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C1.1 Check and Reflect

1. Hooke used a microscope with a compound, three-lens system, where the specimen was illuminated by a beam of light concentrated by passage through a water-filled flask. Van Leeuwenhoek used only a simple single-lens microscope, but produced higher magnification because of the quality of the lens. Hooke observed and recorded plants, animals, and non-living things. He described empty air pockets, which he called "cells" within thin slices of cork. He did not realize that the tiny chambers were the simplest units of life. Van Leeuwenhoek was able to observe bacteria, sperm, and protozoa (single cells) as free-living independent systems.
2. Scientific inquiry involves a cause-and-effect question that leads to a hypothesis, and then experimentation to test the hypothesis. However, the scientist must first observe the system under study to know what questions to ask. Aristotle made careful observations and set up a classification system based on his observations, but did not have the technology to understand the building blocks of life. Hooke and van Leeuwenhoek used the microscope technology that they were developing to make observations on a scale that was previously impossible. Their methods were similar to modern scientific investigations in that they recorded their observations precisely, and made them available to others by publishing through the Royal Society of London.
3. A simple microscope has one lens. A compound microscope has more than one lens.
4. The field of view is the area that can be observed through a given lens.
5. To calculate total magnification using a compound microscope, multiply the power of the objective lens by the power of the eyepiece. For example, when using a low-power 4× objective lens and a 10× eyepiece lens, the total magnification of the system is 40×.
6. Use the conversion 1 mm =1000 μm.

   Therefore $\frac{x}{1000\ \mu m} = \frac{1.50\ mm}{1.00\ mm}$

   $$x = \frac{1.50\ \cancel{mm} \times 1000\ \mu m}{1.00\ \cancel{mm}}$$

   $$= 1500\ \mu m$$

7. To calculate the diameter of the field of view using the 40× objective, use the formula:

   $$\frac{\text{high-power field diameter}}{\text{low-power field diameter}} = \frac{\text{low-power magnification}}{\text{high-power magnification}}$$

   $$\frac{\text{high-power field diameter}}{1500\ \mu m} = \frac{10\times}{40\times}$$

   $$\text{high-power field diameter} = \frac{(10\cancel{\times})(1500\mu m)}{40\cancel{\times}}$$

   $$= 375\ \mu m$$

   The field of view of the high-power objective has a diameter of 375 μm.
8. The measurement 2.5 cm = 25 mm
   The scale of the drawing of an object that is 0.5 mm = 25.0 : 0.5
   = 50 : 1
9. Student answers will vary depending on their previous courses. They may include the points that: convex lenses focus a beam of light to a common point; a compound microscope uses more than one convex lens; and the image formed is inverted when compared to the orientation of the object.

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C1.2 Check and Reflect

1. The improvements in lens technology that occurred in the 1830s allowed scientists to make more detailed observations of the structure of cells. This new technology made it possible for Brown to observe the nucleus in orchid cells. Schleiden observed that all plants are composed of cells and suggested that the nucleus is responsible for the development of the remainder of the cell. The microscope allowed Schwann to observe cells in animal tissue and to identify the nucleus in animal cells. These observations led to the idea that all plants and animals are made of cells, which are the basic units of life.
2. Spontaneous generation is the idea that life could emerge spontaneously from non-living matter. This idea was widely accepted up until the middle of the 19th century. An example is that the maggots that appeared on rotting meat were thought to arise from the meat alone.

3. The three components of the cell theory are:
   - All living things are made up of one or more cells and the materials produced by these cells.
   - All life functions take place in cells, making them the smallest units of life.
   - All cells are produced from pre-existing cells through the process of cell division.
4. Pasteur used a controlled experiment to refute the idea of spontaneous generation. He boiled meat broth in long-necked flasks and kept the type of flask, type of broth, and other conditions constant. He used the possibility of access of dust to the flasks as the manipulated variable in his experiment. To do this he left the neck of one flask completely open to the air. He bent the neck of the other into an S-shape, making sure not to seal it. Micro-organisms grew in the flask that was completely open within a few days. In the flask with the S-shaped neck, nothing grew in the broth. Pasteur inferred that for micro-organisms to grow it was necessary for something in the dust to come in contact with the broth; the micro-organisms could not arise from the broth itself.
5. Answers will vary but may include the following points:
   A scientific inquiry is based on careful observation of a situation, which leads to a question to be solved. The question leads to a hypothesis, a suggestion of a relationship, which can be tested by experiment. A scientific experiment must be controlled in that only one variable, the manipulated variable, changes and all other variables are held constant. There should be an experimental control in which the manipulated variable is not changed from its normal state. The experiment should be repeatable, so that a change in the manipulated variable should produce the same effect on the responding variable if the experiment is repeated. The data should be collected and treated in a standard way, which allows comparison of the inquiry with other inquiries investigating the same question. The report of the experiment should be published in journals available to all the scientific community.
6. Student answers will vary, and may take various formats, such as cartoon, mind map, etc.
7. Student answers will vary but should include the following:
   Redi—controlled access to meat; produced evidence that access of flies to the meat was necessary for maggots to appear.
   Needham—boiled chicken broth which still produced moulds; suggested a life force.
   Spallanzani—suggested micro-organisms in the air were responsible for the moulds in Needham's experiment. He drew off the air and no growth of moulds happened. The suggestion was that air was necessary for mould growth.
   Pasteur—took boiled broth and allowed access to air but used a shape of flask that prevented dust from reaching the broth. Under these conditions there was no growth of moulds.
8. Student answers will vary but will likely include appearance of micro-organisms from a mixture of straw and water as a "recipe" for the life force and therefore evidence for spontaneous generation. In a statement against spontaneous generation, students may say that the organisms must have been in the straw but in a condition in which they were not observable.
9. Student answers will vary but will likely include suggestions such as: living organisms show the following life processes—intake of nutrients, movement, growth, response to stimuli, exchange of gases, waste removal, and reproduction.
10. Student answers will vary. One possible experiment would be to observe the rate of movement of the organisms at five-minute intervals. As the time goes, on the small amount of water on the slide will heat up as a result of the heat from the light source and the effect on the organisms can be observed.

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C1.3 Check and Reflect

1. Live organisms can be observed in light microscopy, but the resolving power of the light microscope is limited by the wavelength of light.
2. Investigators need to stain cells in order to improve contrast between internal structures and to produce better images.
3. Electron microscopy is needed to view objects that are too small, or too close together to be viewed through a light microscope. The resolving power of the electron microscope for biological specimens is one hundred times greater than that of the light microscope.
4. A confocal microscope uses a laser to concentrate light onto the specimen, rather than a regular light source. The magnified image is displayed on a computer screen, rather than viewed directly by the observer's eye. The pinhole arrangement allows an image to be formed of one specific thin layer, which is exactly in focus, and the computer combines many of these thin layers to produce a three-dimensional image.

5. In fluorescence microscopy, fluorescent substances are attached to molecules on the specimen's surface or within the specimen. When the specimen is exposed to ultraviolet light, the fluorescent molecules glow, allowing the structures to be seen. An example of the use of fluorescent microscopy is Coons' demonstration of the presence of antigens on the surface of human red blood cells.
6. Both light and electron microscopes have a source of illumination (lamp/electron gun), a lens or lenses (curved glass/electromagnets), a receiver (human eye/computer screen), and a focussing mechanism (up and down movement of lenses/adjustment of magnetic field).
7. Student answers will vary. Examples might be:
   - The electron microscope provided detail of the structure of mitochondria and Golgi apparatus.
   - Fluorescence microscopy showed the location of certain substances on the surface of cells.
8. Student answers may vary, but may include examples of simple and compound light microscopes, confocal microscope technology, electron microscopes, and contrast enhancing techniques such as staining and fluorescence microscopy. Answers should include how each microscope or technique is specialized for a particular aspect of cell study.

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C1.4 Check and Reflect

1. Student answers will vary, but could include one of the following: gene mapping to manage disease-causing abnormalities, creation of pest-resistant crops through knowledge of the plant's genetic make-up, diagnosis of disease through knowledge of transport through the cell membrane, demonstration of the structure of a particular molecule such as DNA, use of GFP in genetic studies.
2. X-ray crystallography uses X-rays, special sensors that analyze the patterns of X-ray scattering, and computer technology.
3. One advantage of using GFP is that it allows comparison between diseased and healthy *living* cells.
4. Student answers will vary but will likely include benefits such as production of different types of resistance in crop plants, increase in yields and nutritional value, treatment and cure of disease, etc. Risks may include reduction of biodiversity, susceptibility of monocultures to new disease or conditions, accidental acquiring of resistance by weed species, ownership and price of genetically modified seed, difficulty in choosing which human abnormalities should be repaired, etc.
5. Student answers will vary, but positions must be supported.
6. Student answers may include questions about sources of funding for research, ownership of patents on genetically modified organisms, and availability of the results, access of the developing world to this technology, etc.
7. Student answers will vary, but students should identify the new knowledge or treatments and their sources of information. Are the sources reliable? (Determining reliability of Internet sources is also an ICT outcome.)
8. Student answers will vary, but could include researcher, agricultural technologist, quality control technologist in food processing, and medical technologist.

