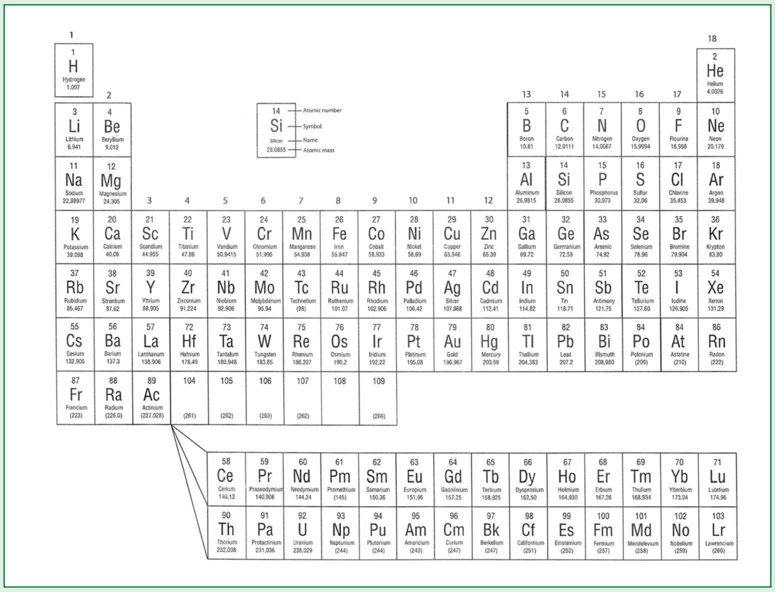
Lesson 1 | Engage

In Search of Essential Nutrients

At a Glance



Overview

Students explore the meaning of essential nutrients. They use periodic tables to compare the elements that are essential to people and plants. Students make predictions as to where in the environment plants obtain each of their essential elements. After a short reading about nitrogen fixation, they are given an opportunity to modify their prediction about nitrogen.

Major Concepts

- Plants require 17 essential nutrients to complete their life cycle.
- Plants and humans require similar sets of essential nutrients.
- Plants obtain their essential nutrients from air, water, and soil.

Objectives

After completing this lesson, students will be able to

- define an essential element,
- compare and contrast the essential nutrient requirements of plants and humans,
- explain why plants cannot use elemental nitrogen found in the atmosphere, and
- identify the sources for each essential nutrient needed by plants.

Teacher Background

Consult the following section in *Teacher Background:*

2.0 Plants and Their Essential Elements

In Advance

Photocopies

Activity 1	Master 1.1, *Essential Nutrients* (Prepare an overhead transparency.) Master 1.2, *The Periodic Table* (Make 1 copy per student and prepare an overhead transparency.) Master 1.3, *Essential Plant Nutrients* (Prepare an overhead transparency.) Master 1.4, *Essential Human Nutrients* (Prepare an overhead transparency.)
Activity 2	Master 1.5, *Sources of Essential Nutrients* (Make 1 copy per student and prepare an overhead transparency.) Master 1.6, *Using Nitrogen* (Make 1 copy per student.)

Materials

Activity 1	1 coloured pencil per student
Activity 2	No materials except photocopies

Preparation

No preparations are needed except for making photocopies and transparencies.

Procedure

Teacher note

In this activity, the terms nutrient and chemical element are used interchangeably. In the context of plant requirements, carbon, oxygen, and hydrogen are called the non-mineral nutrients. Remember, it is not important to discuss each essential element; rather, you should focus on those elements that are important in building proteins, nucleic acids, lipids, and carbohydrates.

Activity 1: Essential Nutrients

1. **Begin the lesson by explaining that scientists who are interested in studying human health must understand the specific needs of the body. Ask students, "What do humans need to live?"**

   Accept all answers. Write student responses on the board or on an overhead transparency. Direct the discussion to elicit air (oxygen), water, and food. Some students may realize that sleep is also required for survival. Other students may suggest environmental conditions such as temperature and pressure or material things such as clothing and shelter.

2. **Remind students that life requires energy for its existence. Ask students, "What do people take into their bodies from their environment to help them survive?"**

   Students should recognize from their previous answers that air, water, and food are obtained from the environment.

