Tapping Saltwater for a Thirsty World

By Melissa Stewart

Water, water, everywhere,

And all the boards did shrink;

Water, water, everywhere,

Nor any drop to drink.

These famous words come from "The Rime of the Ancient Mariner," an epic poem written by Samuel Taylor Coleridge in the late 1700s. Nearly dying of thirst on a storm-damaged vessel, the sailor in the poem refused to drink the ocean water all around him. He knew the salty seawater would kill him more quickly than not drinking anything at all.

Our bodies are, by mass, between 55 and 65% water. If we lose just 2% of that fluid, we will feel extremely thirsty. And if we lose 20%, we will die. That's why it's so important to drink plenty of water every day. A person deprived of water can live for only 2–14 days, depending on the conditions.

Why is water so important? It helps our cells, tissues, and organs do their jobs. The fluid in our bodies helps digest food and circulate blood. Dissolved ions, or electrolytes, in the fluid regulate osmosis—the flow of materials in and out of our cells.

Most of the time, water flows across cell membranes from areas where electrolyte concentrations are low to areas where electrolyte concentrations are high. As a result, the concentrations of sodium (Na^+), chloride (Cl^-), potassium (K^+), and other ions determine the size and shape of cells. If too much fluid moves into a cell, it will expand and eventually burst. If too much liquid flows out of a cell, it will shrink and eventually shrivel up. Cells with too much or too little water cannot function properly.

Like our body fluids, ocean water contains dissolved ions. If you've ever swallowed a bit of seawater, you've tasted these salty particles. The salt in seawater is very similar to the salt you sprinkle on French fries. It consists mostly of sodium chloride, existing as positively charged sodium ions and negatively charged chloride ions. Depending on the location, seawater may also contain smaller amounts of 53 other ions.

When a person drinks too much seawater, the dissolved ions disrupt the normal balance of electrolytes in his or her body fluids. Because too many electrolytes suddenly flood the fluid outside cells, large amounts of water flow out of the cells. If a person's brain cells dehydrate too much, they will collapse, and the person will experience seizures, coma, and finally death.

See for Yourself

You will need:

A 1-L graduated beaker filled to the liter mark with water;
10, 25, and 50-mL graduated cylinders;
Three smaller beakers;
A dropper;
A piece of wax paper;
Measuring spoons;
Table salt (sodium chloride).

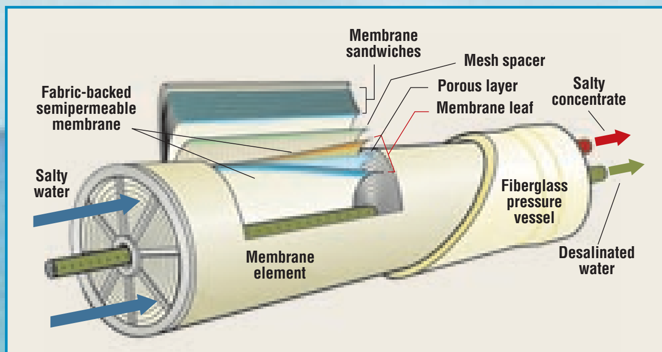
Imagine that the water in the 1-L beaker represents all the water on Earth.

1. Pour 28 mL of water from the 1-L beaker into a smaller beaker, labeled "A".

How many drops to drink?

In the modern world, very few people get lost at sea. But although three-quarters of Earth's surface is covered with water, 97 percent of it is too salty to drink. Another 2.5 percent is either frozen or too far below ground to reach, leaving just 0.5 percent of Earth's water for drinking, washing, flushing toilets, and watering crops.

In the past 50 years, the human population has skyrocketed to more than 6 billion. The United Nations estimates that by 2050, 9 billion people will have to share our planet's limited resources. The International Water Management Institute predicts that by 2025 only about one-quarter of the world's people will have enough clean, fresh water.