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C1.0 Section Review

Knowledge

1. Aristotle used careful direct observation and record making, followed by reasoning and interpretation. Other intellectuals of the time preferred to think out possible answers to questions, without testing their ideas.
2. The Janssens' microscope is considered a compound microscope because it used two lenses (an eyepiece and an objective lens) to magnify objects.
3. Robert Hooke produced a three-lens microscope, and used a water-filled glass flask to concentrate the light illuminating the specimen. His greatest contribution may be that he observed and made illustrations of plant, animal, and non-living objects, as well as of the cells in thin sections of cork, and made these accessible to others through publication of his *Micrographia*. He was the first scientist to use the term "cell."
4. The advantages of laparoscopic surgery are that patients generally lose less blood, experience less pain, have a faster recovery time, and have less scarring, because the incisions are so tiny. Heart surgery can also be performed without the need to open the chest cavity. The surgeon relies on microscope technology through the use of an instrument fitted with a magnifying eyepiece that is inserted in the laparoscope. This provides a

magnified view of the site of the operation, shown on a TV screen.

5. A control in an experiment is the situation where the manipulated variable is not altered. This result is compared to the result found when the manipulated variable is altered (manipulated) in a particular way.
6. Student sketches will be similar to the flasks in Figure C1.8. Pasteur's experiment provided evidence against spontaneous generation by showing that when meat broth was not exposed to air-borne dust, organisms did not appear in the broth, even when air could easily pass into the flask. The inference was that life could not appear from air alone, but had to be contained in some part of the dust.
7. Student answers will vary depending on the observations made in Activity C3 but may include similar or different modes of locomotion and differences in size and the structures present.
8. To make a wet mount slide, take a sample of the material you wish to examine. Place a glass slide in front of you, holding it by the edges. Place two drops of the sample on the slide. Pick up the coverslip by the edges and place one edge of the coverslip at the edge of the drop. Using a toothpick, slowly lower the coverslip onto the drop, being careful not to trap air bubbles under the coverslip.
9. The main points of the cell theory are:
   - All living things are made up of one or more cells and the materials produced by these cells. (Schleiden and Schwann)
   - All life functions take place in cells, making them the smallest units of life. (Schleiden and Schwann)
   - All cells are produced from pre-existing cells through the process of cell division (Virchow).
10. Staining and fluorescence microscopy are two methods for improving contrast within a specimen. Stains bind to particular parts of the cell depending on the chemical make-up of each part. In fluorescence microscopy, fluorescent molecules attached to particular parts of the cell emit light of a different wavelength when the specimen is subjected to ultraviolet light. The fluorescent glow shows the location of the molecules.
11. Confocal laser technology allows an observer to view specific sections of a living specimen, by using a pinhole to exclude the light travelling through other layers. Once images of various layers have been collected in a computer, the images can be put together to show a 3-D image of the specimen. The advantages are that more detail can be seen and the specimen is alive.
12. X-ray crystallography uses X-rays and other technology to allow scientists to view details of molecular structure to help them understand how molecules work. This technique is used in cell research to show the structure of different molecules and in this way to provide insight into function. The model of the DNA molecule is a famous example of the contribution of X-ray crystallography to cell research.
13. GFP is Green Fluorescent Protein. This protein was discovered in the jellyfish *Aequorea victoria*, in which it provides luminescence that occurs in a ring within the animal. Scientists are able to attach this fluorescent protein to parts of cells that they wish to study. In genetics it is used in the study of degenerative diseases of the nervous system, where abnormal proteins clump together to prevent or slow down normal cell functioning. GFP allows scientists to compare the structure and activity of normal proteins and proteins in cells affected by the disease.

Applications

14. 400 μm.

    Solution: HP field diameter

    $$= \frac{(100\not{\times})(1800\mu m)}{(450\not{\times})}$$

    $$= 400\ \mu m$$

15. The minimum magnification needed is ×100. Solution: The minimum size a human eye can detect = 0.1 mm = 100 μm. Therefore, for the eye to see 1μm would require a magnification of at least 100×.
16. The magnification of objectives is inversely proportional to the field size. If the size of the low-power field diameter is known, the following ratio can be used to calculate the diameter of the medium-power lens:

    $$\frac{\text{medium-power field diameter}}{\text{low-power field diameter}} = \frac{\text{low-power magnification}}{\text{medium-power magnification}}$$

17. Air-borne dust must not be allowed to enter the food before or during canning.
18. a) light microscope
    b) light microscope
    c) electron microscope
    d) fluorescence or confocal microscope or scanning electron microscope

19. Student answers will vary but could include knowledge of diseases caused by micro-organisms and availability of vaccines and other treatments for these diseases.
20. Student answers will vary.

Extensions

21. Student Research.
22. Student answers will vary but may include the following:
    – The first simple microscopes (microscopes with a single lens) began to be used following the development of the theory of optics and the discovery of the magnifying properties of lenses. Micro-organisms were observed by van Leeuwenhoek.
    – Compound microscopes were developed following the discovery that combining various lenses can increase the magnification available. Early compound microscopes were less efficient than simple microscopes because as the light passed through the various lenses, it became scattered and the image of the specimen tended to become blurred. In the 1700s, achromatic lens technology was developed.
    – These improvements in lenses controlled the scatter of the light and increased the amount of detail that could be seen.

    Staining techniques.
    – These techniques resulted in improvement in contrast and therefore in detail of what can be seen.

    Fluorescence microscopy
    – This technique led to identification of cell surface molecules.

    Confocal technology
    – This technology provides a three-dimensional view within cells. Along with GFP technology confocal technology allows scientists to follow molecules in cells.
23. Student Research.

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C2.1 Check and Reflect

1. A system is a unit or structure that has many parts that work together for a particular goal.
2. The cell is an open system because it exchanges energy and matter with its surrounding environment.
3. Students' drawings will vary, but should include the structures shown in Figure C2.10(b). The functions listed should be similar to those given in Tables C2.1.
4. Student answers will vary. Examples of appropriate answers follow.
    a) The cell membrane appears as a fluid mosaic structure with proteins embedded in it. The fluid part is a double layer of phospholipids. The cell membrane functions as a protective barrier around the cell that allows transport into and out of the cell. It is important for cell interaction and recognition of molecules
    b) Vacuoles are simple, membrane-bound structures in the cell that store substances (nutrients, secretion products, fats, and water in plants).
    c) Mitochondria are rod-shaped structures with double membranes that are the sites where cellular respiration takes place. Energy stored in sugars is converted into usable energy for the cell.
    d) Chloroplasts are the site of photosynthesis, which uses solar energy to convert carbon dioxide and water into sugar for the plant's use. In the light microscope, chloroplasts appear as oval, green organelles. They are found only in plants and some protists.
5. The associated organelles are:
    intake of nutrients – the cell membrane
    exchange of gases – cell membrane
    removal of wastes – lysosomes and cell membrane
    Note: The identification of the cell membrane as being associated with each of the processes should bring students' attention to the important role the membrane plays in cell functioning.
6. Trace elements are substances that are essential to the cell, but needed only in tiny amounts. Some trace elements in the cell are magnesium, zinc, manganese, and iron.
7. Student answers will vary. One possible answer follows.
    Three similarities in the chemical composition of plant and animal cells are:
    Both contain DNA; both have a cell membrane; both have an internal cytoskeleton made up of proteins and lipids.
    Three differences are:
    Plant cells have a cell wall made of cellulose, animal cells do not; plant cells contain chlorophyll for photosynthesis; plant cells store energy in the form of starch or oils, whereas animal cells store energy in glycogen, or lipids.

8.

Cell Structure	Body Organ
Cell membrane	Skin/lungs
Nucleus	Brain
Vacuole	No equivalent organ; fat storage tissues
Lysosome	Stomach/digestive system
Endoplasmic reticulum	Digestive system/circulatory system
Ribosomes	No equivalent organ
Golgi apparatus	Digestive system
Mitochondrion	Muscles

Note: Students may need some help with this question, but the activity is designed to check their understanding of organelle function. Class discussion may be useful.

9. Student answers will vary. They may point out the negative effects of: cell membrane breakdown with the cell being swamped by substances it doesn't need; mitochondrial breakdown with no energy being produced; ribosome/rough endoplasmic reticulum breakdown with no protein being produced, etc.
10. Student answers will vary. Some points may be as follows.
    Both plant and animal cells have cell membranes, a nucleus and cytoplasm, mitochondria, ribosomes, endoplasmic reticulum, and vacuoles or vesicles. Plant cells have a rigid cell wall enclosing the contents of the cell and giving support, and chloroplasts to perform photosynthesis. Animal cells need support from other structures and cannot make their own nutrients. Plant cells have a large central vacuole; animal cells tend to have smaller vacuoles or vesicles.
11. Student answers will vary.
12. Student answers will vary.

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C2.2 Check and Reflect

1. The four points of the particle model of matter are as follows:
    - All matter is made of particles but the particles in different substances may be different in size and composition.
    - The particles of matter are constantly moving or vibrating: particles move least in solids and most in gases. Adding or taking away energy will affect the movement of particles.
    - The particles of matter are attracted to one another or are bonded together.
    - Particles have spaces between them that are smallest in solids, except for ice, and greatest in gases. The spaces may be occupied by the particles of another substance.
2. Diffusion occurs when particles move from an area of high concentration to an area of low concentration until all areas are at the same concentration and equilibrium is reached. Diffusion does not require energy to be added to move the particles. In facilitated diffusion, proteins in the cell membrane allow molecules that are not lipid-soluble to pass across the lipid bilayer. Channel proteins create channels for the smaller molecules to move through. Carrier proteins transport the larger molecules by changing shape and physically moving the molecule across the membrane and into the cell. No added energy is required to move the molecules, because they are still moving from an area of high concentration to an area of low concentration. Active transport uses carrier proteins to move particles across the cell membrane from an area of low concentration to an area of high concentration, which requires energy input.
3. A concentration gradient exists when there is a difference in the concentration of a substance in two areas. In cells it is usually the difference between the concentrations of a solute on either side of the membrane. Equilibrium occurs when there is no net movement of particles. In the case of simple diffusion, equilibrium occurs when all areas are at the same concentration, with particles still moving, but evenly distributed.
4. To keep the celery crisp, immerse the bottom of the stem in water. Water will be drawn into the stem by osmosis, and the celery will not wilt.
5. Passive transport moves particles from an area of high concentration to an area of low concentration and does not require energy to be added. Active transport moves particles from an area of low concentration to an area of high concentration and requires energy to be added.
6. Student diagrams will vary but should show the similarity of the membrane re-forming in each process and the difference in the direction of the activities, with endocytosis bringing substances into the cell and exocytosis removing substances from the cell.
7. In Beaker A, the cell will shrink and the contents of the cell will move away from the cell membrane because more water will be moving out of the cell than into the cell. In Beaker B, the cell will swell because more water is moving into the cell than out of the cell. If the process

continues for a time, the animal cell may rupture. In Beaker C, no visible change will occur, because water will be moving into and out of the cell at the same rate. The cell will be at equilibrium.

