SCIENCE

Year 8
Answers

Lessons 6–7

Topic: Examining the building blocks of life

Analysing cellular structure and function

Lesson concepts

- Cells are the basic units of living things and have specialised structures and functions
- Questions and problems that can be investigated scientifically can be identified
- Representations can be used to analyse relationships
- Data can be summarised and scientific understanding can be used to identify relationships and draw conclusions
- Ideas, findings can be communicated using scientific knowledge and representations

Learning alerts

Be aware of students thinking that only plant cells contain chloroplasts.

Suggested next steps for learning

- Students need to understand that plant cells as well as algae and some bacteria have chloroplasts for photosynthesis.

Science start-up notes

Students review the major differences between the cellular structure of plant and animal cells. They consider questions scientists might ask themselves about cellular structures they observe under the microscope.

Lesson notes

Students use the **Slideshow — Structure and function of specialised cells** and **Sheet 4 — Cell specialisation** to investigate the relationship between structure and function in specialised plant and animal cells. The slideshow contains notes about the structure of the cells in the various images. Students need to read these notes in order to complete **Sheet 4**. Each slide also contains guiding questions, which will assist students in formulating their responses.

Science start-up answers

1. a–b. Student responses will vary depending on which organelles or structures they choose. Students must include information about the structure and function. For example: The nucleus is a membrane-bound organelle found in all plant and animal cells, It regulates all cell functions and contains genetic material involved in cell division.
Note: Students should not include cell wall or chloroplasts in their response, as these are found only in plant cells.

   c. The rigid cell wall which keeps these cells relatively uniform in shape; the presence of many green organelles that are likely to be chloroplasts.

2. For example:
   - What is the cell wall made of?
   - Are materials able to move through the cell wall? If so, then how?
   - Why do these cells have so many chloroplasts and what role do they perform?
   - Do all the cells in this organism have the same structure as these cells?
   - Do these structures tell me anything about what type of plant it is, where it might grow, how it might carry out metabolic processes or reproduce?
   - How can I go about magnifying these structures further so I can see more of their structure?
   - How do I go about finding out more about how these structures function?

Lesson answers

3. a. The onion cells are more elongated and rectangular than the spider lily cells and arranged in layers. The cell walls are thicker. While the nuclei in the onion cells are clearly visible other organelles are either not visible or not present. The stippling inside the cells could be indicative of granules in the cytoplasm. The spider lily cells vary considerably in size and are more octagonal in shape. They contain a large visible central vacuole which restricts the other organelles to the outside of the cell. Given the number of similar organelles, it could be hypothesised that these are chloroplasts.

   b. Given that the onion cells are epidermal cells, the thick cell wall and layered structure provides a protective barrier between the environment and the internal soft tissue of the onion. Being an underground storage organ it would not be involved in photosynthesis and the absence of chloroplasts would be expected. The more octagonal form of the spider lily cells along with the variable cell sizes enables them to be packed in tightly within the cylindrical shape of the stem, providing support. The presence of possible chloroplasts indicates a role in photosynthesis. The large fluid-filled central vacuole in the cells would assist with movement and storage of water through the stem and provide structural support for the stem and flower head.

4. No answer required

5. **Sheet 4 — Cell specialisation** (attached).

6. a. For example

Cell specialisation	Advantage or disadvantage
Having greater complexity and being able to complete more complicated tasks.	advantage
Specialised cells require less energy to perform their specific role and there is less wastage of resources.	advantage
More simplified individual components.	advantage
The organism can be larger in size and have a variety of body forms.	advantage
Time taken to reproduce is longer and requires more energy and resources.	disadvantage

