Sam’s Puppy

Sam brought home a tiny puppy. Her puppy grew. Four weeks later, her puppy had grown to twice its original size. Which answer below best explains why Sam’s puppy got bigger?

A The number of cells in the puppy’s body increased.

B The puppy’s body absorbed the food it ate.

C The puppy’s body cells grew larger as it got older.

D Parts of the puppy’s body stretched out more.

Describe your thinking. Provide an explanation for your answer.

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**Purpose**
The purpose of this assessment probe is to elicit students’ ideas about growth. The probe can be used to determine whether students recognize that growth occurs as a result of cell division, which increases the number of body cells.

**Related Concepts**
cell division, growth, transformation of matter

**Explanation**
The best response is A: The number of cells in the puppy’s body increased. Body cell reproduction involves producing new daughter cells for growth of tissues as well as repair and replacement of old cells. *Growth* is the term for the overall increase in an organism’s size. It is a complex process, but to describe it in simple terms, growth primarily involves cell enlargement as new molecules are added to the cell’s mass and subsequent cell division. Food and nutrients taken in by the puppy are broken down at a molecular level, transformed within cells, and become the building blocks for new living material, including new cells produced through cell division. Proteins are a main constituent of living tissues in animals and one of the most important raw materials for growth. During growth, the molecules that result from the breaking down of food, such as amino acids from proteins or sugars from carbohydrates, are synthesized into new molecules within cells, adding more molecules and thus more mass to the structures that make up an organism’s body.

Most living body cells eventually divide into two cells through a process called *mitosis*. During mitosis, a body cell enlarges, duplicates its genetic material, and divides into two daughter...
cells. Sometimes the daughter cells are smaller than the original cell and do not become as large as the original cell until new molecules are synthesized within the new cell. However, most body cells generally remain the same size and do not continuously grow larger as an organism develops (there are some exceptions, such as muscle cells). Growth determines not only the size of the puppy but also its shape and form. As long as the puppy grows at the same rate along all its dimensions, its bodily proportions remain generally the same. One part generally does not "stretch out" more than another.

Curricular and Instructional Considerations

Elementary Students
Elementary school students observe a variety of living organisms in the classroom to learn about their life cycles. Growth and development are necessary parts of understanding life cycles. At this grade level, growth is understood at a macroscopic level and connected to the needs of organisms, such as food being a requirement for growth. Students can observe and measure an organism’s growth, but a cellular and molecular explanation is not expected until middle school. However, the probe is useful in determining children’s preconceived ideas about growth.

Middle School Students
In middle school, students learn how food provides the building material for all organisms and that it can be transformed and made part of a growing organism’s body. Students develop basic understandings of cell structure and function. They learn how cells divide to make more cells. The topic of cell division is often taught as a mechanism and memorized as a series of steps and not explicitly linked to the idea of adding new molecules that result in increased body mass and growth. In their study of reproduction, students learn how an egg and sperm unite and that subsequent cell division and differentiation begin the development of the organism. They examine how an organism grows and develops until it reaches adulthood. Because the human organism is of great interest at this age level, middle school curricula often focus on the growth and development of humans and looking for similar patterns in other vertebrate organisms.

High School Students
In high school biology class, students build on basic cell division ideas that were developed in middle school. They learn about details related to cell differentiation and division and how these processes are regulated. They examine how cell division occurs in different types of tissues and the effect of aging and other factors on cell division and growth. A focus on molecular biology helps students understand how food is chemically broken down into the chemical constituents cells need to synthesize other molecules, which contribute to an organism’s mass as it grows.

Administering the Probe
This probe can be used once students understand that all organisms are made up of cells.
The distracters are intentionally kept simple in order to elicit a range of ideas from elementary grades through high school. At the middle school and high school level, the puppy in the probe can be replaced with a human baby, and students can be asked to compare growth from the time the baby was brought home after birth to the same child as a toddler one year later. Photographs showing a “baby” organism and the same organism after it has considerably grown can be used as props. This probe can be combined with the probe “Whale and Shrew” in Volume 2 of this series (Keeley, Eberle, and Tugel 2007) to further explore students’ ideas regarding cell size.