8. a) Brine solution or syrups would be hypertonic to micro-organisms; water would leave the micro-organism by the process of osmosis.
   b) The effect of the solutions on the micro-organisms would be that so much water would leave the cell that the cell would dry out (and die).
9. Diffusion depends on the constant movement of particles and the energy involved in collisions between the particles. Larger particles may be expected to have amounts of energy associated with them different from small particles, to require more energy for movement, and to have fewer collisions than small particles. All of these factors would tend to make the rate of diffusion of large particles slower than that of small particles.
10. The cell tends to maintain equilibrium through the physical processes of osmosis and diffusion. Examples of an attempt to maintain equilibrium may vary. Students may mention examples like the movement of carbon dioxide out of cells and oxygen into cells, or the movement of water out of cells placed in a hypertonic environment.
11. Student answers will vary. Some possible topics are the movement of sodium and potassium ions during a nerve impulse; the movement of products of digestion into cells of the small intestine; sodium and/or chloride movement in the operation of the human kidney; movement of water into the contractile vacuole in *Paramecium*.
12. Student answers and diagrams will vary.

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C2.3 Check and Reflect

1. Dialysis is a way to remove wastes from the blood when a person's kidneys are not functioning. It works on the principles of the particle model that molecules are in continuous movement and will move along their concentration gradients, from a higher concentration to a lower one. The particles will move through the cell membrane. Any substance that is in a high concentration in the blood and a low concentration in the dialysate will tend to move out of the blood. Wastes are removed in this way. Any substance or ion that is essential must be kept in the blood; this is achieved by having a concentration of the essential substance or ion in the dialysate high enough so that there is no concentration difference, and so no tendency for the substance to leave the blood.
2. Student diagrams should be similar to Figure C2.25. Liposomes are used in HIV and cancer treatment to allow medication to stay in the blood stream for a longer time, and in some cases to deliver medication directly to the diseased tissues. In some cancers, liposomes are also used to inject DNA into tumour cells (gene therapy).
3. a) Membranes purify water through reverse osmosis. Water is pumped through semi-permeable membranes against the concentration gradient. The membranes retain other molecules and micro-organisms, but allow the water to be forced through. The larger a molecule is, or the more charge it has, the less likely it is to be passed through the membrane.
   b) In peritoneal dialysis, toxins and wastes pass across the peritoneal membrane into the dialysate by diffusion, leaving the blood clean.
   c) Gene therapy uses manufactured sacs of lipid membrane (liposomes) identical to human cell membranes to deliver medication to diseased body tissues. The liposomes can attach to infected cells because they have exactly the same composition as the cell membranes and can deliver DNA directly into infected cells.
4. Student answers may vary, but should include some of the following: peritoneal dialysis uses a natural membrane; can be performed at home; allows the patient to move around during the process; and cleaning takes place inside the patient's body. Hemodialysis uses a synthetic membrane; must be performed in a medical facility; does not allow patients to move around; and requires blood to be removed from the patient's body for the cleaning process to take place.
5. In osmosis, water moves from an area of high concentration of water to an area of low concentration of water, and the movement does not require energy. In reverse osmosis, water moves from an area of low concentration of water to an area of high concentration of water, and the movement requires the force of pressure of a pump.
6. Insulin binds to the cell membrane of the target cell and the binding stimulates a number of reactions including an increase in movement of glucose into the cell.
7. Student research.
8. Student answers will vary. They may include ideas such as: the lock and key scenario for protection against a virus like HIV may not be specific and may prevent needed substances

getting into the cell; in cancer or HIV treatment, if the recognition proteins were not completely specific to the cancer cells or the HIV-infected cells, healthy cells might be killed as well (as happens in common treatments of cancer today); liposomes might target healthy cells as well as cancer cells and so delivery of medication as well as gene therapy might not be able to be controlled. With kidney diseases there are problems of long-term use of dialysis that include keeping the balance of the fluids constant at the right level, and not losing or gaining water.

9. Student answers will vary.
10. Student answers will vary. Encourage students to present ideas clearly and have a logical approach to connecting the different parts of the Web site in sequence.

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Practice Problems

Example Problem C2.1

1. a) Cube $s = 3.5$ cm; Surface area = $6s^2$;
Volume = s^3

Surface to volume ratio = $\frac{6s^2}{s^3} = \frac{6}{s} = \frac{6}{3.5} = 1.7$

b) Cube $s = 5.5$ cm

Surface to volume ratio = $\frac{6}{5.5} = 1.1$

2. Rectangular prism $l = 2.5$ cm; $w = 2.0$ cm;
$h = 1.0$ cm
Surface area = $2(lw + lh + wh) = 19$ cm ^{2}
Volume = $lwh = 5.0$ cm^3

Surface to volume ratio = $\frac{2(lw + lh + wh)}{lwh} = \frac{19}{5.0} = 3.8$

3. a) Sphere $d = 4.3$ cm
$r = 2.15$ cm
Surface area = $4\ \pi r^2$
Volume = $4/3\ \pi r^3$
Surface to volume ratio

$= \frac{4\pi r^2}{4/3\pi r^3} = \frac{3}{r} = \frac{3}{2.15} = 1.4$

b) Sphere $d = 8.6$ cm
$r = 4.3$ cm

Surface to volume ratio = $\frac{3}{r} = \frac{3}{4.3} = 0.70$

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C2.4 Check and Reflect

1. a) The surface area of an object is the area of material in square measure needed to cover the surface of the object.
b) The volume of an object is the amount of space in cubic measure that is occupied by, or contained in, the object.
c) The surface area to volume ratio is the ratio between the amount of surface area of an object or cell, and the volume contained within the object or cell.
2. The surface area to volume ratio decreases.
3. The efficiency of the cell's transport system is the factor that limits the size of cells. It is related to the amount of surface area available for transport of substances.
4. As the cell grows larger, it will need more cell membrane to survive, because more nutrients will be needed for functioning inside the cell, and more toxins will need to be removed. Many of the processes involved rely on molecules in the cell membrane.
5. Diffusion depends on the amount of cell membrane available for substances to pass through by the different mechanisms. Diffusion of materials across the cell's surface can occur more rapidly in smaller cells, because the surface area to volume ratio is larger, meaning there is relatively more cell membrane available.
6. The function of any cell is a primary factor in determining its size and shape.
7. Because both cells contain the same volume, the more efficient cell would be the one that had the larger surface area. A calculation can be done based on the radius of the sphere and the radius and height of the cylinder. Surface area of a sphere $A=4\pi r^2$;
– Surface area of a cylinder $A=2\pi rh + 2\pi r^2$
8. For a perfect cube of side 4 cm:
a) The surface area of the cube is 96 cm^2.
A = (4 cm)(4 cm)(6) = 96 cm^2
b) The volume of the cube is 64 cm^3.
v = (4 cm)(4 cm)(4 cm) = 64 cm^3
c) Each rectangular prism is 4 cm × 4 cm × 2 cm
The surface area of each is 64 cm^2.
A = 2[(4)(4) + (4)(2) +(2)(4)]= 64 cm^2
d) The combined surface area is 128 cm^2.
e) The volume of each new piece is 32 cm^3.
v = (4 cm)(4 cm)(2 cm) = 32 cm^3.
The combined volume is 64 cm^3.
f) Cutting the cube in half to make two identical rectangular prisms increases the total surface area from 96 cm^2 to 128 cm^2, but the total

volume remains the same. Therefore, the surface area to volume ratio increases (from 1.5 to 2.0).