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Cell specialisation	Advantage or disadvantage
Materials need to be transported further, so the whole organism requires more energy to function.	disadvantage
Ability to live in a range of environments.	advantage
Processes within the organism are more efficient because they can occur in different parts of the organism and at different times.	advantage
Organism has a longer life span and injury or death of some cells has a small impact on the whole organism.	advantage
Separation of functions requires a complex system of coordination and control within the body of the organism.	disadvantage
Reproductive and development processes, and regulation of these processes, is far more complex to ensure cells differentiate correctly.	disadvantage

b. The main advantage of cell specialisation is that organisms can be of variable size and shape, particularly larger sizes. Functions can be compartmentalised and separated over space and time, making processes more energy efficient and less wasteful of resources. For example, plants that require part of their body to be in one medium and another part in a different medium, cell specialisation means that root cells can be in the ground where they can be totally responsible for water and nutrient absorption, while leaf cells can be in positions where they can access the maximum amount of light for photosynthesis. Plants can therefore grow to enormous heights and in variable directions. Water can be stored in the plant and used when conditions are best for photosynthesis and not at times when evaporation rates are high. Cell specialisation enables multicellular organisms to have more complexity in the way their bodies are structured and to perform more complex tasks. This compensates for the disadvantages of increased energy demands for reproduction, transport of materials between systems, coordination and control of processes. It also enables different multicellular organisms to take advantage of different environments on Earth, to survive in varying conditions, to modify their behaviour and/or the way they interact with the environment. This reduces competition for resources over the surface of the planet, increases diversity and improves chances of reproduction and survival. Cell specialisation increases the life span of organisms; having multiple cells means that the death and injury of some cells has little or no effect on the survival of the organism.

7. a. Student response must be a question that could be investigated scientifically, using processes of scientific investigation, for example: hypothesising and modelling, fair testing, measuring, researching to collect data or evidence to support/refute a hypothesis, to provide understanding of the relationship between cell structure and function.

   For example: How does the cell wall still allow materials to move in and out of a plant cell?

   b. For example: By investigating this question you would be collecting observations and information about the structure of the cell wall. You could devise a model of the structure and then isolate cell walls from plant cells and perform biochemical tests to determine what they are composed of. You would examine the cell wall under a high resolution electron microscope. You could observe plant cells in different solutions to see if and what materials are able to pass through the cell wall. Findings about the structure could lead you to hypothesise how the cell wall functions. You would devise experiments to test your hypotheses.

Lesson 8

Topic: Understanding the nature of the cell

Evaluating cell theory

Lesson concepts

- Cells are the basic units of living things
- Scientific knowledge changes as new evidence becomes available and some scientific discoveries have significantly changed people's understanding
- Questions and problems that can be investigated scientifically can be identified
- Data from secondary sources can be summarised and scientific understanding can be used to draw conclusions
- Claims can be evaluated using scientific knowledge and findings from investigations
- Ideas, findings can be communicated using scientific knowledge and representations

Learning alerts

Be aware of students thinking that cell theory is no longer contestable and unable to be refined.

Suggested next steps for learning

- Explain to students that as microscope technology advances, more evidence regarding cell structure and function is collected that may confirm or refute current understandings about cells.

Science start-up notes

This lesson focuses on historical cell theory developed through the work of historical scientists. Students begin by reviewing the work of historical scientists investigating cell structure and the ideas presented as original cell theory tenets.

Lesson notes

Students are encouraged to consider how scientific knowledge changes as new evidence becomes available and how scientific discoveries change people's understanding. To do this, students will evaluate the claims made by historical scientists, using evidence gathered by later scientists. They will consider how new evidence might have changed the principles of historical cell theory and how ongoing advancements in microscope technology are enabling scientists to not only discover new things about cell structure, but to confirm or refute theories and models suggested by historical scientists.

Science start-up answers

1. a. Schleiden and Schwann agreed that all living things are composed of cells and that the cell is the basic unit of life.

b. Schleiden and Schwann disagreed about the way in which new cells are formed. Schleiden believed they resulted through spontaneous generation, while Schwann believed they originated from pre-existing cells.

c. At the time of their research the idea of spontaneous generation was a commonly held view within the scientific community as well as in the general population. Schwann conducted a number of experiments to support his position that cells form from a range of processes.

Lesson answers

2. Personal response required. For example:
   - All living things are composed of cells
   - Cells are the basic unit of life
   - Different groups of living things (for example: prokaryotes and eukaryotes; plants and animals) have different cellular structure and this can be used as a classification criteria
   - Cells in multicellular organisms become specialised and have specific roles
   - Organelles and other structures within the cell are responsible for carrying out the functions of the cell

3.

