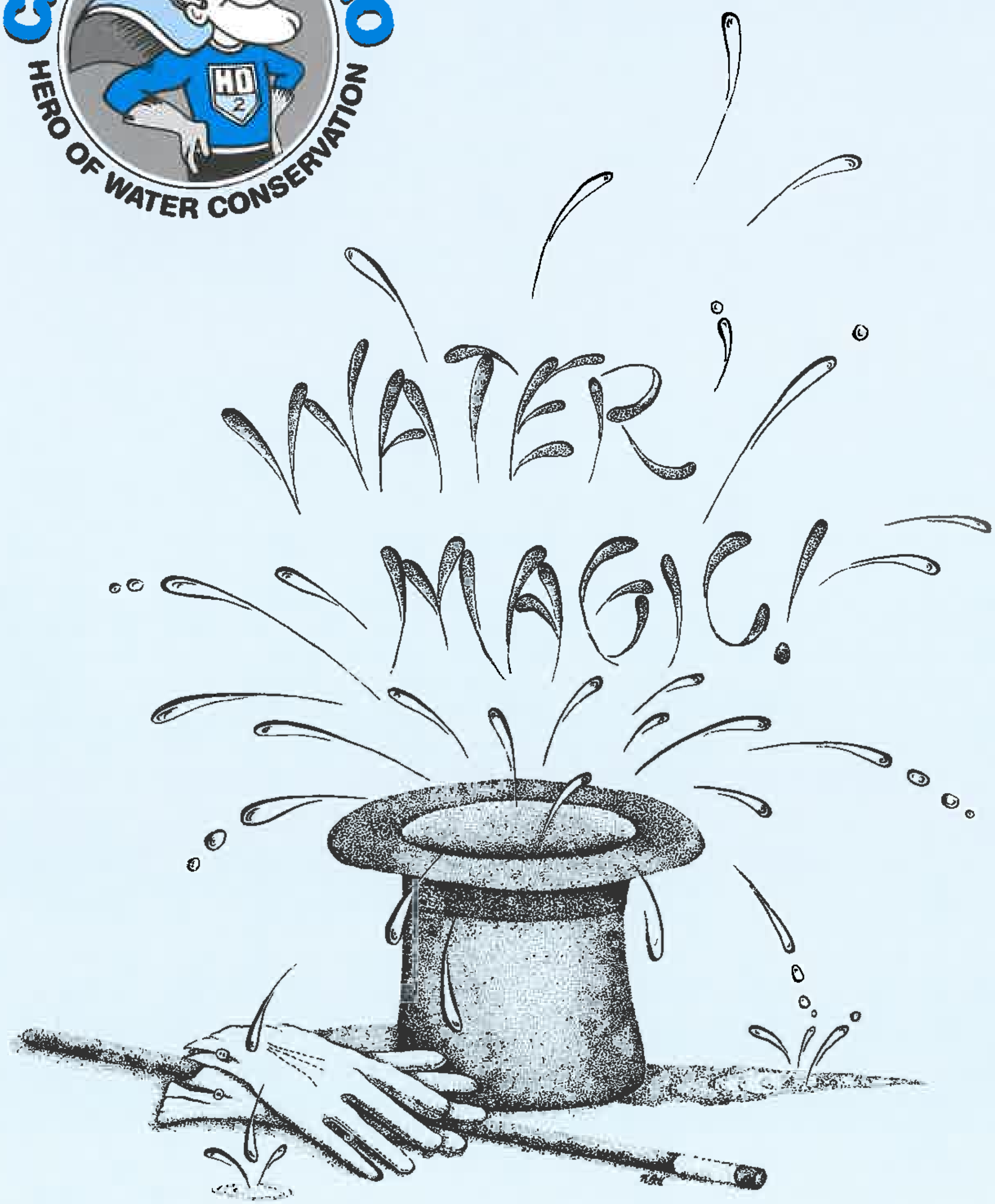
The *FURTHER ADVENTURES OF CAPTAIN HYDRO* Brings You



TEACHER ACTIVITY GUIDE – SCIENCE

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FOREWORD

This Teacher Activity Guide has been prepared as part of Project WATER (Water Awareness Through Education and Research), the school program of East Bay Municipal Utility District, Oakland California. The goals of Project WATER are:

1. To develop an APPRECIATION of water's life-sustaining role in humanity's survival and an AWARENESS of the limitations of its supply.
2. To acquire KNOWLEDGE of water, its physical properties and its uses in our environment.
3. To identify the PROBLEMS relating to water and its use.
4. To select SOLUTIONS, after examining the alternatives, which take into consideration both immediate and long-term effects.
5. To demonstrate the APPLICATION of knowledge and skills in functional water problem-solving.

The Further Adventures of Captain Hydro comic book, first introduced in 1977, is available to reacquaint the students with Captain Hydro as he continues his battle with the Water Bandit. Using *Further Adventures* as a "walk-in" activity provides an opportunity for the teacher to review previous instruction about water that the students may recall from *The Official Captain Hydro Water Conservation Workbook* and other sources.

A Teacher's Guide for *The Further Adventures of Captain Hydro* with lessons concentrated in World History and Geography of Ancient Civilizations continues to be used in Social Science classes. The intent of *Water Magic*, however, is to introduce students in grades six through nine to water and some of its properties through **scientific** concepts. Some of the lessons also deal with reactions and interactions involving water that take place within the human body.

The concepts developed through the activities in this Guide align with the content matrix contained in the *California State Science Framework*. Portions of the Framework which are addressed, relative to grades six through nine, are:

1) What is matter and what are its properties? (pg. 43)
2) What are the basic units of matter? (pg. 45)
3) What principles govern the interactions of matter? (pg. 47)
4) What happens when substances change? (pg. 50)
5) What are cells and the functions of their component structures? (pg. 127)

INTRODUCTION TO THE GUIDE

We live on a "water planet". Over 71% of the earth is covered by water, existing in three states of matter. Water is found as solid water (ice) in snowpacks, glaciers, and the polar ice caps. It is found in a liquid state in lakes, streams, rivers, oceans and seas. It is also found in a gaseous state as water vapor, in the envelope of air surrounding the earth.

Even given the enormous quantity of water on our planet, the amount of fresh water available for use is surprisingly low. Ninety-seven percent of the water on earth is found as salt water in the oceans and seas. Another two percent is frozen, in glaciers and polar ice caps. This leaves a mere one percent as "fresh" water in rivers, lakes, underground aquifers, and related sources. However, even this mere one percent is not entirely "available". Some of it is underground and obtaining it is not economically feasible. "Water, water everywhere, but not..."

Living, as we do, on a watery planet, it is not surprising that water is a major component of our bodies. Much of each individual body cell, within the various tissues, is water. Bone tissue has the least water, with an average of 20%. Brain tissue is comprised of 85% water. In all, about two-thirds of our total body weight is water, equaling about 50 quarts in the average adult person.

Given that such a large percentage of our bodies is water, it is easy to understand the important role it plays in maintaining life. We need water for our survival. However, how much does the average person know about this important ingredient of life, or fully appreciate it for the remarkable substance that it is? The intent of this Teacher Activity Guide is to describe and demonstrate some of the unique attributes of water and to show how a variety of forces and substances interact with it.

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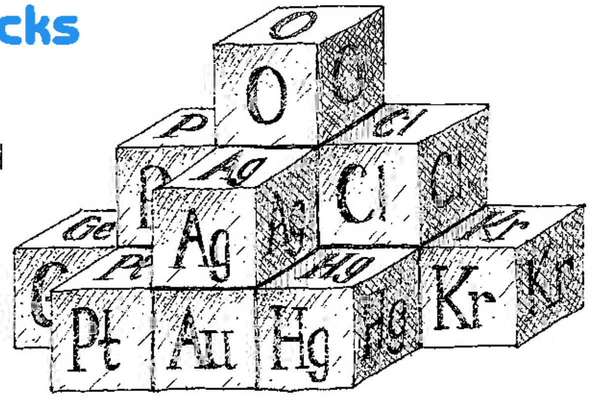
World's Most Basic Building Blocks



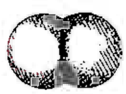
What's the matter? Everything is matter! The word **matter** is used as a scientific term to denote anything that takes up even the smallest amount of space (has volume) and that exhibits even the smallest amount of weight (has mass). A car, a pencil, and water are all examples of matter.

Tiny particles called **atoms** are the building blocks of all matter. These atoms are far too small to see with conventional light microscopes. However, by using electron beams and sophisticated electron microscopes, scientists are getting their first actual glimpses of atoms.

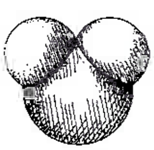
Atoms combine to produce all known substances. A substance which is made of only one type of atom is termed an **element**. About 90 different elements are known to occur naturally. Other elements have been produced in laboratories. Living things are primarily made of four elements: carbon, hydrogen, oxygen, and nitrogen.

Each element has been given a one- or two-letter **chemical symbol**. Often the symbol is part of its name: hydrogen's symbol is (H), helium's is (He), chlorine's is (Cl). Some atoms, however, have a symbol which does not show direct relationship to the English name for the element, such as iron (Fe), sodium (Na), and gold (Au).

All known elements have been organized, by symbol, in a chart called the **Periodic Table of the Elements**. This table is especially useful in studying the relationships that exist between different elements, and in predicting how they will react with each other.

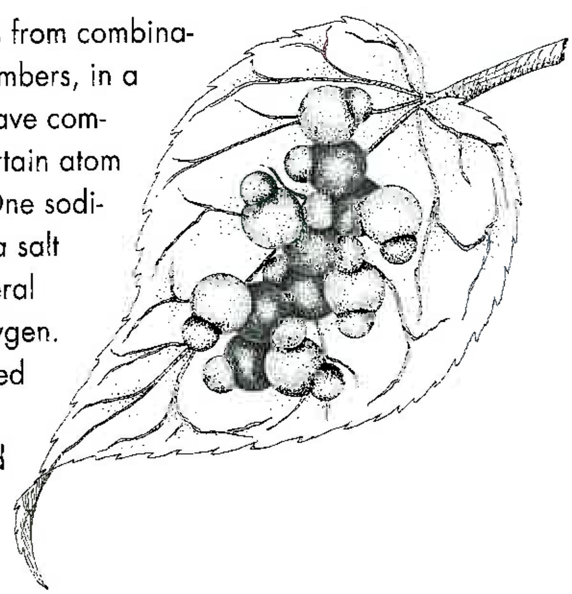


Oxygen molecule



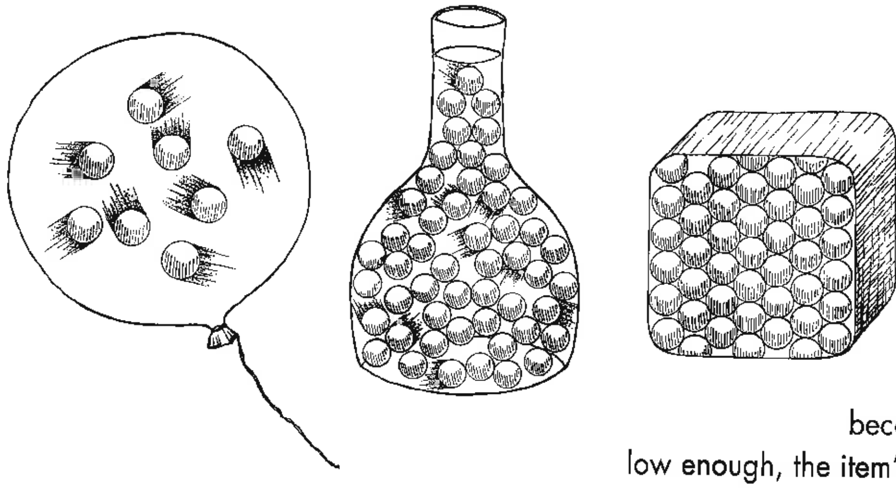
Water molecule

Atoms combine with other atoms to form molecules and compounds. An example of a **molecule** is the oxygen molecule we breathe, which is made of two oxygen atoms bonded together. Water is a molecule in which two hydrogen atoms combine with one oxygen atom. Water is also termed a **compound**, because it is composed of more than one kind of atom in a given proportion.



To identify the formation of molecules and compounds from combinations of atoms, their symbols are combined, often with numbers, in a **chemical formula**. The symbols denote which atoms have combined, the numbers indicate when more than one of a certain atom is involved. NaCl is the chemical formula for table salt. One sodium atom (Na) and one chlorine atom (Cl) bond to make a salt molecule. The chemical formula for water is H_2O. The literal interpretation of this formula is Hydrogen (2 of them) Oxygen. The chemical formula for glucose, a simple sugar produced by plants, is $C_6H_{12}O_6$. This means that 6 carbon atoms, 12 hydrogen atoms, and 6 oxygen atoms have combined to produce one glucose molecule.

There are three basic forms that all matter commonly takes on earth. They are referred to as the three **states of matter**. These states include solid, liquid, and gas. Temperature regulates the state of matter of a particular item. This is the case because all molecules are in constant motion. As temperatures rise, molecules move more and faster; as temperatures drop, they slow down and move less. If the temperature becomes high enough, the atoms in an item move so much that they spread out to the point that the item becomes a gas. If its temperature becomes low enough, the item's molecules compact and it becomes a solid. In between those extremes, the item will be a liquid.



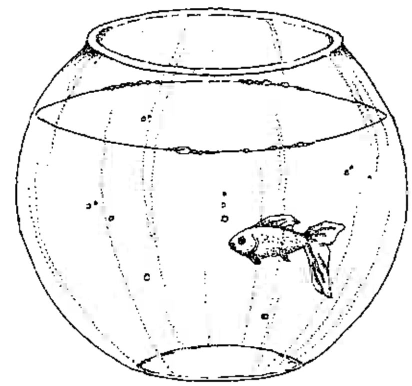
A fourth state of matter is plasma, which only exists at extremely high temperatures. **Plasma** is a state of matter in which individual atoms have broken down to their component parts of bare nuclei and free electrons. The matter making up the sun and other stars is in a plasma state.

TITLE: # A Recipe For Water

KEY QUESTION AND OVERVIEW: "What's In Water?"

The lesson focuses on the concept that all matter is composed of atoms which combine to form molecules. In particular, attention is drawn to the fact that water is a compound composed of three atoms. Students use molecular models to illustrate that two hydrogen atoms combine with one oxygen atom to produce one water molecule. This is reflected by H_2O as the molecular formula for water.

OBJECTIVES:



Students will demonstrate an understanding of atoms as the structural basis of all matter.

Students will, through models, combine atoms to form specific molecules.

Students will show an understanding of chemical formulas as reflections of the component parts of molecules and compounds.

MATERIALS:

Per student: pair of scissors
atom sheet
red and yellow markers or crayons
8 brads

MANAGEMENT SUGGESTIONS:

This activity has students coloring and cutting out paper models of atoms. They then combine these atom models to make molecules. Some students may feel that the coloring and cutting are too "juvenile". Reassure them that the resulting models clearly illustrate atomic concepts and in many respects are preferable to the "gumdrop" models commonly used, at this level, to teach these concepts.

The color-coding is done prior to cutting the models out. This makes the coloring easier; it also means students do not need to color carefully "inside the lines".

Some students will want to stick the atom models together with the brads right away. For this reason, it is suggested that the brads be held back until the appropriate time according to the activity flow.

The chemical bonding concepts in this lesson are introduced in a very basic form. Electrons and their relationship to bonding are not mentioned. Bonding types, including double bonds, are not mentioned. The design of this lesson is simply to introduce very basic atomic information as it relates to the water molecule.

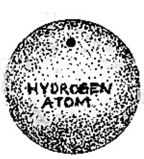
☛ *Have the students save the atom and molecules models for reference and use with other lessons in this series (particularly Presto - Peroxide Becomes Water)*

ACTIVITY

1. Introduce atomic size. All matter is made of sub-microscopic particles called atoms. Students can be given a vague idea of atomic size by being told that 90 billion billion (90,000,000,000,000,000,000) atoms can be found in a single drop of water.

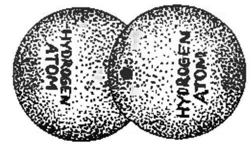
2. Explain atomic models. Since atoms are too small to be seen, scientists use models to represent them and study them. Today's activity will utilize paper models of atoms which are two-dimensional. Actually, atoms are spherical, resulting in molecules somewhat like a group of balls pushed tightly together. These facts need to be made clear to the students.

3. Pass out materials. Give each student scissors, markers, and student sheets. Have the students color-code the atom models first. Scientific convention has designated hydrogen - yellow, oxygen - red, and carbon - black. These paper atom models should be similarly color-coded by the students prior to cutting them out.

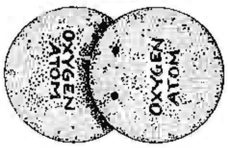


4. Introduce hydrogen. Once the atom models are cut out, direct the students to hold up one hydrogen atom. "Black dots on the atom represent places where that atom wants to attach to (bond with) another atom". Ask the students how many dots the hydrogen has *(1)*. Explain that each hydrogen atom has one place where it will grab onto another atom.

5. Make hydrogen molecule. Each student holds up a hydrogen atom in each hand. They then align the dots with the atoms overlapping, but not directly stacked on top of each other. If they were then to take a brad and connect the two hydrogen atom models through their dots, they would have produced a hydrogen molecule. (Do not have them actually use the brads yet.)

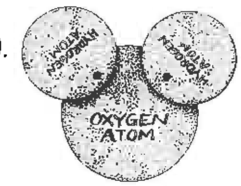


6. Explain chemical symbols and formulas. The chemical symbol for hydrogen is H. The chemical formula for the hydrogen molecule they made is H_2. This can be verbalized by students new to the concept by H *(2 of them)*. The "of them" will be dropped by students as they gain mastery of the system of chemical formula writing.

