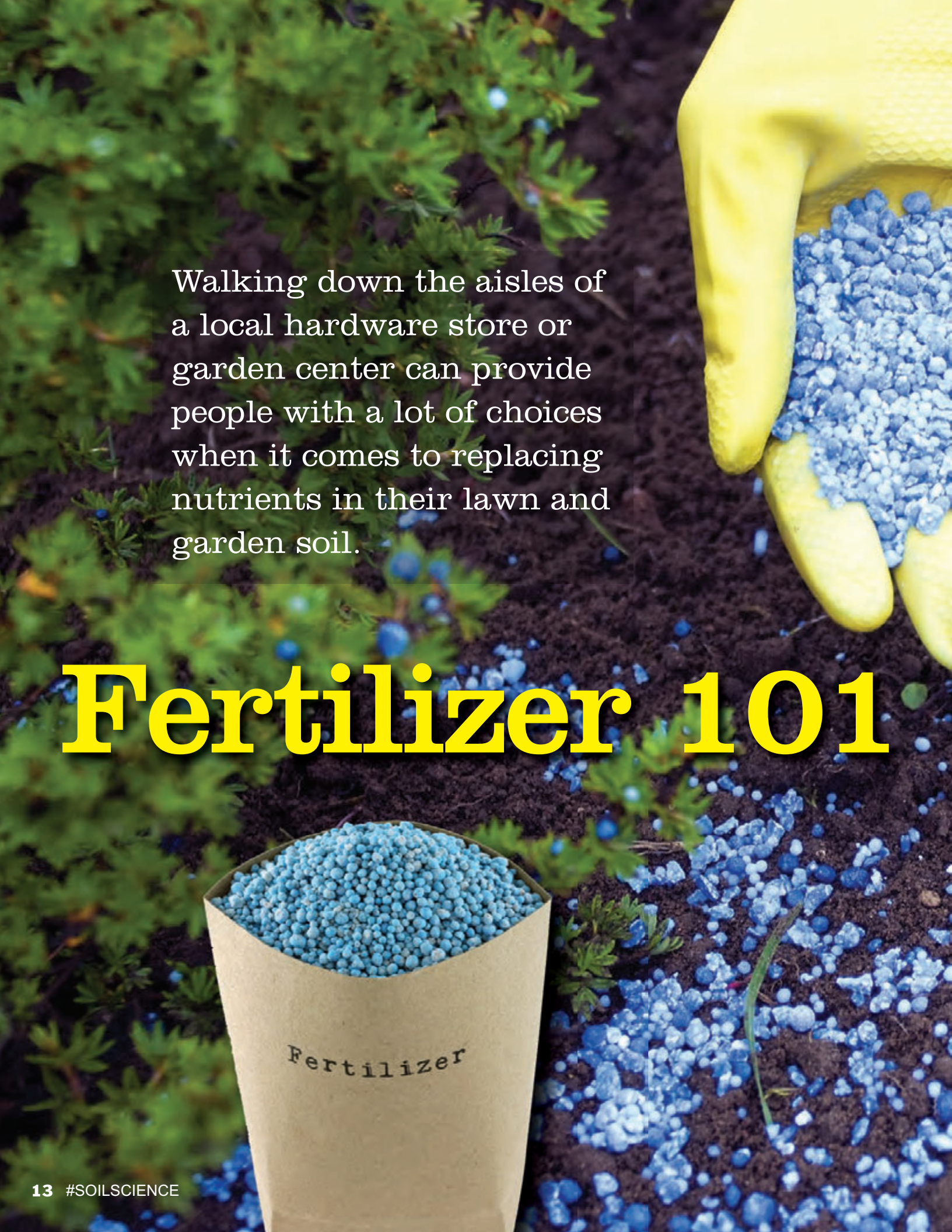
Directions: Unscramble each of the clue words. The clue words are terms you have read in this reader. Copy the letters in the numbered cells to other cells with the same number.

1	2	3	4	5	6	7	8

9	10	11	12
Y			

Walking down the aisles of a local hardware store or garden center can provide people with a lot of choices when it comes to replacing nutrients in their lawn and garden soil.

