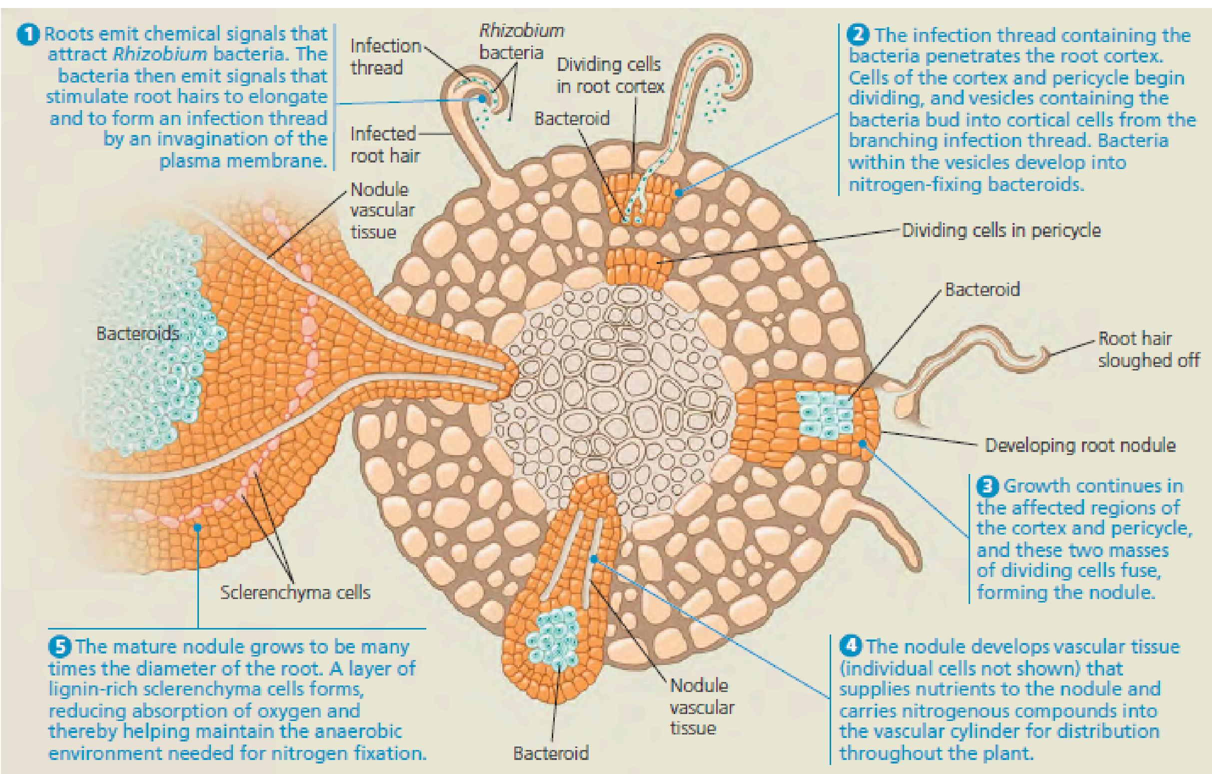
Cheat Sheet

Table 37.1 Essential Elements in Plants

Element	Form Primarily Absorbed by Plants	% Mass in Dry Tissue	Major Functions
Macronutrients			
Carbon	CO_2	45%	Major component of plant's organic compounds
Oxygen	CO_2	45%	Major component of plant's organic compounds
Hydrogen	H_2O	6%	Major component of plant's organic compounds
Nitrogen	NO_3^-, NH_4^+	1.5%	Component of nucleic acids, proteins, hormones, chlorophyll, coenzymes
Potassium	K^+	1.0%	Cofactor that functions in protein synthesis; major solute functioning in water balance; operation of stomata
Calcium	Ca^{2+}	0.5%	Important in formation and stability of cell walls and in maintenance of membrane structure and permeability; activates some enzymes; regulates many responses of cells to stimuli
Magnesium	Mg^{2+}	0.2%	Component of chlorophyll; cofactor and activator of many enzymes
Phosphorus	$H_2PO_4^-$, HPO_4^{2-}	0.2%	Component of nucleic acids, phospholipids, ATP, several coenzymes
Sulfur	SO_4^{2-}	0.1%	Component of proteins, coenzymes
Micronutrients			
Chlorine	Cl^-	0.01%	Required for water-splitting step of photosynthesis; functions in water balance
Iron	Fe^{3+}, Fe^{2+}	0.01%	Component of cytochromes; cofactor of some enzymes; needed for photosynthesis
Manganese	Mn^{2+}	0.005%	Active in formation of amino acids; activates some enzymes; required for water-splitting step of photosynthesis
Boron	$H_2BO_3^-$	0.002%	Cofactor in chlorophyll synthesis; may be involved in carbohydrate transport and nucleic acid synthesis; role in cell wall function
Zinc	Zn^{2+}	0.002%	Active in formation of chlorophyll; cofactor of some enzymes; needed for DNA transcription
Copper	Cu^+, Cu^{2+}	0.001%	Component of many redox and lignin-biosynthetic enzymes
Nickel	Ni^{2+}	0.001%	Cofactor for an enzyme functioning in nitrogen metabolism
Molybdenum	MoO_4^{2-}	0.0001%	Essential for mutualistic relationship with nitrogen-fixing bacteria; cofactor in nitrate reduction



Epiphytes

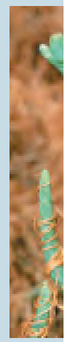