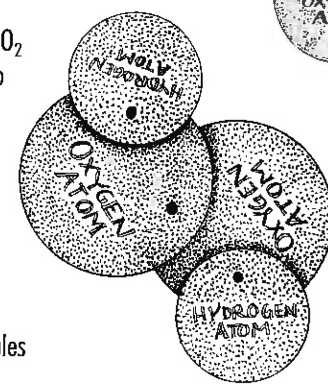


7. Introduce oxygen. Students hold up an oxygen atom model and find its bonding spots *(2)*. Oxygen has two spots where it will attach to another atom. Direct students to align the dot pairs of one oxygen atom with the pairs on another. This produces an oxygen molecule (O_2) model.

8. Make an H_2O molecule. Each student gets 4 brads and makes a molecule of H_2O. Do not show how it's done or that it takes two hydrogens and one oxygen, but rather let them construct it on their own.



9. Construct an H_2O_2 molecule. The students put together an H_2O_2 molecule. This is hydrogen peroxide , which is a household cleansing agent for wounds. Two shapes can occur with this molecule. From current student knowledge, both are equally correct. However, in reality, one is the actual shape, based on the fact that the two hydrogen atoms will try to get as far from each other as they can.

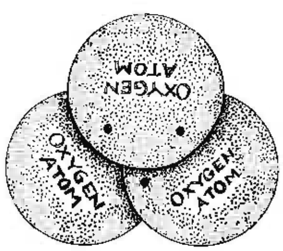


REVIEW AND REFLECTION:

1. Without using brads, have the students quickly hold up representative atoms and molecules as the teacher calls them out.

2. Tell students that C is the chemical symbol for carbon. Ask them to tell which atoms and how many of each are involved in the molecule $C_6H_{12}O_6$. *6 carbon atoms, 12 hydrogen atoms, and 6 oxygen atoms.*

3. If 90 billion billion atoms are in a drop of pure water, how many water molecules are in that drop? *30 billion billion.*



4. Have the students construct an O_3 molecule.

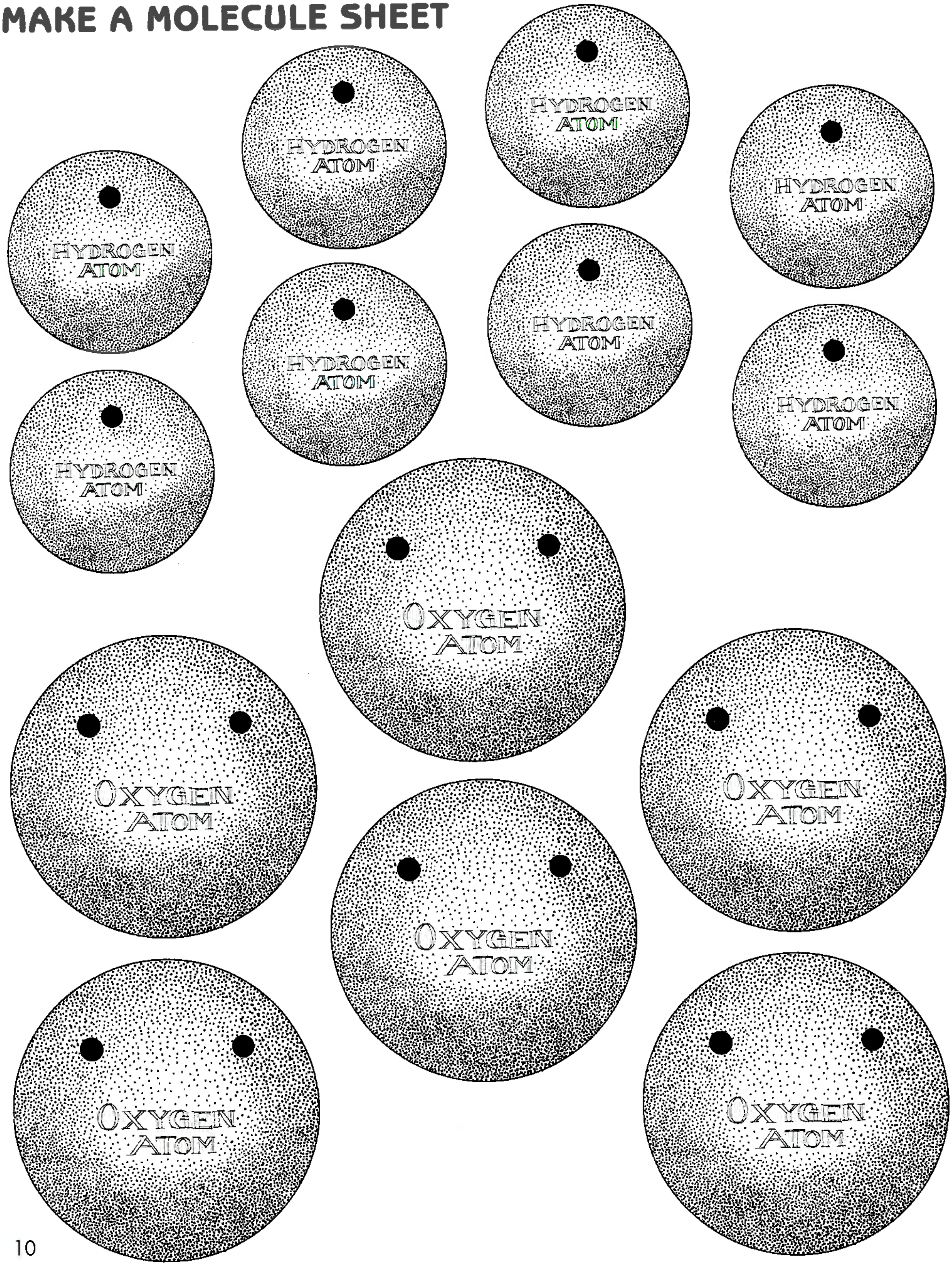
5. The formula for carbon dioxide is CO_2; the formula for methane gas is CH_4. How many bonding spots does a carbon atom (C) have? *4.*

EXTENSIONS:

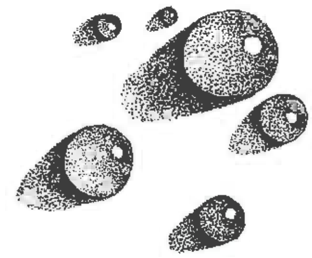
1. The unstable ozone molecule is an important part of our atmosphere. It is also a cause of great concern. Have students research information about the ozone layer, its importance, and the damage being done to it.

2. Have students research the composition of air. Many people think of oxygen molecules (O_2) as air molecules. Oxygen is one component of air. Air is actually a mixture of many different molecules. Most of the air molecules are nitrogen; only ⅕ of them are oxygen.

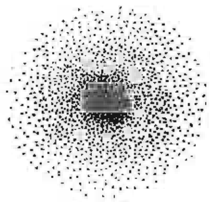
MAKE A MOLECULE SHEET



Water Sticks To Water



Water sticks to water. This important property of water, termed **cohesion**, results from each water molecule being attracted to, and actually attaching to, other water molecules near it. This attraction is due to the properties of the atoms in the water molecule.

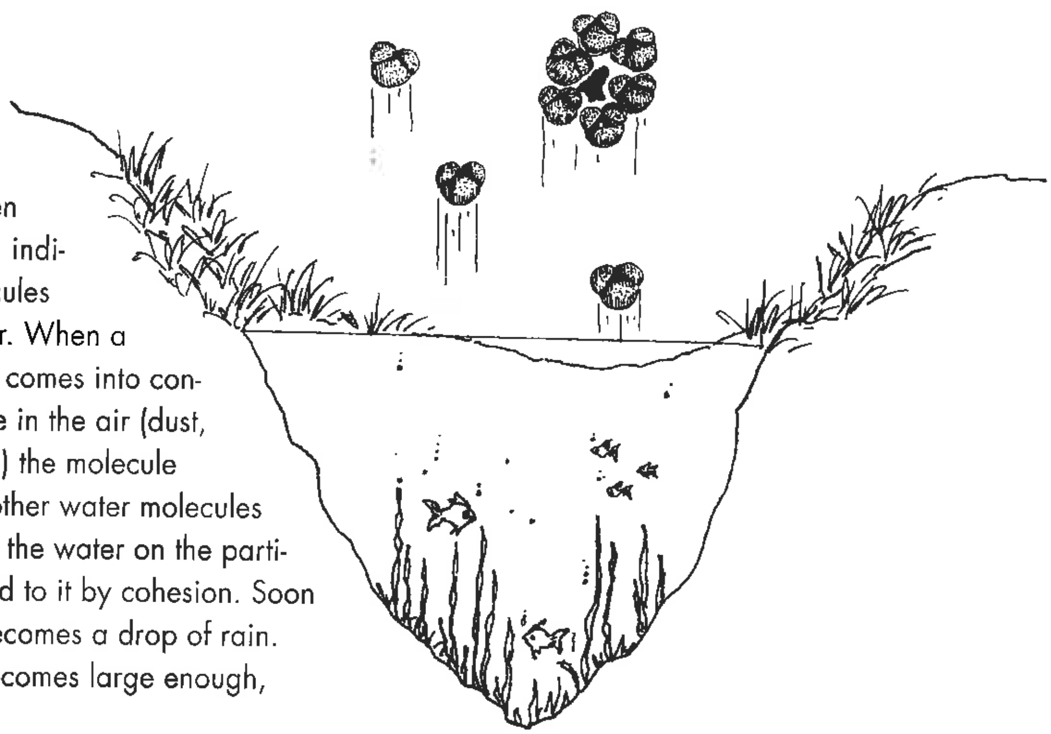


Every atom has a very small, dense, central **nucleus**. The nucleus contains protons with a positive charge. This nucleus is surrounded by a cloud of **electrons** which have a negative charge. The positive charge of the nucleus and the negative charge of the electrons are generally the same strength, balancing each other out. Particles called neutrons, also within the nucleus, have no charge.

A **water molecule** is composed of two hydrogen atoms and one oxygen atom bonded together. Each hydrogen atom has one proton in its nucleus and a single electron in its cloud; the oxygen atom has eight protons and eight electrons. When hydrogen atoms bond to an oxygen atom, hydrogen's negatively-charged electrons are attracted to oxygen's strongly-positive nucleus. Consequently, the electrons end up spending most of the time around the oxygen. Electron rearrangement leaves the hydrogen atoms with a partial positive charge from their unattended nuclei. It also gives the oxygen atom a partial negative charge from the excess of electrons.

The water molecule, therefore, becomes a **"polar" molecule**, with positive and negative ends. A positive oxygen end of one water molecule is attracted to, and binds to, a negative hydrogen end of another water molecule. This hydrogen to oxygen bonding is referred to as a **hydrogen bond**. This attractive binding doesn't result in a larger molecule. It does, however, account for water's cohesive property.

Cohesion is an important factor in the **formation of raindrops**. When water evaporates, individual H_2O molecules "jump" into the air. When a molecule of water comes into contact with a particle in the air (dust, smoke, salt crystal) the molecule adheres to it. As other water molecules make contact with the water on the particle, they are bound to it by cohesion. Soon the wet particle becomes a drop of rain. When the drop becomes large enough, it falls as rain.

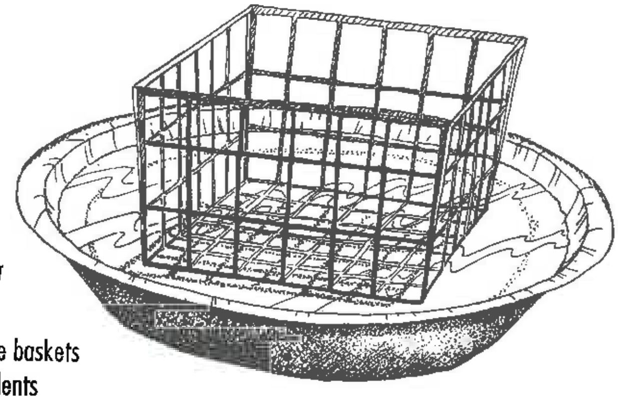


Cohesion also acts at water's surface, where it is given the title **surface tension**. Water molecules on the surface have nothing attracting them from above. They are bonded to the side and below. This creates a relatively strong "film" on the top of the water. The ability of some insects to skim across the top of water is a result of surface tension. It also allows a carefully placed needle to float on water's surface.

Temperature and molecule movement are related. All molecules are moving. Temperature affects the amount of, and speed of, that molecular movement. The warmer a substance is, the faster the molecules move. The colder the substance, the less its molecules move. The amount of movement in water's molecules affects the degree of cohesion that can take place.

Another important property of water is **adhesion**, in which a substance's molecules are attracted to molecules of a different substance. Adhesion takes place under many circumstances, involving many different molecules. Adhesion takes place between glue and paper. Adhesion holds bubbles of gas against the inside of a glass of soda. Adhesion of water to glass will also will be shown with an activity in the extension portion of this lesson.

TITLE: **Berry Basket Boats**



KEY QUESTION AND OVERVIEW:
"How can an item float that's heavier than water?"

The lesson illustrates cohesion, one of water's unique properties. Cohesion is the attraction between molecules of the same substance. Surface tension is evidence of cohesion on water's surface, causing water to behave as if there was an invisible film on it.

Students float berry baskets on water gradually adding to the mass of the baskets until, overcoming the surface tension of the water, the baskets sink. Students will repeat the experiment, using room temperature water, ice water, and hot water.

A related property of water is adhesion, which is the attraction between unlike molecules, such as water's attraction to glass. Adhesion is demonstrated in one of the extension activities.

OBJECTIVES:

Students will define cohesion as a property of water in which water molecules form polar bonds to other water molecules around them.

Students will demonstrate cohesion and surface tension by floating objects heavier than water on its surface.

Students will compare the cohesive behavior of water at various temperatures.

Students will connect the cohesive nature of water to the condensation of rain drops in the water cycle.

MATERIALS:

Per class: Enough water at three different temperatures (room temperature water, ice water, and hot water) to place at least 1" in a basin for each team.

Per team of 2 - 4 students:

a generous supply of paper towels or cloth toweling
1 basin or other small container (at least 5" square and 2" deep)
1 plastic strawberry basket
25 large paper clips (or other items of similar mass)
1 data sheet
1 thermometer

MANAGEMENT SUGGESTIONS:

Tap water will work for this experiment, but best results are achieved using pure water. Tap water contains salts and other minerals dissolved in it. These additional molecules in the water interfere with the ability of the water molecules to bind to each other. It is suggested that students' hands be clean and free from soap.

Students need to carefully and gently place each paper clip into the basket. Dropping the paper clips, being carelessly rough, or jarring the desk will affect the outcome of the experiment.

After a basket sinks, both it and its paper clip load need to be thoroughly dried before they are reused in another experimental trial.

Students need to count the paper clips as they go. The clip that causes the boat to sink doesn't count.

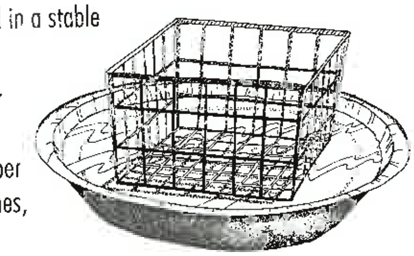
ACTIVITY

1. Review the water molecule. All matter consists of tiny particles called atoms. Hydrogen and oxygen are examples of types of atoms (elements). Atoms combine to form molecules and compounds. Water is a compound composed of two hydrogen atoms and one oxygen atom. Water's chemical symbol (H_2O) shows this relationship.

2. Introduce atomic nucleus and electrons. All atoms have a cloud of negatively-charged electrons around a positively-charged center, or nucleus. Hydrogen has one electron around its nucleus, oxygen has eight.

3. Explain water's polar nature. When hydrogen and oxygen combine to make water, their combined electrons spend most of the time around the oxygen atom. This rearrangement gives the oxygen end of the molecule a negative charge. It also leaves the hydrogen ends with a positive charge. The water molecule then has a polar nature: negative on the oxygen end and positive on the hydrogen ends. Opposites attract.

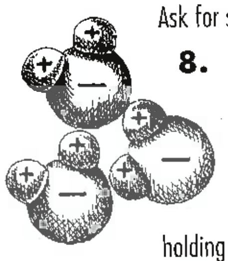
4. Introduce the activity. Tell the students that today they will experiment to find the maximum number of paper clips a berry basket boat can hold before it sinks. The activity will be done with room temperature water, ice water, and hot water. (The intent is to have the students experience the cohesive force of water before they are directly introduced to the concept of cohesion.)



5. Pass out materials. The basins for floating the basket boats should be placed in a stable location and be protected from bumping or jarring during the activity.

6. Begin the activity. Each team puts at least an inch of *room temperature* water into the basin, measures the temperature of the water, and records the result on the data sheet. Students gently lower the berry basket onto the water, so it floats. Finally, they carefully place paper clips into the basket, counting as they go, until the basket sinks. This process is repeated three times, each trial recorded, and an average computed and recorded.

7. Discuss student results. Teams will have varying results, depending on the technique and the care observed during the activity. Have each team share their data and enter the class data on the room temperature graph on their data sheet. Ask for student input regarding why the basket was able to float with extra mass in it.



8. Explain cohesion. Opposites attract. When the positive hydrogen end of one water molecule comes into contact with the negative oxygen end of another water molecule, they bind together. The action is similar to opposite ends of two magnets being drawn together. This bonding "holds water molecules together".

9. Explain surface tension. The cohesive attraction between water molecules is strongest at the surface, creating something acting similar to a thin film. The berry basket boat is heavy enough to sink. However, the water molecules on the surface are holding tightly to each other. The boat is not heavy enough in any one place to push the molecules apart so that it can go under.

10. Students explain cohesion. In their own words on the data sheet, students write a sentence, explaining scientifically why the basket floated.

11. Repeat activity using ice water. Students now repeat the activity steps, using very cold water (ice water) to float the basket boats. The information is shared as a class and recorded on the ice water graph.

12. Repeat activity using hot water. The activity steps are repeated once again, using hot water. The results of this step are not entered on a graph. Instead, students answer the question regarding temperature's affect on cohesion at the bottom of the data sheet.