Fertilizer 101



Weed & Feed? 10-10-10? Slow release? What is in these bags? The answer is life's main ingredient: fertilizer. Fertilizer is used to replenish nutrients in soil. Plants remove nutrients from the soil; nutrients that help them grow healthy. These nutrients must be replaced for the next round of plants or crops. In areas where nothing is harvested, the nutrients removed by plants are returned to the soil after the plants die and decompose. In gardens, farms, and lawns, some of these nutrients are removed in the form of harvested crops and plants, so it is often necessary to replace them with fertilizers.

The essential components of most fertilizer are the macronutrients nitrogen (N), phosphorus (P), and potassium (K). All three of these elements play essential roles in ensuring healthy plant growth. Fertilizers can be applied as liquids or solids, or in some specialized cases on a farm, as a pressurized gas that is injected into the soil. Bags of fertilizer are the most common in garden centers. They are sold in a wide variety of mixtures.

What do those numbers on every bag mean? Each number stands for the percentage of the macronutrient, N, P, and K (in that order), in the container. A 10-10-10 fertilizer contains 10% nitrogen (N), 10% phosphate (P_2O_5), and 10% potash (K_2O). The label is the percentage by weight of the three macronutrients that plants need to be healthy N, P, and K. A label with an NPK ratio of 24-6-6 means that the fertilizer contains 24 percent nitrogen, 6 percent phosphate, 6 percent potash. Fertilizer labels also indicate the amounts of micronutrients and any inert ingredients, such as sand, that are included to provide bulk and make the fertilizer easier to apply.

Where do I start? A soil test analysis can provide some insight on a spectrum of nutrients in your soil, from Aluminum to Zinc. Whether on a large farm or a backyard garden, these tests can give a gardener or farmer important information about the land, help keep plants healthy, and harvests bountiful. The tests also tell you other important details about your soil, like the amount of organic matter and the soil's acidity. Based on your soil test analysis, choose an appropriate fertilizer product that replace the deficient nutrients in your soil. Also, consider the 4Rs when applying fertilizer:

Fertilizer 101

RIGHT SOURCE Matches fertilizer type to crop needs. Gardeners should ensure that the type of fertilizer used matches their garden's needs. Soil tests provide guidance for the use of appropriate soil amendments.

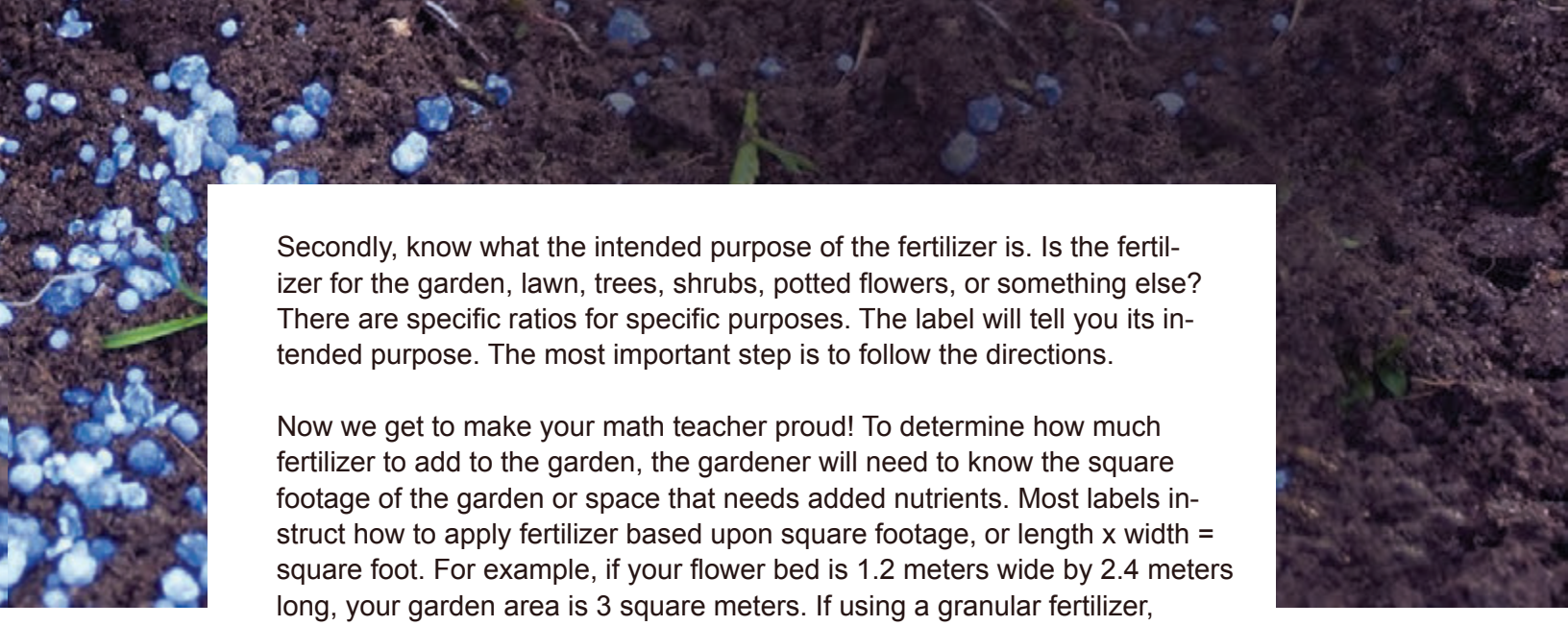
RIGHT RATE Matches amount of fertilizer to crop needs. Apply fertilizer at a rate that the plant can use. If the rate is too low, then your garden might suffer with less produce, flowering and growth. If the rate is too high then fertilizer is wasted and can leak into the environment.