3. **Ask students, "Why do we need air, water, and food to survive?"**
   - Students should recognize that it is the oxygen in the air that we require.
   - Students should be able to explain that our cells are mostly made of water. Water is the medium in which life has evolved. It is required for the chemistry of life.
   - Students should recognize that we derive chemical energy from food and that it supplies the chemical building blocks needed by our cells.
4. **Remind students that humans (and animals) eat plants and other animals to obtain chemical energy and provide them with the building blocks needed by their cells. Ask students, "Do plants need food?"**

   Keep in mind that 'food' is an imprecise term that includes both a source of chemical energy and nutrients. Some students may respond that plants do not need food because they can obtain energy from photosynthesis. Other students may mention that plants need water or that they obtain nutrients from the soil. If not mentioned by a student, remind the class that fertilizers can be considered food for plants.
5. **Explain that they will now investigate the chemical elements that are essential for plant growth. Display a transparency of Master 1.1, Essential Nutrients. Ask different students to read aloud the criteria that describe an essential element.**

Expectations:

Students will:

- describe the characteristic physical and chemical properties of common elements and compounds.
- explain the relationships between the properties of elements and their position in the periodic table (e.g., with reference to atomic structure, group, and period)

6. **Pass out to each student a copy of Master 1.2, *The Periodic Table*. Instruct the class to think about the definition of "essential element" and use a coloured pencil to shade those elements on the periodic table that they think are essential for healthy plant growth. If possible, students should think of an example of how a given element is used by the plant (such as nitrogen being used to make protein or phosphorus being used to make ATP).**

   Give students about 5 minutes to complete this task. This step gives you an opportunity to assess how well students can relate their knowledge of chemistry to biology. For example, students may respond that carbon is used to make sugar. Students likely will not be able to suggest a function for elements needed in trace amounts. Usually, such elements are needed as cofactors for enzymes. It is not important to discuss the uses of each element, but it is important that students understand that these elements are needed to build cell structures and to carry out the cell's chemistry through enzymatic reactions.
7. **Display a transparency of Master 1.2, *The Periodic Table*. Ask a student volunteer to read aloud the elements shaded on his or her periodic table. Have the volunteer explain why he or she selected those particular elements. Have additional students add to the list with their predictions.**

As the elements are read off, circle them on the transparency. Students are not expected to identify the complete list of essential elements. Their responses however, will reflect their relative knowledge about the biology of plants.

8. **Explain that you are now going to reveal which elements have been shown to be essential for plant growth and compare them with students' predictions. Display a transparency of Master 1.3, *Essential Plant Nutrients*.**

   Students likely will be surprised that so many elements are essential for plant growth. The comparison between the elements predicted by the students and the accepted ones should show some overlap, especially among the most abundant elements: carbon (C), hydrogen (H), nitrogen (N), oxygen (O), phosphorus (P), and sulphur (S). If not already mentioned, ask students to name an important molecule in the cell that requires the element phosphorus. If not mentioned, you can explain that the most important energy molecule in the cell is adenosine triphosphate (ATP) and it includes the element phosphorus.

Expectations:

Students will:

- describe the structure of important biochemical compounds, including carbohydrates, proteins, lipids, and nucleic acids, and explaintheir function within cells.

9. **Ask, "Do you think that humans require the same essential elements as plants?"**

   Responses will vary. Some students may think that since humans and plants are very different from each other, they will need different sets of elements. Others may reason that since plants and humans are each made of cells, the essential elements needed by both will be similar.

10. **Display a transparency of Master 1.4, *Essential Human Nutrients.* Ask students to comment on how similar or dissimilar the pattern of elements is compared with that shown previously for plants.**

    Students should notice that the two patterns are more alike than different. To make this point clearer, you can align and overlap the transparencies of Masters 1.3, *Essential Plant Nutrients* and 1.4, *Essential Human Nutrients*.

Activity 2: Sources of Essential Nutrients

Teacher note

This activity is designed to get students thinking about where plants obtain their essential nutrients. Some essential nutrients are obtained from more than one source. For the purpose of this activity, you want students to realize that plants obtain their non-mineral nutrients (carbon, hydrogen, and oxygen) from the air and water, while the rest come from the soil.

