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Final Project

Cornell Center for Materials Research
Research Experience for Teachers 2000

Outline of Project

Title: "Show Me What You're Made Of!": Studying Biological Materials

Target Audience: Grade 7 Life Science class

Questions to Answer: What are the materials that build organisms? What are their properties? Why are these properties important to their function?

Lessons:

1. "All Matter is the Same"—atoms and molecules
2. The Study of Tiny Things—equipment and procedures
3. Structure vs. Function—the design of something is related to its purpose
4. Nonliving vs. Living Material—compare a microcircuit to a cell
5. Biomaterials—carbohydrates, lipids, proteins, nucleic acids
6. The Interconnectedness of Science—biology, chemistry, physics, materials science

Major Skills Practiced:

Visualization, Data Collection, Cooperative Group Work, Experimental Design, Documenting Observations, Microscopy, Measurement

Supplemental Resources That Might Be Helpful:

Any Biochemistry textbook, for in-depth information on properties of molecules

CCMR's website (http://www.ccmr.cornell.edu/index.html), for information on facilities and equipment used to study "tiny things"

A large collection of diagrams, pictures, and other representations of cells, molecules, atoms, microcircuits, etc.

Access to research facilities/personnel who are willing to show students what they do

Collections of stories, in multiple formats, about scientific research

The Definitive Middle School Guide. Imogene Forte and Sandra Schurr. 1993: Incentive Publications, Nashville, TN.

Lesson One

Title: All Matter is the Same

Objectives: Students will see that the macroscopic appearance of an object is often very different from its microscopic structure; students will appreciate that all matter in the universe is composed of atoms of elements arranged into some collection or pattern. Furthermore, students will understand that atoms of the same element can look and behave very differently depending on their environment.

Materials: prepared photographs/slides, toothpicks, colored marshmallows or gumdrops, **Josh Pomeroy**'s activity on building molecules

Structure of Lesson:

Introduction—Slides or pictures of familiar objects. What happens when you look at the object up close? What if you start asking questions about how the object was made? How does the object accomplish its purpose? What if you kept getting "smaller and smaller" with your questions? What's the limit to how small you can get? Good example: A building: made of bricks and plaster and wires and nails, etc.; take electricity for an example—it happens because there are wires in the walls and ceilings; wires made of insulation and copper, which carries current; if you kept getting smaller and smaller you'd discover the metallic conducting properties of the element copper in this particular configuration. [15 minutes]

On the blackboard—*All matter in the universe is made up of atoms, and all atoms are one of about 110 different kinds of elements.* Talk about this statement for a few minutes. Show students the periodic table of elements. Introduce the idea that elements often "team up" with others to make molecules possessing new properties. Water behaves differently from either hydrogen or oxygen. Even water itself behaves differently in different situations; it can be solid, liquid, or gas. It would be helpful to have some ice and some room temperature and boiling water available to look at. [10 minutes]

Activity—Students should be divided into groups and materials passed out. Discussion might turn now toward living material, and which atoms are found in it. Predominantly, these are carbon, hydrogen, oxygen, nitrogen, and phosphorus. There are "rules" about the kinds of bonds these atoms have with each other, and the activity will help us to discover these rules and how they determine the structure of living material. Thanks to Josh Pomeroy for the development of this activity! [45 minutes]

Conclusion and Clean-up—While students clean up their materials, the teacher should review the lesson and preview the discussion for next class: how scientists go about studying/working with such tiny things. [10 minutes]

Assessment: Participation in group, observations about molecules built (Anecdotal)

Modification/Extension Suggestions: Special needs students should work well in this lesson as long as they're in a cooperative group. Advanced students might enjoy learning more about the principles of bonding behind the arbitrary "rules" of building these molecules.

Lesson Two

Title: Studying Tiny Things

Objectives: Students will try to imagine how small an atom or molecule really is. Students will discover the metric units used to measure objects this small, and practice measuring things less than one millimeter in length. Finally, students will be introduced to the kinds of research and techniques happening today in materials science and nanofabrication.