RIGHT TIME Makes nutrients available when crops need them. Choose the best time to apply fertilizer. This means that the fertilizer should be applied when your garden needs the nutrients. For example, with regard to nitrogen, the fertilizer should be applied as close to plant roots as possible.

RIGHT PLACE Keeps nutrients where crops can use them. Gardens should apply fertilizer following the instructions and labels on the product. This helps avoid runoff or leaching into surface or groundwater.

> **"I am a little obsessed with fertilizer. I mean I'm fascinated with its role, not with using it. I go to meetings where it's a serious topic of conversation. I read books about its benefits and the problems with overusing it."**
>
> **- BILL GATES, NOV. 23, 2013**

How do you choose? First, decide to purchase organic or commercial fertilizer. Whether you choose organic or a commercial fertilizer, the ratio of nutrients will be listed the same way. Plants don't have a preference between organic and commercial. A nutrient is a nutrient to them. Generally, if you buy organic fertilizer the ratios will be lower. For example, fertilizer A is an organic fertilizer and is labeled 3-4-4 on the bag. Fertilizer B is a commercial fertilizer and is labeled 24-8-16. If a person chooses to use the organic fertilizer and the plants are showing a nitrogen deficiency, they will have to add more of the organic fertilizer than if they chose commercial fertilizer.



Secondly, know what the intended purpose of the fertilizer is. Is the fertilizer for the garden, lawn, trees, shrubs, potted flowers, or something else? There are specific ratios for specific purposes. The label will tell you its intended purpose. The most important step is to follow the directions.

Now we get to make your math teacher proud! To determine how much fertilizer to add to the garden, the gardener will need to know the square footage of the garden or space that needs added nutrients. Most labels instruct how to apply fertilizer based upon square footage, or length x width = square foot. For example, if your flower bed is 1.2 meters wide by 2.4 meters long, your garden area is 3 square meters. If using a granular fertilizer, be sure to work the fertilizer into the soil. Too much or too little will result in negative consequences so be sure to do the math and measure correctly! As the garden season progresses, gardeners need a bit of chemistry and math to have fertile soil and healthy vegetables and plants.

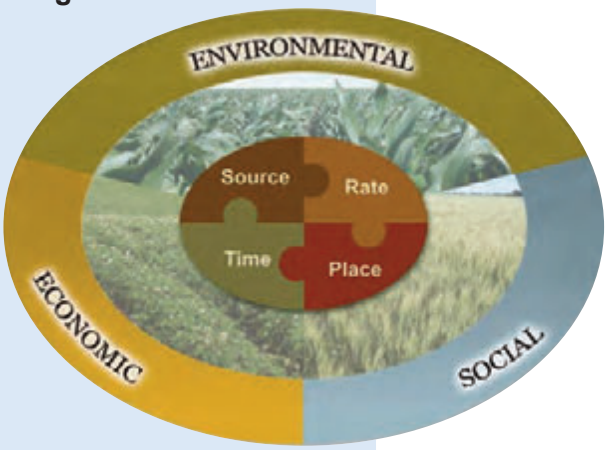
Think About It!

nutrient stewardship

A few years ago, the vegetable garden at Marcy's school was full of delicious produce. Now, the vegetable plants are barely blooming and have not grown very much this season.