Related Ideas in National Science Education Standards (NRC 1996)

K–4 Life Cycles of Organisms
★ Plants and animals have life cycles that include being born, developing into adults, reproducing, and eventually dying. The details of this life cycle are different for different organisms.

5–8 Structure and Function in Living Systems
★ Cells carry on the many functions needed to sustain life. They grow and divide, thereby producing more cells. This requires that organisms take in nutrients, which cells use to provide energy for the work that they do and to make the materials that they or their organism needs.

9–12 The Cell
- Most cell functions involve chemical reactions. Food molecules taken into cells react to provide the chemical constituents needed to synthesize other molecules.
- Cell functions are regulated. Regulation occurs both through changes in activity of the functions performed by proteins and through selective expression of individual genes. This regulation allows cells to respond to their environment and to control and coordinate cell growth and division.

Related Ideas in Benchmarks for Science Literacy (AAAS 1993)

3–5 Basic Functions
- People obtain energy and materials from food for body repair and growth.

3–5 Flow of Matter and Energy
- Some source of energy is needed for all organisms to stay alive and grow.

6–8 Cells
★ Cells continually divide to make more cells for growth and repair.
- Food provides the fuel and building material for all organisms.

6–8 Basic Functions
- For the body to use food for energy and building materials, the food must first be digested into molecules that are absorbed and transported to cells.

★ Indicates a strong match between the ideas elicited by the probe and a national standard’s learning goal.
9–12 Cells

- Complex interactions among the different kinds of molecules in the cell cause distinct cycles of activities such as growth and division.

Related Research

- Students of all ages think food is a requirement for growth rather than a source of matter for growth. They have little knowledge about food being transformed and made part of a growing organism’s body (AAAS 1993).
- Several studies have shown students’ difficulties in assimilating taught concepts of cell division, cell enlargement, and cell differentiation. One study showed that only 69% of respondents who were asked what accounts for growth realized that growth was occurring when a cell divides in two (Driver et al. 1994).
- Children understand at an early age that eating or absorbing food is necessary for growth. However, they do not recognize that these materials are the material for growth and that they are transformed and taken into the body, thus making it bigger (Driver et al. 1994).
- A study by Russell and Watt (1990) found that children think animals grow or stretch to accommodate the food they eat.

Suggestions for Instruction and Assessment

- At the middle school level and above, explicitly connect the idea of growth to cell division. Also, explicitly connect the idea of food to the material that makes up the matter of a growing organism. Often these concepts—cell division, food, and growth—are taught separately without explicit links made between them.
- Avoid teaching mitosis as a sequence of mechanistic steps in somatic cell division. Help students link the process of mitosis to growth (as well as repair) of an organism.
- For older students, particularly students who think growth occurs because cells keep getting larger, use activities that demonstrate why cells cannot carry out their functions if they grow to a very large size.
- Recognize that grow, in the common meaning of the word, means “gets bigger.” Help students understand the biological meaning of grow.
- Do not separate teaching about growth from teaching about development. Growth and development are essential components of understanding life cycles. When students are ready to utilize cell concepts, build on elementary students’ macroscopic observations of growth and development by having them investigate and explain growth and development at the cellular level.
- To get a sense of the amount of matter resulting from cell divisions, have students mathematically determine exponential increases to see how rapidly numbers of cells can build up as they undergo cell division. Starting with a single cell, have students calculate or graph how many new cells can
result in one day from cell divisions every 30 minutes.

- To go from macroscopic ideas about growth to microscopic ideas, have students compare sizes and increase in mass of organs in adults versus organs in children. Probe students to think about and explain how additional mass is added as a result of adding additional molecules. Since the original cells cannot contain all these additional molecules, new cells are added that account for the increase in mass, and thus size.

Related Curriculum Topic Study Guides
(Keeley 2005)
“Cells”
“Reproduction, Growth, and Development (Life Cycles)”

References