Materials: prepared photos/slides, rulers, pennies, rice grains or other small objects, dissecting and compound light microscopes, prepared microscope slides of onion root cells or frog oocytes

Structure of Lesson:

Introduction—a quick review of the metric measurement of length (meters and the prefixes kilo-, centi-, and milli-). A discussion of how well we can see something that is a millimeter in length should follow, and an introduction to the idea of resolution. The human eye can resolve objects about 0.2 mm (200 microns) apart. Ask students to imagine the millimeter divided up into a thousand parts (1000 lines drawn on the ruler between the markings for a millimeter), and then tell them that this unit also has a name: the micron or micrometer. Most cells range in size from a few microns to about 100 microns. Now ask them to imagine a micron also divided into a thousand parts (the nanometer). Proteins, DNA, and other large molecules are measured in nanometers. Finally, if you divide a nanometer in ten parts (one ten-billionth of a meter), you have an angstrom, the unit typically used to measure atoms. Inform students that scientists today are working everyday with samples this small, and ask them what kinds of instruments must they need to do that. [15 minutes]

Photos/Slides—Show students pictures of the equipment used to do materials science. Light and electron microscopes, x-ray diffraction instruments, ion beam analysis machines, various detectors and sensors, and nanofabrication equipment should all be included. Talk about sample preparation and about the various lines of research going on in these fields. Focus attention specifically on the biological applications of this type of research. Ask students what kinds of things they might study if they could use equipment like this. [15 minutes]

Activity—Groups of students should be supplied with rulers, pennies, microscopes, and a prepared microscope slide with an aggregate of cells on it. Ask groups to use these materials to measure features of the penny (Lincoln's eye or nose, the width of a letter or number, etc.), and also to determine the size of a typical cell on their slide to the best degree of accuracy possible. Encourage students to convert their measurements to angstroms, nanometers, and microns. Help groups discover the best technique for doing their measurements given the materials available. [40 minutes]

Conclusion and Clean-up—As students clean up, review the lesson and encourage them again to imagine the types of experiments they might do with access to "nanofab" equipment. [10 minutes]

Assessment: Reasonable measurements for samples

Modification/Extension Suggestions: Special needs students might be exempted from doing conversions, or they might be given larger objects to measure. Advanced students might be encouraged to find more everyday "tiny" objects to bring in and measure.

Lesson Three

Title: Structure vs. Function

Objectives: Students will practice looking critically at the design of an object in order to infer information about its function. Students will understand that the materials that make an object are just as important as the structure itself.

Materials: eggs; shopping bags cut in small strips; several work stations equipped with clamps, buckets, weights, and "tight seal" clips; schematic diagram of stomach; pogo stick (or other unusual object); **Emily Hackett**'s activity on testing strength of shopping bags

Structure of Lesson:

Introduction—Teacher begins with an egg, talking to the class about what it does while at the same time asking students about its properties. A student may be invited to try and break the egg by squeezing along its longitudinal axis (almost impossible). Groups of students may be given eggs to carefully break open, turning an observant and critical eye to its structure. Discussion should follow about the particular functions of the parts of an egg. [15 minutes]

Demonstrations—Teacher makes the point that function is almost always a product of the structure of an object. Ask students to list all the things they know about the functions of our stomachs (store food, partially digest food by mixture and addition of acids and enzymes, protect itself from the acids, move food along from esophagus to small intestine, etc.). Show a diagram of the stomach and point out the structural elements that make these functions possible. Take out the pogo stick. It's not too common an item any more—ask students if they know what it is. Ask them to imagine they have no idea what it is; how would they guess what it's for? Would they be able to guess its function simply by looking at its structure? Inform students that this is often exactly what scientists must do with the things they are studying. [15 minutes]

Activity—Test the strength of plastic shopping bags in both the vertical and horizontal orientation. Thanks to Emily Hackett for this activity! [30 minutes]

Clean-up—Restore order to the classroom. [10 minutes]

Conclusions—Ask students what our discussions about structure and function had to do with the shopping bag activity. Make the point that we sometimes have to think about a structure that is not obvious simply by outward appearance. Furthermore, sometimes structure and function is intimately tied to the composition of an object. How would the same egg, stomach, or pogo stick perform their functions if they were made of different material, even if they had exactly the same designs? [10 minutes]

Assessment: Reasonable data collected from the experiment

Modification/Extension Suggestions: Special needs students should have no trouble with this lesson, as long as they're with a cooperative group. Advanced students might enjoy learning more about the molecular structure and flexibility of the polymers in the bags.

Lesson Four

Title: Nonliving vs. Living Material

Objectives: Students will explore the differences between living and nonliving materials. Students will appreciate the complexities of living tissues, and explore the unique "problems to be solved" by organisms on the cellular level.

Materials: computer microchip (or other microcircuitry), some schematic diagrams of cells (especially the cell membrane), 3-D representational diagrams of proteins and inorganic crystals, microscopes, prepared slides, overhead projector

Structure of Lesson:

Introduction—Review discussions of structure and composition as related to function. Ask students to think now as designers: how would they build something like an overhead projector? What kinds of problems would need to be solved? What materials would they need? How would they put it together? How do you make it work?