1. What is the first action Marcy should take to fix her garden?

- ❒ Add fertilizer to the soil
- ❒ Switch out all of the plants for new ones
- ❒ Get a soil analysis
- ❒ Prune the plants

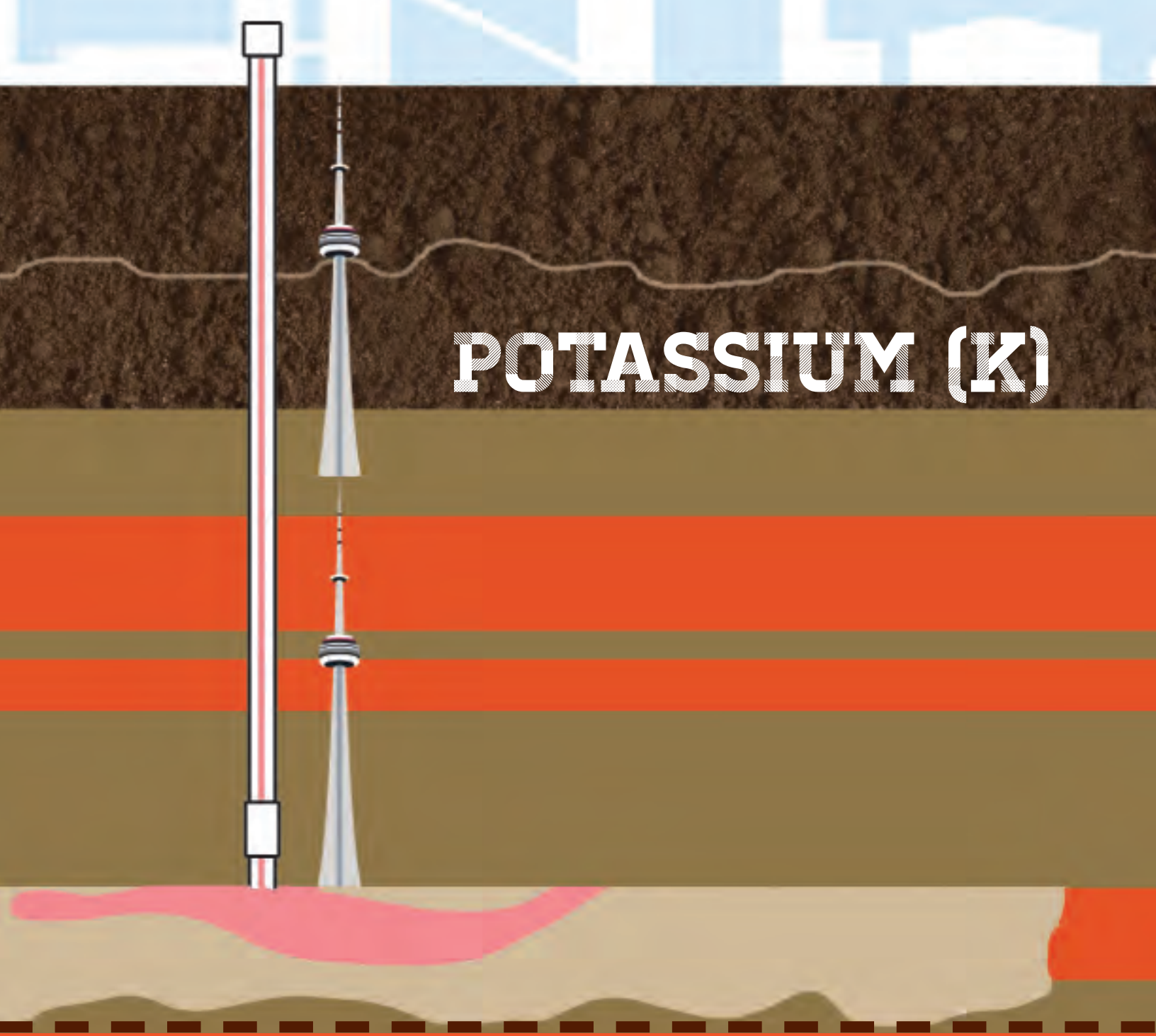


2. The garden at Marcy's school is 2.4 meters wide by 1.2 meters long. How many square feet is her garden?

- ❒ 1 square meter
- ❒ 1.5 square meters
- ❒ 3 square meters
- ❒ 9 square meters

3. Marcy's soil analysis recommends adding potassium to the soil. What is the percentage of potassium found in fertilizer labeled 24-8-16?