13. Discuss temperature, molecule movement, and cohesion. All molecules are moving. The warmer molecules are, the faster they move. The more and faster they are moving, the harder it is going to be for them to be attracted to each other. The warmer water is, the less cohesion it will exhibit. The opposite is, of course, true as the temperature of the water decreases.

14. Relate cohesion to raindrop formation. When water molecules in the air come into contact with tiny particles of dust, salt crystals, or other substance in the air, the molecules adhere to it. As other water molecules contact the water on the particle, they bind to it by cohesion. As more water molecules are added, the wet particle becomes a drop of rain. When the drop becomes large enough, it falls as rain.

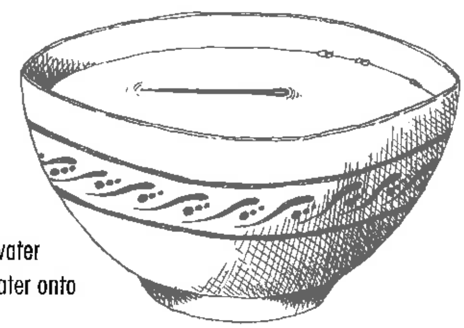
15. Clean up. Retrieve the materials. Make sure to leave the paper clips out to dry as they will rust if left wet in a closed container.

REVIEW AND REFLECTION:

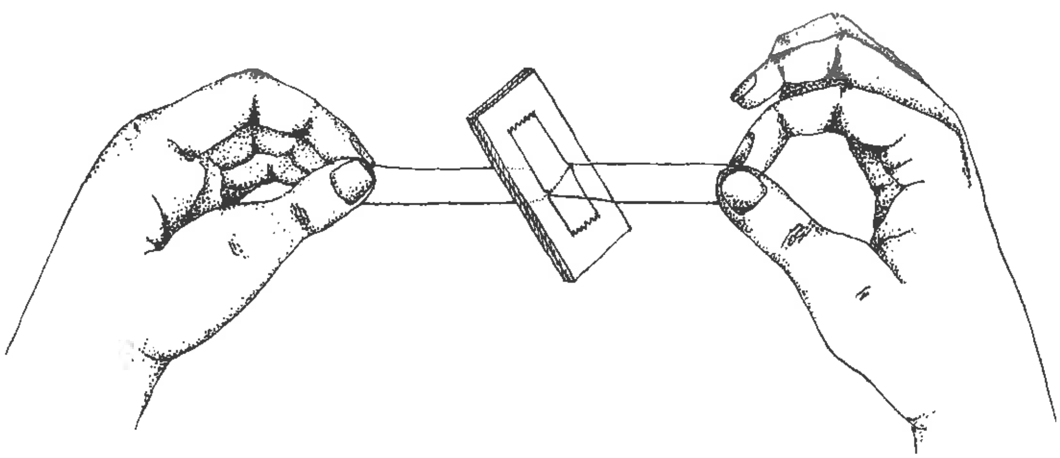
1. What are the component parts of an atom? *A nucleus containing protons and neutrons, with a cloud of electrons around it.*
2. Describe the charges involved with different parts of a water molecule. *Positive at the hydrogen ends, negative at the oxygen end.*
3. Exactly how does cohesion relate to the formation of raindrops? *See teacher background or #13 of the activity.*
4. How is cohesion different from surface tension? *It's not. Surface tension is simply cohesion acting at the surface level. If there's a difference, it's relative strength. At the surface, the binding between water molecules is somewhat stronger than below the surface.*
5. How would the world be different if water did not stick to water?

EXTENSIONS:

1. As a demonstration or separate class activity, do a trial berry basket float using water that has soap in it. How does this affect the results?
2. As a demonstration, or short student activity, float a small needle on water's surface. Lay a very small piece of cheap tissue on the surface of a glass or bowl of water. Gently place a small sewing needle on the tissue. As adhesion draws water into the tissue, it sinks. The needle remains on the surface, held up by water's surface tension.



3. Have students predict how many drops of water can be placed on a penny, using a water dropper (eyedropper). After recording their predictions, have the students gently drop water onto the penny, counting the drops.
4. An example of adhesion can be done with two glass microscope slides. Tape a short loop of thread or floss to the middle of each slide. Wet the other side of each slide and press them together. Now, pull on the thread loops to try to separate the two slides. Adhesion between the glass and the water will bond the unit together, making them difficult to separate.



BERRY BASKET BOATS

WATER	TEMPERATURE	1ST TRY	2ND TRY	3RD TRY	AVERAGE
ROOM TEMPERATURE	°C				
ICE COLD	°C				
HOT	°C				

Why does the basket float? ______________________

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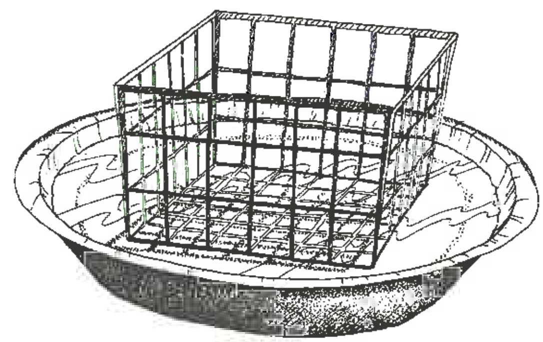

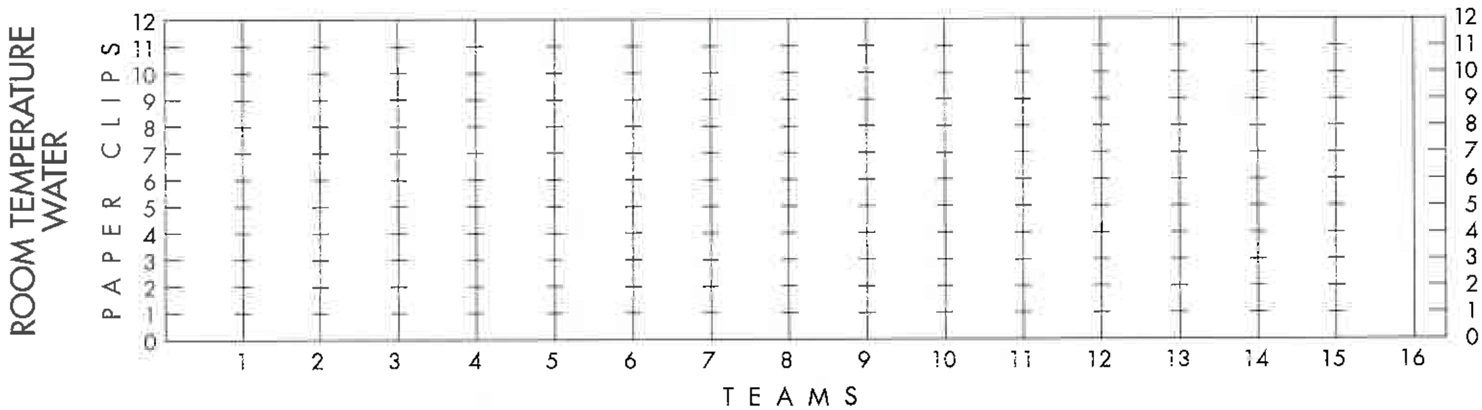

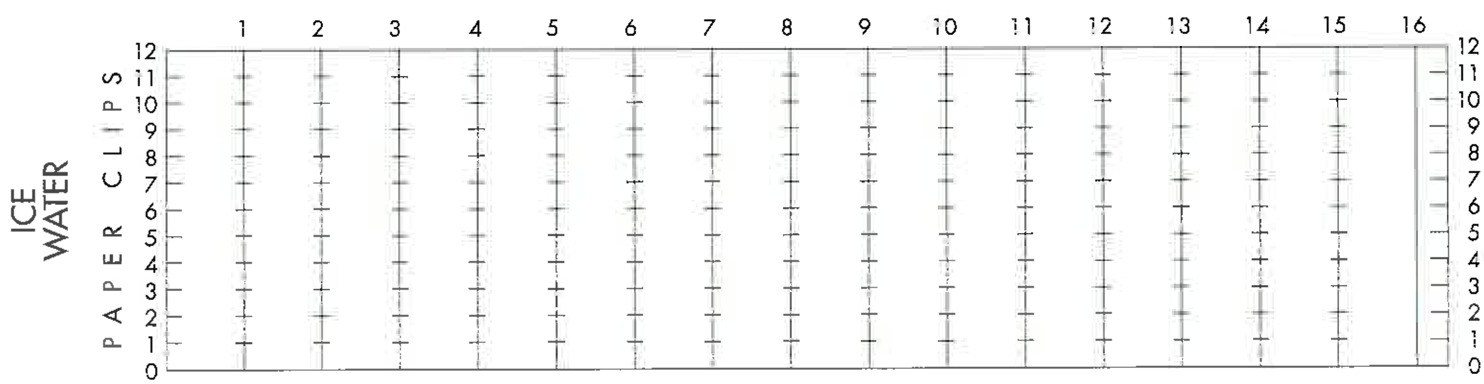

Why does temperature affect cohesion? ______________________

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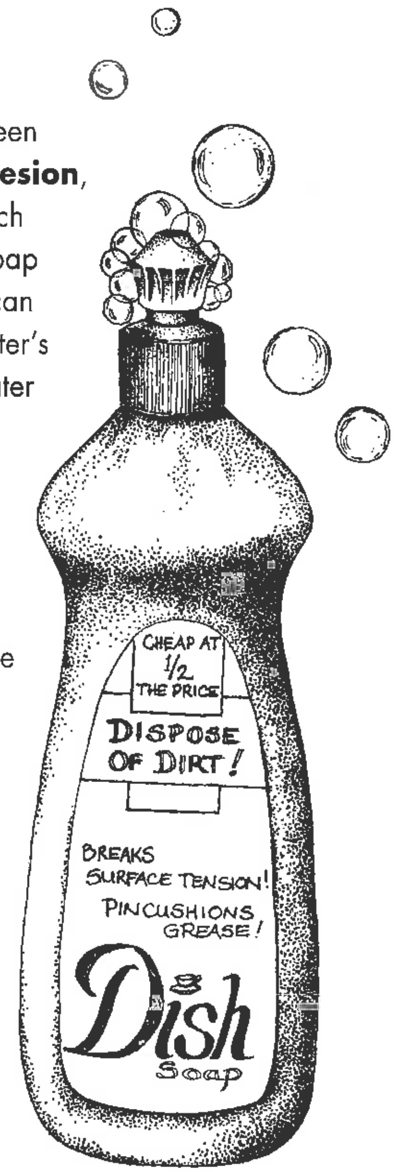
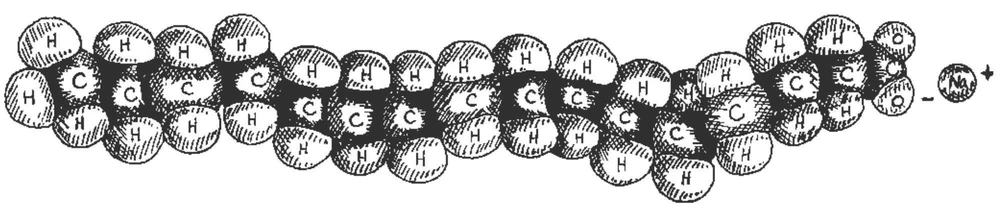
Soap Interferes With Water

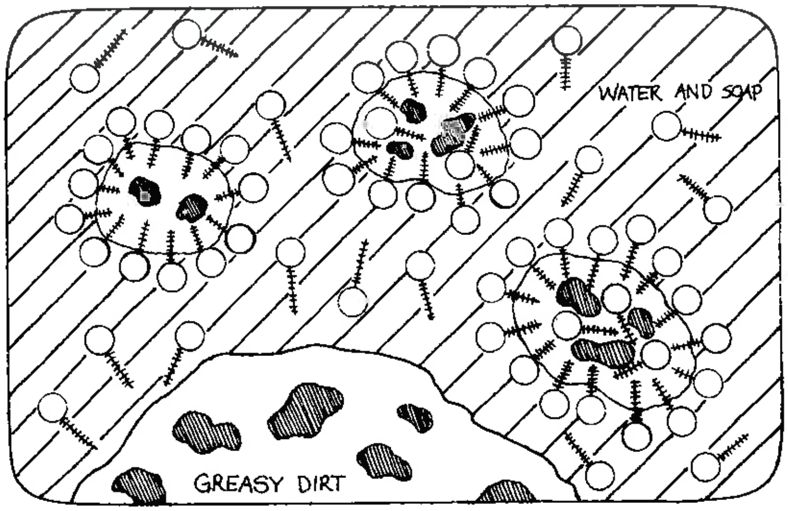


Water molecules stick together. The term for this attraction between molecules of the same substance is **cohesion**. A related term, **adhesion**, is applied when molecules of different substances are attracted to each other. Soap causes water molecules to quit sticking to each other. Soap does this by interfering with water's cohesive nature, so that water can then devote itself more to its adhesive nature. The importance of water's adhesive nature is in its ability to "wet" things. To clean an item, water needs to get the item, and the dirt on it, "wet". However, water's attraction to itself is stronger than its attraction to other things. Therefore, we need to cancel out some of water's attraction to itself (cohesion), so that it can exhibit increased attraction to dishes, hands, clothes, and dirt (adhesion). Soap does this.

First, a word about the **soap molecule's appearance**. At one end of a typical soap molecule (often called the head) are two oxygen atoms and a sodium atom. This "head end" is polar. The rest of the molecule (often called the tail) is a non-polar hydrocarbon chain, composed of 12 to 18 carbon atoms connected to hydrogen atoms. Because they are composed of two distinct and differently acting parts, soap molecules have a "split personality". The head is attracted to water; the tail repels water. The soap molecule's size, polar nature, and split personality set the stage for soap's unique role as a cleansing agent.



To break surface tension, soap's relatively large molecules get between the water molecules, reducing their attraction to each other. The surface tension of soapy water is only about $\frac{1}{3}$ the strength of the surface tension of plain water.



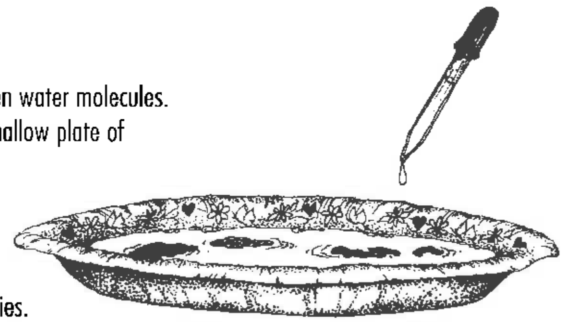
To dispose of dirt, soap utilizes its split personality. Since grease and oil do not dissolve in water, washing with water alone does little good. This is where soap comes in. The polar head dissolves in water, since water itself is also polar. The hydrocarbon chain tails, which are repelled by water, are attracted to grease, oil, and dirt. As millions of soap molecules stick their tails into a glob of grease, they "pincushion" it. The polar head ends of each molecule, which stick out of the grease ball, take on a negative charge. This gives the grease droplet a negatively-charged surface. It then, repels all the other similarly charged "pincushioned" globs of grease. The result is that large globs of grease are broken into tiny droplets, which then spread out and go down the drain.

This action by soap, producing tiny droplets of grease or oil in water, is an example of emulsification. An **emulsion** is a mixture of liquids in which tiny droplets, containing many molecules of one liquid are evenly distributed throughout another liquid. This differs from a **solution**, in which individual molecules of a substance are distributed throughout a liquid. Sugar water is an example of a solution, wherein the sugar molecules disperse evenly throughout the water. Mayonnaise is an example of an emulsion, containing droplets of vegetable oil.

Temperature affects interactions between molecules. All molecules move. As molecules become warmer, they move more; as they cool down, they move less. Of course the more molecules move, the greater will be their opportunities to interact with each other.

Of final note in relation to the following activity, is the colloidal nature of milk. A **colloid** is a substance made of insoluble particles suspended in a fluid. In size, the particles of a colloid are larger than those in a solution, but not so large that they will eventually settle to the bottom, as those in a **suspension** will do. As a colloid, milk affects the interaction of soap and water molecules. The particles in milk interfere with the movement of the soap molecules placed into it. This causes the action of the soap on the water to remain localized, instead of affecting the whole container immediately.

TITLE: Milk Storms



OVERVIEW AND KEY QUESTION:
"Why do we use soapy water to wash?"

This lesson concerns the use of soap to break the cohesive attraction between water molecules. The activity centers on having the students put single drops of soap into a shallow plate of milk with food coloring drops in it. Temperature is introduced as a variable. The results are graphed and the data analyzed.

OBJECTIVES:

Students will define cohesion and adhesion as two of water's unique properties.

Students will illustrate the breaking of water cohesion by the use of soap.

Students will time and graph the effect of temperature changes on water cohesion strength within milk.

MATERIALS:

Per class:

- 1 gallon 2% low fat milk
- container for disposing of used milk
- heat source to warm the milk
- ice container in which to cool milk
- clock with a second hand that entire class can see

Per student team of four:

Activity I

- 1 coated paper plate or similar container (at least 7" diameter/¼" deep)
- access to food coloring (3 different colors are best)
- small (3 oz) cup of Dove dishwashing soap labeled "mystery liquid"(other brands may work)
- dropper to use for soap *only*
- cup of milk (6-8 oz)

Activity II

- 3 coated paper plates (similar to those used in Activity 1)
- small (3 oz) cup of Dove dishwashing soap with dropper
- small (3-5 oz) cup for milk transfer
- access to food coloring (3 different colors are best)
- thermometer
- paper towels for clean-up
- cup of milk (6-8 oz)
- 4 data sheets

MANAGEMENT SUGGESTIONS:

It's not unusual for some students at any particular grade to be unfamiliar with the use of droppers. Initial instruction should be given in dropper use. "Dip the dropper end into the liquid, squeeze the bulb once, release the bulb, remove the dropper end from the liquid, and gently squeeze the bulb to release single drops."