Reverse-osmosis systems are frequently spiral wound. Each membrane leaf contains a water-collecting porous layer sandwiched between two fabric-backed semipermeable membranes. Individual membrane leaves are separated from each other by a porous mesh spacer through which high-pressure saline water is passed. Purified water separates from the saline solution and passes through the membranes into the sandwich's central layer, which conducts the water spirally to the central perforated collection tube. Briny concentrate is collected in a separate tube.

What's the solution to the water dilemma? People all over the world must learn to use water more wisely and, at the same time, look for new sources of water. In the United States, many of the communities at greatest risk are located in coastal states. As a result, the ocean seems like an obvious potential source of water. But there's one major problem with this idea. Before seawater can pass human lips, the salt must be removed.

From deadly to drinkable

The process of removing salt from ocean water is called desalination. There are currently about 11,000 desalination plants in operation worldwide. But they provide less than 0.2% of the total global water supply.

About two-thirds of the world's desalination plants are located in the Middle East. Most of these facilities take advantage of distillation—a technique that imitates the natural water cycle to separate the salt from the water. During distillation, seawater is heated until the water molecules evaporate, leaving the dissolved salts behind. Next, the water vapor is trapped and cooled until the gas condenses, or returns to its liquid state. The pure water flows into a large collection tank. From there, it is piped to homes and businesses as needed.

Distillation is a good solution for water-poor, oil-rich Middle Eastern nations, but the high cost of heating the water makes the process less attractive in other parts of the world. On the island of Majorca, off the east coast of Spain, one of the largest desalination plants in Europe meets drinking water demands by using a process known as reverse osmosis.

After removing large solids from the seawater, the salty water is pressed against a series of thin membranes. The membranes have tiny holes that allow water molecules, but not salt particles, to flow through them. The final result is drinkable freshwater. The process is called reverse osmosis because pressure forces the water to flow from an area where the concentration of ions is higher to an area when the concentration is lower.

In the past, the membranes used during reverse osmosis were extremely expensive and wore out quickly. In addition, they caught only about 85% of the salt. But recently, scientists have developed sturdier membranes that last three times longer and cost 20% less than older models. The new membranes also filter out nearly all of the salt.

These improvements have led many American communities to take a serious look at how desalination technology may help solve their water problems. In Florida, the Tampa Bay Water Authority is currently constructing the largest desalinated seawater facility in North America. When the plant is completed in December 2002, it will be able to process 25 million gallons of ocean water per day—about 10% of the daily volume for the region.

Melissa Stewart is a science writer living in Marlborough, MA. She has written more than 30 books for children and young adults.

REFERENCES

Brennan, M.B. Waterworks, *Chemical and Engineering News.* April 9, 2001, pp 32–38.

Martindale, D. Sweating the Small Stuff: Extracting Freshwater from the Salty Oceans, *Scientific American.* February 2001, pp 52–55.

2. Dissolve 1 tablespoon of salt (sodium chloride) into the water in the large beaker. This now represents the saltwater in the Earth's oceans—unfit for drinking.

The water in the small beaker A represents all the Earth's freshwater.

3. Pour 6.5 mL of water from Beaker A into another beaker labeled "B".

Now the water in Beaker A represents inaccessible freshwater tied up in glaciers and polar ice caps. You can make this more dramatic by placing Beaker A into a freezer, turning its contents into ice.

The water in Beaker B represents the remaining freshwater.

4. Pour 3.4 mL of water from Beaker B into another small beaker, labeled "C".

Now the water remaining in Beaker B represents inaccessible groundwater.

The water in Beaker C represents the entire supply of freshwater on Earth. But much of this accessible freshwater is either polluted or otherwise unavailable for use.

5. Finally, use the dropper to remove 5 drops of water from Beaker C and place them on the piece of wax paper.

These five drops are a reasonable estimate of how much drinkable water is actually available from the original 1 liter of water you started with!

