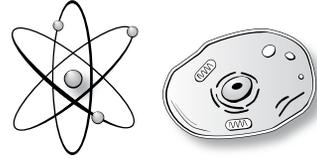


Atoms and Cells

The chart below shows a variety of things sorted into two different groups.



Group A	Group B
leaf of a plant	spoonful of salt
horse's muscle	piece of metal
cap of a mushroom	diamond necklace
baby elephant	protein
seed of a bean plant	sugar cube
blood	air

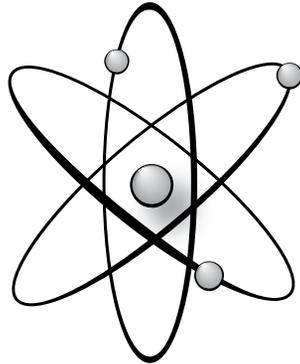
Circle the statement you think best describes the two groups.

- A** Both groups are made up of cells.
- B** Both groups are made up of atoms.
- C** Group A is made up of cells; Group B is made up of atoms.
- D** Group A is made up of cells and atoms; Group B is made up of atoms.
- E** Some things in Group A are made up of cells and some things in group B are made up of atoms.
- F** Group A and Group B are made up of both cells and atoms.

Explain your thinking. Provide an explanation for your answer.

Atoms and Cells

Teacher Notes



Purpose

The purpose of this assessment probe is to elicit students' ideas about the smallest parts of living and nonliving things. The probe is designed to determine how students distinguish between cells and atoms in living and nonliving contexts.

Related Concepts

Cells, atom, living

Explanation

The best answer is: D—Group A is made up of cells and atoms; Group B is made up of atoms. (*Note:* Students who choose answer B—Both groups are made of atoms—are correct. However, that would not be the *best* way to describe the two groups in order to differentiate between them.) All of the things in Group A are of a biological origin; that is, they are made up of cells. Cells are not the smallest unit of matter. They can be further broken down into molecules, which are made up of

atoms. Except for the protein and sugar cube in Group B, all these things have a nonbiological origin and are also made up of atoms. The sugar in the cube and the protein were made by a living thing. Sugars and protein are made within a cell, but they are not made of cells. They are biomolecules, which can be further broken down into atoms.

Curricular and Instructional Considerations

Elementary Students

In the early grades, students explore parts and wholes and discover that objects and materials are made up of parts. They use magnifiers to examine small parts that are not obvious to the naked eye. At the upper elementary level, they are just beginning to learn that living things are made up of cells. They use simple microscopes to observe cells in familiar plant and animal parts as well as single-celled organisms. They begin to form a particle model of

matter, but details about atoms should wait until middle school.

Middle School Students

In middle school, students deepen their understanding of cells and recognize that cells are not only the basic unit of structure in living things but are also the basic unit of function. They develop a hierarchy to describe organization in living things from cell to tissue to organ to organ system to organism. They begin to use a particulate model of matter to explain various phenomena as well as to organize matter from its smallest unit, the atom, to molecules made up of atoms, to substances made up of molecules or arrays of atoms. By middle school, they should know that all living and nonliving matter is made up of atoms, but only living or once-living matter is made up of cells.

High School Students

Students' knowledge of cells has deepened to include cell organelles and biomolecules. Their knowledge of atoms now includes parts of the atom and interactions between atoms and between molecules. At this level, once students acquire a deeper understanding of atoms and molecules and of cellular structure and function, their atomic and molecular knowledge in chemistry and biology converge.

Administering the Probe

For high school students, consider adding more examples to Group A and B. For example, add DNA or a cell organelle such as a chloroplast to Group B, as some students may confuse DNA and cell organelles with cells if they lack an understanding of hierarchical structure. If this probe is used with upper elementary students, consider replacing unfamiliar items with familiar items.

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

K–4 Properties of Objects and Materials

- Objects are made up of different kinds of materials.

5–8 Structure and Function in Living Systems

- ★ All organisms are composed of cells, the fundamental units of life.
- ★ Important levels of organization for structure and function include cells, organs, tissues, organ systems, whole organisms, and ecosystems.
- Specialized cells perform specialized functions in multicellular organisms. Groups of specialized cells cooperate to form a tissue, such as a muscle. Different tissues are in turn grouped together to form larger functional units, called organs.

5–8 Structure and Function in Living Systems

- There are more than 100 elements that combine in a multitude of ways to produce compounds, which account for the living and nonliving substances that we encounter.

9–12 The Cell

- Cells have particular structures that underlie their functions. Every cell is surrounded by a membrane that separates it from the outside world. Inside the cell is a concentrated mixture of thousands of different molecules that form a variety of specialized structures.

9–12 Structure of Matter

- ★ Matter is made of minute particles called atoms, and atoms are composed of even smaller components.

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

- ★ Atoms often join with one another in various combinations in distinct molecules or in repeating three-dimensional crystal patterns.

Related Ideas in Benchmarks for Science Literacy (AAAS 2009)

K–2 Systems

- Most things are made of parts.

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. Some organisms' cells vary greatly in appearance and perform very different roles in the organism.

3–5 Structure of Matter

- Materials may be composed of parts that are too small to be seen without magnification.

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.

6–8 Structure of Matter

- ★ All matter is made up of atoms, which are far too small to see directly through a microscope.
- Atoms may link together in well-defined molecules, or may be packed together in crystal patterns. Different arrangements of atoms into groups compose all substances and determine the characteristic properties of substances.