Remind the students to use the materials during the activity *only* as described. There should be no squirting, tasting the milk, etc.

It is important that the dropper used for transferring the soap be used only for soap. It must not contaminate the food colorings or milk sources.

The activity plate for each team may be placed on a larger (9") paper or plastic plate to minimize messes and facilitate clean-up.

Initially, do not identify the dishwashing liquid or explain soap's role in breaking water's cohesive nature.

Prior to Activity II, plan for and set up the "milk station". It consists of four containers of milk at differing temperatures (very cold, cool, room, very warm).

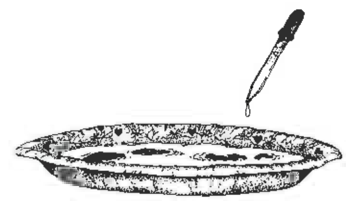
ACTIVITY

1. Review cohesion. Water molecules are attracted to each other due to their polar nature. Larger molecules are not created by this attraction. The result is, however, a relatively strong bonding between adjacent water molecules.

2. Introduce adhesion. Molecules of one substance are often attracted to molecules of a different substance. Water experiences adhesion when it comes into contact with a paper towel. The water molecules are attracted to the paper molecules and the water is "absorbed" by the paper toweling.

3. Distribute materials for Part I of the activity. Each student team receives a plate and cup of room temperature milk. All teams have access to food coloring, an unlabeled container of Dove dishwashing liquid (the mystery liquid), and a dropper.

4. Begin Part I. Students carefully pour ⅛" - ¼" milk into their plate. They then add a drop of *each* of 3 - 4 different food colorings to the milk. The drops should be spread as far apart from each other on the plate as is possible. Students are not to use 3 - 4 drops of each color. They need 1 drop each of 3 - 4 different colors.



5. Add one drop of mystery liquid. Students place one drop of the "mystery liquid" into the milk anywhere on the plate. They observe the interaction taking place, which will be a general mixing of the milk and food coloring.

6. Continue Part I. When the mixing action in the milk stops, students should add another single drop of soap to a different area on the plate. This procedure can continue through several "mystery solution" applications.

7. Class discussion about Part I. Two separate questions are addressed:

1) What is the "mystery liquid"? *Dove dishwashing liquid.* (Students often think it is a hand lotion.)

2) What is happening in the plate? *The cohesive attraction of the water molecules is being broken, causing the movement observed in the milk. Somehow, the soap must be causing this.*

8. Discuss the soap molecule and its affect on water's cohesion. A soap molecule is a long chain of carbon atoms, with hydrogen atoms attached to them. At one end of the chain (the head) are two oxygen atoms and a sodium atom. This "head end" is polar and is attracted to the polar water molecule, but repelled from other soap molecules. As soap is added to water, the relatively large soap molecules come between the water molecules, interfering with the cohesive attraction between them.

9. Introduce Part II. The students will explore the relationship between temperature and the movement of the colored milk caused by soap.

10. Distribute new materials for Part II of the activity. Each student team receives 3 plates; access to food coloring ; a container of Dove dishwashing liquid with a dropper; a thermometer; a cup to transfer milk; and a data sheet.

11. Introduce the "milk station". Refer to Management Suggestions to prepare the milk station. Explain to students that a member of each team will come to the milk station and get a cup of their designated temperature milk for each trial of the activity. They will use the thermometer to determine the temperature of their milk.

12. Designate team temperatures. For a class of 32, there will be 8 teams of four students. Designate two teams for each of the four temperatures (cold, cool, room, and warm). It's best that no two adjacent teams be assigned the same temperature.

13. Begin the activity. The student data sheets will lead the students through the activity. Each student team will repeat the activity three times with their designated temperature of milk. The object will be to record the period of time movement is observed after the introduction of a soap drop into the milk and food coloring. The teacher will monitor the progress. Students will compute the average amount from the results of the three trials.

14. Share results as a class. Through directed discussion, the data from each team will be shared. Each student will record this information on the data sheet.

15. Discuss the relationship between temperature and molecule activity. For molecules to interact, they must come into contact with each other. All molecules are moving. The more rapidly they move, the more opportunity they will have to come into contact with each other and interact. Temperature affects how much, and how rapidly, molecules move. The colder – the slower and less; the warmer – the faster and more.

16. Clean up.

REVIEW AND REFLECTION:

1. What is the difference between cohesion and adhesion? *Cohesion is molecules of the same kind sticking to each other. Adhesion involves molecules of different kinds.*

2. How do cohesion and adhesion allow a tree to pull water up to its top branches? *Adhesion pulls the water up inside the roots, trunk and branches. Cohesion allows the water being drawn up through adhesion to pull other water along with it.*

3. What is soap's role in helping water to clean things? *Soap causes water to lose some of its cohesive nature, so that it more freely utilizes its adhesive nature.*

4. How did temperature affect the experiment results? *Higher temperature caused a faster reaction, which took less time to complete.*

5. If you had only water (no soap) to clean with, why might hot water clean better than cold water? *The water molecules would be moving more. They would be less able to hold onto each other and more likely to come into contact with dirt.*

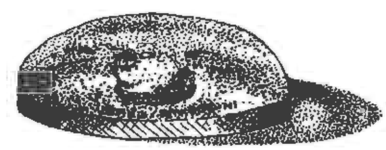
EXTENSIONS:

1. Repeat Part II of the experiment, investigating different milk types rather than different temperatures of milk. Suggestions might include non-fat, 1%, 2%, and whole.

2. As a demonstration, attempt to float a berry basket in water to which soap has been added.

3. Find out how many drops of water will pile up on a penny that has a little soap on it.

4. Sprinkle pepper on a shallow bowl of water. Touch some soap to the water at one side of the bowl.



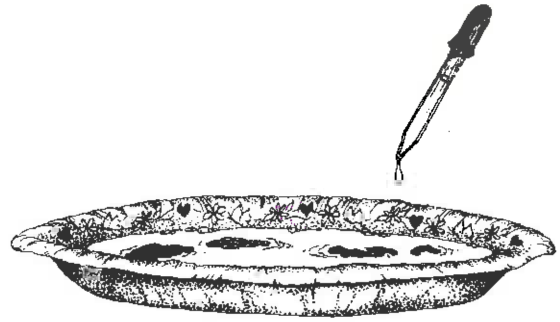
MILK STORMS

TEAM # ________

CHECK ONE

MILK – ICE COLD ____ REFRIGERATOR TEMP. ___

ROOM TEMP. ____ VERY WARM ____



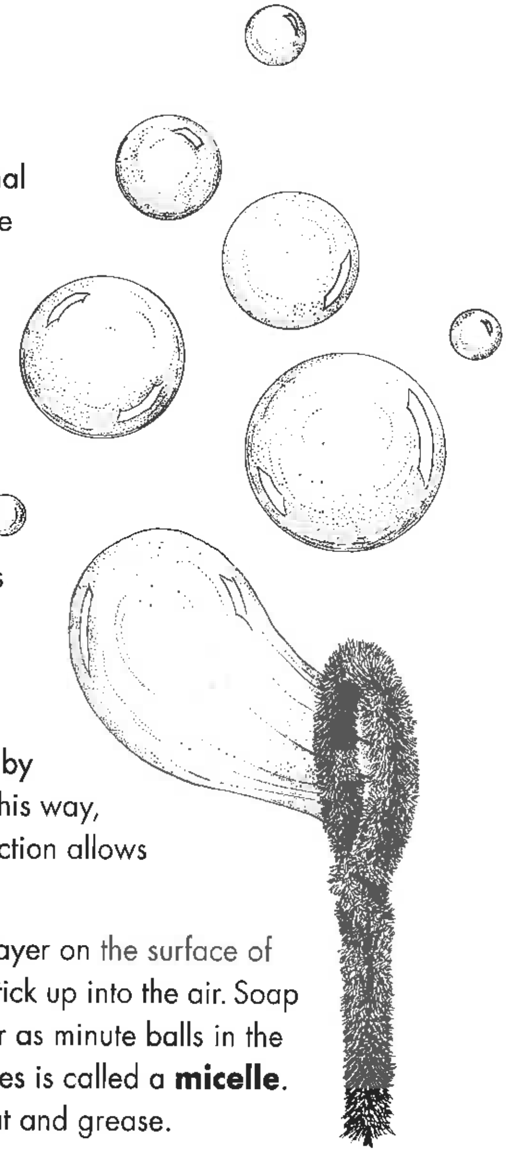
Record how long movement lasts once a drop of soap is added.

TEMPERATURE	1ST TRY	2ND TRY	3RD TRY	FINAL RESULTS AVERAGE TIME

C L A S S   R E S U L T S

TEAM	TEMPERATURE	AVERAGED TEAM RESULTS	FINAL AVERAGE
ICE COLD TEAM 1			}
TEAM 2			
REFRIGERATED TEAM 3			}
TEAM 4			
ROOM TEMP. TEAM 5			}
TEAM 6			
VERY WARM TEAM 7			}
TEAM 8			

Soap Spheres And Rain Balls



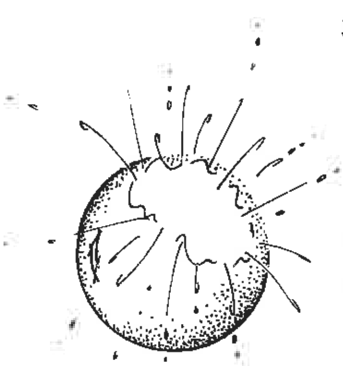
Three primary concepts are covered within this informational page: the structural composition of soap bubbles; the inevitable shape of free-floating soap bubbles; and the natural shape taken by a raindrop. The basis for these concepts will be shown to be both scientific and mathematical.

Strong **cohesion** is one of water's unique properties. Each polar water molecule sticks to the other water molecules near it. This results in a fairly tightly-bound unit. In fact, water molecules have such a strong attraction to each other that bubbles can't be blown from water. As a water film begins stretching out to enclose some air, the molecules pull together and effectively return the water to a compact unit.

Soap molecules are also polar, with a "head" end that's attracted to water and the hydrocarbon tail end that's repelled by water. Soap molecules come between the water molecules. In this way, **soap interrupts cohesion** between water molecules. This action allows water to "stretch out".

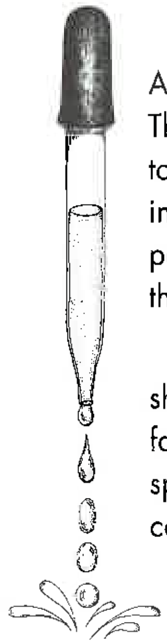
When soap is added to water, the soap molecules form a layer on the surface of the water. Their polar heads stick into the water and their tails stick up into the air. Soap molecules that can't become part of the layer on the top, gather as minute balls in the water with their tails pointing inward. This ball of soap molecules is called a **micelle**. Micelles help clean clothes, dishes, and hands by picking up fat and grease.

The chemical and physical structure of soap and water dictates the formation of **soap bubbles**. When air is blown through a solution of soapy water, a thin film develops, forming bubbles. The film is a soap and water "sandwich", composed of a layer of water molecules, bordered on both sides by layers of soap molecules with their tails sticking out into the air.



Soap bubbles have fairly long "lives". This happens because the water, that would evaporate, is "sandwiched" between layers of soap, which do not evaporate. Why don't bubbles last indefinitely? One reason lies in the fact that the water molecules within the soap layers are drawn together by cohesion, and drawn down by gravity. As the water layer drains out from between the polar soap molecules at the top of the bubble, the soap "heads" of the two layers repel each other. The bubble bursts.

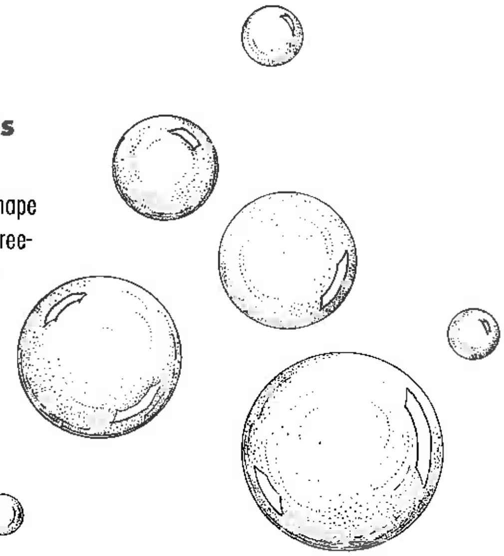
Soap bubbles, floating freely in the air, are spheres. Why? This question is tackled by first considering two-dimensional geometric shapes. When we compare a variety of two-dimensional geometric shapes, all having the same perimeter, a **circle** is found to encompass the greatest area. In other words a round rug which measures 8 feet around its edge, will cover more floor than a square rug which is 2 feet on each side, making it also 8 feet around its edge.



This amazing truth transfers from two-dimensional shapes to three-dimensional shapes. A **sphere** holds more inside of it than any other shape made from a given amount of material. The bubble takes on a spherical shape for two reasons. First, the molecules in the bubble film pull together, producing the most economical surface area possible. Also, the air molecules trapped inside the film move rapidly and randomly. They push on the film, making the largest container possible. A sphere allows for more room inside for the least amount of material outside. Therefore, the container that results *must* be a sphere.

Raindrops also assume spherical shapes. Water drops, drawn as illustrations, are usually shown in a classic "teardrop" shape. That is the shape of water just as it pulls away from a water faucet or eyedropper. However, as the drop begins to fall freely, it takes on the shape of a perfect sphere. Similarly, as water vapor in the air forms rain, the molecules are drawn tightly together by cohesion. The rain drop assumes the most economical shape possible – a perfect sphere.

TITLE: # Great Balls of Water



KEY QUESTION AND OVERVIEW: "What Shape Is A Rain Drop?"

Using a line of a given length, a circle will contain the largest area of any geometric shape the line can make. Similarly, a sphere will have more space inside it than any other three-dimensional shape made from a fixed amount of building material. Using graph paper, measured lengths of pipe cleaner or string, and adjustable wire bubble wands, students explore these geometric facts. They then use this knowledge to explain the constant spherical nature of bubbles and raindrops.

OBJECTIVES:

Students will demonstrate the relationship between area and geometric shape through the use of a fixed-length of pipe cleaner or string and graph paper.

Students will observe and describe the consistent spherical shape of bubbles.

Students will identify a sphere as the shape taken by various natural objects, including rain drops.

MATERIALS:

Per student team of 2 - 4:

Part I	length of pipe cleaner or substitute (25 cm or longer)		
	activity sheet	ruler	plate
Part II	9 oz cup of soap bubble solution		paper towels

MANAGEMENT SUGGESTIONS:

A recipe for a bubble solution, recommended by the Exploratorium in San Francisco, is ⅔ cup of Dawn dishwashing liquid in a gallon of water. One tablespoon of glycerin (available at any drug store) can be added for increased bubble strength. The bubble solution should be aged for about a week for best results.

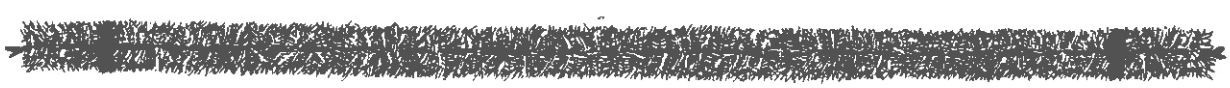
It is important that students view all the activities as science investigations. Time should be spent explaining "bubble rules" for Part II: 1) No bubble popping 2) No blowing bubbles at other students 3) No intentional, unnecessary messes.

The graph paper on the activity guide is constructed of 1 cm grids.

ACTIVITY

1. Distribute materials for Part I. Each team receives an activity sheet, a ruler, and a length of pipe cleaner (string, or easily bent wire, may be substituted). The objectives of the activity are not shared with the students at this time. The goal is to have the students discover independently that a circle is the most economical geometric shape.

2. Explain the general flow to the activity. Teams measure a length of pipe cleaner and secure the ends together. They carefully bend the pipe cleaner into three different shapes (square, triangle, and circle). The triangle and rectangle will have straight sides and sharp corners. The circle will be as smooth and round as possible. Teams will place the shapes on graph paper and accurately record the areas of each.



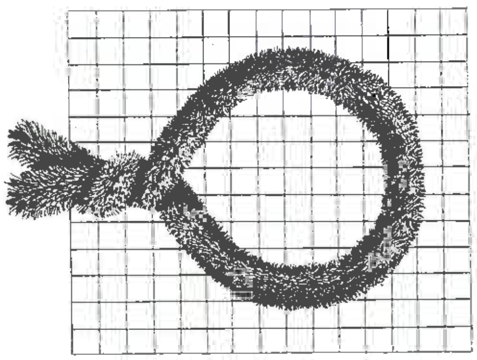
3. Measure the pipe cleaner. Each team measures a 20 cm length in the middle of the pipe cleaner. A mark is made at each end of the measured length. The two marks are carefully brought into contact and the pipe cleaner is twisted together where the marks meet. This results in a loop, with two ends sticking out like a handle.

4. Make a square. The pipe cleaner loop is carefully bent into a square (or other rectangle). The sides of the square are straightened and the corners are sharply bent into right angles.

5. Directly measure the area of the square. The pipe cleaner square is placed on the graph paper section of the data sheet. The square's edges are aligned with the graph paper. The sections of graph paper within the boundaries of the square are then carefully counted. (A rule might be that any ½ section or larger within the outline of the square is counted as a section.) The number of graph sections is recorded. The length and width of the square are also recorded on the data sheet.

6. Mathematically find the area of the square. Students use the rectangle area formula (length X width) to calculate the area of the square, which they record.

7. Repeat steps 4 - 6, making a triangle. At this point, the activity can remain teacher directed, or can be more student activated, depending on the class. Physically counting the grid sections within the triangle will be more difficult than for the square. The mathematical method for finding area of a triangle is explained to the students. It is found by multiplying ½ the base length times the height (½ bh).



