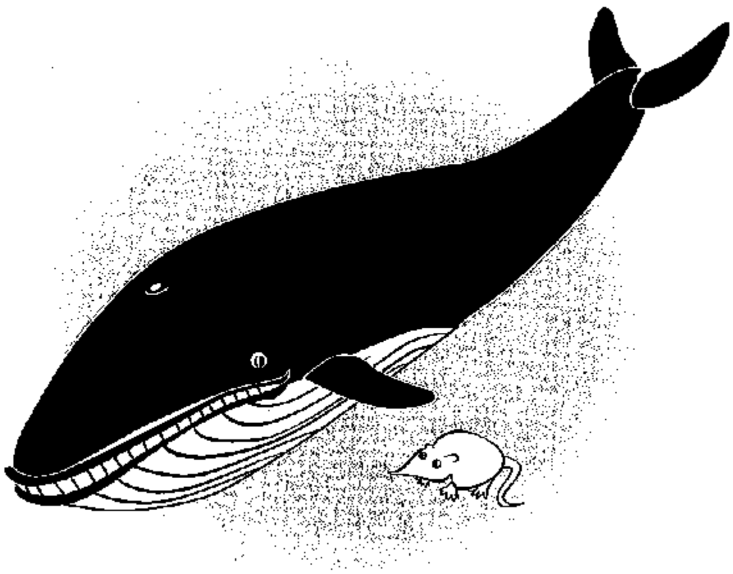
Whale and Shrew

The blue whale is the largest mammal in the world. The pygmy shrew is one of the smallest mammals in the world. How does the size of average cells compare between a blue whale and a pygmy shrew? Circle the answer that best matches your thinking.



A The average cell of a blue whale is smaller than the average cell of a pygmy shrew.

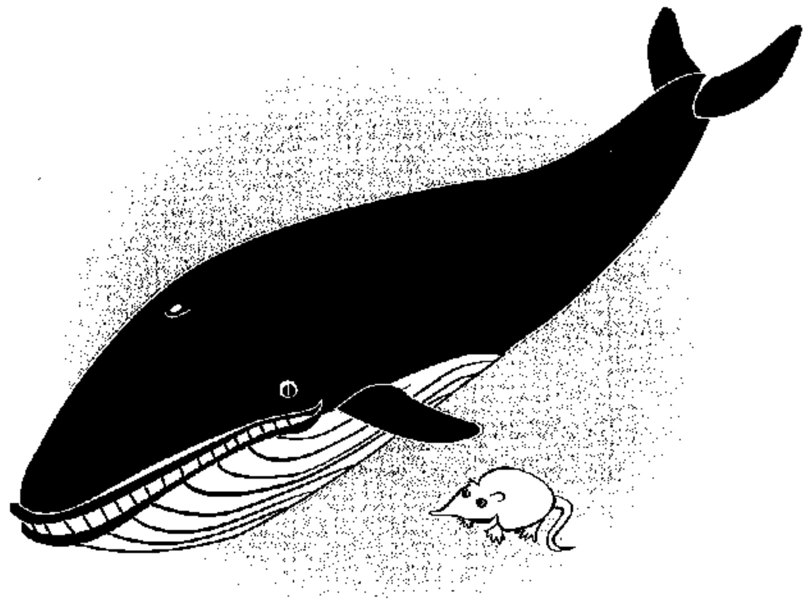
B The average cell of a blue whale is larger than the average cell of a pygmy shrew.

C The average cell of a blue whale is about the same size as the average cell of a pygmy shrew.

Explain your thinking. Describe the "rule" or reasoning you used to choose your answer.

Whale and Shrew

Teacher Notes



Purpose
The purpose of this assessment probe is to elicit students' ideas about cell size. The probe is designed to find out if students think that animal cell size is related to the overall size of an animal.

Related Concepts
cells, growth, cell division

Explanation
The best answer is C: The average cell of a blue whale is about the same size as the average cell of a pygmy shrew. The size of average mammal cells (this excludes cells that are unusually large, such as neurons) is similar in all mammal species. Even though some body cells (such as neurons) can be very large and cells vary, the average body cells of most mammals are about 10 micrometers in diameter. Interestingly, the earliest-stage embryos of the whale and shrew are also a similar size, even though a whale eventually reaches a mass of 150,000 kg whereas a mouse only reaches 15g—a 10-million-fold difference!

Cells are limited in how large they can be because the surface area-to-volume ratio does not stay the same as the size of a cell increases. Cells need to be able to move materials into and out of a cell, and it is harder for a large cell to pass materials in and out of the membrane and to move materials through the cell. The reason blue whales are larger than pygmy shrews is because they have more cells, not because their cells are larger.

Curricular and Instructional Considerations

Elementary Students

In the upper elementary grades students are just beginning to learn about cells as the fundamental unit of all living organisms. They observe a variety of cells of single-celled and multicelled organisms in pictures and with simple microscopes. At this level, students are not ready to compare cell sizes, but they do observe that larger animals have larger body parts such as legs and teeth as well as larger organs such as heart, lungs, and stomach. This can lead to a preconception that their cells are also larger. Students learn about growth in the context of life cycles but do not yet equate growth with an increase in the number of cells. However, this probe is useful in determining if the idea of cell size increasing with overall animal size and size of body parts is a conception that develops early on.

Middle School Students

Middle school students extend their observations of cells to making comparisons of similar cell types across animal species. Students develop the idea of similarities among species by examining internal structures as well as cells. They can also begin to recognize the very small size of most cells and that most cells repeatedly divide to make more cells. Organisms and the organs they contain generally grow in size from birth until they reach adulthood. Yet, students may believe that the cells that make up organs are proportional to the size of the organ and thus the size of the animal, not recognizing that it is the process of cell division that contributes to growth, not the individual cells getting larger.