- ❒ 24%
- ❒ 8%
- ❒ 16%
- ❒ 48%

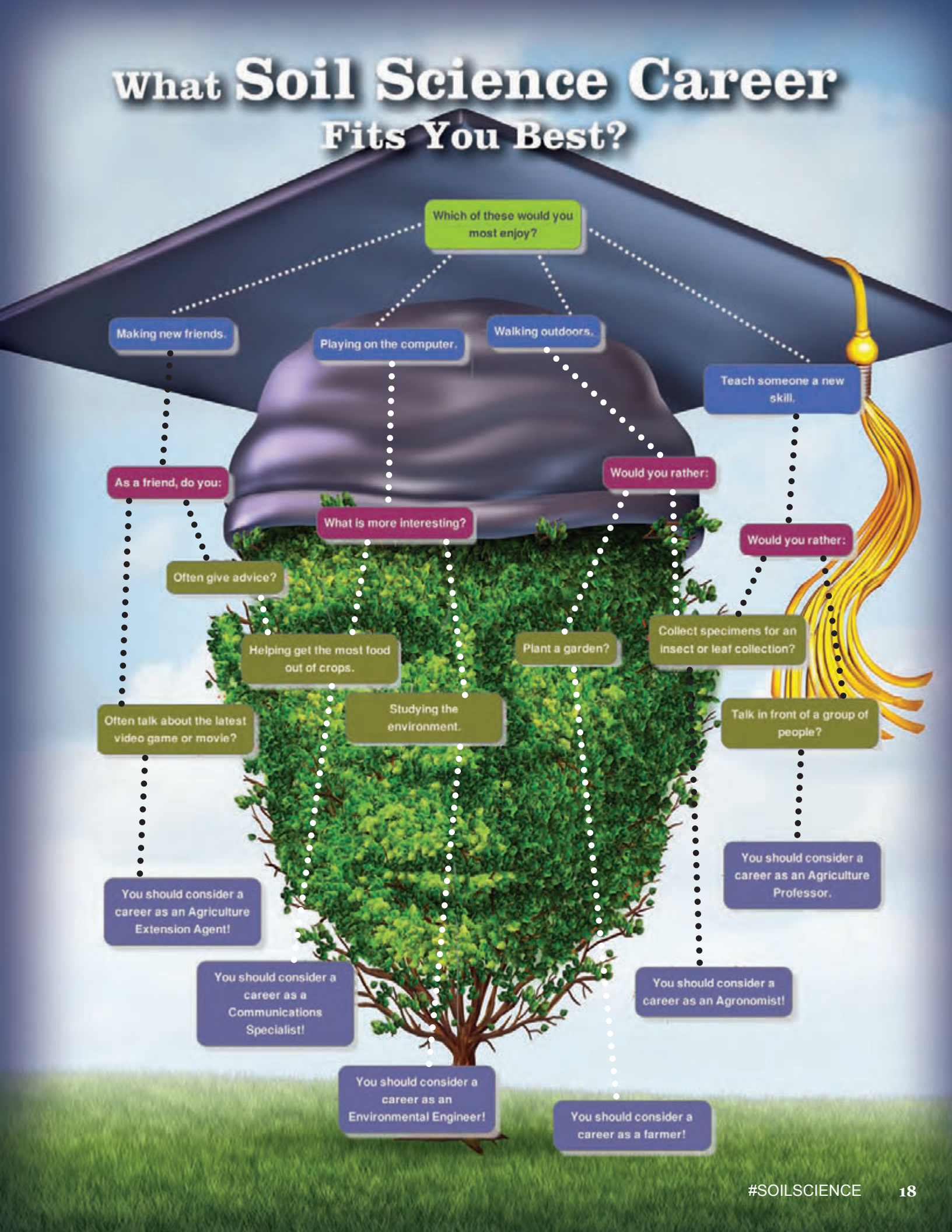


POTASSIUM (K)

When soil is lacking Potassium, plants simply can't grow as they should. Luckily, science has taught us how to reintroduce these important elements to the soil. Replacing nutrients in the soil is really important because by 2050 the world's population will likely reach 9.6 billion people. That's why farmers turn to fertilizers.