8. Repeat steps 4 - 6 making a circle. Again this may, or may not, be teacher directed. Counting the grid sections will be difficult for the circle. There will be many partial sections within the circle confines. Students should be encouraged to be as accurate as possible in their tally. The formula for mathematically finding the area of a circle is the radius (½ the diameter), times the radius, times pi (3.14). Students need to measure carefully across the widest possible span of the circle to ascertain the diameter. They will then, of course, use only ½ of this diameter in the calculation.

9. Discuss the results. The line that made each shape was the same, but the area inside each shape varied. It is found that a circle encompasses a larger area than either of the other two shapes. This would be true no matter what other shapes were compared to the circle. A circle has a larger area than any other geometric shape with the same length perimeter.

10. Pass out materials for Part II. The teams are given a cup of soap bubble solution, a plate to set it on, and paper toweling. They use these and the pipe cleaner to make bubble wands.

11. Discuss and begin Part II. Have each student bend ½ of the pipe cleaner into a circle. The other end acts as a handle. They use these materials to blow bubbles, which will be spherical in shape. Allow a few minutes for bubble blowing.

12. Explain soap's role in bubbles. Soap causes water to lose some of its cohesion so that it will "stretch out". Soap molecule layers also "sandwich" a water molecule layer between them so that the water doesn't evaporate, allowing the bubble to resist popping. When the water drains out from between the polar soap molecule layers, they repel each other, and the bubble pops (see background for a more in-depth explanation).

13. Change wand shape. The students alter the shape of the opening of the bubble wand opening and blow bubbles using these new shapes. The students are encouraged to try square and triangular shaped openings.

14. Discuss the results of bubble blowing. *All* bubbles, freely floating in the air, become spheres. There are no bubble cubes, bubble pyramids, or bubbles of nebulous shape. All are perfect spheres. Again, a circle has a larger internal area than any other geometric shape with the same length perimeter. The same result happens in three dimensions. A sphere holds more inside of it than any other three-dimensional geometric shape with the same outside area. The bubble juice pulls together to make a tight film. The air inside the bubble pushes on the film to achieve the largest space inside. A sphere contains the largest amount of space for its outside surface.

15. Apply spheres to raindrops. Contrary to pictures often drawn by artists, raindrops are also perfect spheres as they fall through the air. The same is true of teardrops, dog drool drops, and leaky faucet drops. When a droplet of water is pulling away from an object such as a faucet, a "tail" of water is stretched out from the object. However, as the liquid drop becomes free within the air, it takes on the most economical three-dimensional shape possible – a sphere.

REVIEW AND REFLECTION:

1. Why can't bubbles be blown using only water? *Water can't stretch out to make a bubble; its cohesion is too strong.*

2. If a square piece of cloth and a round piece of cloth each cover the same amount of desk, which cloth has a larger perimeter? *If they both had the same perimeter, the circle would have a larger area. Therefore, since they have the same area, the square must have the larger perimeter.*

3. If a certain amount of wood and other building materials was used to make the largest shelter possible, what would be the shelter's shape? *The structure would be spherical. However, a flat floor is desirable, so it would be a half sphere.*

4. Illustrate, on the board or paper, the formation of a drop of water as it leaves an eyedropper and then hits the ground. *See illustration in the reading.*

5. Why does a sleeping dog curl up into a tight ball when it's really cold outside? *With its body in more of a sphere shape, less outside surface is exposed to the cold.*

EXTENSIONS:

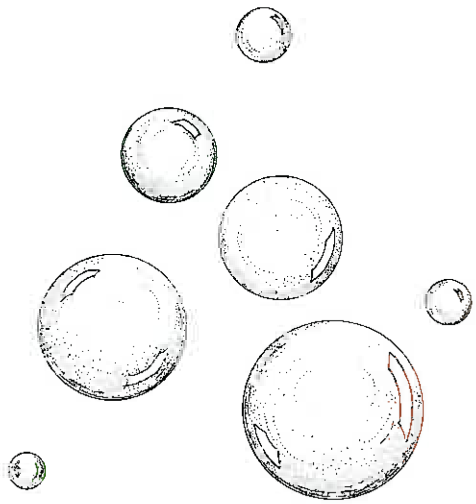
1. Students might research R. Buckminster Fuller, the pioneer of the geodesic dome.

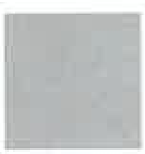
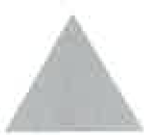
2. Put several separate drops of colored salad oil on the surface of water in a glass or bowl. The drops will all pull together to form a round drop. Very slowly, pour rubbing alcohol into the glass until it covers the salad oil drops. The drops become spheres.

3. Pour warm water into a glass. Pour a layer of warm cooking oil on top of the water. Carefully place 3 drops of food coloring into the layered mixture. The food coloring will sink through the cooking oil and gather at the surface of the water. It eventually breaks through the oil/water interface and spreads out into the water.

4. Research the variety of organisms in nature that have taken a spherical shape. Examples found will include some cacti, sea urchins, *Volvox* and other protozoans.

GREAT BALLS OF WATER

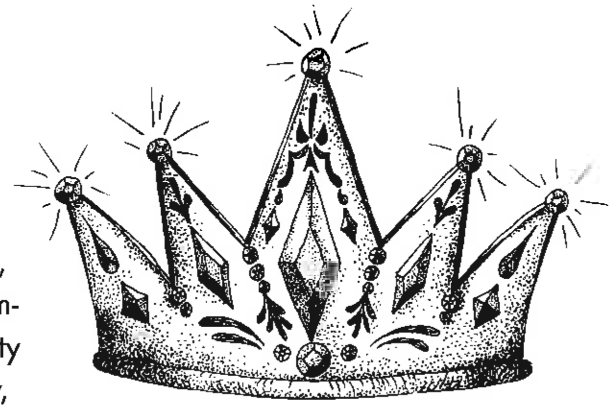


SHAPE	PERIMETER LENGTH	DIMENSIONS	FORMULA	COMPUTATION	MATH RESULT	NUMBER OF GRAPH SECTIONS
	20 cm	L ______ W ______	L x W= AREA______	___x___=___	________	________
	20 cm	BASE ______ HEIGHT______	½bh ____	½___x___=___	________	________
	20 cm	________ DIAMETER ________ RADIUS	$\pi r^2 =$ ____	3.14 x___x___ = ______	________	________

Order the shapes by most to least area.

MOST ______ ______ ______ LEAST

The Matter With Density



Matter is defined as anything that has mass (heaviness) and occupies volume (takes up space). Matter can be described and categorized by a variety of physical properties, including color, odor, and hardness. Other physical properties are the temperature at which an item boils or freezes, the ability to conduct heat, the capability to conduct electricity, and the density of the item.

Density deals with how "much" of something is in a given space. Matter is defined as anything that has mass and occupies volume; density measures the compactness of matter by dividing an item's mass by its volume (Density = m/V).

To say that something is dense is to say that it is closely packed, such as a "dense stand of trees". The word density deals with how closely the component parts of a volume are compacted together.

Density is expressed in grams per cubic centimeter (g/cm^3). The **density of water** is used as a standard; water has a density of 1 g/cm^3 at 4° C. Some other densities are listed in g/cm^3 below:

Gases	Liquids	Solids
Helium 0.00018	Gasoline 0.66	Pine Wood 0.50
Oxygen 0.00143	Mercury 13.6	Aluminum 2.70
Carbon dioxide 0.00198		Gold 19.3

The density of a substance may be used to help identify it or verify its purity. A story about King Hieron III and the scientist **Archimedes** will illustrate. The king had given a jeweler some gold to make a crown. When the crown arrived, the king suspected that silver, a less valuable metal, had been substituted for some of the gold. The king asked Archimedes to investigate. Archimedes decided to measure the crown to see if its density matched that of pure gold. Since the crown was an irregular shape, Archimedes devised a "new" way to measure its volume, and in a related fashion, its density. He submerged the crown into a full container of water, caught the water that spilled out of the container, and then measured the volume of water that overflowed. This displaced volume of water equaled the crown's volume and was compared to the mass of the crown. Archimedes discovered that the crown had a lesser density than pure gold, and had, therefore, been tampered with.

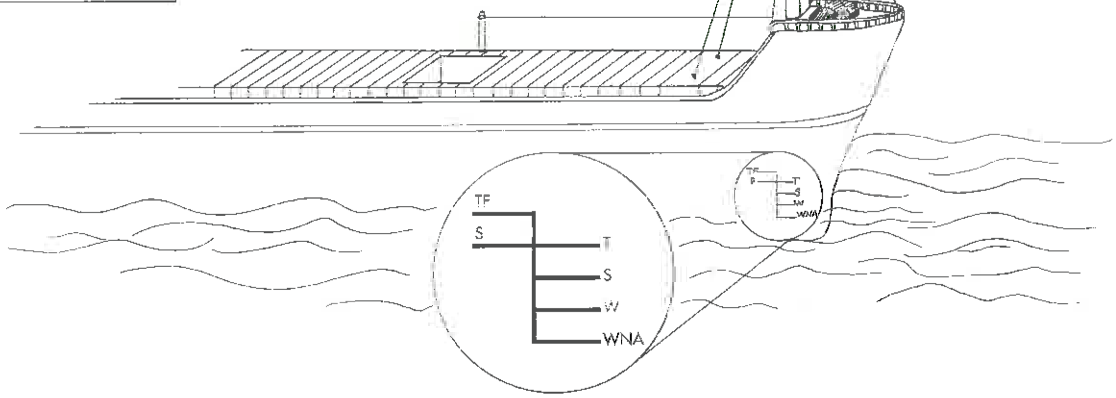
Modern tests use density to measure product purity. Antifreeze concentration in automobile cooling systems and acid concentration in car batteries are monitored by making density calculations, using a hydrometer.

The density of water increases when salt is added. Therefore, ocean water is more dense than river water. As river and ocean water meet, the intermediate density mixture is termed **brackish water**. The mixing zone between the Sacramento River and the Pacific Ocean generally occurs between Antioch and the Suisun Bay. Local aquatic biologists term this zone the "entrapment zone" for the fact that it is the area richest in aquatic life and therefore best for collecting samples of aquatic animals.

Water's density also changes with temperature. Warm water is more dense than cold water. Cargo ships crews must take into account the variety of densities of salt water, fresh water, warm water, and cool water. To facilitate safe loading, there is a series of lines painted on the outside of the ship's hull. These lines show the various safe loading levels for safe travel in the various types of water.

Environmental problems are affected by density differences. When an oil tanker is wrecked at sea much of the oil, being less dense than the water, floats on top of the water. The result is a devastating oil "slick".

TF	tropical fresh water
F	fresh water
T	tropics
S	summer
W	winter
WNA	winter North Atlantic



TITLE: **Density Detectives**

KEY QUESTION AND OVERVIEW:
"Can the density of water be changed?"

The lesson consists of an experimental series of activities using six colored solutions of salt water having differing densities. Students, in teams of three, are given random sets containing three of the six liquids. They layer these in a straw until they have them correctly arranged with the most dense on the bottom and the least dense on top. Intrateam collaboration occurs, with the resulting data then shared at the class level. The final class goal is to order the entire set of six liquids on a continuum from least dense to most dense.

OBJECTIVES:

Students will define density and use the formula for density.

Students will relate density to the act of floating or sinking in water.

Students will analyze personally gathered data and data gathered by the class to evaluate the relative densities of six liquids.

MATERIALS:

Per laboratory exercise:

For demonstration:

3 9 oz clear plastic cups
water
quart of motor oil
balance and masses

For activity: food coloring – green, yellow, red, orange, blue
non-iodized salt

For the recording of classroom data:

overhead projector and colored pens, chalkboard and colored chalk, or large sheet of paper and colored markers or substitute

Per team:

paper plate
2 - 3 drinking straws
crayons or colored pencils
9 oz empty plastic cup for waste water disposal
three 9 oz cups of differently colored water (see management section)
work sheet
paper towel

MANAGEMENT SUGGESTIONS:

As advance preparation, the instructor makes 2½ quarts each of six different colors of water. To achieve the first five colors, add enough food coloring to five different containers of water (red, orange, yellow, green, and blue) to make each color fairly dark. Test the colors by layering them in a straw before the lesson to assure good contrast between the colors. To make purple, add red and blue food colorings to the sixth container of water. To make each solution the correct density, add the following grams of non-iodized salt to each color:

Green – 750g, Yellow – 600g, Red – 450g, Purple – 300g, Orange – 150g, Blue – 0g. Prepare the colored water cups for each team prior to the activity. Each cup will have about 2½" of liquid in it. To assure the correct number of cups of each color, prepare 8 green, 9 yellow, 8 red, 7 purple, 8 orange, and 8 blue cups.

Practice the technique of drawing water into the straw and then sealing the straw with a finger or thumb. Dip the straw ½" into a liquid. Seal the upper end of the straw with a finger or thumb. Remove the straw from the liquid while keeping the finger in place. Lower the sealed straw 1" into the second liquid, release the thumb from the opening, reseal the opening, and again withdraw the straw from the liquid. Become familiar with this easy technique before the activity so it can be explained to students.

ACTIVITY

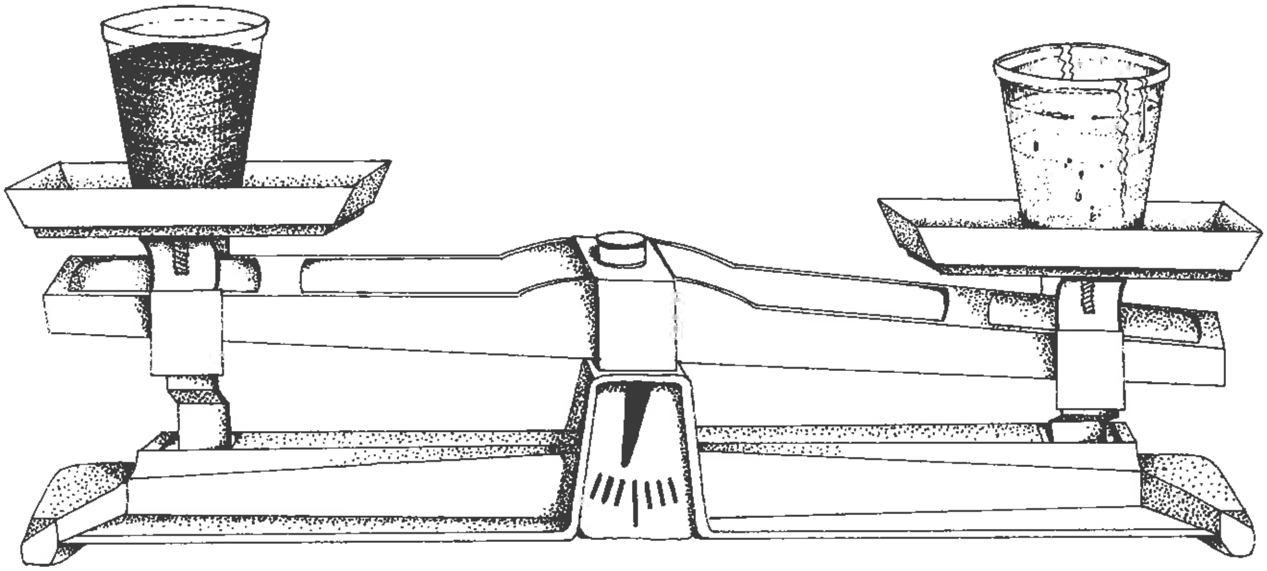
1. Review matter. Matter is anything and everything that takes up even a little space (has volume) and has even the slightest amount of heaviness (has mass).

2. Explain density. All matter has mass and volume.These two characteristics can be related to each other and used to describe one of matter's physical characteristics – density. Density is "how much of something is in a given space". An easy example of density change involves a loaf of bread. If a one pound loaf of bread is squeezed into a ball half its original size, it still weighs one pound. However, it is only half as large. Therefore, its density is greater; the same amount of "stuff" (bread) is in a smaller volume. Another example can be given using trees on an acre of land. If a woman buys an acre of land that has two hundred trees growing on it and she plants 100 more trees, the forest on that acre will be more dense. It is the same size piece of land, but there are more trees on it.

Density is found by dividing an item's mass by its volume ($D=m/V$) and recorded in grams per cubic centimeter (g/cm^3).

3. Relate water as a standard of density. Every cubic centimeter of water weighs 1 gram. The density of water is 1 gram per cubic centimeter. This 1:1 ratio, and the importance of water in floating vs sinking situations, contributes to water as the standard of density measurement. (An incidental note: a milliliter [ml] is the same as a cubic centimeter.)

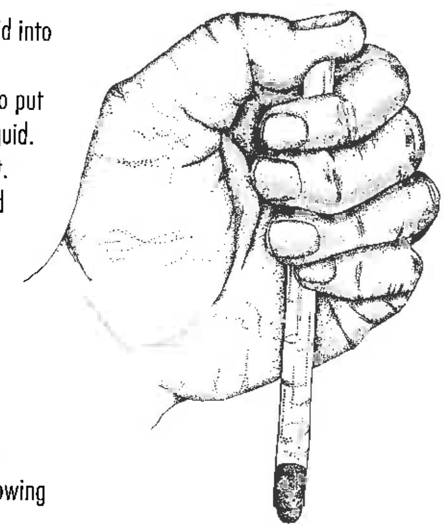
4. Demonstrate the comparative densities of water and motor oil. The students are asked which is heavier (more dense), a quart of water or a quart of oil? To aid the students in their decision, the instructor pours an *equal amount* of each liquid into separate cups. The oil, being more thick, will appear relatively more heavy. Once the students have responded as to which liquid they believe is more heavy, the two cups are placed on separate sides of the balance for mass comparison. Surprisingly, the water will be the heavier (more dense). Some of the oil and water can then be poured into the third cup to illustrate that the least dense liquid will rise to the top. The fact that oil is less dense than water can then be related to oil spills.