1. **Explain that you will conclude the lesson with a brief activity that explores from where plants obtain their essential nutrients.**

2. **Pass out to each student a copy of Master 1.5, *Sources of Essential Nutrients*. Explain that the handout lists the 17 essential plant nutrients. Instruct students to think about where a corn plant obtains its essential nutrients. Students should indicate the source—air, water, and soil—of each nutrient (that is, each chemical element) by checking the appropriate boxes on the handout.**

For the purpose of this activity, students should think about water as rainfall (before it reaches the ground). It therefore should not include those elements found in soil that may be dissolved in it. Students are free to check more than one box for any element. Give students about 5 minutes to complete this task.

Expectations:

Students will:

- explain the concept of the cycling of substances in ecosystems (e.g., fertilizers made from biosolids leach into ground water or run off into rivers and streams, where the chemicals are absorbed by aquatic life, which is in turn consumed by humans).

3. **Display a transparency of Master 1.5, *Sources of Essential Nutrients.* Ask a student volunteer to describe which elements he or she listed as coming from water.**

   Put a "W" next to the elements named by the students. Of course, students should mention hydrogen and oxygen. Actually, rainwater may contain small amounts of other elements derived from atmospheric gases and dust particles. Other elements that could be mentioned include C, Cl, N, and S.

4. **Ask another volunteer to describe which elements he or she listed as coming from the air.**

   Put an "A" next to the elements named by the students. Students should recognize that the corn plant obtains carbon (via CO_2) and oxygen (via O_2) from the air. Some students may know that most of the atmosphere is nitrogen (as N_2). Most students will not realize that nitrogen gas is not available to the corn plant in a usable form. Do not correct this misconception yet. This issue will be addressed in Step 7. As with water, small amounts of other elements also may be present due to air pollution.

5. **Ask another volunteer to describe which elements he or she listed as coming from the soil.**

   Put an "S" next to the elements named by the students. Students should list most if not all of the essential elements. The soil not only contains many elements that reflect its geological history, but it also contains organic material from once-living plants and animals as well as from the abundant microbial life that resides there.

Answers to Master 1.5, *Sources of Essential Nutrients*

Essential Nutrient		Source	
	Air	Water	Soil
Boron (B)			S
Calcium (Ca)			S
Carbon (C)	A		S
Chlorine (Cl)			S
Copper (Cu)			S
Hydrogen (H)	A	W	S
Iron (Fe)			S
Magnesium (Mg)			S
Manganese (Mn)			S
Molybdenum (Mo)			S
Nickel (Ni)			S
Nitrogen (N)			S
Oxygen (O)	A	W	S
Phosphorous (P)			S
Potassium (K)			S
Sulphur (S)			S
Zinc (Zn)			S

6. **Pass out to each student a copy of Master 1.6, *Using Nitrogen*. Instruct students to read the description and answer the questions.**
7. **After students have completed their tasks, ask them, "In the light of what you just read, would you change your prediction of where the corn plant obtains its nitrogen?"**

   Students should answer that the corn plant must obtain its nitrogen from the soil rather than from the air.
8. **Ask for a volunteer to read his or her answer to Question 1 on Master 1.6, *Using Nitrogen*.**

Answer to Question 1:

1. What do you think is responsible for converting most of the nitrogen used by plants into a usable form?

   Students should conclude that bacteria are responsible for fixing most of the nitrogen used by plants. Some nitrogen also is fixed by lightning and industrial processes, but these are much smaller amounts.

9. **Ask for a volunteer to read his or her answer to Question 2 on Master 1.6, *Using Nitrogen*.**

   Answer to Question 2:

2. Why is this ability of legumes to carry out their own nitrogen fixation important to farmers?

   Since the legumes can supply their own nitrogen in a usable form, farmers need not be concerned with replenishing the soil using nitrogen-containing fertilizers.