Follow up this discussion with the idea of "designing" a living cell (the simplest functional component of a living thing). What problems face the designer? What kind of materials would you need? How do you make it "work"? Attempt to guide understanding in the direction of complexity: which is a more difficult task—building the living or nonliving thing? Why? [15 minutes]

Comparison—Display the diagram of the cell and show the example of a micro-circuit. Briefly describe the similarities and differences of function. Each must be insulated. Each must obtain and process information, responding appropriately. Each has layers of structure, and must coordinate the functions of the layers so that the overall functions are achieved. Each must receive energy in order to do its work. Designers of circuits must solve all of these problems in turn, and the same can be said of the cell. Discuss the differences in the "solutions" to these problems. [15 minutes]

Activity—Use the microscopes and prepared slides to look critically at a variety of cell types. What are the particular functions and "designs" of these cells? How is their structure related to their function? Each group of students should sketch their cells, write down their ideas and be prepared to share them with the class. [40 minutes]

Clean-up and Conclusion—While students clean up, discussion can center around particularly interesting observations collected during the activity. [10 minutes]

Assessment: Finished product of activity (drawings and observations) can be graded.

Modification/Extension Suggestions: Special needs students will need help understanding the function of cells and what problems they face. Advanced students might want to do some extra research on how microcircuits are manufactured.

Lesson Five

Title: Biomaterials

Objectives: Students are introduced to the types of organic materials that make living things. Further, students will make connections to function of these materials by learning about their properties.

Materials: handouts and school library/computer room

Structure of Lesson:

Introduction—Tell students that we will finally be looking at the actual materials that make up living organisms. Pass out handouts to all students and help them analyze the chart describing carbohydrates, lipids, proteins, and nucleic acids. Focus attention on the functions of these molecules and the particular places where they are found in an organism, and challenge students to guess what kinds of properties the molecules must have. As an example, describe the hydrophobic and hydrophilic ends of the phospholipids that make up the bulk of our cell membrane bilayer. [15 minutes]

Activity—Assign different groups of students one of the four large classes of molecules above. Work in the library/computer room to research some of their occurrences in organisms and how their particular properties might relate to their functions. For groups having trouble, help them along by focusing their attention on particular biological "products" like bone, chitin, cellulose, etc. This is probably a relatively difficult assignment for seventh graders: they will need some guidance. [50 minutes]

Conclusions—End the class by discussing some of the findings. Each group of students should turn in their research notes. [15 minutes]

Assessment: Final product of research can be graded.

Modification/Extension Suggestions: A library research project like this can be tailored to suit just about anyone's needs. Simply broaden or narrow the scope of the research as needed.

Lesson Six

Title: The Interconnectedness of Science

Background: Students should be familiar with the major branches of science (Biology, Chemistry, Physics, Earth Science, with as many or as few subdivisions as appropriate)

Objective: Students will see that most scientific endeavors require a mixture of disciplines, not only including branches of science, but also elements of history, politics, math, language arts, etc.

Materials: a collection of "stories" about scientific research

Structure of Lesson:

Introduction—Begin by reviewing the work done in this unit. If we were going to classify the unit into one of the main branches of science, which would it be? Biology? Chemistry? Materials Science? Hopefully students will see how difficult a classification like this is, considering how many different aspects of all of these sciences we used during the unit. Describe the everyday work of a scientist, including the problems of funding, ethical considerations, publication and defense of research, data processing, etc. Help students understand how interdisciplinary all of science can be. If possible, refer to other common experiences you have had with the class (field trips, other lessons or units, books that were read) and explore those for interdisciplinary influence. [15 minutes]

Activity—Divide the class into groups and give each a short story about some scientific research. These can be magazine articles, audio tapes of news reports, chapters from books, etc. Each group should make a chart that lists as many different subject areas or disciplines that they can think of that apply to the story. Encourage them to infer information that is not necessarily spelled out in the stories. Let them relax with this final activity in the unit and use their imaginations in seeing as many different connections as they can. It might help create a good atmosphere by playing music while they work, or setting up refreshments. The teacher should take time to talk and interact with each group. [60 minutes]

Clean-up and Conclusion—Congratulate the group for completing the unit, recap the main objectives, and prepare them for the next unit to come. [5 minutes]

Assessment: Charts can be graded.

Modification/Extension Suggestions: This is a lesson designed to be fun and all-inclusive. It should be appropriate for all ability levels.

Project Contributors

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