5. Explain the activity. The oil and water demonstration illustrated that not all liquids have the same density. The following student activity is a scientific investigation to rank several differently colored liquids according to their relative densities. Each team will compare the densities of three of the six liquids. The information from each team will then be shared with the entire class. Using the combined information from all the groups, each team will order the entire set of six liquids by increasing density.

The density of the liquids will be compared by putting the liquids together into a straw. If they are ordered correctly in the straw, with the most dense on the bottom and the least dense on top, the liquids will remain separated in the straw. If they are incorrectly placed in the straw by density, they will mix together.

6. Explain the method of filling the straws. To put a liquid into the straw, lower the straw ½" into the liquid. Seal the upper end of the straw with a finger or thumb. Carefully remove the straw from the liquid, while continuing to seal the straw's end. To put a second liquid into the straw with the first, lower the still-sealed straw 1" into the second liquid. Release the seal on the straw end; the second liquid will be drawn into the straw with the first. Reseal the straw and withdraw it from the second liquid. Both liquids will now be in the sealed straw. If the least dense liquid was put into the straw first, it will have been pushed up by the entry of the second liquid. There will be two separately colored layers. If the most dense liquid was placed in the straw first, the two liquids will have mixed together and be an intermediate color. To put the third liquid in the straw, lower the straw with two correctly placed colors 1½" into the third liquid, release the seal and reseal. (The least dense liquid must be put in the straw first).



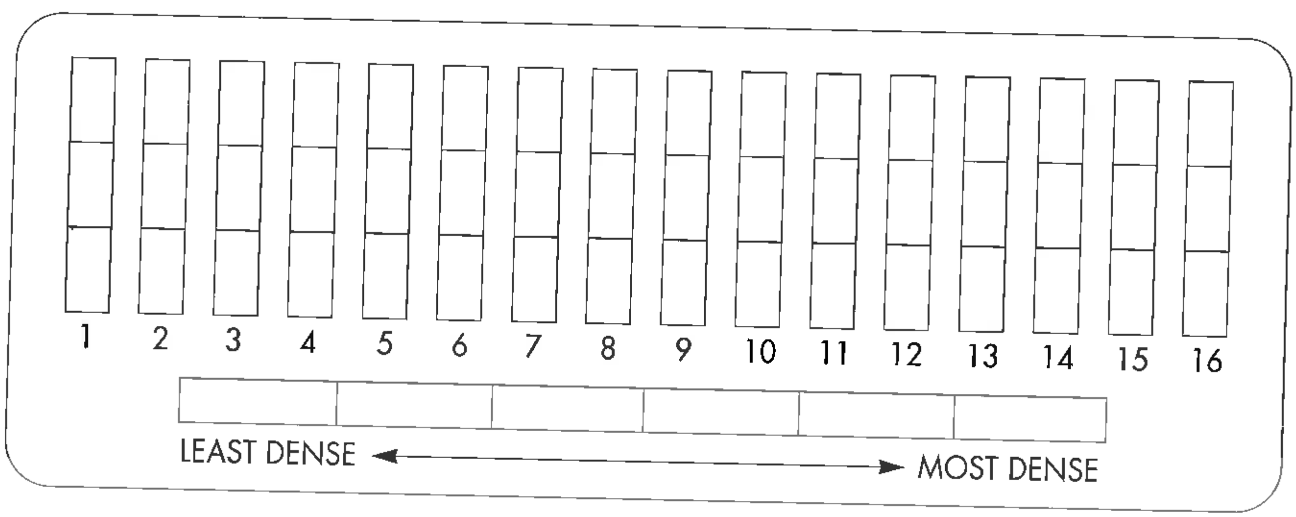
7. Distribute the materials. Student teams can be identified by number. To give three colors to each team and also evenly distribute the colors, give each team the following color combinations:

Team	Color	Team	Color	Team	Color	Team	Color	Team	Color
1	GOB	5	ORB	8	YBR	11	OYB	14	YOR
2	YBP	6	BPG	9	GPY	12	BRG	15	RBP
3	ROG	7	GOY	10	POG	13	GPY	16	GYR
4	POY								

8. Begin the activity. The students are reminded about the method of getting the three liquids into the straw. The students are also reminded about putting the color they think will be least dense into the straw first. As a final note before beginning, the students are directed to place used samples into the waste cup. They are also reminded to keep the original solutions unpolluted.

9. Retrieve materials. As soon as each team discovers the order of their liquids according to relative density, they should return the materials to the central materials station. Otherwise, unproductive play will result.

10. Sharing data with the class. A member of each team comes to the board or overhead and records, in color, the order of the liquids according to relative densities. They are reminded that the color representing the most dense liquid is recorded on the bottom.



11. Interpreting the class data to order all six liquids by density. Using the combined data gathered by all the teams, each individual team will record its hypothesis regarding the most dense liquid, the least dense liquid, and the order of those liquids in between. (most - green, yellow, red, purple, orange, blue - least)

The students are told that salt has been added to all the liquid solutions except blue. They should also note that the more salt that was added, the more dense that liquid became, with the green solution having had 750 grams of salt added.

REVIEW AND REFLECTION:

1. What does density measure? *It measures how much material [mass] is in a certain sized container [or volume].*

2. A 10 cm^3 block of copper weighs 99 grams. What is the density of copper? *D=m/V   D = 99g / 10cm^3 D = 9.9 g/cm^3*
Actually copper's density is 9.93 g/cm^3.

3. Which is more dense, sea water or fresh water? *The activity should have proven that the more salty water is, the more dense it is. Sea water is more dense than fresh water, with a density of 1.03.*

4. The following densities are given in gm/cm^3: iron - 7.9, gold - 19.3, mercury - 13.6. A heavy iron bar and a gold ring were both placed in a large bowl of mercury. What happened to the bar and the ring? *Mercury is a liquid, so the bar floated and the ring sank.*

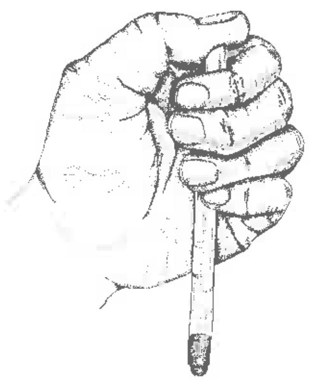
5. A clear solid block of matter has a density of .917. Will it float or sink when placed in water? *It will float. Water has a density of 1.0. Therefore the clear block is less dense. The clear block is ice, which does have a density of .917.*

EXTENSIONS:

1. Gather a balance, some masses, 25 pennies minted before 1982, and 25 pennies minted after 1982. Have the students weigh the pre-'82 and post-'82 pennies separately and record the results. They will notice a discrepant result. The pennies minted before 1982 are heavier (have more mass) than those minted after 1982. All the pennies have the same volume, it's the density that is different. In 1982, the government stopped making pennies out of copper, which has a density of 9.93 g/cm^3. Since then, pennies are made primarily of zinc, with just a thin copper coating. Zinc has a density of 7.14 g/cm^3.

2. Ask students if they hypothesize that a can of diet Pepsi and a can of regular Pepsi have the same volume? Place each in a container of water. The diet soda will float.

3. Test each colored solution to find which one or ones will cause a golf ball or hard boiled egg to float. Try different brands of golf balls for some interesting results.

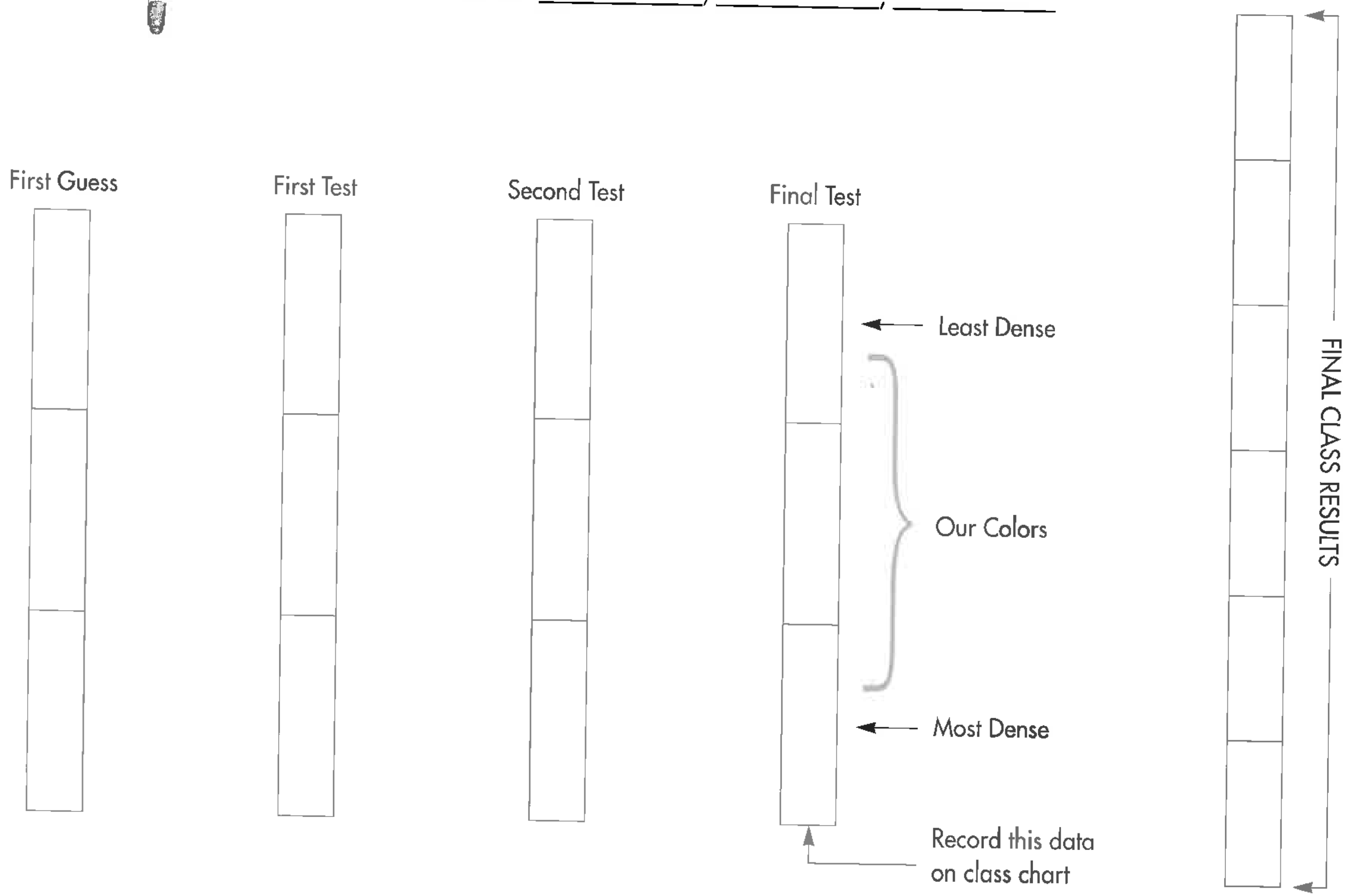


DENSITY DETECTIVES

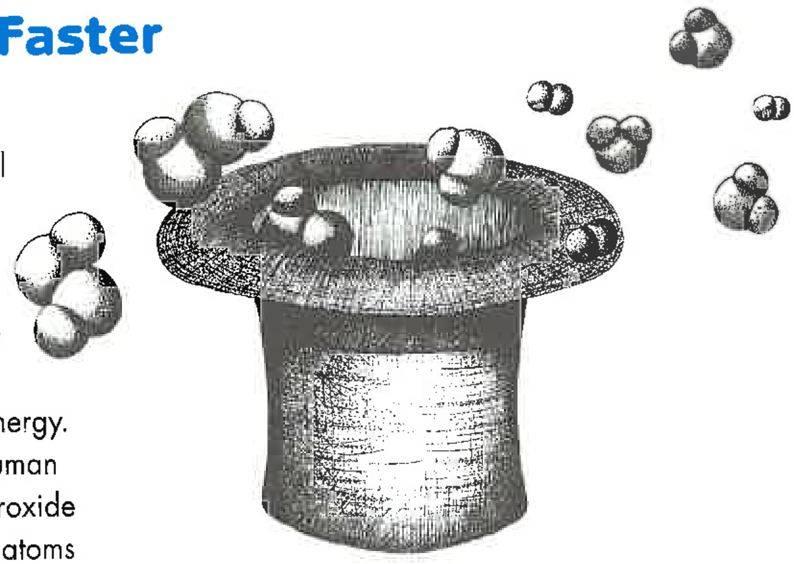
Names ______________ ______________

TEAM # ______

OUR TEAM'S COLORS: __________, __________, __________



A Catalyst Makes Water Faster



Water is involved in many chemical reactions within the human body. In a **chemical reaction**, matter changes from one substance with certain properties to one or more other substances with new properties. Chemical reactions can also release energy. An example of a reaction within the human body is shown when two hydrogen peroxide molecules (H_2O_2) come apart and the atoms rearrange into one water molecule (H_2O) and two oxygen (O_2) molecules.

The **Law of the Conservation of Matter** states that atoms are neither created nor destroyed in a chemical reaction, they are simply rearranged. This means that there are the same kinds and number of atoms in the molecules that react in a reaction as there are in the molecules that are produced.

There are three ways to make a reaction occur faster or sooner. One way is to *increase the concentration of molecules*. The more molecules, the greater the chance they will react with each other. Another way is to *heat the molecules* so they collide with greater speed and force. The third way is to *add a catalyst.*

A **catalyst** is a substance that speeds up a reaction, but is not consumed in the reaction. It generally works because it provides an alternative reaction pathway that requires less energy. When a catalyst is added, the reaction then has a "choice" of pathways to take to completion. The reaction takes the easier pathway, coming to completion sooner.

Enzymes are catalysts that act within living things. Enzymes are protein molecules and are usually very specific about which reactions they affect. Examples of enzymes are: **peroxidase**, typically found in plants; and **catalase**, which is found in the blood and liver of animals. Both enzymes facilitate the rapid breakdown of hydrogen peroxide molecules into water molecules and oxygen molecules.

Hydrogen peroxide (H_2O_2) is a toxic by-product produced in various living organisms, including humans. Since peroxide is toxic, it must be broken down by catalase into safe and usable substances (water and oxygen).

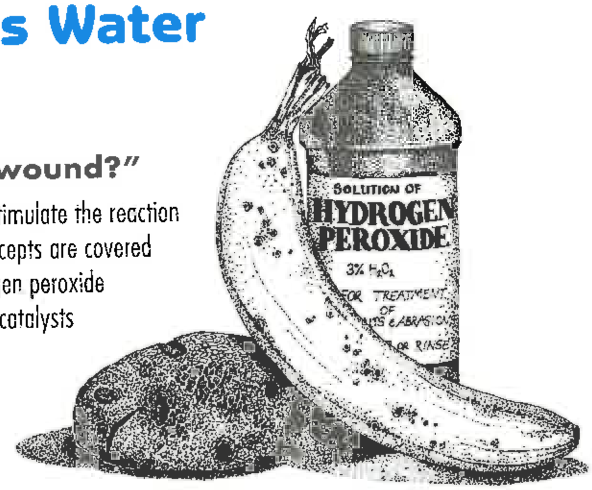
One of the important components of the catalase molecule is an iron atom (Fe). Iron will break down peroxide by itself. However, whereas one molecule of catalase will decompose 83,000 molecules of H_2O_2 in one second, it would take the iron atom, working alone, 300 years to do the same thing.

When hydrogen peroxide is put on a wound, the H_2O_2 comes into contact with catalase. This contact initiates a rapid breakdown of the peroxide into water and oxygen. The oxygen molecules combine to form bubbles, which rise to the top of the liquid and burst. This bubbling action mechanically cleanses the wound of germs and dirt.

Additionally, as the hydrogen peroxide molecule comes apart in the reaction, free radicals are formed. A **free radical** is an atom or group of atoms with a single, unpaired electron. The importance of having an unpaired electron is that free radicals "attack" germs for their electrons. As this happens, germs are destroyed.

One drawback is that the hydrogen atoms don't "care" where they go for electrons. Consequently, they also attack healthy body cells and kill them. However, this loss of body cells is far outweighed by the cleansing of the wound and killing of the associated germs.

TITLE: # Presto! – Peroxide Becomes Water



KEY QUESTION AND OVERVIEW:

"Why do we put hydrogen peroxide on a wound?"

Students use the catalyst present in carrots, potatoes, bananas, and liver to stimulate the reaction that changes hydrogen peroxide into water and oxygen. Several scientific concepts are covered within the span of this activity. Primarily, a chemical reaction involving hydrogen peroxide becoming water and oxygen is shown and modeled, Secondarily, the role of catalysts in facilitating chemical reactions is explored. Finally, this is all connected to enzymes as biological catalysts and the reasoning behind the medical use of hydrogen peroxide.

OBJECTIVES:

Students will model and describe the decomposition of hydrogen peroxide into water and oxygen.

Students will compare the effect on the hydrogen peroxide reaction rate of the catalysts from a variety of plant materials.

Students will relate the breakdown of hydrogen peroxide to the cleansing and treatment of wounds.

MATERIALS:

Per class session:

5 pint bottles of 2% hydrogen peroxide (available at drug stores)
1 potato 1 banana 1 carrot
about 2 oz chopped or blended liver (see management suggestions)

Per team of 2 – 4 students

1 data sheet for each student
1 coated paper plate or plastic plate
5 small clear plastic cups (9 oz or smaller)
atom models produced by the students during Lesson 1

MANAGEMENT SUGGESTIONS:

The atom and molecule models from Lesson 1 will now be needed. They should have been saved by the students or teacher for use in this lesson.

If *thin* paper plates are used, it is advisable to use a double thickness. This helps keep any spilled liquid from soaking through and also adds more rigidity at clean-up time.

The liver is best prepared by purchasing beef liver from the local supermarket, placing it into a blender with some water, and letting the blender run for a few minutes, or until the result is the consistency of very soft pudding.