An **epiphyte** (from the Greek *epi*, upon, and *phyton*, plant) is a plant that grows on another plant. Epiphytes produce and gather their own nutrients; they do not tap into their hosts for sustenance. Usually anchored to the branches or trunks of living trees, epiphytes absorb water and minerals from rain, mostly through leaves rather than roots. Some examples are staghorn ferns, bromeliads, and many orchids, including the vanilla plant.

► **Staghorn fern**, an epiphyte

Parasitic Plants

Unlike epiphytes, parasitic plants absorb water, minerals, and sometimes products of photosynthesis from their living hosts. Many species have roots that function as haustoria, nutrient-absorbing projections that tap into the host plant. Some parasitic species, such as orange-colored, spaghetti-like dodder (genus *Cuscuta*), lack chlorophyll entirely, whereas others, such as mistletoe (genus *Phoradendron*), are photosynthetic. Still others, such as Indian pipe (*Monotropa uniflora*), absorb nutrients from the hyphae of mycorrhizae associated with other plants.

◄ **Mistletoe**, a photosynthetic parasite



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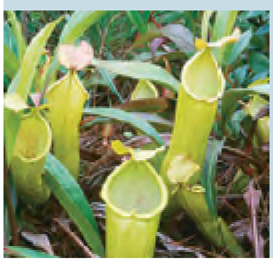
Carnivorous Plants

Carnivorous plants are photosynthetic but supplement their mineral diet by capturing insects and other small animals. They live in acid bogs and other habitats where soils are poor in nitrogen and other minerals. Pitcher plants such as *Nepenthes* and *Sarracenia* have water-filled funnels into which prey slip and drown, eventually to be digested by enzymes (see also Figure 37.1). Sundews (genus *Drosera*) exude a sticky fluid from tentacle-like glands on highly modified leaves. Stalked glands secrete sweet mucilage that attracts and ensnares insects, and they also release digestive enzymes. Other glands then absorb the nutrient "soup." The highly modified leaves of Venus flytrap (*Dionaea muscipula*) close quickly but partially when a prey hits two trigger hairs in rapid enough succession. Smaller insects can escape, but larger ones are trapped by the teeth lining the margins of the lobes. Excitation by the prey causes the trap to narrow more and digestive enzymes to be released.