10. **Ask students to help you summarize where the corn plant gets its essential elements.**

    Likely student responses are the following:

    - Water: Hydrogen and oxygen.
    - Air: Carbon and oxygen.
    - Soil: All essential elements.

11. **Conclude the lesson by summarizing that the plant obtains the nutrients carbon, hydrogen, and oxygen from the water and the air, while the rest are obtained from the soil.**

12. **Explain that farmers need to know which essential elements are found in the soil and how much of each is present. Ask students to think of where the essential nutrients found in the soil come from.**

    Student responses will vary. At this time, accept all answers. If not mentioned, use guided questions to bring out the fact that essential elements in the soil come from multiple sources that include

    - natural ones, such as the erosion of rocks;
    - the action of lightning;
    - the decomposition of plant and animal material, including soil organic matter (the dark layer at the soil surface);
    - human-associated activities, such as organic and commercial fertilizer use by farmers and the public, as well as from waste that humans produce; and
    - emissions from industry and automobiles.

13. **Explain that in the next lesson they will investigate the composition of soils and explore how plants and soils interact with each other.**

Optional Homework Assignment

Dieticians use the food pyramid to represent a healthy diet, balanced between the four food groups. Plants, too, must take in a balance of nutrients. Instruct students to prepare a "meal plan" for plants.

Students should recall that plants obtain their essential nutrients from three sources: air, water, and soil. These three sources can be thought of as the plant's food groups. Refer students to the sources for each essential element that they listed on Master 1.5, *Sources of Essential Nutrients*. The needed percentages from each food group (source) in their meal plan can be estimated by counting the number of elements from each food group and dividing by the total number of essential elements (17). For example, if a student listed just hydrogen and oxygen as coming from the air, then the percentage of needed nutrients from that group would be 2 ÷ 17 = 0.12 or 12 percent.

Teacher note

Note that this calculation assumes that each essential element is needed in equal amounts, which is not true. The main point of this exercise is to emphasize that the majority of the nutrients needed by the plant come from the soil.

Lesson 1 Organizer

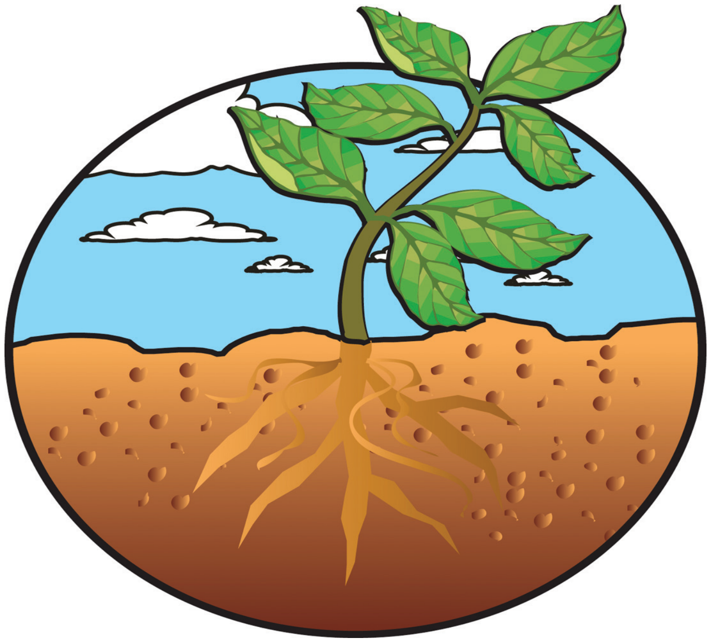
Activity 1: *Essential Nutrients* **What the Teacher Does**	**Procedure Reference**
Explain that health scientists must understand the needs of the body. Ask students, "What do humans need to live?"	Page 52 Step 1
Remind students that life requires energy. Ask students: ■ "What do people take into their bodies from their environment to help them survive?" ■ "Why do we need air, water, and food to survive?"	Page 52 Step 2 Page 53 Step 3
Remind students that humans eat plants and animals to obtain chemical energy and the building blocks needed by their cells. ■ Ask students, "Do plants need food?"	Page 53 Step 4
Explain that they will investigate the chemical elements needed for plant growth. ■ Display a transparency of Master 1.1., *Essential Nutrients*. ■ Have students read it aloud.	Page 53 Steps 5
Give each student 1 copy of Master 1.2, *The Periodic Table*. ■ Instruct students to shade those elements that they think are essential to plant growth.	Page 53 Step 6
Display a transparency of Master 1.2, *The Periodic Table*. ■ Ask a volunteer to read aloud the elements he or she shaded. ■ Ask the volunteer to explain his or her reasoning. ■ Solicit responses from other students.	Page 53 Step 7
Explain that they will reveal which elements are known to be essential for plant growth. ■ Display a transparency of Master 1.3., *Essential Plants Nutrients*.	Page 54 Step 8
Ask, "Do you think that humans require the same essential elements as plants?".	Page 54 Step 9
Display a transparency of Master 1.4, *Essential Human Nutrients*. ■ Ask students how similar or dissimilar the pattern is compared with that shown previously for plants.	Page 54 Step 10