Tenet of historical cell theory	Schleiden's evidence	Schwann's evidence	My evidence
All living things are composed of cells.	Microscopic observation revealed that plant tissues were composed of cells and the nucleus was commonly found in plant cells.	Comparison of observations of plant and animal cells revealed similar structure.	Personal response required.
The cell is the basic unit of life.	Microscopic observation revealed that plant tissues were composed of cells and the nucleus was commonly found in plant cells.	Microscopic observation revealed that animal cells from different tissues all contained a nucleus.	Personal response required.
Cells form from free-cell formation (spontaneous generation).	Based on general understanding applied to everyday experiences without scientific testing.	Still held onto some aspects of this belief, based on general perception and religious faith.	Personal response required.
Cells form from materials inside pre-existing cells.	No evidence provided.	Recorded developmental stages of different types of cells noting that each stage was the same for all cell types examined. Broth experiment in which no microorganisms grew in the sterilised broth because they had all been killed.	Personal response required.

4. The least valid tenet is the one concerning the formation of cells through spontaneous generation. This belief was based on people's general understanding and religious beliefs and was untested through scientific investigation. Evidence provided by Schwann discounted spontaneous generation as a valid theory.

5–7. No answer required.

8. **Sheet 5 — Cell theory** (attached).

9. a. For example: What is the mechanism for cell division?

   b. For example: In order to answer this question, scientists need to know what changes in the cell during cell division, and what chemicals inside the cell trigger and regulate cell division. These functions are associated with structures in the cell and cell division involves structural changes, so to study these functions scientists must also study the associated structures.

   c. Scientists might have gone about investigating this question by observing tissues that are known to be actively dividing under the microscope to compare cells in the tissue sample. Different types of cell could be isolated and cultured in the laboratory. They could then be observed under the microscope as they divide to see which structures are involved. Molecules in the cell could be tagged with fluorescent dyes or markers so their movements can be tracked during cell division. Specific organelles involved in cell division could be extracted through differential centrifugation and tested biochemically to determine their role in cell division.

Cell specialisation

Sheet 4 Answers

Student resource

Slideshow — Structure and function of specialised cells

Instructions

Choose at least three animal cells and three plant cells from the slideshow. For each specialised cell describe what is unique about its structure. This may include its form, shape and absence/presence of specific organelles and cellular structures. Draw a basic sketch of each cell to show its form and shape. Explain how the identified features contribute to the overall function of the cell, tissue or organ. The slideshow contains guiding questions to assist you with your explanation. An example has been completed for you.

Specialised animal cell sketch	Description of specialised structural features and explanation of how features relate to the function of the cell, tissue or organ
Smooth muscle cell 	Smooth muscle cells are spindle-shaped (wide in the middle and tapering at both ends), which enables them to be densely packed and function as a single unit, so that the whole muscle either contracts or relaxes. In the walls of hollow organs such as blood vessels, the stomach, intestines and lung bronchi, constriction of muscle cells in one section and relaxation in another will push materials forward through a vessel or organ. Their spindle shape, and the presence of thin protein strands that contract and relax, increase elasticity. This is particularly suited to organs like the stomach, bladder and uterus, which are stretched and deformed extensively and repeatedly, but need to return to their original size and shape. Like other muscle cells, you would expect smooth muscle cells to contain extra endoplasmic reticulum and ribosomes to support the production of the protein strands. You would also expect them to contain numerous mitochondria for energy production, due to the role of muscle cells in movement.
Skeletal muscle cells	Fusion of the cells lengthens the muscle tissue, which means it can span the length of different sized bones in the body. It also thickens and strengthens the tissue making it capable of moving limbs of different sizes and shapes. Various lengths and thicknesses of fibre bundles provides variable muscle strength to adjust to the effects of different forces on the skeleton during movement. The protein strands shorten and lengthen to enable the cells to contract and relax. Muscle cells would have active endoplasmic reticulum and Golgi apparatus, plus increased numbers of ribosomes to facilitate the production, packaging and movement of the protein strands in the cytoplasm. Mitochondria for the production of energy-containing molecules would also be plentiful. These molecules would be required to supply the energy needed for muscular contraction.