Teacher's guide: OCTOBER 2002

A supplement to *ChemMatters* magazine

ABOUT THE ARTICLES

Tapping Salt Water for a Thirsty World

Background Information

The four lines from *The Rime of the Ancient Mariner* that introduce the article, represent only a fraction of the epic poem. Written by Samuel Taylor Coleridge (1772-1834), and first published in 1798, it runs to more than 3,900 words and almost 150 stanzas. The work relates a story told by an ancient mariner at a wedding. Some students may have read the entire poem as an assignment, perhaps in an English Literature class.

The original poem used spelling that was considered archaic even at the time of publication, as evidenced by the original title, *The Rime of the Ancyent Marinere*. The poem was revised and much of the spelling altered over the years. The version that is generally used today appeared in 1817.

Any Google search using the title will produce a large number of "hits." If you want to read or assign the entire poem, some good sites are:

http://etext.lib.virginia.edu/stc/Coleridge/poems/Rime_Ancient_Mariner.html http://www.yoga.com/raw/readings/TheRimeofTheAncientMariner.html

http://www.bartleby.com/101/549.html

The last site also includes a side-by-side explanation of what is being described in the poem.

Although the average human body may be about 65% water, different body tissues contain different percentages. Muscle tissue is about 75% water, while fat is only about 25%. Blood is about 83% water, the heart 79%, the brain 75%, skin 72% and even bone is about 22% water.

The need to consume water during extended exercise is well known. In one hour of vigorous exercise, the human body can lose between 1-2 liters of water, depending on the outside temperature and the intensity of the exercise. Since a liter of water weighs over two pounds, the need to replace this fluid is obvious.

We typically feel thirsty if we lose even 1% of our body's water. A loss of 5% results in a significant decline in both muscle strength and endurance. At 10% delirium and blurred vision occur, and, as the article points out, death occurs around 20%. If a 150-lb person were to lose as little as three lbs of water (less than 1.5 liters), this would represent 3% of their body weight.

The *osmolarity* (see ***Connections to Chemistry Concepts***) of human blood and the fluid inside cells is approximately equal. Seawater, on the other hand, is about three times more concentrated. Consequently, if you drink seawater, the osmolarity of your blood increases. This situation results in water moving out of all the other cells in your body and into your blood stream, causing the cells to shrink in volume. Dehydrated cells cease to function properly, resulting in symptoms such as muscle ache and fatigue, irregular heartbeat, and mental confusion. Another unfortunate result is that as the salt concentration of the blood increases because of the ingestion of seawater, the kidneys work harder to remove the excess salt by increasing the amount of urine being produced. This only accelerates dehydration.

If seawater is separated from freshwater by a semipermeable membrane, water will diffuse from the freshwater into the seawater. If the seawater is contained in a closed pressure vessel, this diffusion continues until the pressure on the seawater side builds up to about 400 psi (pounds per square inch). This is called the osmotic pressure of seawater, and when the pressure exerted by the seawater reaches this value, diffusion of water from the freshwater side to the seawater side ceases.

Which leads to an interesting question. What if we artificially increase the pressure on the seawater side to something *greater* than 400 psi? Could that actually force water molecules *from* the seawater side *into* the freshwater side? Of course! And the result is *reverse osmosis*—a way that freshwater can be extracted from seawater.

In practice, the pressure used to desalinate seawater is around 800 psi.

For a description of how a specific reverse osmosis device operates, see

http://goals.com/ClassRm/SailSci/osmosis1.htm

There are several different methods for desalinating water, although distillation and reverse osmosis dominate. For a table listing the global production of desalinated water by various procedures go to:

http://www.desware.net/desware/desa3.asp

As the article points out, there are about 11,000 desalination plants in the world today. Although they are located in about 120 different nations, more than 60% of them are in the Middle East. The first modern full-scale plant was built in Saudi Arabia in 1938, with two smaller experimental plants preceding it. Other nations with desalination plants include Cyprus, Malta, Gibraltar, the Caribbean, Cape Verde, Portugal, Spain, Greece, Italy, India, China, Japan and Australia.

It is estimated that about 37% of the world's population lives within 1000 km (about 60 miles) of a coastline.