Chapter 37 Questions

1. **What is *Genlisea*?**
2. **What does the texture of soil depend on (range)?**
3. **What is humus?**
4. **What is topsoil?**
5. **What are soil horizons?**
6. **What are loams?**
7. **Why do smaller spaces in the soil retain water?**
8. **What is leaching?**
9. **What is cation exchange?**
10. **What is fertilization?**
11. **What is sustainable agriculture?**
12. **What are aquifers?**
13. **What is land subsidence?**
14. **What is soil salinization?**
15. **What is drip irrigation?**
16. **What elements are fertilizers enriched with?**
17. **How is soil pH adjusted and why?**
18. **Why is very acidic soil (pH 5 or lower) toxic to plants?**
19. **What is no-till agriculture?**
20. **What is phytoremediation?**
21. **What is *Thlaspi caerulescens*?**
22. **Describe the percentages of materials that make up a plant's mass?**
23. **What is an essential element?**
24. **What is a hydroponic culture?**
25. **What are macronutrients?**
26. **What mineral nutrient contributes the most to plant growth?**
27. **What are micronutrients?**
28. **What does a magnesium deficiency cause?**
29. **What does iron deficiency cause?**
30. **How does mobility affect the symptoms of mineral deficiency?**
31. **What does excess nitrogen cause in tomato plants?**
32. **How have scientists induced aluminum resistance in plants?**
33. **What are smart plants?**
34. **What are rhizobacteria?**
35. **What are endophytes?**
36. **What are the 3 ways that soil nitrogen is produced?**
37. **What is the nitrogen cycle?**
38. **In what form do plants commonly acquire nitrogen?**
39. **How is soil nitrate formed?**
40. **How do plants utilize soil nitrate?**

41. How is soil nitrogen lost?
42. What is nitrogen fixation?
43. What is *Rhizobium*?
44. What are nodules?
45. What are bacteroids?
46. What conditions do *Rhizobium* bacteria require?
47. How does a nodule develop?
48. What is crop rotation?
49. What are *Alnus rubra* and *Azolla*?
50. What are mycorrhizae?
51. What are ectomycorrhizae?
52. What are arbuscular mycorrhizae?
53. Describe epiphytes, parasitic plants, and carnivorous plants.

Chapter 37 Answers

1. Wetland herb with root-like modified leaves that trap and digest small soil inhabitants
2. particle size (2 mm - less than 0.002 mm)
3. REmains of dead organisms and other organic matter, prevents packing of clay particles, forms crumbly soil that retains water, aerates roots, increases soil's capacity to exchange cations, acts as reservoir of mineral nutrients
4. Mineral particles mixed with living organisms and humus
5. Topsoil and other soil layers (topsoil = A horizon,
6. Topsoils that are the most fertile, composed of roughly equal amounts of sand (0.02-2 mm), silt (0.002 - 0.02 mm) and clay (less than 0.002 mm).
7. Water molecules are attracted to the negatively charged surfaces of clay/other particles
8. Percolation of water through the soil, drains anions but soil particles (negative) adhere to cations
9. Process where cations are displaced from soil particles by other cations, roots secrete CO_2 and hydrogen ions into soil to promote it
10. Addition of mineral nutrients to soil, could make soil a renewable resource
11. Commitment to farming practices that are conservative, environmentally safe, profitable
12. Underground water reserves, primary sources of irrigation water
13. Gradual settling or sudden sinking of Earth's surface, alters drainage patterns, causes damage to structures, contributes to loss of underground springs, increases risk of flooding, caused when rate of water removal exceeds natural refilling of aquifers
14. Addition of salts to soil that make it too salty for cultivating plants (salts diminish water uptake by decreasing water potential of soil)
15. Slow release of water to soil and plants from perforated plastic tubing at root zone
16. Nitrogen, phosphorus, potassium (nutrients most commonly deficient in depleted soils). Fertilizers labeled with 3 number code (N-P-K ratio, "15-10-5" = 15 % N (ammonium or nitrate), 10% phosphorus (phosphate), 5% potassium (mineral potash))
17. Sulfate lowers pH, lime (calcium carbonate/hydroxide) increases pH, pH makes some minerals available and some not so ideal pH depends on plant's needs
18. Makes toxic aluminum ions more soluble so are absorbed by roots, stunts root growth and prevents uptake of calcium, some plants secrete organic anions that render Al^{3+} harmless
19. Plowing technique that reduces erosion, special plow creates narrow furrows for seeds and fertilizer, field is seeded with minimal soil disturbance, less fertilizer necessary
20. Nondestructive biotechnology that uses plants to extract soil pollutants and concentrate them in easily-removable parts of the plant
21. Alpine pennycress, accumulates zinc in shoots, shoots harvested to remove zinc
22. 80-90% water, 96% of remaining is carbs.Substances from soil are only 4% of dry mass
23. Chemical element required for plant to complete life cycle/reproduce
24. Plants grown in mineral solutions instead of soil, used to identify 17 essential elements
25. 9 of the essential elements, required in relatively large amounts, see picture