Sheet 4 Answers

Specialised animal cell sketch	Description of specialised structural features and explanation of how features relate to the function of the cell, tissue or organ
Neuron (Nerve cell)	Neurons have a branching structure that enables them to form complex networks and connections throughout the entire body, so that electro-chemical signals can travel quickly and to multiple areas simultaneously. This enables the nervous system to coordinate a response from multiple systems, organs and/or tissues at the same time or one after the other. The structure of the cell membrane enables rapid transmission of electro-chemical signals from one nerve ending to another and along the length of nerves. The neuron would have a highly developed nucleus, given the processes involved in detecting and responding to stimuli. Endoplasmic reticulum, Golgi apparatus and ribosomes would be very active in the production and packaging of complex structural proteins and lipids. Mitochondria would be plentiful to produce the energy-containing molecules needed to supply energy for producing and transporting chemical and electrical signals throughout the neuron network.
Epithelial cells	The epithelial cells of the respiratory system are ciliated, so they secrete mucous, and trap and move dirt, organisms and toxins entering the nose and tubes of the respiratory system to protect the delicate lung tissues. The mucous ensures the respiratory system doesn't dry out and become irritated by gases and materials moving through the tubes. The mouth and oesophagus are involved in the breakdown of solid and liquid foods. The cells lining the walls of the mouth and oesophagus protect the underlying tissues from damage by food materials as they are chewed, swallowed and pushed through by waves of muscular contraction. They also protect the tissues from damage by acids in food and in the saliva and stomach that help break down food. They also protect from invading organisms like bacteria that might be in/on our food, in the air we breathe, or that grow on our teeth/tongue. Being flattened, thin and flexible, the cells can be stacked tightly in thin layers and the epidermis is able to move freely with the movements of the digestive and respiratory systems. If the top layer of cells is removed during chewing and movement of food or breathing, then there are more layers underneath. The thin, flat cells enable the products of digestion to move from the digestive system into blood vessels and gases to move between lungs and the blood. Epithelial cells secrete mucous and enzymes, so you would expect them to have very active endoplasmic reticulum and ribosomes to produce complex proteins, and Golgi apparatus to package and move proteins. You'd also expect lots of lysosomes to aid with digestion.

Specialised animal cell sketch	Description of specialised structural features and explanation of how features relate to the function of the cell, tissue or organ
Goblet cells	Goblet cells are elongated, narrow at one end and bulbous at the other. They have a large elongated nucleus confined to the narrow end of the cell. The cell membrane at the wider end is folded into finger-like projections (microvilli). There is an active endoplasmic reticulum with many ribosomes. The wider end of the cell is full of tightly packed secretory vesicles. Goblet cells function as glands that produce and release complex proteins inside vesicles, which are then combined with other molecules to make mucous. Mucous in the intestinal and respiratory linings and in the upper eyelids keep these areas moist and clean, help trap and remove dirt, and keep materials moving along the structures of these systems. Goblet cells have an active endoplasmic reticulum and numerous ribosomes that would contribute to the production and transport of the complex protein molecules. The active Golgi apparatus would be involved in the packaging of protein molecules into the vesicles for secretion. The folding of the cell membrane increases the surface area over which the vesicles can be secreted.
Liver cells (hepatocytes)	The evidence of ribosomes and endoplasmic reticulum in the cytoplasm corresponds with the protein synthesis function of liver cells. The metabolism and break down of carbohydrates and lipids and removal of toxins would be expected to be carried out by lysosomes. The Golgi apparatus would have an active role in packaging of digestion products and wastes for transport and/or removal from the cell.