M = Involves copying a master

T = Involves making a transparency

Lesson 1 Organizer *continued*

Activity 2: *Sources of Essential Elements* What the Teacher Does	Procedure Reference
Explain to students that they will explore from where plants obtain their essential nutrients.	Page 54 Step 1
Give each student 1 copy of Master 1.5, *Sources of Essential Nutrients*. ■ Instruct students to indicate on the master from where (air, water, or soil) the plant gets each nutrient.	Page 54 Step 2 M
Display a transparency of Master 1.5, *Sources of Essential Elements*. ■ Ask a volunteer to describe which elements he or she listed as coming from water. ■ Ask another volunteer which elements he or she listed as coming from the air. ■ Ask a volunteer to describe which elements he or she listed as coming from the soil.	Page 55 Step 3–5 T
Give each student 1 copy of Master 1.6, *Using Nitrogen*. ■ Instruct students to read the description and answer the questions.	Page 56 Steps 6 M
Ask students if they want to change their prediction of where the corn plant gets its nitrogen.	Page 56 Step 7
Ask a volunteer to read his or her answer to Question 1. Ask a volunteer to read his or her answer to Question 2.	Page 56 Steps 8 and 9
Ask students to summarize where the corn plant gets its essential elements. ■ Carbon, hydrogen, and oxygen come from water and air, while the rest come from the soil.	Page 57 Step 10 and 11
Explain that farmers must know which essential elements are found in their soil and in what amounts. ■ Ask students where the essential elements in soil come from.	Page 57 Step 12
Explain that in the next lesson, they will investigate the composition of soils and explore how plants and soils interact.	Page 57 Step 13 M



An essential element

1. is required for a plant to complete its life cycle;
2. cannot be replaced by another element;
3. is directly involved in the plant's metabolism; and
4. is required by many different plants.

Adapted from Arnon, D., & Stout, P. (1939, July). The essentiality of certain elements in minute quantity for plants with special reference to copper. *Plant Physiology, 14(3), 599–602.*