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C2.0 Section Review

Knowledge

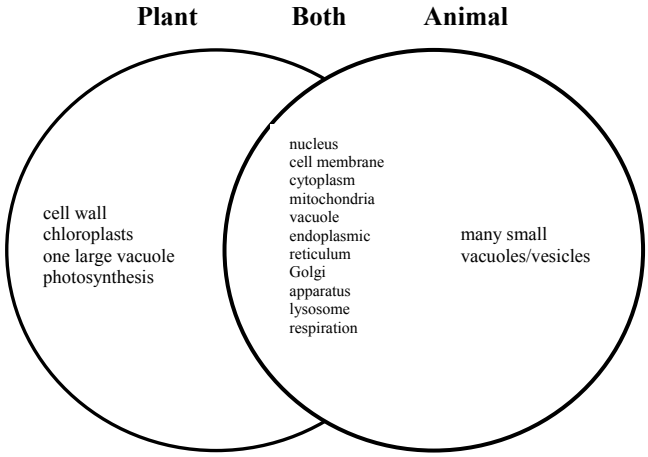
1. The processes necessary for an organism to survive are intake of nutrients, exchange of gases, and removal of wastes.
2. a) The cell membrane is a protective barrier that allows transport into and out of the cell, communication with other cells, and recognition of molecules.
   b) Mitochondria perform cellular respiration (convert chemical energy from sugars into energy that the cell can use).
   c) Chloroplasts are the site of photosynthesis, converting carbon dioxide and water into sugars for the plant's use.
3. The four main types of organic compounds found in the cell are lipids like stored fat, carbohydrates like starch or glucose, proteins like insulin or muscle fibre, and nucleic acids like DNA.
4. Student diagrams will vary, but should resemble Figure C2.12(b).
5. The four points of the particle theory of matter are as follows:
   - All matter is made of particles but the particles in different substances may be different in size and composition.
   - The particles of matter are constantly moving or vibrating: particles move least in solids and most in gases. Adding or taking away energy will affect the movement of particles.
   - The particles of matter are attracted to one another or are bonded together.
   - Particles have spaces between them that are smallest in solids, except for ice, and greatest in gases. The spaces may be occupied by the particles of another substance.
6. Semi-permeable means that certain substances can pass through, and other substances cannot.
7. Isotonic: a solution that has the same amount of water and solutes when compared with another specific solution.
   Hypotonic: a solution that has more water and less solutes when compared with another specific solution.
   Hypertonic: a solution that has less water and more solutes when compared with another specific solution.
8. Energy use determines whether transport is active or passive. If energy is used the transport is active. If energy is not used the transport is passive.
9. Diffusion and facilitated diffusion are similar in that neither requires additional energy to be added, but facilitated diffusion requires membrane proteins. Facilitated diffusion and active transport are similar in that they both use proteins in the cell membrane to transport larger molecules into the cell, but they are different in that active transport uses energy, and facilitated diffusion does not.
10. Student answers may vary. Some examples are: a cell would use endocytosis in the case of an amoeba taking in a large food particle and in the case of a cell taking in a virus or bacterium; a cell would use exocytosis in the case of secreting a substance like insulin to the outside, or removing waste particles.
11. A hormone is a molecule secreted at one location, which binds with membrane receptors at another location at a distance from the point of secretion. Insulin is an example of a hormone.
12. Recognition proteins are proteins embedded in the cell membrane that allow cells to recognize one another. Recognition proteins help cells of the human immune system to identify particular bacteria, and help sperm and egg cells recognize each other and link together.
13. One drawback to using liposomes is that healthy cells may also be susceptible to the medications or genes that the liposomes transport.
14. A model is a working representation of a concept, object, or process, to help in the visualization of abstract concepts. Example: a globe as a model of Earth.
15. Surface area is the area of surface, in square units, exposed to the environment. Volume is the measure in cubic units of the space occupied or contained by an object. The ratio is the amount of surface area per unit volume. For a cube:
    surface area, $A = 6s^2$; volume $v = s^3$;
    surface area to volume ratio $A/v = 6\ s^2/s^3 = 6/s$
16.

Cell #	Length (cm)	Width (cm)	Height (cm)	Surface Area (A) cm^2	Volume (v) cm^3	Surface Area to Volume ratio (A/v)
1	5	3	2	62	30	2.1
2	12	5	1	154	60	2.6
3	40	27	20	4840	21 600	0.22

17. Cell #2 should have the fastest rate of diffusion across the surface. It has the greatest surface to volume ratio.
18. Student answers will vary, but could be similar to the following: When the packet of coffee (or popcorn) was opened in the class room, the smell of coffee (or popcorn) moved through the room from the place where it was opened and where the coffee (or popcorn) smell was strong, to places where there was no smell of coffee (or popcorn), until the entire room smelled a little bit like coffee (or popcorn) and no part smelled more like coffee (or popcorn) than any other part.
19. A concentration gradient is the relationship between two areas when one area has a higher concentration of a substance than another.
20. a) Ions and water will cross the permeable membrane; there will be a net movement of ions from the solution of 12 g/L NaCl to the 10 g/L NaCl solution and a net movement of water from the solution of 10 g/L NaCl to the 12 g/L NaCl solution until both solutions are at approximately 11g/L NaCl.
    b) Student diagrams will vary.
21. Osmosis is the movement of water by diffusion along its concentration gradient.
22. In reverse osmosis, water is moved from an area of low concentration of water to an area of high concentration of water, and the movement requires the force of pressure of a pump. Reverse osmosis requires added energy, while osmosis is a passive process.

Applications

23. Student answers will vary. They should include all parts shown in Figure C2.10(b). Some comparisons may include: the nucleus being like city hall in a community; the lysosomes being like garbage disposal; the mitochondria being like power companies; the endoplasmic reticulum being like roadways or canals, the ribosomes being like small factories; the Golgi apparatus being like companies that market products; and the vacuoles being like storage warehouses.
24. Diagrams will vary. The overlap should include presence of cell membrane, organelles, and most characteristics. The differences should be in the cell wall, chloroplasts, and ability to perform photosynthesis.



25. A cell's plasma membrane regulates what substances enter or leave the cell. Diffusion of small, lipid-soluble particles occurs; osmosis occurs when there are concentration differences across the membrane. Proteins in the membrane may facilitate the movement of particles that cannot move by diffusion and move them passively from high concentration to low concentration. Other proteins may use energy to move particles against their concentration gradients.
26. The rate of diffusion is affected by size, charge on the particle, concentration, and the distance the particle has to travel. Each factor affects the movement of the particles and the likelihood of collisions, and so will affect how quickly the particles move along the concentration gradient.
27. The basis of peritoneal dialysis is that diffusion will occur through the cell membrane along the concentration gradient and may be at different rates for different substances. Student reports may describe criteria for patient selection for each procedure.
28. The purpose of a hypothesis is to identify the question under investigation and to make a reasonable suggestion of an answer.
29. Grocery store owners spray vegetables with water so that water will not evaporate causing them to wilt. This is a bad idea for vegetables that cannot take in water and that are waxed or in plastic bags. If more water is given than can be absorbed the vegetables begin to rot.
30. Student answers will vary. One example is: recognition proteins could be used in cancer treatment if they could be identified and attached to medications so that the medication would have an effect only on the cancer cells.
31. The advantage of having a large surface area is that diffusion can occur more quickly.

32. In Situation (a) it might be expected that glucose would penetrate the membrane, and enter the solution. This hypothesis could be tested by performing a test for glucose on water from outside the tubing. In Situation (b) it might be expected that the starch molecules would be too large to penetrate the membrane. This hypothesis could be tested by performing the iodine test for starch on water from outside the membrane.
33. a) It would be expected that the group with the fine salt would be able to dissolve the 10 g more quickly than the group with the rock salt.
    b) The fine salt will dissolve more quickly because the surface area to volume ratio is larger in small particles than large ones, so there will be more places for the dissolving process to go on.
34. The students who have been given coarse rock salt could swirl the solution around the beaker to speed up the rate of diffusion. They might also crush the particles into smaller pieces or heat the mixture to increase movement of particles.

Extensions

35. High salt in the blood will result in the loss of water from the body cells by osmosis.
    The crew will probably die because the concentration of salt in the water is high enough to upset the body's sodium-potassium balance.
36. The lipid part of the membrane allows lipid-soluble substances and very small particles to enter easily. The channel proteins function to form channels for small non-lipid-soluble substances to enter and receptor proteins may facilitate movement of larger molecules by passive or active means. The ability of the phospholipid bilayer to re-form in different ways makes endo- and exocytosis possible.
37. Student models will vary. Possible examples to start students off are the clothespins and gummy candies model or the gelatin plus puzzle pieces model described in this resource in the teaching suggestions at the beginning of the section.
38. Student answers will vary but could be similar to the following: Proteins in the cell membrane act like a person standing in front of the sensor for an automatic "Out" door at a grocery store. Without exerting any energy, the person allows other people to enter the store. If the person were not there to keep the door open, the other people would not be able to enter through that door.
39. Student answers will vary.
40. Student research.
41. Student research.
42. Student answers will vary.
43. They would probably not survive because their surface to volume ratio would be low. Insects need diffusion of gases through their spiracles for gas exchange. It would be unlikely that they could obtain sufficient oxygen. Also, insects depend on the hard outer skeleton for support, and the number of outer cells present would probably not be enough to support the large volume.

Student Book page 302

C3.1 Check and Reflect

1. a) unicellular: consisting of one cell
   b) multicellular: consisting of more than one cell
   c) tissue: a group of cells performing the same function
   d) organ: tissues involved in the same function at one location
   e) organ systems: a group of organs that work together to perform a specific function
   f) meristem: in plants, the areas of maximum cell division; different meristems act as growth centres for different parts of the plant
2. There are two main organ systems in plants, the root system and the shoot system. The shoot system in plants consists of everything above ground, leaves, stem, flowers, and fruits and also modified stems such as tubers. It is primarily responsible for gas exchange of carbon dioxide and oxygen and for photosynthesis. The root system is everything that is below ground, and aerial roots in some species. It is responsible for the uptake of water and mineral salts from the soil and for storage of some products. Student diagrams will vary but should resemble Figure C3.3.
3. Students' charts may vary but should show the following: The advantage of being multicellular is that different groups of specialized cells can perform different functions for the benefit of the whole. This allows the organism to increase in size. The disadvantage is that cells cannot survive alone because they have to rely on other cells to perform certain tasks.
4. Student examples may vary but may include the following:
   Root hairs absorb water from the soil; epidermal cells of the shoot system produce a waxy coating to protect the cells from water loss; lower epidermal surfaces of leaves develop guard cells to control gas exchange; and cells that are part of the xylem are able to conduct water to adjacent cells.