Desalination plants now produce about 4 billion gallons of freshwater daily—an amount capable of providing about 4% of the World's population with about 15 gallons per day. But even this represents only about 0.25% of the world's needs.

While we typically think of desalination of seawater by distillation as a modern development there were actually attempts made by the legions of Julius Caesar to distill Mediterranean seawater as early as 49 B.C.

As the article points out, the two major processes by which seawater is desalinated are distillation and reverse osmosis. There are several modifications to the basic methods involved in both of these processes. For example, while we may think of "distillation" the way we normally perform it in our classrooms, one of the most common techniques is called Mobile Multistage Flash (MSF) Distillation System, developed by Dr. Safwat Moustafa of Sun Utility Network. This system can produce 13,000 gallons of potable water each day. MSF involves the exposure of a thin film of water to high heat, causing "flash" evaporation. The water is flashed repeatedly. There are over 2000 desalination plants using this technique, including one in Saudi Arabia that produces 250 million gallons of freshwater each day.

An obvious drawback to any distillation procedure is the cost of the energy required to evaporate the water, and this often determines whether the process is economically viable. Consequently a lot of effort is going into finding the most economical sources of heat, such as renewable solar energy or waste heat from conventional internal combustion engines or gas turbines.

Another technique to desalinate water is called electrodialysis. Salt water contains ions. When salt water is placed in a container with a positive electrode at one end and a negative electrode at the other, the ions migrate towards these electrodes. As they do so, they are filtered by membranes and become trapped between them. This leaves desalinated water in the area outside the membranes. This process was first used in South Africa in 1958, but it is still basically impractical on a large scale because of the electrical requirements for the process.

Currently reverse osmosis is the most economical way of desalinating water for most nations. The cost of desalinating water by reverse osmosis is typically half that for MSF distillation.

The Middle East Desalination Research Center notes that despite the critical importance of obtaining freshwater to the future of the Middle East, research and development really hasn't changed very much in the past 30 years, and it describes all current processes as being "very inefficient," even though desalting costs have been reduced by a factor of 15 in the past 50 years.

Connections to Chemistry Concepts

All human cells are enclosed by semipermeable membranes. *Semi*permeable means that the cell membranes allow some particles to pass through them, while others are restricted. Water flows freely through the cell membranes, so if the membrane separates two solutions with different concentrations of dissolved particles, water flows from the solution of lower concentration to the solution of higher concentration until equilibrium is achieved and the concentrations are equal. This process is referred to as *osmosis*, and the "concentration" of dissolved particles in a solution is expressed in terms of something called its *osmolarity*.

The osmolarity (osM) of a solution is conceptually similar to the molarity of the solution, but it takes into account the entire concentration of all particles produced in the solution regardless of their identity.

Consequently one must take into consideration whether the dissolved substance breaks apart into ions when it dissolves. For example, a 0.30 M solution of a nonelectrolyte like glucose ($C_6H_{12}O_6$) would also have an osM of 0.30, but a 0.30 M of an electrolyte like sodium chloride, NaCl, which dissociates into two ions (Na^+ and Cl^-) would have an osM of 0.60, and a 0.30 M solution of magnesium chloride, $MgCl_2$ would be a 0.90 osM solution.

In somewhat simplified terms, if a semipermeable membrane separates two solutions with equal osmolarities, the solutions are said to be *isotonic*, and one would not expect any net flow of water across the membrane. In reality things are somewhat more complicated. For example, some molecules, like urea, can easily cross a cell membrane. Consequently, while they do contribute to the osmolarity of the solution, they basically do not contribute to the tonicity. Nonideal behaviors must also be taken into consideration.

Plasma has an osmolarity of about 0.30 osM, so a 0.15 osM solution of NaCl is essentially isotonic with plasma, assuming that neither sodium nor chloride ions can cross a cell membrane, which is nearly true. But while a 0.30 osM solution of urea would be isoosmotic with plasma, it would not be isotonic, since urea can cross a cell membrane.