Specialised plant cell sketch	Description of specialised structural features and explanation of their contribution to the function of the cell, tissue or organ
Epidermal cells	Plant epidermal cells have strengthened cell walls. The cells are in a single layer of tightly packed cells. These features ensure that the epidermis provides a protective barrier against surface damage and water loss. Specialised guard cells in the epidermis surround pores or stomata. These cells regulate the opening and closing of the stomata so that gas exchange and water loss are regulated. Epidermal cells can secrete metabolic compounds and absorb water and nutrients, and would therefore be expected to have vacuoles. Apart from the guard cells they do not have chloroplasts, so are not involved in photosynthesis, but being thin and transparent, light energy is able to penetrate through to the photosynthetic cells below.

Sheet 4 Answers

Specialised plant cell sketch	Description of specialised structural features and explanation of their contribution to the function of the cell, tissue or organ
Guard cells	Guard cells occur in pairs around stomatal openings in the epidermis of plants. The pair of cells are elongated and firmly attached at either end. The inside cell wall next to the stomatal opening is thickened. Each guard cell has a large vacuole, which water and nutrients can move into and out of. When the vacuole is full the increased pressure inside the cell, combined with the irregular thickening of the cell wall, causes each guard cell to elongate and bend outwards, opening the stoma or pore. When the stoma is open, gases for photosynthesis or respiration can be exchanged and water inside the leaf can evaporate through the open pores. Movement of materials across the vacuole membrane requires energy. Energy-containing molecules could be produced by the many chloroplasts or by mitochondria in the guard cells.
Chloroplasts and leucoplasts	Chloroplasts contain chlorophyll and are located mostly in the mesophyll tissue of plant leaves. Chlorophyll absorbs sunlight energy, which drives the process of photosynthesis to produce organic molecules and oxygen from carbon dioxide and water. In comparison leucoplasts are located in non-photosynthetic tissue in roots, bulbs, seeds and fruits. These are more likely to have a storage function in these organs.
Vascular tissue	The conducting cells in phloem tissue are joined end-on-end with a 'food filter' in between, which might contribute to cleaning the organic material before it passes into living cells. At maturity these cells have lost most of their organelles so they are long hollow tubes which help the phloem transport dissolved organic products of photosynthesis to storage sites and where they are needed for growth and metabolism. Phloem cells have their own connected 'companion' cells with the typical plant organelles to keep the phloem alive. They also have extra ribosomes for protein construction and mitochondria for extra energy to transport the materials. At maturity most xylem tissue is dead and the cells have no organelles, but they develop two layers of cell wall and reinforcing structures inside the tubes. This provides additional support enabling xylem tubes to stretch the height of the plant and support the stem. Xylem cells have openings at either end and are connected to similar tubular cells, so that water can travel the entire length/height of the plant, unimpeded. Thinner pits in the walls of the cells allow for sideways movement of water between adjacent cells. They are also surrounded and protected by living cells.
Root hair cell	The root hair cell has an extension of the cell body to form the hair. This increases the surface area available to absorb water and dissolved nutrients into the plant. The thickening of the cell wall protects the cell from physical damage as the root grows between the surrounding soil particles, and from predation by soil organisms. The large central vacuole extending into the hair assists in the absorption and storage of water and dissolved nutrients along the length of the hair.

Cell theory

Sheet 5 Answers

Student resources

- **Sheet 6 — The work of Remak, Virchow and Pasteur**
- **Sheet 7 — Studying cells: Microscopy**

If you have internet access you might find these other resources useful:

- **Video — The wacky history of cell theory** (TED Conferences)
  http://ed.ted.com/lessons/the-wacky-history-of-cell-theory
- **Website — Expansion microscopy stretches limits of conventional microscopes** (The New York Times)
  https://www.nytimes.com/2015/01/20/science/microscopy-stretches-limits-of-conventional-microscopes.html#
- **Website — World's most powerful microscope** (AZO Nano)
  http://www.azonano.com/nanotechnology-video-details.aspx?VidID=354

Background

With the development of microscope technology, scientists were becoming more fascinated with the microscopic structure of organisms. The work of Schleiden led him to document the first 'cell theory' and the three original tenets (principles or beliefs):

1. All living things are composed of cells.
2. The cell is the basic unit of life.
3. Cells form by free-cell formation, similar to the formation of crystals (spontaneous generation).