5. Plant stems and leaves have a layer of cuticle to reduce the amount of water that is lost by evaporation. There is usually more water in the plant than in the surrounding environment. Plant roots do not need to be covered by cuticle because there is usually more water in the soil than in the plant, so water will not be lost through the roots; in fact water is taken into the plant through the root epidermis.
6. Students' diagrams may vary, but should show the three tissues types preferably in both root and shoot systems. Their description should include the following points: There are three basic tissues in plants, dermal tissue, ground tissue, and vascular tissue. Dermal tissue is the outer layer of cells. It is responsible for gas exchange and provides protection of other layers through the presence of the cuticle. Ground tissue provides strength and support in the stem, stores food and water in the roots, and is the site of photosynthesis in the leaves. Ground tissue cells are loosely packed together and the spaces allow gases to diffuse rapidly within the tissue. Vascular tissue is responsible for the transport of materials throughout the plant. Xylem tissue moves water and dissolved minerals from the roots up the stem to the leaves. Phloem tissue transports sucrose and other sugars from the leaves to the rest of the plant. Phloem is composed of sieve tube cells and companion cells.
7. a) By understanding plant structure as well as the ways plants develop and function, scientists will be able to develop environmentally sound and sustainable agricultural practices. Research will be needed to find ways to understand and use the physical characteristics of plants to improve resistance to pests and adverse environmental conditions such as frost and drought. The nutritional value of crops may need to be enhanced, for example through fertilizers, because the reduced land available for agriculture will become overused. This discussion may lead to a debate on the value of genetically modified food as it relates to research and understanding of plant structure.
   b) Deeper understanding of plant structure and function allows scientists to develop better practices for maintaining and enhancing biological diversity. Understanding this diversity could also lead to increased productivity through the choice of optimal varieties of species. The best way to solve existing and emerging problems and challenges is through knowledge of how and why things work as they do.
8. Plants are key elements in the carbon cycle and can be used to produce valuable oils, waxes, bio-fuels, fibres, and polymers. Students explored these varied uses in grade 7 "Plants for Food and Fibre." Some of these substances can be produced and used with less environmental impact, such as reduced greenhouses gases, and/or less damage to air, soil, and water, and can be cleaned using biological means. The inference is that the new processes may contribute to addressing the concerns regarding climate change and environmental degradation. This discussion can be used as foreshadowing for Unit D.

Student Book page 308

C3.2 Check and Reflect

1. Plants convert carbon dioxide and water into glucose and oxygen when chloroplasts absorb light energy.
   The word equation for photosynthesis is:
   $\text{water + carbon dioxide} \xrightarrow{\text{chlorophyll+light}} \text{glucose + oxygen}$
   The balanced chemical equation for photosynthesis is:
   $6H_2O_{(l)} + 6CO_{2(g)} \xrightarrow{\text{chlorophyll+light}} C_6H_{12}O_{6(aq)} + 6O_{2(g)}$
2. Chlorophyll absorbs the light energy that is necessary for photosynthesis to occur.
3. In sunlight, the plant carries out both photosynthesis and cellular respiration. In the dark, photosynthesis stops, but cellular respiration continues.
4. Students may suggest ideas such as that knowing the size helps scientists to understand the function of the cell or organelle and its relationship with other cells or organelles.
5. Students will agree with this statement because the chloroplasts are the site of photosynthesis and produce glucose from carbon dioxide and water according to the following equation:
   $6H_2O_{(l)} + 6CO_{2(g)} \xrightarrow{\textit{chlorophyll+light}} C_6H_{12}O_{6(aq)} + 6O_{2(g)}$
   while the mitochondria are the sites of cellular respiration and break down glucose to carbon dioxide and water, according to the following equation:
   $C_6H_{12}O_{6(aq)} + 6O_{2(g)} \rightarrow 6CO_{2(g)} + 6H_2O_{(l)} + \text{energy}$
6. a) cotton shirt __1__ cotton plant
   b) ham __1__ pig __2__ plants as pig food
   cheese __1__ cows __2__ plants as cow food
   bread __1__ grain, plant material

c) coal 1 prehistoric plants became compressed
d) Students should be able to defend their own answers.

7. a) Students may suggest that if more carbon dioxide were available, photosynthesis would continue at a faster rate or for a longer time. The situation is complex, depending on time and light intensity as well as carbon dioxide concentration.
   b) Students may suggest that the rate of photosynthesis would increase with the light intensity because there would be more light energy available for the process. This is true for low light intensities, but at higher light intensities the situation is more complex and depends on temperature and carbon dioxide concentration.
8. Student answers may vary. One possible explanation is: The warmer temperature within the greenhouse will cause more water to evaporate through the leaves, which will keep water and nutrients flowing up through the plant at a faster rate. Students may not have been introduced to the concept of Q_{10}, the doubling in rate of reactions for every 10-degree rise in temperature.
9. The chloroplasts drift through the cell with the movement of cytoplasmic streaming. Students' models will vary.

Student Book page 314

C3.3 Check and Reflect

1. Student diagrams will vary, but should resemble Figure C3.15.
2. a) The epidermis allows exchange of gases with the environment and protects the inner cells of the leaf. It produces cuticle that prevents water loss.
   b) Guard cells swell and shrink in response to sunlight and other conditions and regulate size of the stomata in a leaf.
   c) Palisade tissue cells contain many chloroplasts and are responsible for photosynthesis.
   d) Spongy mesophyll conducts gas exchange by diffusion throughout the leaf, moving oxygen towards the stomata, and carbon dioxide toward the palisade cells.
   e) Xylem tissue transports water and dissolved salts from the roots to the leaf.
   f) Phloem tissue transports the sugar manufactured in photosynthesis to the rest of the plant.
3. Stomata regulate the amount of water that is lost by the plant into the surrounding environment. They also allow for gas exchange.
4. Over time, a hot dry climate and/or a lack of carbon dioxide in the air could affect the number of stomata. This would be a response to provide carbon dioxide and reduce water loss. **Note:** Thinking about this question in some detail may help students to be prepared for the Unit C project: The Impact of Environmental Factors on Plant Function.
5. Palisade cells are tightly compacted to increase the number of cells exposed to the Sun's rays and so that the sugars that are produced within them can be transported across the cell membrane. Spongy mesophyll cells are more loosely organized because their primary function is gas exchange throughout the leaf; space allows gas to diffuse.
6. Heat and dryness would cause stomata to close. The closure of the stomata in both cases would avoid excess evaporation of water from the leaves.
7. When the palisade cells are directly below the epidermis there is maximum exposure of the cells to light energy from the Sun. This means maximum possible photosynthesis.
8. Student answers will vary but should include a reference to the evaporation caused by direct sunlight on the leaf's upper surface.
9. Student paragraphs will vary but should include a statement that lenticels operate in a similar way to stomata, allowing for gas exchange, but that they do not have a control mechanism like the guard cells to moderate the gas exchange.
10. Greenhouse plants may have more trouble surviving in a natural environment because they are used to higher temperatures and therefore more rapid chemical reactions. They are also used to controlled humidity, which is not the case in nature.
11. Student models will vary.
12. a) Stomatal density, being less in needles of coniferous trees than in deciduous trees, allows the conifers to minimize water loss in the drier atmospheres at high elevations. The structure of the needles, with the stomata recessed and the epidermis covered with a thick cuticle, also minimizes water loss.
    b) Student answers will vary. One possibility for a long-term experiment would be to grow two sets of the same plants under controlled conditions. The only difference in the plant's environment would be the concentration of carbon dioxide in the atmosphere of the plant.

The effect on stomatal density could then be investigated.

c) Student answers will vary.
   i) One possibility is as follows: If stomatal density in fossil trees is different from the stomatal density found in similar types of modern trees, a level of CO_2 different from the level present today, or a more or less humid environment, might be inferred.
   ii) The research of paleobotanists might be used to associate certain growth conditions like stomatal density with conditions of the atmosphere that are known from measures made by other scientists.

Note: The issues addressed in this question provide foreshadowing for Unit D.

Student Book page 322

C3.4 Check and Reflect

1. The properties of adhesion and cohesion aid in water transport in plants.
2. When a plant cell is placed in a solution that is hypertonic to the cell contents, the vacuole shrinks and the contents of the cell move away from the cell wall as water moves down the concentration gradient and out of the cell. In a hypotonic solution, the vacuole will increase in size and there will be pressure against the cell wall, until the cell is turgid, because water moves into the cell from the surrounding solution.
3. Plants that have access to the air use stomata to control the amount of water that is lost. Stomata close in response to external conditions and water loss is reduced. Stomata are located mainly on the lower surface of the leaf away from the direct rays of the Sun.
4. The two types of vascular tissues are the xylem and the phloem. The xylem transports water and minerals from the root to the leaf. The phloem transports sugars from the leaf to other parts of the plant.
5. Turgidity keeps the stems straight and the leaves exposed to the maximum amount of light, which allows photosynthesis to occur.
6. Only certain of the cells were stained because they were the cells in which water with dye was left for long enough for the dye to deposit. These are cells of the xylem.
7. To move water from the roots to the leaves, the root hairs absorb minerals from the soil by active transport and water enters by osmosis because of the high concentration of solutes in the roots. This leads to root pressure, which forces water through the cells or along cell walls into the xylem. Once the water is in the xylem, it moves upward through the rest of the plant because of transpiration pull. Transpiration pull is caused by each water molecule's attraction to the water molecule next to it, so that as water evaporates through the stomata in the leaves, the water molecules are drawn up the xylem. The processes occur more rapidly if the temperature is warmer.
8. Sugars from photosynthesis are transported from the leaves to other parts of the plant through the phloem. At the source (i.e., the leaves) companion cells take in sugar molecules by active transport. Water then moves into the cells by osmosis. The pressure of the water pushes the water and sugars through the phloem to the other parts of the plant (root, tuber, fruit, etc.).
9. Student concept maps will vary.