Master 1.2, *The Periodic Table*

Name

Date

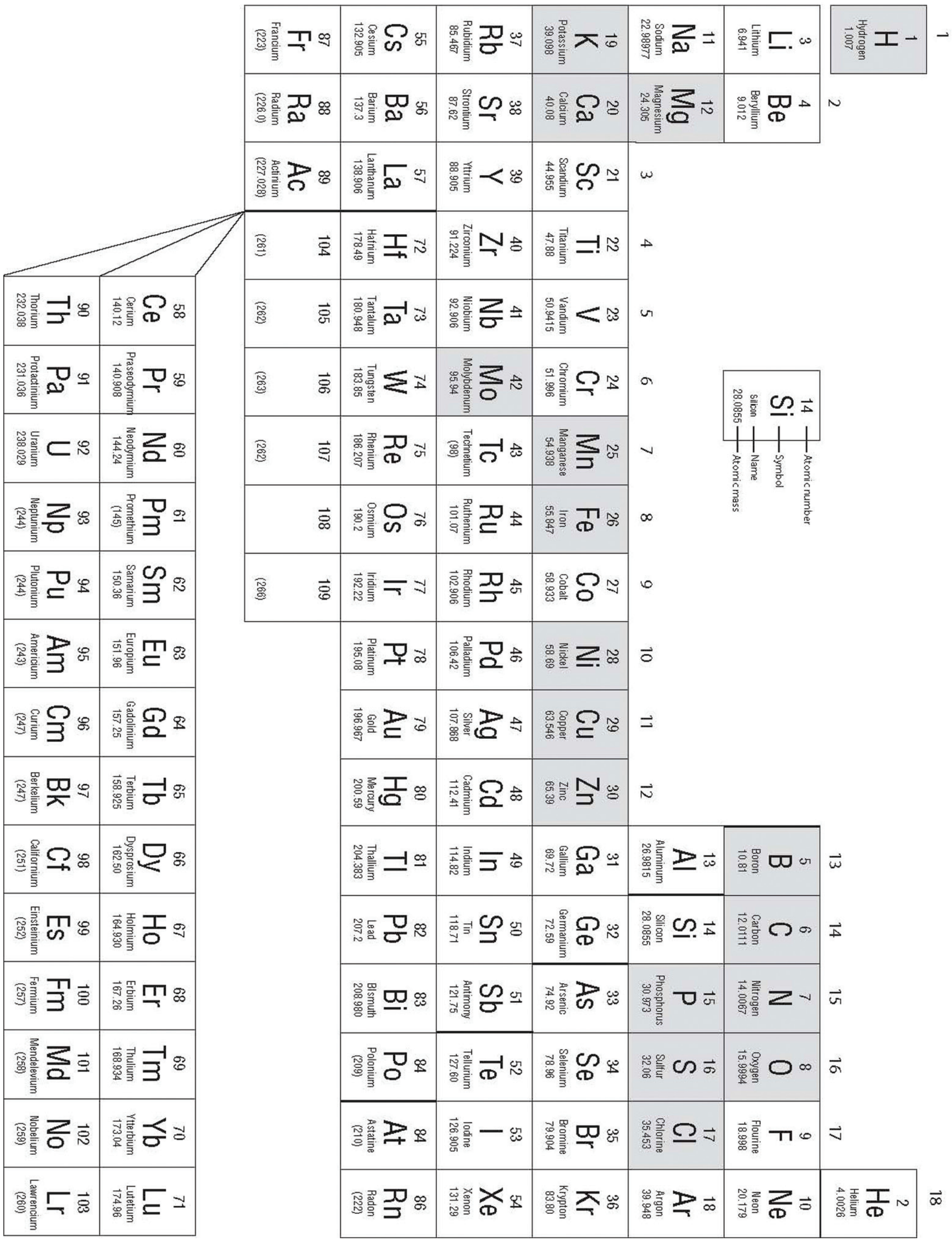
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H Hydrogen 1.007																	2 He Helium 4.0026
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.81	6 C Carbon 12.0111	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Flourine 18.998	10 Ne Neon 20.179
11 Na Sodium 22.98977	12 Mg Magnesium 24.305											13 Al Aluminum 26.9815	14 Si Silicon 28.0855	15 P Phosphorus 30.973	16 S Sulfur 32.06	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.08	21 Sc Scandium 44.955	22 Ti Titanium 47.88	23 V Vandium 50.9415	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.847	27 Co Cobalt 58.933	28 Ni Nickel 58.69	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.72	32 Ge Germanium 72.59	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80
37 Rb Rubidium 85.467	38 Sr Strontium 87.62	39 Y Yttrium 88.905	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.75	52 Te Tellurium 127.60	53 I Iodine 126.905	54 Xe Xenon 131.29
55 Cs Cesium 132.905	56 Ba Barium 137.3	57 La Lanthanum 138.906	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.2	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.967	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium (209)	84 At Astatine (210)	86 Rn Radon (222)
87 Fr Francium (223)	88 Ra Radium (226.0)	89 Ac Actinium (227.028)	104 (261)	105 (262)	106 (263)	107 (262)	108	109 (266)									

58 Ce Cerium 140.12	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.50	67 Ho Holmium 164.930	68 Er Erbium 167.26	69 Tm Thulium 168.934	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.96
90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium (244)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (260)