Reserves of potassium were deposited in prehistoric inland oceans. When they evaporated, the potassium salts crystallized into beds of potash ore. Today, most potash mines are deep shaft mines, up to 1,341 metres underground. That's about twice the height of the CN Tower.

What Soil Science Career Fits You Best?



Ladies and Gentlemen, Start Your Engines!

NASCAR Sprint Cup Series (NSCS) #51 BRANDT Professional Agriculture driver Justin Allgaier is racing to the feed the world. The world's population is expected to reach 9 billion people by 2050. One of the obstacles will be feeding this ever-growing population. That's why Justin's car is an "all agriculture" car - he wants people to understand that with a growing world population, fertilizers are essential to a healthy world food supply.

RACING

TO FEED THE WORLD THROUGH SOIL SCIENCE

Q: What is agriculture? Why is it important?

A: *Agriculture is so many things that it would be hard to define in such few words, but I'll do my best. Agriculture is the cultivation of plants and animals for food, fiber and fuel among many other things. Also, animals rely on plants for survival, so I guess it all goes back to the cultivation of plants. So many aspects of our everyday lives rely on agriculture... from the food we eat, to clothes, fuel in vehicles and even things like medicine and make-up.*

Q: Why do farmers and gardeners use fertilizer?

A: *I try to answer this question by making an analogy. Being an athlete, I need to be in top physical condition to properly perform my job. A big part of that is feeding my body correctly through balanced nutrition and having enough nutrients to build muscle and metabolism. Fertilizer provides plants a similar "balanced nutrition". For plants to grow to produce good quality food, they need to be fed additional nutrients as the soil often doesn't have an adequate supply.*

Q: Tell us more about why you have an "all agriculture" car?

A: *Most of the general public doesn't understand how important agriculture is to the global population and, we are using the "all agriculture" car to help raise awareness about the importance of agriculture. In the United States, just 2 percent of the population are farmers...that means that 2 percent of the population is required not only to feed the other 98% of the U.S. population, but even the population in other countries. This is why fertilizer is so important as we need to produce as much quality food as we can for a growing population.*