Student Book page 328

C3.5 Check and Reflect

1. Tropisms are responses of a plant to stimuli and are important control mechanisms to ensure survival of the plant. Tropisms are ways for the plant to meet its needs.
2. Positive phototropism means that the plant reacts toward the direction of the stimulus of the Sun and so the shoot grows toward light. Negative gravitropism means that the plant reacts in the opposite direction to the stimulus of gravity. This also results in the shoot growing up away from the ground.
3. Phototropism ensures that the plant receives enough light to perform photosynthesis. Gravitropism ensures that the roots of the plant can find soil, nutrients, and water.
4. Charles and Francis Darwin found that seedlings with the tips covered did not respond to light, but seedlings with the tips uncovered, but with all other parts covered, did respond to light. They concluded that the tip of the stem was the area responsible for the detection of the light stimulus, but was not the place where the bending response was carried out. They inferred that the cells of the tip were somehow communicating with the area of bending. These observations led to further studies on movement of substances in plants.
5. The work of Boysen-Jensen is an example of scientific inquiry because he used manipulated and responding variables to test effects on plants. His manipulated variable was the possibility for movement from the tip to the area of elongation; his responding variable was the bending of the

plant towards the light. He had a control in the normally growing plants and another in the plants in which the tip was completely removed.

6. Tropisms are the plant's control mechanisms because the way in which plants respond to various stimuli determines the way in which the plants develop.
7. It was important to ensure that the Petri dish was not exposed to light in order to make sure that the effect on the growth of the seedlings was due entirely to the effect of gravitropism.
8. Student answers will vary, but could include the use of various synthetic hormones to speed up and synchronize the ripening of tomatoes, cherries, and other fruits, to slow the growth of commercially produced potted plants, and to discourage growth of weeds among crops.
9. Students' lists will vary but should be logically arranged with regard to long day, short day, and day neutral plants. These terms have not been included in the text, so students are not required to use them but should suggest similar categories.
10. Student responses will vary but should include a logical sequence of data collection, including lists of species selected for study, bloom dates, and temperature.

Student Book page 330

C3.0 Section Review

Knowledge

1. The benefits of being multicellular are that different functions can be performed by specialized groups of cells. Each cell is not responsible for carrying out all the life processes. This allows organisms to grow to an increased size.
2. Individual cells take on a particular job within an organism. A red blood cell, which is specially designed to transport oxygen and carbon dioxide through the body, is a good example. Tissues are made up of a group of cells all specialized to perform the same function. An example of a tissue is connective tissue, which is designed to provide structural support to vessels, nerves, and other body parts. An organ is a group of tissues that work together for the same function. The heart, which functions to pump blood throughout the body, is an example of an organ.
3. The two main plant systems are the shoot system and the root system. Generally speaking, the shoot system is made up of everything above ground, and the root system of everything below ground. Tissues in the shoot system are designed to conduct photosynthesis, and transport the products throughout the plant. Tissues in the root system are designed to absorb water and nutrients from the soil and in some cases to store substances.
4. a) Dermal tissue is the outer layer of cells responsible for the exchange of oxygen and carbon dioxide in plants. This layer also helps to reduce the amount of water lost by the plant, and protects it from disease.
   b) Ground tissue makes up the majority of the plant and is found as a layer beneath the dermal tissue. In the stem it provides strength and support to the plant, in the roots it is involved in food and water storage, and in the leaves it is the location where photosynthesis takes place.
   c) Vascular tissues transport materials through the plant.
   d) Xylem tissue moves water and dissolved minerals from the roots up the stem to the leaves.
   e) Phloem tissue transports sugars from the leaves to other parts of the plant.
5. The cuticle serves to reduce water loss from the plant and also to protect it against infection.
6. Cells in the meristems are much more active in cell division than cells in other areas of the plant. They are also less specialized.
7. Chloroplasts are almost spherical organelles in plant cells. They are green in colour because of the presence of chlorophyll. They are found mainly in the ground tissue of stems and leaves. The function of chloroplasts is to carry out photosynthesis, by converting carbon dioxide and water in the presence of chlorophyll and light energy to glucose and oxygen.
8. The word equation for photosynthesis is
   water + carbon dioxide $\xrightarrow{\text{chlorophyll+light}}$ glucose + oxygen
   The balanced chemical equation is
   $6H_2O_{(l)} + 6CO_{2(g)} \xrightarrow{\text{chlorophyll+light}} C_6H_{12}O_{6(aq)} + 6O_{2(g)}$
9. Movement of chloroplasts within the cell gives us evidence of cytoplasmic streaming. It is indirect evidence because we are not observing the streaming itself, but rather its effects on other cell components.
10. Another sequence of reactions that produces a gas in cells is called cellular respiration.
11. Student diagrams will vary but should resemble Figure C3.15.

12. Cohesion is the attraction between molecules of water. Adhesion is the attraction between molecules of water and molecules of some other substance. The two forces of attraction work to draw water up through the plant stem as water evaporates from the leaves.
13. Plants can be divided into those which require more than 12 hours of darkness to flower (chrysanthemums, pointsettias, Christmas cactus), those which require more than 12 hours of daylight to flower (coneflowers, lettuce, spinach, potatoes), and those for which flowering is unaffected by length of daylight (tomatoes, strawberries, corn).
14. During the formation of the xylem, the cells fuse together and end walls become perforated. The cytoplasm then breaks down and the cells die leaving the non-living cell walls attached like a long straw.
15. Sieve tube cells transport sugars through the plant from the source where they are produced to the sink where they are stored. Companion cells use active transport to move sugars into and out of the sieve tube cells. They also supply other needs of the sieve tube cells.

Applications

16. Animals are not able to manufacture their own food because they lack chloroplasts, which plants use to convert solar energy into useable chemical energy.
17. Photosynthesis and cellular respiration are opposite processes. In photosynthesis, the plant uses water and carbon dioxide in the presence of light energy and chlorophyll to produce glucose and oxygen. In cellular respiration, the plant takes glucose and oxygen to produce carbon dioxide and water and release energy.
18. If a human red blood cell were placed in a hypotonic solution, water from the solution would enter the cell by osmosis. Because animal cells lack a cell wall to hold in the contents, the cell would continue to increase in size until it exploded through rupture of the membrane.
19. Student diagrams will vary, but should show the opening of the stomata as turgor pressure in the guard cells increases, causing the cell to become crescent-shaped, and the closing of the stomata due to the flattening of the limp cells when turgor pressure decreases.
20. The air spaces between the mesophyll allow gas exchange to occur more easily, because diffusion occurs more rapidly in a gas than in a liquid.
21. The major force for the movement of water from roots to leaves is transpiration pull. As water molecules evaporate through the stomata in transpiration, a pressure difference exists between water at the leaf and water at the root. The cohesion between the evaporating molecule and adjacent molecules of water causes a pull on the molecules in the xylem tubes in response to the pressure difference. This causes the water to rise through the plant. This is transpiration pull. Adhesion of the water molecules to molecules of other substances on the way up the xylem also helps the water to rise.
22. If a strong light were placed below the shoot, the shoot would begin to bend downwards towards the light because of positive phototropism.
23. Water movement is stimulated by transpiration pull and by the use of water in photosynthesis. The rate of transpiration depends in great part on temperature and humidity. In most cases, temperature drops at night, so transpiration decreases and the need for water movement also decreases. Photosynthesis does not take place at night, so this stimulus to water movement is also absent. For these reasons, although there may still be root pressure forcing water upward, you would not expect significant water movement at night.
24. Sugars from photosynthesis are transported from the leaves to other parts of the plant through the phloem. At the source (leaves), companion cells take in sugar molecules by active transport. Water then moves into the cells by osmosis. In turn, these substances move into the sieve tube cells. The pressure of the water pushes the water and sugars through the phloem to the other parts of the plant (root, tuber, fruit, etc.): that is, from source to sink.
25. The epidermis regulates gas exchange through the opening and closing of the stomata, because the remainder of the epidermis is covered by cuticle, which prevents water loss. The epidermis also regulates water movement through the opening and closing of the stomata. The two processes are opposed because for increased gas transport the stomata should be open, but this means increased water loss.

Extensions

26. Student experimental designs will vary, but should use principles of scientific investigation, and the use of controlled, manipulated, and responding variables.
27. Student answers will vary.