The amount of hydrogen peroxide listed in the materials section assumes the lesson will be performed by teams consisting of two students. If teams of four students are organized, only half as much hydrogen peroxide will be necessary.

It is important to use clear cups, so that students can see the reaction easily.

Cut a portion of each vegetable into very small cubes, less than 1 cm on a side.

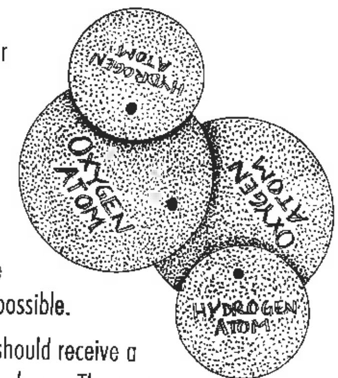
An interesting dimension is added if the names of the vegetables and liver are taken off the data sheet prior to distribution to the students. The students hypothesize about the identity of the materials as they use them, and record the names on the data sheet as they are verified.

ACTIVITY

1. Review atoms and molecules. All matter is composed of infinitesimally small particles called atoms. These atoms combine in predictable ways to form molecules and compounds. The atoms used in a previous lesson were hydrogen and oxygen. Models of these atoms were used to construct molecule models of hydrogen, oxygen, water, and hydrogen peroxide.

2. Introduce chemical reaction. As molecules collide with each other, their atoms may break apart and recombine to form different molecules with different properties. The term for this molecular recombination is chemical reaction. During the reaction, energy is often released.

3. Students model the H_2O_2 reaction. The students locate the paper models of the hydrogen peroxide molecule they made in the first lesson. Students are then organized into teams of two. The teams are directed to take the peroxide molecule models apart, combine the atoms, and construct as many of the other molecules they have already worked with as possible. (Some students may make two H_2 molecules and two O_2 molecules. However, the intended result is that they make two H_2O molecules and one O_2 molecule.)



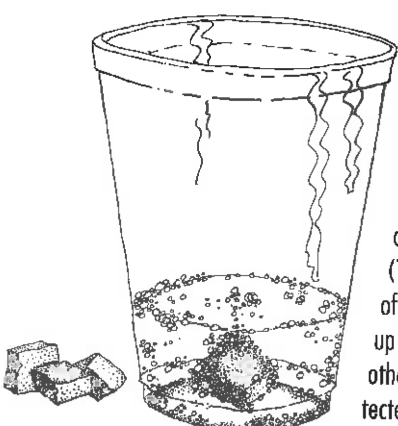
4. Explain the hydrogen peroxide reaction. Hydrogen peroxide is fairly unstable as a molecule. It will undergo a reaction to produce water and oxygen as soon as possible.

5. Distribute materials for the activity. Each team of two students should receive a data sheet for each student, a plate, and 3 cups with approximately 2 oz of hydrogen peroxide in each cup. The cups should be placed on the plate to contain possible spills. Each team also receives a cube each of banana, potato, and carrot.

6. Explain the flow of the activity. During this activity, pieces of several different fruits and vegetables will be placed into cups of hydrogen peroxide. Observations will be made regarding any activity that takes place within each cup.

7. Distribute vegetable pieces and begin Part I of the activity. Each team receives one piece of each vegetable. They refer to the data sheet to complete the first part of the activity, which consists of placing a piece of each vegetable into a cup of peroxide, observing the reaction that takes place, and recording the results.

8. Discuss the reactions. It must be understood that a reaction actually began as soon as hydrogen peroxide was poured into each cup. But, the reaction takes place at such a slow rate that it's not readily noticeable. However, by placing a piece of vegetable in each cup, the reaction rate was increased. Recorded observations would include the formation of bubbles, different sized bubbles produced by different vegetables, differing rates of bubble formation, movement of the vegetable pieces, and the formation of foam on the top of the peroxide.



9. Student hypotheses and discussion of catalysts. As a class discussion, students should hypothesize about why the vegetable pieces caused the peroxide to react faster. (There must be "something special" in each vegetable that breaks up hydrogen peroxide. Also, there is more of this "something" in some vegetables than in others. This "special something" is a catalyst.) Heat speeds up the peroxide reaction by causing the molecules to move around more, and move faster, bumping into each other more frequently and violently. Sunlight also speeds up the reaction, which explains why peroxide is protected by packaging it in opaque brown bottles. Agents which initiate or speed up chemical reactions are called catalysts. Each of the vegetables used in the activity contains a catalyst called peroxidase which speeds up the changing of peroxide into water and oxygen.

10. Begin Part II of the activity. Each team removes the cups from activity Part I from the plate. Each team receives a cup containing about 2 oz of peroxide and a different cup containing a very *small* (size of a quarter) portion of blended liver. These two cups are placed on the plate. The teams are then instructed to pour the peroxide into the liver, observe any reaction, and record their observations on their data sheets.

11. Discuss the results. The liver produced a much more dramatic reaction with the peroxide than any of the vegetables. The human body produces hydrogen peroxide as a toxic waste product. The liver contains a catalyst called *catalase* that breaks down hydrogen peroxide. Catalase rids the body of hydrogen peroxide and produces water and oxygen molecules which the body can use. Catalase is carried throughout the body by the blood. Therefore, hydrogen peroxide rapidly decomposes whenever it comes into contact with liver or blood.

12. Make the connection to the medical use of hydrogen peroxide. When hydrogen peroxide is put on a wound, catalase in the blood causes the peroxide to rapidly change into water and oxygen. This produces a bubbling action which physically cleanses the wound. Additionally, as the peroxide breaks down, free radicals are formed. These free radicals need electrons and "attack" germs to get the electron. This "attack" destroys the germs. Unfortunately, healthy body cells are also attacked and killed. Fortunately, the end result is that the germs are destroyed and the body repairs itself, including replacing the body cells lost to the peroxide.

REVIEW AND REFLECTION:

1. Describe, using words or chemical symbols, the decomposition of hydrogen peroxide. *H_2O_2 breaks down to make H_2O and O_2.*

2. Define and compare catalysts and enzymes. *A catalyst is a substance that initiates or speeds up a chemical reaction, but isn't used up in the reaction. An enzyme is a catalyst produced by a living organism.*

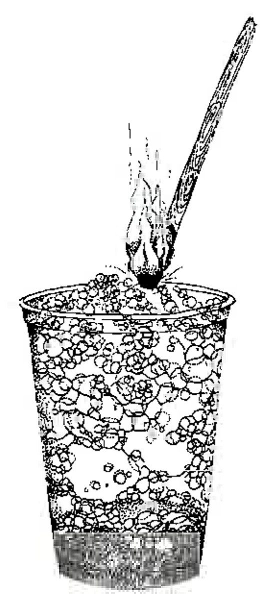
3. Describe the apparent strengths of enzymes in plants compared to enzymes in animals. *The experiment showed a much stronger enzyme in the liver than in any of the plant materials.*

4. Hypothesize about why peroxide is used by some people as a mouthwash and is an ingredient in some of the new toothpastes? *It attacks and kills germs in the mouth in the same way as with injuries to the body.*

5. A miner is trapped deep in a cave. Help is almost there, but she is running out of oxygen. All she has with her is: a knife, a broom, a barrel of hydrogen peroxide, 30 candles, some matches, a flashlight, her pet monkey, and a bag of potatoes. What can she possibly do to save her life? *Kill the monkey; he's competing for oxygen. Don't light any matches or candles; they will use oxygen. Peel some potatoes and drop them in the barrel of hydrogen peroxide to produce oxygen. Breathe slowly.*

EXTENSIONS:

1. Verbally model the concept of catalyst by talking about reactions between people. An example might be two people that are on the verge of getting into an argument. A third person comes along and bumps one of the two into the other. The reaction begins. However, that third person who did the bumping isn't a part of the argument. He or she just acted as a catalyst to initiate the reaction. That person can go off and start another reaction between two different people who are ready to argue. Additionally, the catalyst in this example (in fact, all catalysts) can't start a reaction that isn't already on the verge of happening. In response to the bumping, there could be just some polite apologies and acceptances. Catalysts can only initiate reactions that will eventually happen on their own anyway.



2. As a demonstration, put some liver in a cup of hydrogen peroxide. When the reaction is completed, lower a glowing wood splint into the mass of bubbles. In response to the oxygen content of the bubbles, the splint will burst into flame. It can be blown out to the glowing stage again and reignited by lowering it into the bubble mass. This is a determining test to prove the gas produced during the hydrogen peroxide break-down reaction is oxygen.

3. Amylase is an enzyme, produced in the mouth, which speeds up the breakdown of starch into sugar. Have students chew an unsalted soda cracker and hold it in their mouth for five minutes. As time goes by, the students will realize that the cracker taste changes from a starch taste to a sweet taste. This is due to the action of the amylase.

4. Have students research the use of rennet in the production of cheese. (Rennin is an enzyme found in the stomachs of calves. It acts to "curdle" milk and make it partly solid. Rennet is prepared from rennin and is used to commercially curdle milk. This partly solidified curdled milk can then be shaped into blocks. Additionally, bacteria act on the milk to turn it into ripe cheese.)

PRESTO!
Peroxide Becomes Water

Name ______________________________

Include the following in your recorded observations:

- ▲ Amount of bubbles produced
- ▲ Size of bubbles produced
- ▲ Speed of bubble formation
- ▲ Movement of vegetable pieces
- ▲ Formation of foam

PART I – Record observations here

CARROT	BANANA	POTATO

PART II

LIVER

RANK THE 4 ITEMS

1. Strongest Catalyst = ______________________________
2. ______________________________
3. ______________________________
4. Weakest Catalyst = ______________________________

Summarize the relationship between a potato (or carrot, banana, or liver), H_2O_2, and catalysts.

____

____

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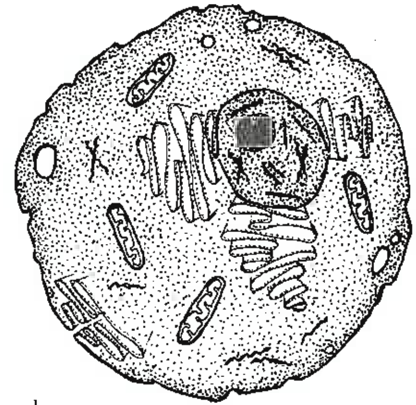
Water Movement Within You

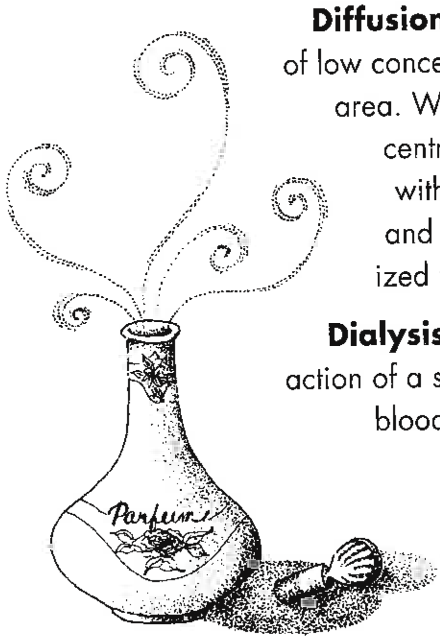


All organisms are composed of basic living units called **cells**. As a living entity, each cell grows, reproduces, repairs itself, and performs other life functions. Included in the life functions of each cell are: taking in nutrients, getting rid of wastes, and maintaining an adequate water balance.

Each cell is surrounded by a **plasma membrane**. This membrane separates the living contents, or **protoplasm**, of the cell from the "outside world". The plasma membrane is **semi-permeable**, meaning that it allows some, but not all, substances to pass through.

The semi-permeable nature of the cell's plasma membrane allows it to act as a filter to help regulate which molecules are able to pass into, or out of, the cell. Water, a relatively small molecule, regularly passes through the plasma membrane.

One of the forces that causes molecules to pass into, and out of, cells is the molecules' constant motion. They hit each other, bounce off, hit again, etc. This constant motion causes molecules to spread out from each other, especially if the molecules are part of a liquid or gas.



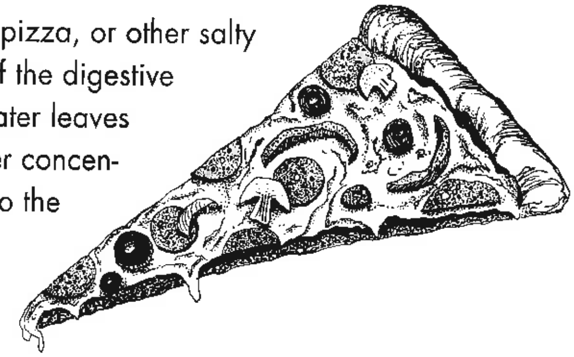
Diffusion is the movement of molecules from an area of high concentration to an area of low concentration. Eventually the molecules are evenly distributed throughout the entire area. When a perfume bottle is opened, the perfume molecules diffuse from their concentrated state in the bottle to "fill" the surrounding air with fragrance. Diffusion within the body causes CO_2 molecules to pass out of cells into blood for disposal and causes O_2 molecules to pass from blood into the cells for use. Two specialized forms of diffusion are dialysis and osmosis.

Dialysis is the separation of small molecules from large molecules by the filtering action of a semi-permeable membrane. In dialysis done by artificial kidney machines, blood is passed across a semi-permeable membrane outside the body. Small waste products pass from the blood through this membrane into a solution around the membrane, cleansing the blood.

While dialysis is the diffusion of molecules that are in a watery medium, osmosis is the diffusion of water only. **Osmosis** is the diffusion of water across a semi-permeable membrane from an area of high water concentration to an area of low water concentration (from an area with a lot of water to an area with less water).

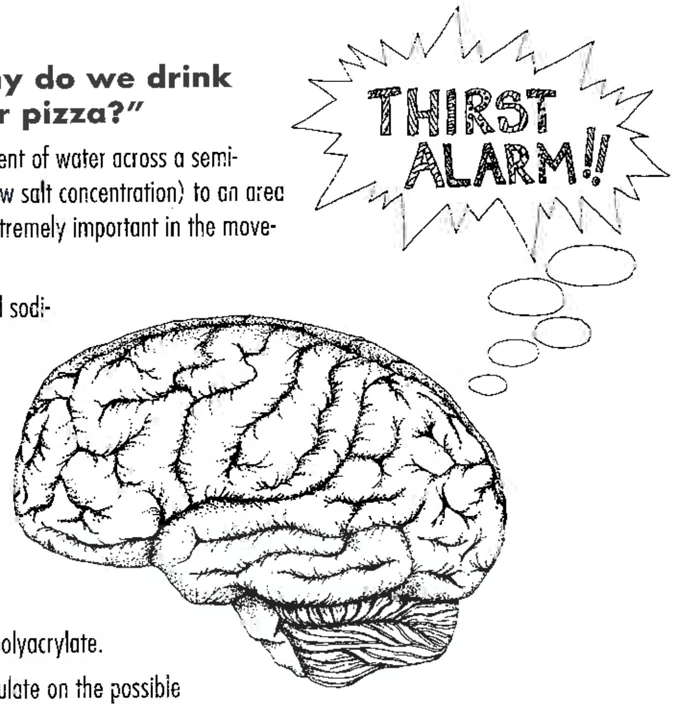
Water concentration is affected when substances dissolve in water. Each molecule of a dissolved substance takes away an available space for the water to occupy. Therefore, the more "stuff" that dissolves in a container of water, the less water can be in that same container. As water moves by osmosis toward an area of relatively lower water concentration, it is also moving toward an area of higher "dissolved stuff" concentration.

The effects of osmosis are experienced every time pizza, or other salty food is eaten. This food raises the salt concentration of the digestive tract, conversely lowering the water concentration. Water leaves body cells by osmosis in response to the lowered water concentration in the digestive tract. The cells send messages to the brain that they need water. The brain responds by putting out a general "thirst alarm". The response to this alarm is an overwhelming desire to drink water.



Sodium polyacrylate and potassium polyacrylate are chemicals used commercially to "soak up" water. They are semi-permeable grains with a high salt content, inducing water to travel by osmosis into each grain. The "salt polyacrylates" absorb 800 times their weight in pure water or 300 times their weight in tap water, which has some salts in it. Sodium polyacrylate is a major component of disposable diapers, keeping baby "wetness" far from baby's delicate skin. Potassium polyacrylate is often mixed with soil, to capture irrigation water and hold it for plants' utilization.

TITLE: **The Wizard of Osmosis**



KEY QUESTION AND OVERVIEW: "Why do we drink a lot of water after eating peanuts or pizza?"

The following lesson demonstrates osmosis. Osmosis is the movement of water across a semi-permeable membrane from an area of high water concentration (low salt concentration) to an area of low water concentration (high salt concentration). Osmosis is extremely important in the movement of water within living organisms.

The main activity portion of the lesson utilizes pure water, salt, and sodium polyacrylate or potassium polyacrylate. Students find that the polyacrylate will absorb hundreds of times its own weight in water. Sodium polyacrylate is used in disposable diapers. Potassium polyacrylate is used to capture water in soil for plants to utilize.

OBJECTIVES:

Students will describe the basic structure of a cell.

Students will define osmosis.

Students analyze the absorption capacity of potassium or sodium polyacrylate.

Students will model the discovery of sodium polyacrylate and speculate on the possible commercial uses.

MATERIALS:

Per class: paper towels; 1 gallon pure water

Per team of 3 - 4 students:

- coated paper plate
- plastic spoon
- 8 oz cup of pure water
- safety goggles for each student
- pair of disposable plastic gloves for each student (available from school cafeteria or district warehouse)
- small pile sodium or potassium polyacrylate (less than 1 gm/about ¼ tsp)

MANAGEMENT SUGGESTIONS:

This is a very effective activity illustrating both osmosis and scientific discovery. However, this activity utilizes white powder. Students should be advised to take safety precautions very seriously: 1) no illegal drug inferences by students 2) no horseplay or practical jokes 3) no ingestion or pretended ingestion of the powder.