26. Nitrogen, used in proteins, nucleic acids, chlorophyll, and other important molecules
27. Needed only in tiny quantities (chlorine, iron, manganese, boron, zinc, copper, nickel, molybdenum). Sodium in C_4 and CAM plants, used for regeneration of PEP. Function mainly as cofactors, see picture
28. Chlorosis, yellowing of leaves because magnesium needed in chlorophyll
29. Chlorosis because iron ions required as cofactor in an enzymatic step of chlorophyll synthesis
30. If nutrient moves freely (like magnesium), symptoms appear in older because young, growing tissues are preferentially sent nutrients
    If nutrient is immobile (like iron), symptoms appear in younger leaves
31. Excessive vine growth at expense of good fruits
32. Introduced citrate synthase gene from a bacterium into plant genomes, results in overproduction of citric acid that binds aluminum ions
33. Plants that signal when nutrient deficiency is imminent before damage has occured, one type uses promoter that binds RNA polymerase more when phosphorus content of plant tissues begins to decline, linked to reporter gene that leads to production of light blue pigment
34. Bacteria that live either in close association with plant roots or in rhizosphere (soil closely surrounding plant roots, many form mutually beneficial associations with plant roots, depend on nutrients secreted by plant cells
35. Bacteria that live between the cells of the plant
36. Weathering of rocks, lightning (produces small amounts of NO_3^-), and activity of bacteria
37. Series of natural processes by which certain nitrogen containing substances from the air/soil are made useful to living things, used by them, then returned to air/soil
38. NO_3^- (nitrate)
39. Two-step process nitrification, consists of oxidation of ammonia to nitrite followed by oxidation to NO_3^-, mediated by nitrifying bacteria
40. Plant enzyme reduces nitrate back to NH_4^+ after absorption, other enzymes incorporate NH_4^+ into organic compounds, nitrogen exported to shoots as NO_3^- or as organic compounds.
41. Denitrifying bacteria convert NO_3^- to N_2, which diffuses into atmosphere.
42. Reduction of N_2 to NH_3 (N_2 is unusable because of triple bond between atoms), only carried out by bacteria, summarized by equation:
    $N_2 + 8e^- + 8H^+ + 16ATP \rightarrow 2NH_3 + H_2 + 16ADP + 16P_i$
    Driven by nitrogenase (enzyme complex)
43. Genus of bacteria that form efficient and intimate associations with roots of legumes
44. Swellings composed of plant cells infected by *Rhizobium* bacteria
45. Form of *Rhizobium* bacteria within each nodule, contained within vesicles of root cells
46. Anaerobic environment, facilitated by location inside living cells. Lignified layers of root nodules limits gas exchange. Leghemoglobin (iron-containing protein that binds reversibly to oxygen) gives root nodules reddish appearance, acts as oxygen buffer
47. See picture.

48. Nonlegume is planted one year, legume is planted next to restore concentration of fixed nitrogen in soil, seeds exposed to bacteria before sowing, legume crop plowed under ("green manure")
49. Red alder tree hosting nitrogen-fixing actinomycete bacteria
    Free-floating aquatic fern, has mutualistic cyanobacteria that fix N_2, rice shades/kills *Azolla*, decomposition increases paddy's fertility.
50. Intimate mutualistic associations of roots and fungi. Host provides fungi sugar, fungus increases surface area for water/mineral uptake
51. Form dense sheath (mantle) of mycelia over surface of root, hyphae form network in the apoplast, do not form root hairs, in 10% of plants (mostly woody)
52. Embedded within root, hyphae penetrate epidermal cells, enter root cortex, digest cell wall but don't pierce plasma membrane, hyphae grows into tube formed by invagination of root cell's membrane, hyphae branches to form arbuscules, found in 85% of plant species
53. see picture