Unit C Review

Vocabulary

1. The vocabulary items should be defined in a similar way to the definition of terms in the glossary.

Knowledge

C1.0

2. Hooke's microscope used a three-lens system; that is, it was a compound microscope, whereas van Leeuwenhoek's microscope used only one hand-held lens. Hooke used light directed onto the specimen through a water-filled glass. Van Leeuwenhoek used only bright daylight.
3. Blurry images seen through early compound light microscopes were associated with problems in lens technology. These problem were overcome by using achromatic lenses to control the halo of light around the specimen, and the amount of detail seen.
4. Francesco Redi's investigation was a controlled experiment in the sense that he manipulated one variable (the access of flies to the meat) in order to see the response in another variable (development of maggots in the meat) and he held all other variables, such as the type and amount of meat and the type of container, constant.
5. Redi observed the development of maggots in covered and uncovered meat in an attempt to disprove the theory. John Needham heated chicken broth in a flask, and then observed the development of micro-organisms. It was accepted that heating the liquid would have killed any micro-organisms present in the broth, so it appeared that spontaneous generation was supported. Spallanzani repeated Needham's experiment, but removed the air from the flask, and nothing grew in the broth. Pasteur finally ended the debate with his experiment, in which he placed meat broth into flasks and heated them to boiling point. One flask was left open to the air completely. The neck of the other was bent into an S shape, which would allow air to pass into the flask, but would trap air-borne particles in the S bend. In this way he showed that the air-borne particles were necessary for the growth of the mould.
6. a) Brown was the first scientist who in observing the nucleus (in orchid cells) suggested that it must have some importance in cell function.
   b) Schleiden observed that all plants were composed of cells and proposed that the nucleus was the structure responsible for the development of the rest of the cell.
   c) Schwann identified both cells and nuclei in animal tissue.
   d) Virchow made the statement that all cells arise only from pre-existing cells.
7. Resolving power is the ability to distinguish between two structures that are very close together. The wavelength of light limits the resolving power of light microscopes.
8. The advantage of using an electron microscope is that the resolution of the system is many times greater than that of a light microscope, so the detail that can be seen in images is much greater. Surface structures can be examined. Disadvantages are that specimens must be fixed in the TEM, and therefore living specimens cannot be examined and also that building up a three-dimensional picture from thin sections is difficult because the area covered by each image is very small.
9. The advantages of conducting cell research at the molecular level are that new information and understanding are gained about the way that molecules function in cells. This increases our understanding of the cell as a whole and may allow applications to medicine and other subjects. For example, research into the structure and function of DNA has led to an understanding of the function of genes and therefore to gene therapy and fetal diagnosis.
10. One advantage of staining a specimen is that it allows us to see the structures of the specimen more clearly. One disadvantage is that stains "fix" the cells, so they are no longer alive.
11. Fluorescence microscopy allows us to observe the location of specific structures in the cell and may allow study of differences in protein structure between healthy and diseased tissues.
12. The micrometre is the unit of measurement most commonly used to measure the cell and its parts. $1\ \mu m = 10^{-6}\ m$

C2.0

13. An open system is a system that can exchange energy and matter with its surrounding environment. A cell is considered to be an open system because it takes in nutrients and energy and puts out waste products, as well as exchanging gases with its environment.

14. a) The nucleus directs all cell activities and contains the genetic material of the cell.
    b) The central vacuole is a structure in plant cells that stores water and nutrients for the cell's use. The vacuole swells when fluids enter, and causes the cell to become firm or rigid. This condition is called turgidity.
    c) The cell wall is a structure found in plants, bacteria, protists, and fungi. It provides strength and support to the cell.
15. The rate of diffusion decreases as the ratio of surface area to volume decreases.
16. The cell membrane, nucleus, cytoplasm, cell wall, and chloroplasts are visible through a light microscope.
17. Diffusion is the natural movement of particles from an area of high concentration to an area of low concentration, with the end result being a state of equilibrium. Osmosis is the term used to describe the diffusion of water.
18. Cells must be able to take in nutrients, grow, respond to stimuli, exchange gases, and remove wastes.
19. The particle model is useful in understanding the movement of matter because knowledge of concentration gradients and membranes within the body can be used to understand how substances are transported around the body.
20. The term concentration gradient refers to a difference in the proportions of solute and solvent in two different areas. A concentration gradient may exist across a membrane. If the membrane is permeable, both the solute and the solvent will diffuse across the membrane until the solution on either side of the membrane is at the same concentration. If the membrane is semi-permeable, and permits only the passage of water, only water molecules will be able to cross the membrane, by osmosis, to bring the two solutions to equilibrium.
21. In Activity C8, starch was placed inside a sac made of a zipper lock bag, which was then placed in a beaker of water containing iodine tincture. Students tested the colour of iodine in water and iodine in starch solution. After 20–30 minutes, students observed a colour change in the starch solution inside the bag, but no colour change in the water surrounding the bag. They also observed an increase in the "tightness" of the bag due to the entry of water by osmosis. They can infer that iodine ions passed through the membrane but starch did not. They may explain this by the difference in size of the two particles.
22. A vesicle is a sac formed from a section of the cell membrane that pinches off to surround and contain a large particle. In endocytosis, a vesicle forms around a particle and pinches off from the cell membrane, to encompass the particle within the cell. In exocytosis the vesicle surrounds the particle, moves to the cell membrane and fuses with it. At that point, the vesicle ruptures and releases its contents into the surrounding environment.
23. Liposomes can transport water-soluble medications in the water trapped on the inside of the sac and fat-soluble medications in the phospholipid membrane.
24. To desalinate water at the McMurdo Research Station, the water is first warmed slightly, then it is pumped through a 25 μm filter to eliminate coarse materials. The water is then filtered through smaller and smaller semi-permeable membranes using reverse osmosis. As the water is forced through the filters, more and more particles are filtered out, and the solute concentration in the unfiltered volume builds up, meaning that more energy is required to push the water through the filter.
25. Student answers will depend on the size of the published text. The book "cell" would be efficient in the transport of materials because it has a large surface area to volume ratio.

C3.0

26. a) Meristem: an area in the plant in which growth occurs, due to a high rate of mitosis (cell division).
    b) Shoot system: all those parts of the plant that are above the level of the ground and also any modified stems like tubers.
27. Some examples of cell specialization are root cells with root hairs, epidermal tissues with cuticle and guard cells, and the long hollow tubes formed by the dead cells of the xylem. Root hairs increase the surface area for absorption of water and therefore the amount of water that can be taken in by the root cell. The cuticle and guard cells within the epidermal layer act to reduce the amount of water lost by the plant. Xylem tubes conduct water through the plant.
28. The three main types of plant tissues are dermal tissue, ground tissue, and vascular tissue. Dermal tissue is responsible for the exchange of matter and gases with the environment. Depending on its location within the plant, ground tissue provides strength and support, stores food and water, and performs photosynthesis. Vascular tissues move materials through the plant; xylem moves water and dissolved minerals, phloem moves sugars and water.

29. Light and chlorophyll are not considered reactants or products because they are not produced or used up during the chemical reaction.
30. Turgor pressure is the pressure applied by water against the cell wall in plants, when water enters the cell due to concentration differences. It is important to the plant cells because it gives rigidity to the plant as a whole and helps to keep the leaves spread out for exposure to light energy from the Sun.
31. Transpiration is the process of water leaving the leaf through stomata. Transpiration has the effect of drawing water upwards through the plant from the roots, due to the cohesion between water molecules.
32. A vascular bundle is made up of grouped xylem and phloem tissues. Xylem transports water and salts; phloem transports sugars.
33. Root pressure works to move water up a plant stem through a combination of active transport and diffusion. Minerals are transported actively into the root cells. Because the concentration in the cells becomes higher, water then diffuses into the root cells, creating a positive pressure that forces fluid up the xylem.
34. Xylem and phloem are the same in that they are the pathways for transportation within the plants and both the xylem tubes and the sieve cell tubes of the phloem result from development involving many cells. They are different in that the cells of the xylem tubes are dead by the time they are mature while the sieve tube cells of the phloem are still living. Also, xylem carries water and salts from the roots to the other parts of the plant. Phloem carries sugars from the leaves (source) to the sink (other parts of the plants).
35. Xylem is composed of dead cells. As cylindrical xylem cells mature, they fuse together and the walls at each end become perforated. The contents of the cytoplasm break down and the cells die, leaving the non-living cell walls attached together like a straw. Although phloem cells also have perforated end walls, and lack a nucleus, cytoplasmic streaming between cells ensures that the cells remain alive.
36. A tropism is a plant's response to a stimulus. Phototropism is growth movement in response to light. Gravitropism is growth movement in response to gravity.
37. One method to determine the presence of carbon dioxide in water is to add bromothymol blue, which changes colour from blue to green to yellow with increasing concentration of carbon dioxide in water.

Applications

38. Conducting controlled experiments, maintaining detailed records of observations, and connecting results to conclusions are important because they allow the experiment to be tested and recreated by other experimenters. Student answers will vary.
    Example of a controlled experiment: Activity C13. In the comparison of effects of light and dark on the evidence of carbon dioxide production, the vial size, length of *Elodea* frond, and other conditions of the experiment were kept the same for the dark treatment and the light treatment. Observations of the colour of the solution in the vials were made at the same time and in the same way. Control vials of water in both light and dark treatments were part of the experiment. Conclusions were drawn from the results and future experiments were suggested.
39. 16 protists fit across 4800 μm.
    Therefore the dimensions of one protist are:
    $$1 \text{ protist} = \frac{4800\ \mu\text{m}}{16} = 300\ \mu\text{m}$$
40. Student examples will vary. A possible answer is as follows:
    The development of the light microscope led to the initial discovery of cells, as well as structures within the cell, like the nucleus, cell membrane, and chloroplasts. Fluorescence microscopy has allowed the study of antigens on the surface of cells. Antigens on blood cells determine human blood groups. Electron microscopy allows thin sections of tissue to be studied in much greater detail than is possible in other forms of microscopy. This study revealed details of known structures like the Golgi apparatus and structures that had never been seen before, like the two layers making up the cell membrane.
41. The processes of diffusion and osmosis in the cell take place according to the principles of the particle model. The higher the concentration of a substance, the more particles will be present and the faster they will move through the cell or the cell membrane, providing the membrane is permeable to the substance.
    If the membrane is not permeable to a substance, the proteins present in the membrane, according to the fluid mosaic model, may move the substance by facilitated diffusion or by active transport. Substances that cannot be moved by any of the above methods may be enclosed in a portion of cell membrane called a vesicle. The vesicle forms due to rearrangement of the components of the fluid phospholipid part of the membrane.