For more information about these concepts:

http://www.liv.ac.uk/~petesmif/teaching/1bds_mb/notes/common/osmo.htm

http://physioweb.med.uvm.edu/bodyfluids/calculat.htm

http://arbl.cvmbs.colostate.edu/hbooks/cmb/cells/pmemb/osmosis.html

http://qldanaesthesia.com/FluidBook/FL2_3.htm

Possible Student Misconceptions

Because there is no net movement of water across a membrane separating two isotonic solutions, students may think that no water molecules are actually moving through the membrane. Actually it has been estimated that *each second* an amount of water equal to approximately 250 times the volume of the cell *diffuses* across a red cell membrane. There is no net change because the amount diffusing into and out of the cell is equal.

Students may "logically" assume that the size of a particle in solution would naturally affect its ability to diffuse across a semipermeable membrane and the osmotic pressure it would produce. This is not the case. Assuming that the dissolved particles cannot move through the cell membrane at any appreciable rate, the osmotic pressure exerted by a given solution depends only on its osmolarity, and not upon the identity of the solution. See Connections to Chemistry Concepts.

Demonstrations and Lessons

1. The *See for Yourself* activity described in the article would make a good classroom exercise. It would tie in especially well with the first unit in the ***ChemCom*** curriculum, "Water: Exploring Solutions."

2. This article provides an excellent context for introducing the technique of distillation.

3. One of the most common ways to demonstrate osmosis occurring through a cell wall is the classic demo using a de-shelled egg placed first in distilled water and then in solutions of various substances such as salt or Karo syrup. If you are interested in doing this as a demonstration or as a class activity, there are Web sites offering different variations of this activity, from the very simple to more complex activities that involve the use of a graphing calculator or actually constructing an osmometer from an egg. Web sites of interest include:

http://www.usoe.k12.ut.us/curr/science/sciber00/7th/cells/sciber/osmosis1.htm

http://www.accessexcellence.org/atg/data/released/0519-NancyIversen/activity.html

http://members.aol.com/KSmith9526/DiffusionOsmosis.htm

http://education.ti.com/activity/courses/biology/kostc/kostc15.html

Connections to the Chemistry Curriculum

Desalination ties into many topics that are typically included in both “traditional” courses and the *ChemCom* curriculum. The first unit of the ***ChemCom*** curriculum, “Water: Exploring Solutions” explores the topic of water, its properties and its distribution in detail. The *See for Yourself* activity described in the article would make a good classroom activity for any class using ***ChemCom***. Most curricula treat the topic of distillation at some point, and this will tie in beautifully with the technique of distillation as it is applied to the desalination of seawater. A comparison can be made between the “simple” distillation techniques that are normally used in a high school laboratory and the more sophisticated techniques actually used to distill large amounts of seawater, such as the Mobile Multistage Flash (MSF) Distillation System (see ***Background Information***).

The process of reverse osmosis relates to a number of topics. While the article doesn’t directly deal with the concentration unit *osmolarity*, if your curriculum includes the topic of colligative properties, any discussion of reverse osmosis should easily connect to both this concentration unit as well as the notion of how different substances such as ionic solids and weak acids and bases ionize in solution. More advanced courses may approach these concepts in a quantitative way, such as calculating the osmotic pressure that would theoretically be exerted by a solution of given concentration.

Suggestions for Student Projects

1. So often, in our departmentalized high school curricula there is minimal chance for the sciences and humanities to meet. Wouldn’t it be interesting to have a student or a group of students present a “science” report in an English Literature class where they discussed exactly why the Ancient Mariner could not drink the ocean water and the efforts being made today to desalinate seawater and then give a presentation in a science class about the poem itself and its literary significance? Some ideas for projects related to the poem are offered at http://www.shunsley.eril.net/armoore/poetry/mariner.htm

2. Students attracted to the more mathematical and theoretical sides of chemistry might enjoy learning about and reporting on what osmotic pressure really is and how it is determined experimentally and calculated theoretically. An individual or group might try to teach these concepts to their classmates. Students attempting to do something like this often leave with a much higher respect for the difficulties involved in teaching and occasionally there will be a student for whom the attempt will either uncover or spark an interest in teaching as a career.