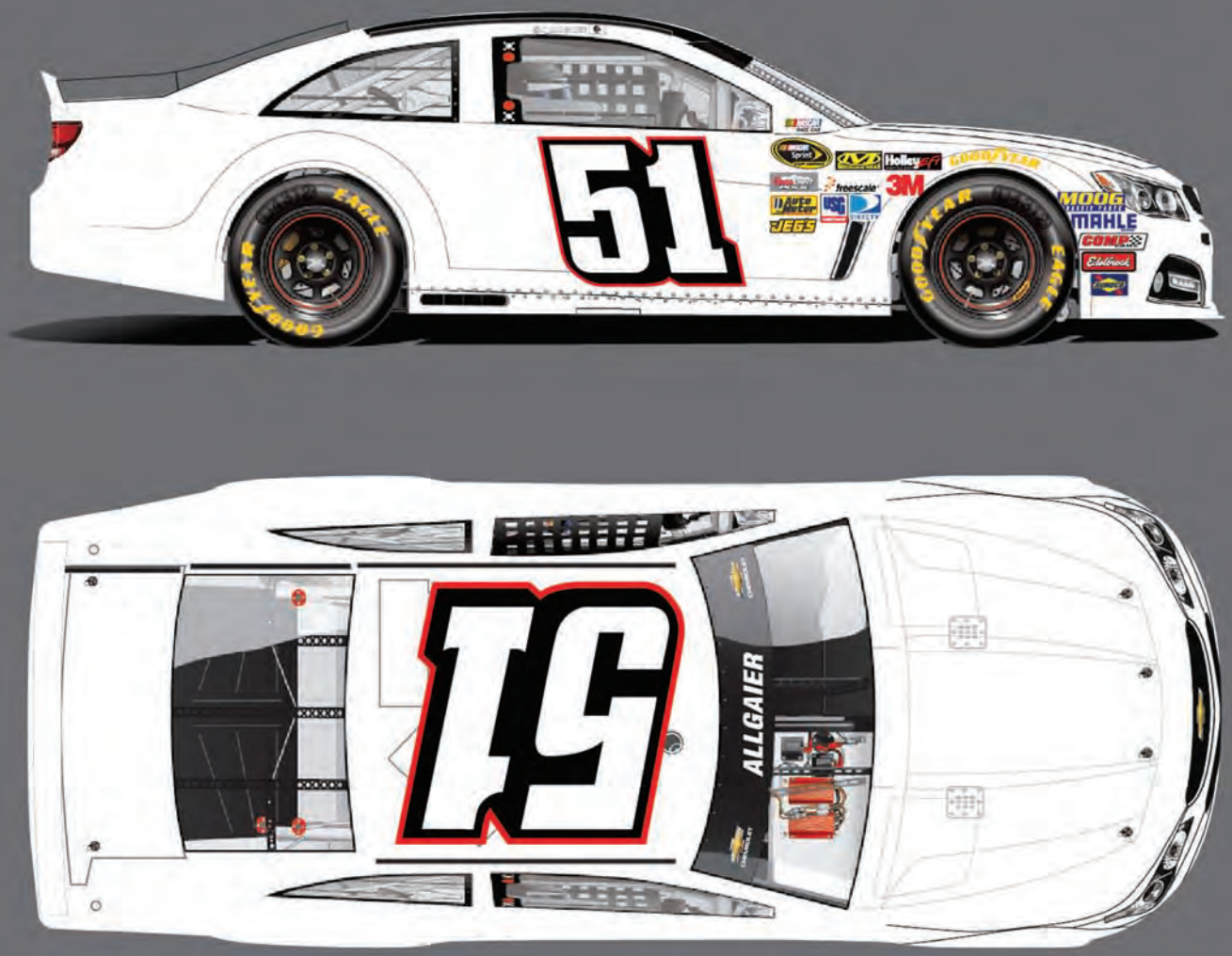
Q: What are the logos on your car?

A: *The main logo on my car is BRANDT Professional Agriculture. BRANDT is across the hood and the down the sides of the car. BRANDT logos are the largest on the car because they are the primary sponsor. The other agriculture related logos you will see on my racecar are located on the deck lid. It's basically the trunk lid on regular cars. We have the logos of Nutrients for Life, Future Farmers of America (FFA), Grigg Brothers, Monterey Lawn and Garden Products, TradeMark Nitrogen and Precision Tank and Equipment (PT&E).*

We are using the "all agriculture" car to help raise awareness about the importance of agriculture.

Q: What is your favorite thing about being a race car driver?

A: *First, it's my dream job and not a lot of people can say they have their dream job. My favorite part is meeting different people all over the country. I travel almost every week of the year, and I get to meet the fans at the race track. I also go to a lot of industry trade shows for BRANDT, so it gives me the opportunity to connect with a lot of people outside of racing. One of the neat things that happens is when people first meet me and they know nothing about racing. Then I run into them a couple of months later and they say "Hey, we met you in San Antonio, Texas, (or wherever it may have been), and we went to our first race to see what it was all about and had so much fun."*