High School Students

High school students have a deeper understanding of the cell, including cell division and what controls it. Mathematically they develop an understanding of the relationship between volume and surface area and how the total surface area decreases with an increase in volume. Through lab experiences with model cells made of gels, they observe how the surface area-to-volume ratio affects the passage of materials into, around, and out of a cell, thus limiting the size of a cell. This probe is useful in eliciting students' ideas before designing experiences that help students understand that cell size is limited by the surface area-to-volume ratio and thus is relatively similar for most mammals' cells.

Administering the Probe

Show a picture of a whale and a shrew to contrast size. Make sure middle and high school students focus on the concept of "averagesized" cells. You might explain that some cells, such as neurons, vary considerably in size. If necessary, choose a particular cell, such as a red blood cell or a cell from the liver. Alert students to the fact that the picture on the probe handout is not drawn to scale. In a scale drawing, the shrew would be several times smaller than the size of the whale's eye and would be a mere dot next to the whale.

Related Ideas In *National Science Education Standards* (NRC 1996)

5–8 Structure and Function in Living Systems

- All organisms are composed of cells—the fundamental unit of life.
- ★ Cells carry on the many functions needed to sustain life. They grow and divide, thereby producing more cells.

5–8 Diversity and Adaptations of Organisms

- ★ Millions of species of animals, plants, and microorganisms are alive today. Although different species might look dissimilar, the unity among organisms becomes apparent from an analysis of internal structures, the similarity of their chemical processes, and evidence of common ancestry.

9–12 The Cell

- Cells can differentiate, and complex multicellular organisms are formed as a highly organized arrangement of differentiated cells. In the development of these multicellular organisms, the progeny from a single cell form an embryo in which the cells multiply and differentiate to form the many specialized cells, tissues, and organs that comprise the final organism.

Related Ideas in *Benchmarks for Science Literacy* (AAAS 1993)

3–5 Cells

- Microscopes make it possible to see that living things are made mostly of cells. Some organisms are made of a collection of similar cells that benefit from cooperating.

6–8 Cells

- All living things are composed of cells, from just one to many millions, whose details usually are visible only through a microscope. Different body tissues and organs are made up of different kinds of cells. The cells in similar tissues and organs in other animals are similar to those in human beings but differ somewhat from cells found in plants.
- ★ Cells continually divide to make more cells for growth and repair.

Related Research

- Stavy and Tirosh (2000) asked students in grades 7–12 a question similar to the one in this probe, comparing muscle cells of a mouse to muscle cells of an elephant. The majority of students, especially in grades 7

★ Indicates a strong match between the ideas elicited by the probe and a national standard's learning goal.

and 8, thought that larger animals have larger cells. The common justification was that "according to the dimensions of the elephants and those of the mice, it is obvious that the muscle cells of the mice are smaller than those of the elephants" (p. 30). This is an example of the intuitive rule "more A, more B." Most of the younger students who answered correctly explained the equality in terms of the cells having the same function and therefore being the same size. Most of the high school students who responded correctly used formal biological knowledge of cells and also described the elephant as having more cells.

- Available research on cells is limited. However, in piloting this probe with more than 100 middle and high school students, many students chose answer B (the blue whale has larger cells than a shrew). Their reasoning matched Stavy and Tirosh's results and was based on the idea that whales are much larger and therefore need larger cells.

Suggestions for Instruction and Assessment

- When students are examining the same cell types of different organisms, encourage them to look not only at the similarity in the shape of the cells but also the size. For example, when comparing the muscle cells of frogs to the blood cells of humans, notice the similar size.
- Develop the idea that cell size is limited by the ability of molecules to pass in, around, and out of cells. Older students can test this idea by making model cells out of blocks of agar of different volume to surface area-to-volume ratios and measuring the rate and depth of penetration of a dye into the model cell. Calculate the volume to surface area ratios of the different cell sizes and compare the results of the diffusion based on the ratios.
- Have students investigate the question, "Is bigger always better?" in the context of a cell's ability to carry out its life functions. Encourage them to develop a way to research and test their idea and have them share their results.
- Ask students why a paramecium can never be the size of human. Develop the idea of why single-celled organisms must be microscopic to carry out the same life processes carried out by multicellular organisms.

Related NSTA Science Store Publications and Journal Articles

American Association for the Advancement of Science (AAAS). 1993. *Benchmarks for science literacy.* New York: Oxford University Press.

Driver, R., A. Squires, P. Rushworth, and V. Wood-Robinson. 1994. *Making sense of secondary science: Research into children's ideas.* London: RoutledgeFalmer.

Keeley, P. 2005. *Science curriculum topic study: Bridging the gap between standards and practice.* Thousand Oaks, CA: Corwin Press.

National Research Council (NRC). 1996. *National science education standards.* Washington, DC: National Academy Press.

Rau, G. 2004. How small is a cell? *The Science Teacher* (Oct.): 38–41.

Related Curriculum Topic Study Guides

(Keeley 2005)

"Cells"

References

American Association for the Advancement of Science (AAAS). 1993. *Benchmarks for science literacy.* New York: Oxford University Press.

Keeley, P. 2005. *Science curriculum topic study: Bridging the gap between standards and practice.* Thousand Oaks, CA: Corwin Press.

National Research Council (NRC). 1996. *National science education standards.* Washington, DC: National Academy Press.

Stavy, R., and D. Tirosh. 2000. *How students (mis-) understand science and mathematics: Intuitive rules.* New York: Teachers College Press.