- Carbon and hydrogen are common elements of living matter.

9–12 Cells

- The work of the cell is carried out by the many different types of molecules it assembles, mostly proteins.

9–12 Structure of Matter

- Atoms often join with one another in various combinations in distinct molecules or in repeating three-dimensional crystal patterns.
- An enormous variety of biological, chemical, and physical phenomena can be explained by changes in the arrangement and motion of atoms and molecules.

Related Research

- Understanding how molecules make up other small objects such as cells may be tied to the difficulty students have understanding how small something can be (Driver et al. 1994).
- Research conducted by Arnold (1983) indicated that students have difficulty differentiating between the concepts of *cell* and *molecule*. There is a tendency for students to overapply the idea that cells are smaller components of *living* things. Students identified any materials encountered in a biology class (carbohydrates, proteins, and water) as being made up of smaller parts called cells. Arnold coined the term *molecell* to describe the notion of organic molecules being considered as cells.
- Although many students eventually construct the idea that an atom or molecule is the smallest structural unit of a substance, they often have difficulty appreciating the minuteness of atoms and molecules (Driver et al. 1994).
- Students are unsure about the hierarchy of atoms, molecules, and cells. Cells are

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

described as the components of many things, including carbohydrates and proteins (Berthelsen 1999).

Suggestions for Instruction and Assessment

- Combine this probe with “Is It Made of Cells?” and “Is It Made of Molecules?” in *Uncovering Student Ideas in Science, Vol. 1: 25 Formative Assessment Probes* (Keeley, Eberle, and Farrin 2005).
- Use graphic organizers, such as Venn diagrams, to sort objects into things that are made of cells, things that are made of atoms, and things that are made of both cells and atoms.
- This probe can be turned into a FACT (formative assessment classroom technique) called a card sort (Keeley 2008). Instead of providing the chart on page 39, write each of the items listed on the chart on a card. Ask students to sort the cards into three groups: those items made up of cells, those items made up of atoms, and those items made up of cells and atoms. You may even add a fourth category—those made up of neither cells nor atoms (although no items go in this category, students may think otherwise). As students work in small groups to sort the cards, they must justify their reasoning for why they place each card in a category. As you circulate among the class, note how the cards are categorized and listen carefully to students’ reasoning. Probe with further questions as needed. Use the information from this activity to inform a lesson on parts and wholes that addresses the students’ misconceptions.
- To practice and learn the idea that big things are made of smaller parts, or for students to comprehend the relative sizes of things they learn about in one lesson compared to things in a new lesson, write a variety of terms on card stock (one item per

card) and hand them out to the students in the class. Start with two random students and ask them to arrange themselves in size order (who is bigger). Then another student joins them and they all discuss “Where do I go?” Listen for various ways of reasoning, such as “I’m smaller than you because you are made up of me.” For high school students, the cards might include items such as eukaryotic cell, bacterium, atom, electron, water molecule, glucose, seeds, cell nucleus, DNA, nucleotide, pinecone, ATP, protein, cat, nucleus, and mitochondrion.

- There are a number of video demonstrations that can help students understand the relative hierarchy of atoms, molecules, and cells. The best known example, although it may be a bit dated, is the Charles and Ray Eames *Powers of Ten* movie at www.powersoftent.com.

Related NSTA Science Store Publications, NSTA Journal Articles, NSTA SciGuides, NSTA SciPacks, and NSTA Science Objects

- American Association for the Advancement of Science (AAAS). 2001. *Atlas of science literacy*. Vol. 1. (See “Cells and Organs” map, pp. 74–75, and “Atoms and Molecules” map, pp. 54–55.) Washington, DC: AAAS.
- Jones, G., A. Taylor, and M. Falvo. 2009. *Extreme science: From nano to galactic*. Arlington, VA: NSTA Press.
- Minogue, J., G. Jones, B. Broadwell, and T. Oppewall. 2006. Exploring cells from the inside out: New tools for the classroom. *Science Scope* 29 (6): 28–32.
- Science Object: *Cell Structure and Function: Cells—The Basis of Life*
- Science Object: *Cell Structure and Function: The Molecular Machinery of Life*
- SciPack: *Atomic Structure*

Related Curriculum Topic Study Guides (in Keeley 2005)

“Cells”

“Particulate Nature of Matter (Atoms and Molecules)”

References

- American Association for the Advancement of Science (AAAS). 2009. Benchmarks for science literacy online. www.project2061.org/publications/bsll/online
- Arnold, B. 1983. Beware the molecell! *Biology Newsletter* (Aberdeen College of Education) 42: 2–6.
- Berthelsen, B. 1999. Students’ naive conceptions in life science. *Michigan Science Teachers Association Journal* 44 (1): 13–19. www.msta-mich.org
- 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 and Arlington, VA: NSTA Press.
- Keeley, P. 2008. *Science formative assessment: 75 practical strategies for linking assessment, instruction, and learning*. Thousand Oaks, CA: Corwin Press and Arlington, VA: NSTA Press.
- Keeley, P., F. Eberle, and L. Farrin. 2005. *Uncovering student ideas in science, vol. 1: 25 formative assessment probes*. Arlington, VA: NSTA Press.
- National Research Council (NRC). 1996. *National science education standards*. Washington, DC: National Academies Press.