Future scientific work paved the way for the refinement of the original three tenets into what we regard as modern cell theory. **Sheet 6 — The work of Remak, Virchow and Pasteur** provides details of additional historical evidence. Use this sheet and any of the other suggested resources to answer the following questions.

Evaluating cell theory

1. What main idea about the nature of the cell did historical scientists disagree on?

   Historical scientists disagreed on the origins of the cell. Most believed that cells formed from inorganic materials in the environment through a process of spontaneous generation. Some scientists, however, believed that cells formed from pre-existing cells.

Sheet 5 Answers

2. Describe what and how investigable questions and scientific investigation helped solve this disagreement.

   Investigable questions asked by historical scientists, for example: Where do cells come from? Could new cells be produced from other cells? If I removed all living cells from a sample, would new cells appear? How can I remove all the living cells in a solution so I can test my theory? If an open sterilised solution shows evidence of living organisms, does this indicate that the organisms spontaneously generated from the air, or something else?

   Scientific investigation, involving questioning, hypothesising, microscopic examination and comparison of tissues in the processes of development; fair testing involving exposure of sterilised solutions to air, for example:

   - Two sterilised cultures with no living cells, one open to the air and one sealed left for a period of time. The open culture shows evidence of living cells after the time period, but not the sealed culture. This could indicate that cells come from pre-existing cells, but some scientists still believed this showed that cells originated from the non-living particles in the air.
   - Pasteur's uniquely-designed flask enabled sterilised samples to be exposed to the air, but living microorganisms in the air were trapped in the swan neck preventing them from entering the sterilised broth. The broth in the swan neck flask showed no evidence of living cells, leading Pasteur to conclude that their needed to be pre-existing living microorganisms in the broths to produce more living cells.

3. Evaluate the validity of each of the original cell theory tenets in light of further scientific evidence collected by Remak, Virchow and Pasteur. (**Hint:** You could use a table like the one you used in the lesson.)

Tenet of historical cell theory	Remak's evidence	Pasteur's evidence
All living things are composed of cells.	Stained the cell membrane and established existence of cells.	Concluded from flask experiment that 'germs' or microorganisms entered the broth and multiplied.
The cell is the basic unit of life.	Study of tissue formation showed the involvement of cells in embryonic development from ovum. Study of muscle development showed involvement of cells in living systems.	Boiling and sterilisation process for treatment of milk and beer to kill living organisms present.
Cells form from spontaneous generation.	Evidence provided refutes this hypothesis.	Evidence provided refutes this hypothesis.
Cells form from materials inside pre-existing cells.	Red blood cell formation, muscle development, and tissue formation in chicken and dog embryos from fertilised ovum showed new cells arise from pre-existing cells through cell division.	Boiled two flasks and allowed them to sit for several weeks. Over time the one with the opening at the top began to become discoloured and cloudy, while one with swan neck didn't change. Confirmed the idea of cell division.

4. Describe what changes were made to historical cell theory and explain why these changes were made.

   While the first two statements regarding historical cell theory still stand, Pasteur's research refuted the idea of spontaneous generation and so this statement was replaced with the one regarding the origin of cells from pre-existing cells. As scientists have been able to see microscopic structures more clearly our understanding of the cell has expanded, so the body of evidence supporting the principles of cell theory increases and the theory evolves over time.

5. What impact has microscope technology had on modern-day understanding of cellular structure and function?

   Microscope technology has advanced to enable scientists to view smaller and smaller objects. The use of electron microscopes, staining techniques and tagging of molecules enables scientists to view the structure of individual organelles and other structures in detail under the microscope. Models that were previously suggested to explain the structure of parts of the cells, for example the cell membrane, can now be confirmed with microscopic images and biochemical analysis. There are techniques available that isolate and culture individual cell types and individual organelles. This enables scientists to study cell structure and function, cell growth and development. Most of modern research in cell biology is focused on the genetic material inside cells and how the genetic material can be manipulated, particularly with respect to disease control and treatment. The other area of interest is the use of unspecialised stem cells to grow tissues for repairing and replacing tissues in the human body.