Anticipating Student Questions

Is there a daily requirement for water intake, sort of like the RDA (Recommended Dietary Allowance) for vitamins?

No. How much water one needs to take in each day is very dependent upon the climate (such as temperature), the level of your physical activity, your age, your general state of health, and your body size. It is probably better to err of the side of consuming somewhat more water than your body’s minimal needs rather than less. Excess water will just be eliminated by the kidneys. Of course one can obtain water from many sources, not just in the form of “pure” water alone. All beverages and other fluids are sources of water. Many foods are also high in water content, including many solid foods. Some crisp vegetables may be over 90% water. Protein-rich foods can be over half water.

Websites for Additional Information and Ideas

Using any common search engine with search words like *desalination* will result in a tremendous number of hits. Here are a few recommended sites:
http://www.world-wide-water.com/

http://www.msnbc.com/news/319483.asp

http://www.factmonster.com/ce6/sci/A0851566.html

http://www.goals.com/ClassRm/SailSci/osmosis1.htm

Antibacterials--Fighting Infection Where it Lives

Background Information

There are an amazing number of soaps currently on the market, and soaps containing some sort of antibacterial agents continue to increase in number. In 2001, 76% of 395 liquid soaps and 29% of 733 bar soaps contained antibacterial agents like troclosan or triclocarban.

The varieties of all products containing antibacterial agents are increasing in number. Included are not only the expected soaps, cleansers, and dishwashing detergents, but also things like toothbrushes, hand lotions and window cleaners. In England, antibacterials can even be found in some plastic food storage containers. It is even possible to purchase antibacterial pillows, sheets, towels, and slippers!

The Federal Trade Commission (FTC) has acted in at least one instance to stop what it considers to be unfounded claims for an antibacterial product. In September 1999, Conopco, Inc. agreed to withdraw advertising claims that it was making on behalf of Vaseline Brand Intensive Care Anti-Bacterial Hand Lotion. Included in their advertising were statements such as “Stops Germs for Hours,” and “Stops Germs Longer than Washing Alone.” One example was:

A teacher is mastering a new form of self defense. A salesman is learning hand to hand combat. A mother is launching a counterattack. Now it’s your turn. Arm your hands against dryness and against germs. The first Anti-Bacterial Hand Lotion from Vaseline Intensive Care is here. It’s time to arm your hands.”

The FTC alleged that such claims were deceptive and that there was no substantive evidence that the product: stops germs on hands longer than washing alone; provides continuous protection from germs for hours; and is effective against disease-causing germs, such as cold and flu viruses. It also noted that the active ingredient in the product was *triclosan*, and as the article points out, triclosan is found in many consumer products.

There are some interesting statistics regarding handwashing with regular vs. antibacterial soaps. Ralph Cordell, an epidemiologist at the Centers for Disease Control says that studies comparing antibacterial soaps to regular soaps do support the claim that antibacterial soaps kill more pathogens. But the difference appears to be very small. He indicates that handwashing using an antibacterial soap removes about 97% of the bacteria, but regular soap appears to remove about 95%.

The frequency of handwashing and the technique one uses may be more important than the type of soap employed. See *Anticipating Student Questions.*

Although not discussed in the article, some studies appear to support the hypothesis that the great strides that have been made in the past several centuries in combating infectious diseases may have had an unintended consequence of increasing the incidence of asthma, allergies and even some autoimmune

Answers to Student Questions

Antibacterials--Fighting Infection Where it Lives

1. The kitchen and the bathroom. Food is prepared in the kitchen, and moist food products can provide an excellent breeding ground for bacteria. Bacteria are easily spread from hands to raw meat, cutting boards, rags or sponges, and other kitchen surfaces where they can multiply. Human waste contains bacteria, so the bathroom is an area that can be host to large numbers of undesirable germs.