Caution the students not to touch the powder *at all*. If it gets on the hands, and the hands rub the eye, the powder will irritate the eye. If some powder does somehow get into the eye, wash the eye for 15 minutes with water.

Sodium polyacrylate absorbs water. Protect it from moisture until it is used.

Dispose of the gel in the trash. Do not put it down a sink; it might clog the pipes.

Sodium polyacrylate is available from Flinn Scientific, P.O. Box 219, Batavia, Ill. 60510, phone (708) 879-6900. Prices quoted on 6/1/95 were:

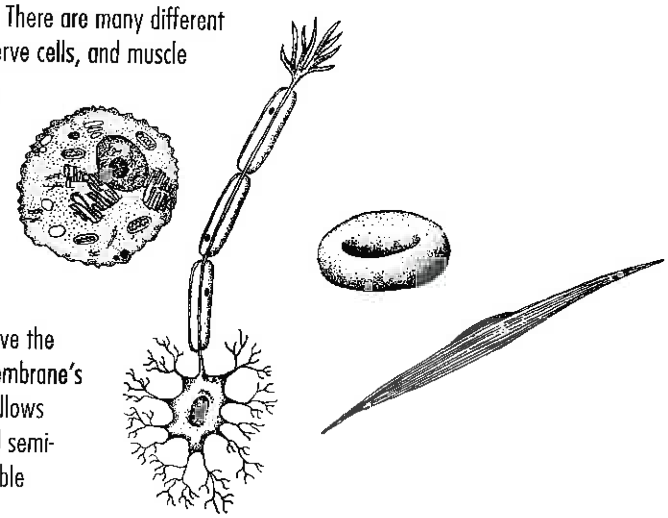
Catalog number	Amount	Price
W0012	25 grams	$ 4.80
W0013	100 grams	$ 8.90
W0014	500 grams	$22.15

☛ *Please do not be put off by the cautions regarding the activity or the extra effort required to obtain the polyacrylate. The activity is definitely worth any time and energy involved in preparation or presentation.*

ACTIVITY

1. Introduce the concept of cells. All living things (organisms) are made of individual living compartments called cells. An *Amoeba* is only one cell in size; each human is composed of approximately 100 trillion cells. Each cell is alive, and therefore has the same basic needs as the organism that it's a part of: the ability to obtain nourishment, a method of "breathing", surroundings that are of a favorable temperature, a way to get rid of wastes, and an adequate supply of water.

2. Define generalized cell structure. There are many different types of cells in a human body, including skin cells, bone cells, nerve cells, and muscle cells. Each type has its own distinctive appearance and job to do. However, all cells are primarily made from protoplasm, a clear jelly-like substance. Each compartment of protoplasm (cell) is surrounded by a delicate, elastic covering called the plasma membrane.



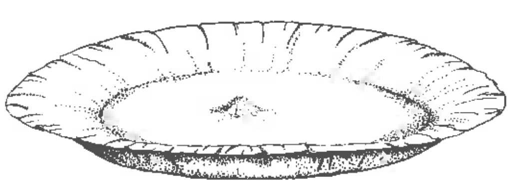
3. Explain the plasma membrane. The plasma membrane separates the cell from the outside world. Its primary responsibility is to regulate what materials enter or leave the cell. Anything going in or out of the cell must pass through the membrane's ultramicroscopic pores. Since not all molecules are of a size that allows them to travel through the pores, the plasma membrane is labeled semi-permeable. Permeable means anything passes through. Impermeable means that nothing can pass through.

4. Introduce osmosis. Water, being a relatively small molecule, is able to pass easily through the pores in the membrane. The force that causes water to go through the plasma membrane is water itself. Water tends to travel from where it is in high concentration to where it is in low concentration. This is called osmosis. An example is shown when a salt and water solution is on one side of a semi-permeable membrane and pure water is on the other side. The salt water side has less water (part of it is salt) and so has a lower water concentration. Water will travel to this low concentration side from the pure water side.

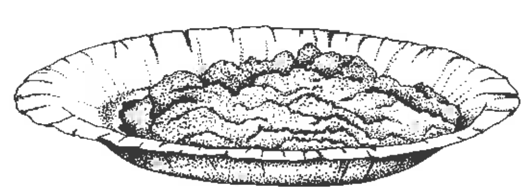
5. Distribute the activity materials. Each team of three to four students receives a coated paper plate, a plastic spoon, an 8 oz clear plastic cup at least ¾ full of pure water, and goggles and disposable gloves for each student.

The teacher then walks around the room personally placing a small pile (less than 1 gm or about 1/4 tsp) of the sodium or potassium polyacrylate in the middle of each team's plate. The students are *strongly* cautioned regarding the experiment and use of the materials (see management suggestions).

6. Explain the activity. Each team is to *carefully* pour a spoonful of water on the pile of powder. Once this is accomplished, the teams are directed to put more spoonfuls of water on the pile, one spoon at a time. They count each spoonful as they go, until extra water accumulates around the pile's edge. Once extra water appears on the plate, they should stop. The instructor continues to circulate around the room, monitoring the students. The final number of spoonfuls indicates the amount of water it took to saturate the pile of powder.



BEFORE



AFTER

7. Share and discuss class results. Students may find that they didn't have enough water. The instructor can decide whether to distribute more water. The pile will have grown dramatically. Discussion regarding the results and speculation about the identification of the powder will be lively.

8. Students hypothesize about the composition of the powder. Hopefully the students will connect the activity with the concept of osmosis. After they relate their ideas and hypotheses, the students can be told that the powder is sodium polyacrylate, which is a semi-permeable salt grain that will absorb, by osmosis, 800 times its own weight in pure water!

9. Students speculate on possible uses for the powder. The students are not told what the polyacrylate is currently used for (see reading). Instead they are encouraged to view this powder as something they just invented in their laboratory. Now that they have discovered this interesting powder, they need to make some use of it. Their discovery can bring wealth and also provide the public with an important new product. But, who wants this new powder? Who needs it? Who will buy it?

10. Relate the actual commercial uses of salt polyacrylates. Sodium polyacrylate and potassium polyacrylate are used commercially to "soak up" water. Because they are semi-permeable grains with a high salt content, osmosis pulls water into each grain. Each grain will absorb 800 times its weight in pure water. It will absorb only 300 times its weight in tap water, which has some salts in it. Sodium polyacrylate is a major component of diapers, where it only absorbs 60 times its weight in salty urine, but still keeps baby's delicate skin dry. Potassium polyacrylate is mixed with soil to capture water and hold it for plants' utilization. It is also used as a medium to germinate seeds and grow seedling plants.

11. Add salt to the piles. As a demonstration, or continuation of the activity, the teacher should pour a little table salt on one pile of saturated sodium polyacrylate or on each team's pile. The pile will appear to "melt" as water pours out of the individual grains in response to the heavy concentration of salt on the outside. Again this is osmosis at work, with the water going from an area of high water concentration (inside each grain) to an area of lower water concentration.

12. Clean up. Students should be cautioned against touching any of the powder, wet or dry. They should also be reminded to maintain strict laboratory discipline. It is suggested that the instructor take total charge of disposing of the plates with the powder. This is accomplished most easily if the instructor circulates through the room with a garbage can that has a plastic bag liner in it. Each plate can then be carefully moved the least distance directly into the can. Gloves should also be disposed of. Be sure none of the students leaves the room with any of the wet or dry powder. As one last step, have students wash their hands and desktops.

REVIEW AND REFLECTION:

1. Describe the inside and surface of a typical cell. *An inside of jelly-like protoplasm. A membrane surface with extremely small holes through which some materials pass.*

2. Explain osmosis. *The diffusion of water across a semi-permeable membrane from an area of high water concentration to an area of low water concentration.*

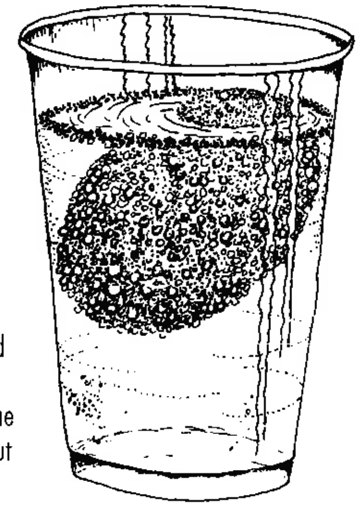
3. Name one use for sodium polyacrylate? *As an absorbent in disposable diapers.*

4. Why might water relieve thirst better than soda? *Soda contains a high sugar concentration. This might encourage water to be pulled out of tissue into the digestive tract, actually increasing thirst.*

5. Why might a person swimming in the ocean get more thirsty than a person swimming in a lake? *Sea water has a higher concentration of salt than our bodies. Therefore sea water would "pull" water out of our tissues, creating thirst.*

EXTENSIONS:

1. Diffusion can be shown by placing one drop of food coloring in a cup of water. Do not stir the food coloring and water in the cup. In time, the food coloring will spread out in the cup as the molecules move from the area of high concentration. The temperature of the water in the cup can be varied to illustrate how temperature affects the rate at which molecules move and diffusion occurs.



2. To illustrate osmosis, use a raw egg. The first step of this demonstration requires that the egg shell be removed, while keeping the membrane under the shell intact. To accomplish this, soak the egg in vinegar for a couple days. The vinegar will dissolve the egg shell, but leave the rest of the egg untouched. It may be necessary to change the vinegar once or twice during this process. Once the shell has been dissolved, place the membrane-covered egg into pure water. The egg will gradually swell as water enters it by osmosis. Next, place the egg in corn syrup. Now the egg will shrink as water leaves the egg through osmosis. (Keep another egg on hand to compare size changes. This "control" egg can be hard-boiled for safe handling.)

3. A good "magic" demonstration can be done using sodium polyacrylate in a styrofoam cup. Prior to the demonstration, place ¼ gm of sodium polyacrylate into the cup. Also, pour some water into a separate clear plastic cup. You're ready. Explain to students that styrofoam cups are designed only to be used with hot liquids. Cold liquids placed in styrofoam cups will be lost through evaporation. (Of course, the preceding statement is not true, but is necessary for the "magic" to work.) Next, pour the water from the plastic cup into the styrofoam cup that has the polyacrylate in it. Silently count to five while talking about evaporation, and water, and styrofoam, and... Then turn the cup upside down over a student. Nothing comes out! The water has vanished! Actually, the water and polyacrylate simply turned to a gel which is stuck in the cup. (Be sure to allow sufficient "wait time" for the water and polyacrylate to gel and to use a styrofoam cup. Other cups lack the roughness on the inside surface which is needed for the gel to stick.)

REFERENCES

To list and describe all the available audio-visual and curriculum materials about water and water science is a task well beyond the scope of this Teacher Activity Guide. The following materials are included for their quality, recency, and relevance. Educators may also wish to contact their local water agencies to determine the extent to which they can provide local materials to supplement the list below.

CURRICULUM MATERIALS

Asimov's New Guide to Science. Isaac Asimov. A detailed treatment of content through all the disciplines of science by one of the most prolific writers of all time. 1984. Basic Books Inc., New York.

Bubbleology. GEMS Teacher's Guide. This publication is one in a series of resources for teaching activity-based science and math. The ten sessions for grades five to nine cover a variety of progressive bubble building activities which illustrate the science concepts involved in soap films. Lawrence Hall of Science, University of California, Berkeley, CA 94720; 510-642-7771.

California Water Works and Why It Does. A 15-page color booklet in English or Spanish for grades three through eight which presents an overview of water in California, including the need for water conservation. 1978. Department of Water Resources, Publications Unit, P.O. Box 942836, Sacramento, CA 94236-0001.

Conceptual Physics. Paul G. Hewitt. A very readable book that communicates physical science concepts through simple language. 1984. Addison-Wesley Publishing Co., Inc.

Dictionary of Science. Dorling Kindersley Family Library. More than 2,000 word entries are arranged under 80 main topics.*

Discovering Density. GEMS Teacher's Guide. This publication contains five sessions for grades six to ten which center on a series of challenging investigations into the densities of liquids. Lawrence Hall of Science, University of California, Berkeley, CA 94720; 510-642-7771.

The Dorling Kindersley Science Encyclopedia. Dorling Kindersley Family Library. This single volume contains 2,000 basic science and technology entries, arranged under twelve themes.*

Earth: The Water Planet. A 204-page book with reproducible sheets designed for science teaching in grades six through ten. The book is divided into five modules on different aspects of water and uses a variety of instructional methods. 1992 rev. National Science Teachers Association, Publication Sales, 1840 Wilson Blvd, Arlington, VA 22201-3000; 1-800-722-NSTA.

Environmental Education Compendium for Water Resources. A cooperative presentation on water curriculum materials by the California Department of Education, California Department of Water Resources and Sonoma State University. 1991. Department of Water Resources, Publications Unit, P.O. Box 942836, Sacramento, CA 94236-0001.

Eyewitness Science – Chemistry; Eyewitness Science – Matter. Dorling Kindersley Family Library. Two titles from the famous Eyewitness series of thematic information books.*

The Further Adventures of Captain Hydro. A 16-page full-color comic book presenting Captain Hydro in his continuing battle with the Water Bandit. 1977. East Bay Municipal Utility District, P.O. Box 24055, Oakland, CA 94623-1055; 510-287-0138.

Minn of the Mississippi; Seabird; Paddle-to-the-Sea. Holling C. Holling. These three literature books are all fascinating, and packed with natural science, social science, history and geography. 1975. Trumpet Club, New York.

More About Water: Where It Comes From, Where It Goes. A booklet for grades five to twelve about the source of EBMUD's drinking water, how both drinking water and wastewater are treated; and the kinds of careers available and career preparation necessary for EBMUD employees. 1994. East Bay Municipal Utility District, P.O. Box 24055, Oakland, CA 94623-1055; 510-287-0138.

The Official Captain Hydro Water Conservation Workbook. This is a 40-page workbook for grades 5 to 9 that concentrates on units in science and social science. Included are ten pages of comics about Captain Hydro, hero of water conservation. 1992 rev. East Bay Municipal Utility District, P.O. Box 24055, Oakland, CA 94623-1055; 510-287-0138.

Science Matters. Robert M. Hazen and James Trefill. This book is designed to make the reader "scientifically literate"and covers a wide range of science topics in a very concise manner. 1991. Doubleday and Co., New York.

700 Science Experiments for Everyone. Originally published as *UNESCO Science Sourcebook for Science Teaching.* This is a classic science resource book. It includes everything from how to make simple equipment to a treasury of simple, but effective, activities. Doubleday and Co., New York.

Soap Films and Bubbles. This publication by Ann Wiebe for Project AIMS is a very comprehensive bubble book. It is full of background information and hands-on activities integrating math and science for students in grades four to nine. AIMS Education Foundation, P.O. Box 8120, Fresno, CA 93747; 209-255-4094.

The Story of Drinking Water. This 16-page booklet is targeted for students in grades four through eight, and includes information on ground-water, water quality, and water conservation. 1990. American Water Works Association, 6666 W Quincy Avenue, Denver, CO 80235; 303-794-7711.

Water Wisdom: A Curriculum for Grades Four through Eight. This publication includes three instructional units with sequential lessons within each unit. Each unit emphasizes a particular content area: science, social science, or literature while drawing from the other areas. 1990. Alameda County Office of Education, Media Sales, 313 W Winton Avenue, Hayward, CA 94544; 510-670-4168.

*To locate an independent distributor, contact Jay Bell at 209-369-7708.

AUDIO-VISUAL – Most of the films listed below are referenced to specific lessons in this Guide

Areas, Volumes, Angles. (19 minutes) *Great Balls of Water!*
This film introduces two- and three-dimension concepts. Handel Film Corporation, 1984.

The Atom. (14 minutes) *A Recipe for Water*
This film explains how atomic structure determines chemical behavior and describes the historical development of atomic theory and the evidence on which it is based. (World of Chemistry - A Series) ITS, 1992.

Bubbleology. (60 minutes) *Great Balls of Water! and Milk Storms*
Shows how bubbles are used in science experiments to demonstrate chemical composition, surface tension, pressure and volume, among other concepts. Insights Visual Productions, 1988.

Bubbleology. (14 minutes) *Great Balls of Water! and Milk Storms*
Explains surface tension by experimenting with soap films and shows how molecules of water on the surface cling to those below. (3-2-1 Classroom Contact - A Series) PBS Video, 1991.

Catalysts. (14 minutes) *Presto - Peroxide Becomes Water*
This film examines catalysts and their role in chemical reactions. (World of Chemistry - A Series) ITS, 1990.

Heat and Temperature. (25 minutes) *A Recipe for Water*
Molecules in solids, molecules in liquids, evaporation, condensation, etc. (Eureka! - A Series) TV Ontario, 1981.

Mass and Density. (20 minutes) *Density Detectives*
Detective Will Slater, expert on the concepts of mass and density, is called upon to help students in a science class. AIMS Media, 1986.

States of Matter. (19 minutes) *A Recipe for Water*
A simulated mystery involving dry ice with experiment on observing its behavior. (Minds-On-Science - A Series) AIT, 1992.

States of Matter. (14 minutes) *A Recipe for Water*
Demonstrations with gases to use the Kinetic Theory to explain states of matter. (World of Chemistry - A Series) ITS, 1990.

Water. (9 minutes)
Experiments with water in fruits and vegetables; simple distillation and filtration methods, how water works. (Science Alliance - A Series) TV Ontario, 1984.

Water. (26 minutes) *The Wizard of Osmosis*
Shows the crucial part water plays in the body's functioning and the system for keeping it in balance. (Living Body - A Series) Films for the Humanities, 1985.

Water. (14 minutes)
Identifies and discusses the properties and various states of water. (World of Chemistry - A Series) ITS, 1990.

NOTES

EBMUD
EAST BAY MUNICIPAL UTILITY DISTRICT
P.O. Box 24055, Oakland, CA 94623-1055

Printed on recycled and recyclable paper