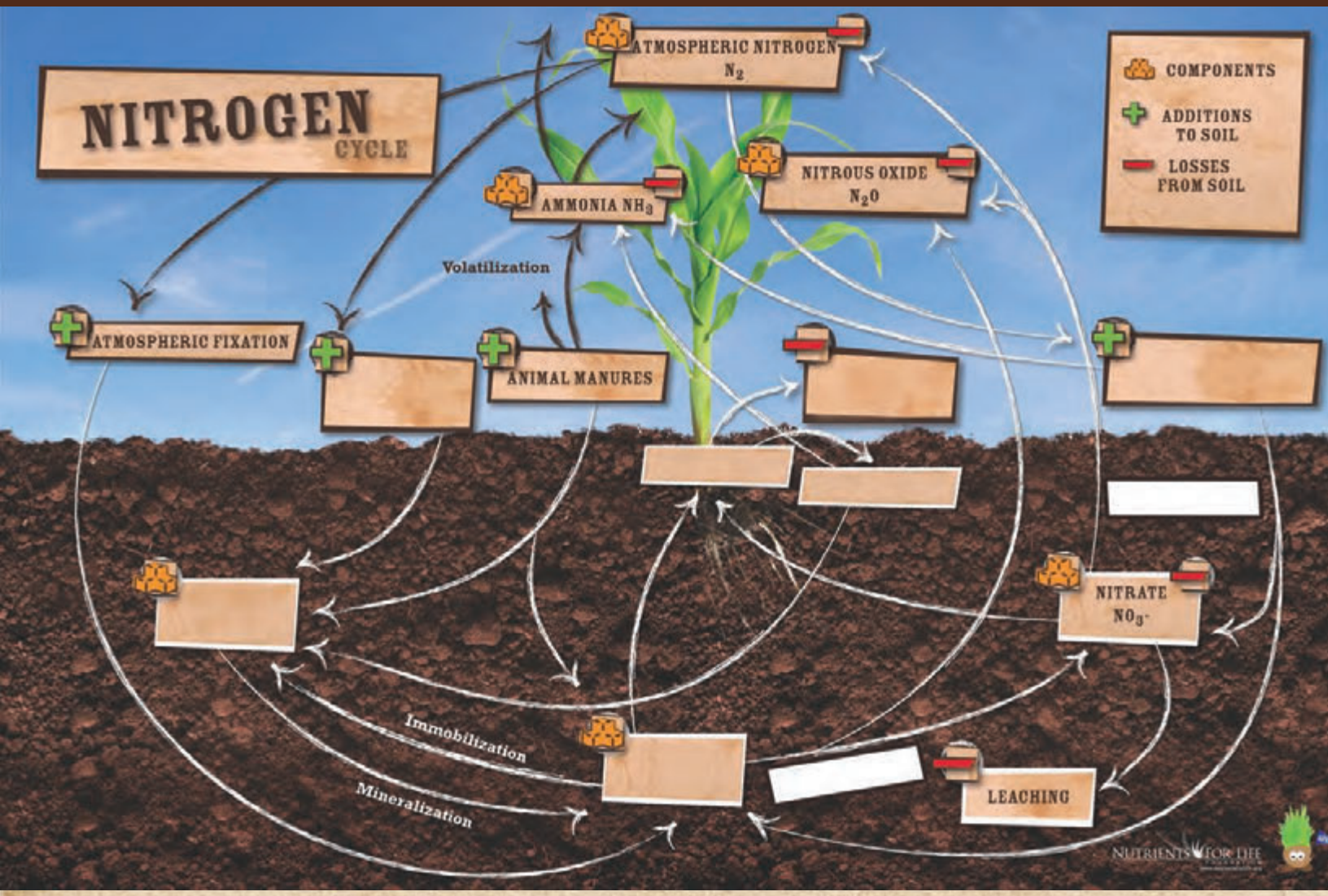
DESIGN YOUR OWN AGRICULTURE-BASED CAR!

Q: When you were in eighth grade, did you race cars?

A: *I did race cars in eighth grade. I was gone every night and weekend that I could be racing. My parents were very supportive of me wanting to race. They encouraged me to try a few other sports, and I did, but I enjoyed racing the most and decided to focus on it. I'm a little bit vertically challenged, that's a nice way of saying short, and so it always took me longer to get down the basketball court or the soccer field than everyone else. One thing I did have to do in order to keep racing is maintain a B average in school. My parents would drive me wherever they could for a race, but I had to keep my grades up if I wanted to* ***race.***

Q: What can the readers do to help feed the world in 2050?

A: *I think it's very important to learn how and where food is grown. That is from the farmer down to the individual growing food in a garden. It's also going to take science. It's going to take a collaborative effort to try to grow more food on less land, with less water. Getting the proper nutrients to the plant will be an essential part of the equation.*



Test Yourself!

Fill in the blanks using the word box provided without referring to earlier articles in the reader.

- ☐ NITRIFICATION
- ☐ DENITRIFICATION
- ☐ BIOLOGICAL FIXATION
- ☐ AMMONIUM (NH_4+)
- ☐ HARVESTABLE PRODUCT
- ☐ INDUSTRIAL FIXATION (COMMERCIAL FERTILIZER)
- ☐ ORGANIC MATTER
- ☐ PLANT UPTAKE
- ☐ PLANT RESIDUES

For more soil science and crop nutrient resources:

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