42. Student diagrams will vary, but should show an area with higher concentration and an area with lower concentration of solutes and an arrow to indicate the movement of water.
43. The strawberries will be covered with juice because the sugar on the outside of the fruit will cause water to move out of surface cells by osmosis.
44. Facilitated diffusion occurs when carrier proteins allow particles that are too large to pass the cell membrane on their own to move along the concentration gradient from areas of high concentration to areas of low concentration. An example of facilitated diffusion is movement of glucose.
45. The climate in the desert is very dry, which can easily lead to dehydration, so desert plants need to conserve water as much as they can. For this reason, it is preferable for cacti to have large thick stems, and few or no leaves so that the surface area to volume ratio is small and less water is lost through evaporation. In the rain forest, the climate is very humid, so evaporation of water from the leaves occurs more slowly. Rain forest plants need to have many large flat leaves so that the surface area to volume ratio is high and evaporation can keep water moving through the plant efficiently.
46. Nerve cells are long and slender, which helps them to transport impulses over a distance. Blood cells are "donut" shaped in a biconcave disc, to provide the greatest possible surface area in relation to the volume, in order to provide more efficient transport of oxygen and carbon dioxide. Root hair cells increase the surface area for absorption of water, so that the amount of water that is able to enter the root by osmosis is maximized.
47. Cytoplasmic streaming allows the products of photosynthesis to move more quickly throughout the cell because the cytoplasm carries with it the chloroplasts that perform the process.
48. Plants can maintain firm cells due to the cell structure called the cell wall, which exists in plants but not in animal cells. When water rushes into the cell, pressure is exerted against the cell wall, which makes the plant stand up firmly. It is the ground tissue in the stems that maintains that firmness.
49. The advantage to having the palisade mesophyll cells arranged in a fence-like pattern is that they are packed tightly together and a greater number of cells are exposed to the Sun. The palisade mesophyll cells contain the bulk of the chloroplasts in the leaf, so the greater the number of cells exposed to sunlight, the more photosynthesis can be performed in the leaf.
50. The experiment that we performed tested the effect of gravitropism and phototropism on oat and corn seed germination. In the first part of the experiment, seeds were placed in Petri dishes at 12, 3, 6, and 9 o'clock positions, covered with with wet paper towel, and kept in place with cotton batting. The Petri dish was attached to the inside of a cupboard door that was in the dark and the seeds were allowed to germinate. The roots of all the seeds grew towards the floor of the cupboard, even in the dark. This showed that it is a reaction to gravity (positive gravitropism), rather than to light (negative phototropism) that causes roots to grow downwards. In the second part of the experiment, oat seeds were allowed to germinate in a tray that was lit only from one side. One third of the seedlings were then transplanted more deeply, so that only their tips were exposed to the light, one third of the seedlings had just their tips covered, and the final third were left unaltered. All three trays of seedlings were placed back in their initial position relative to the light source. Where the seedlings were planted more deeply, they still bent towards the light. Where the tips of the seedlings were covered, they did not bend towards the light. The unaltered (control) group of seedlings bent towards the light. This experiment seemed to show that the tip of the seedling is the part that controls the growth towards light (positive phototropism) in plants.
51. During plasmolysis in plant cells, water leaves the cell through osmosis, and the central vacuole shrinks. The cell membrane around the cytoplasm also shrinks away from the cell wall. The cell wall is rigid, so the shape of the cell is maintained, but it loses some of its firmness. The plant wilts because of this loss of firmness. This process can be reversed by watering the plant, so that the root hairs in the root cells absorb water, which is then transferred to the rest of the plant and the cells become turgid again.
52. The pressure-flow theory describes the movement of sugar molecules through the phloem from the sites of photosynthesis. Carrier proteins in the companion cells use active transport to move sugars into the sieve tube cells. Water follows by osmosis, and also enters the sieve tube cells. As the pressure increases in the cells, the water and the sugars get pushed along through the phloem to a sink (root, tuber, fruit, etc.). The pressure differences drive the movement of substances through the phloem.

53. Agree. The two gas exchange functions in plants are photosynthesis and cellular respiration. In cellular respiration, plants use glucose and oxygen and produce carbon dioxide, just like animals do, but at much lower levels than in animals. At night, plants cannot continue with photosynthesis, and so they conduct only cellular respiration. In this way, plants act more like animals at night.
54. Water transport occurs in the xylem and transports substances from roots to leaves. Sugar transport occurs in the phloem and transports sugars from the site of photosynthesis at the leaves to other parts of the plant, which may be the roots, shoot, or fruits. Water transport depends mainly on the transpiration pull exerted as a result of loss of water through stomata, whereas sugar transport depends on pressure differences resulting from active transport of sugars into the companion cells of the phloem followed by movement of water by osmosis.
55. Turgidity is important particularly in the stem because it makes the plant rigid and able to stand upright. Pea plants have a response to touch that results in tendrils coiling around structures; this supplements turgidity in holding the plant up. Students may not know that the term for this tropism is thigmotropism.
56. Students' examples may vary. One possibility is to discuss gas exchange. Gas exchange occurs in a single cell by diffusion. In the multicellular plant the actual exchange is by diffusion but there are specialized cells that channel the gases to each individual cell. These specialized cells are the guard cells that form the stomata. When the stomata are open, gases enter the leaf very easily. Once in the leaf, the arrangement of the spongy mesophyll cells with many air spaces between them allows the gases to circulate easily to all parts of the plant.
57. The cell theory replaced the concept of spontaneous generation in the time that discoveries of the presence of cells in all types of organisms, both plant and animal, were being made. As well as these observations, experiments such as those of Redi, Spallazani, and Pasteur provided evidence that went against the concept of spontaneous generation.
58. Students study sheets will vary, but they should include the material provided in Student Reference 8: The Compound Light Microscope.

Extensions

59. Student answers may vary. There are a number of problems that land-plants may face that water-plants do not. The first is an adequate supply of water to be taken in through the root hairs on roots. Water loss in air is another problem that aquatic plants do not have. Land plants must develop a system of stomata to control access to air and to control water loss. In some places, temperature may be a problem for all cellular reactions as well as for its tendency to increase evaporation and so loss of water.
60. Student answers may vary. The answer may depend on the conditions, time of year, etc. Students should point out that since water transport involves active transport of minerals into the roots which is then followed by osmosis, the process does requires some energy. However, phloem transport involves first the loading of the companion cells with sugars by active transport, followed by osmosis, so it too is an energy-requiring process.
61. Students may need to research the meaning of hydroponic. Since the make-up of a hydroponic solution can be known exactly, experiments could be carried out in which some plants received the mineral being tested but others did not. This would show if the mineral was necessary or not.
62. Student answers will vary. Plants respond quickly to environmental change in defined ways. The response of the plant to different levels of greenhouse gases could be tested under controlled conditions. The number of chloroplasts, their activity in producing oxygen, which is one of the products of photosynthesis, or their consumption of carbon dioxide, could be regarded as a measure of the plant's photosynthetic activity.
63. Student answers will vary. Students may suggest that having stomata on the undersurface of the leaf is a mechanism to conserve water because the stomata will be out of the direct rays of the Sun. With regard to conditions that could affect the placement of stomata, water plants are excellent examples. Plants on the surface of the water, such as water lilies, will have their stomata on the upper surface of the leaf because this is the location that gives access to the air. Completely submerged plants like *Elodea* do not have stomata. These plants obtain carbon dioxide and oxygen by diffusion of these gases dissolved in the water.
64. Student answers will vary.
65. Student answers will vary.
66. The sphere is the shape with the smallest surface area to volume ratio for any particular volume, so there will be a tendency for this shape to be avoided.
67. Leaving the cut stem out of water will adversely affect its ability to transport water, because the xylem cells at the cut surface will lose water and

therefore air will be introduced into the tubes. When the stem is placed in water again, the air gap prevents attraction between the water molecules in the stem and in the container, so transpiration pull cannot happen. The stem must be cut above the air pocket and inserted into water right away (or preferably cut under water) to restore the continuous "chain" of water molecules.

68. Student answers will vary.
69. Student answers and presentations will vary, but will probably include the central role of the microscope in the discovery of the cellular nature of life and the development of cellular biology, which has led to scientists' understanding of the transport processes at the cellular level and systems level.
70. Student answers will vary. One possible answer would be to have plant type and initial size, pot type, soil type, and growing conditions of light, temperature, and humidity as controlled variables. The manipulated variable would be the amount of fertilizer. The concentration of the fertilizer should range from zero, similar to fresh water, by a series of increments.
71. Student reports will vary, but should include a statement of the purpose of the project, and a brief description of the methods used.

Skills Practice

72. Student answers will vary but should include all points in Student Reference 8: The Compound Light Microscope, that have to do with wet mounts.
73. A hypothesis provides an explanation or answer to the question, which can then be tested by further experiments.
74. Objects chosen will vary.
75. Students will begin by measuring the actual diameter of the field of view under low power. They will then use inverse proportion to calculate the diameter of the field of view on high power. Once the diameter is known, an estimate of the size of the object can be made.

Self Assessment

76. Student answers will vary, but will probably include the ideas that technology applies scientific knowledge in a practical way, and technology allows for scientific investigation. Students may use spontaneous generation as an example of the difficulty in getting people to modify or reject a theory that is widely accepted.
77. Student answers will vary.
78. Student answers will vary.