Key:

14 Si Silicon 28.0855	
14	Atomic number
Si	Symbol
Silicon	Name
28.0855	Atomic mass

Master 1.3, *Essential Plant Nutrients*



Master 1.4, *Essential Human Nutrients*

14	Atomic number
Si	Symbol
Silicon	Name
28.0855	Atomic mass

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H Hydrogen 1.007																	2 He Helium 4.0026
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.81	6 C Carbon 12.0111	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Flourine 18.998	10 Ne Neon 20.179
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19 K Potassium 39.098	20 Ca Calcium 40.08	21 Sc Scandium 44.955	22 Ti Titanium 47.88	23 V Vandium 50.9415	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.847	27 Co Cobalt 58.933	28 Ni Nickel 58.69	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.72	32 Ge Germanium 72.59	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80
37 Rb Rubidium 85.467	38 Sr Strontium 87.62	39 Y Yttrium 88.905	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.75	52 Te Tellurium 127.60	53 I Iodine 126.905	54 Xe Xenon 131.29
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Master 1.5, *Sources of Essential Nutrients*

Name

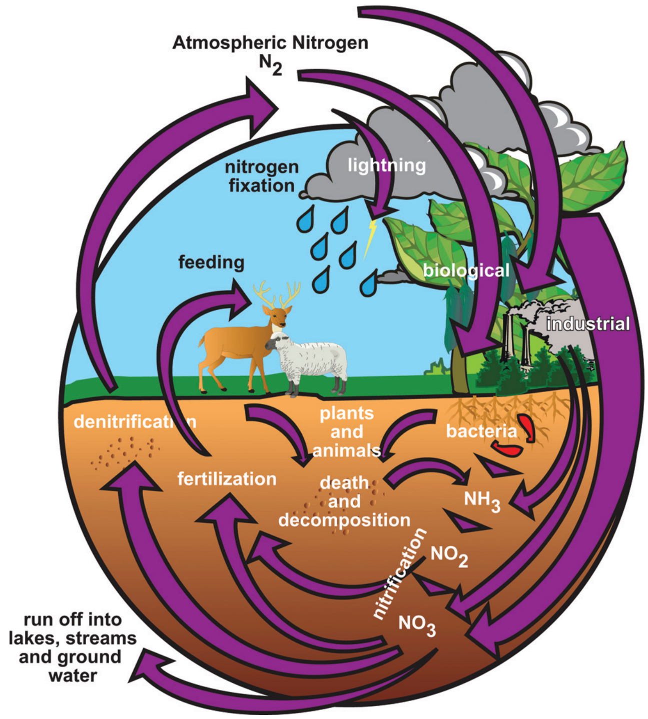
Date

		Source	
Essential Nutrient	Air	Water	Soil
Boron (B)			
Calcium (Ca)			
Carbon (C)			
Chlorine (Cl)			
Copper (Cu)			
Hydrogen (H)			
Iron (Fe)			
Magnesium (Mg)			
Manganese (Mn)			
Molybdenum (Mo)			
Nickel (N)			
Nitrogen (N)			
Oxygen (O)			
Phosphorous (P)			
Potassium (K)			
Sulphur (S)			
Zinc (Zn)			

Master 1.6, *Using Nitrogen*

Name

Date



For many plants, the availability of nitrogen limits their growth. This fact is surprising since the air is nearly 80 percent nitrogen. However, the nitrogen gas (N_2) in the air cannot be used directly by plants. First, it must be combined with other elements such as hydrogen or oxygen in the form of ammonium (NH_4+) or nitrate (NO_3-) before plants can use it.

Questions

1. Look at the graphic of the nitrogen cycle. What do you think is responsible for converting most of the nitrogen used by plants into a usable form?

2. Plants of the legume family, such as peas and beans, live in a symbiotic relationship with bacteria that live in their roots. The bacteria use sugars from the plants to produce energy. In return, the bacteria take nitrogen from the air and convert it to a form that the plants can use. Why is this ability of legumes to carry out their own nitrogen fixation important to farmers?