2. You would need to use the product that contained triclocarban. Alcohol kills bacteria upon contact, but leaves no residue that can continue to kill bacteria after the alcohol has evaporated. Triclocarban and similar products leave a residue that can continue to kill bacteria for several hours.

3. Alcohol kills bacteria by destroying the bacteria's cell walls. Triclosan kills by inhibiting an enzyme that bacteria require for growth.

4. First, the products kill not only pathogenic bacteria, but "good" bacteria as well. Secondly, there is some concern that the use of these products may eventually lead to the development of resistant bacteria.

5. There are no "real world" studies to date that have been able to document that the use of antibacterial products has led to the development of any strain of resistant bacteria. They argue that the use of antibacterial products should be a natural part of personal hygiene.

The Search for Martian Water

1. All molecules emit radiation. The kind of radiation emitted depends on the molecule itself and the conditions that are placed on it. The specific kinds of radiation emitted are unique for every different molecule. The Odyssey spacecraft that is orbiting Mars carries instruments that can detect radiation emitted by hydrogen under the conditions that exist on the surface of Mars. Large amounts of hydrogen have been detected on the surface. The surface conditions make it highly unlikely that elemental hydrogen could exist there, but it is very likely that the detected hydrogen is contained in water molecules, H_2O.

2. Cosmic rays are constantly bombarding the surface of Mars. Some of these "rays" are actually high speed neutrons. When these neutrons strike hydrogen, they cause the hydrogen to emit gamma rays, which are very high frequency, short-wavelength electromagnetic radiation. The GRS can detect the presence of these gamma rays.

3. When the high speed neutrons that are part of the cosmic rays bombarding Mars strike hydrogen, they are slowed down. The Neutron Spectrometer can detect the presence of these slowed-down neutrons, and their presence is indicates the presence of hydrogen on the surface of Mars.

4. Validation is a process by which the same thing is measured or detected by at least two different techniques. If these two separate techniques produce the same results, this provides very strong evidence for the validity of what has been measured or detected. Thus the term validation.

5. It is too warm for hydrogen to exist as either a solid or liquid, and if it were in gaseous form, its very low density would have caused it to have left the surface long ago. Also, if it were a gas, it should be distributed across the entire surface of Mars, but hydrogen appears to exist mainly in the polar regions. If water exists on the Martian surface, it should be found in the form of ice, and since a water molecule contains two hydrogen atoms, the presence of so much hydrogen provides a strong indication that the surface actually contains an abundance of ice.

Tapping Salt Water for a Thirsty World

1. Seawater contains a relatively high concentration of salt. Salt consists of ions. If a person drinks seawater it will increase the concentration of these ions in his/her blood. Water diffuses out of cells to “even out” the concentrations of ions in the blood compared to inside the cells. The resulting dehydration disrupts the proper functioning of the cells. For brain cells, this can eventually cause them to collapse. The result can be seizures, coma and ultimately death.

2. When water is heated until it boils, only the water boils away, turning into a vapor. The salt, being a solid, is left behind. When the water vapor is cooled it condenses into relative pure water virtually free of any dissolved substances.

3. Desalination requires a great deal of energy to evaporate the water. Consequently it is only economically feasible in areas of the world that have limited supplies of available fresh water, but have access to relatively cheap energy sources. The Middle East has very limited access to fresh water sources, but has an abundance of cheap oil, which can be burned to provide the heat necessary to distill the seawater.

4. Water will naturally flow across a semi-permeable membrane from an area where the concentration of ions is low to an area where the concentration of ions is high. This process is called osmosis, and the tendency of the water to flow in this preferred direction creates osmotic pressure—a “pushing” of the water molecules in one direction. But if a greater pressure is artificially applied in the opposite direction, water can be made to flow from a region of high ion concentration (like seawater) to a region of low concentration. This allows relatively pure water to be obtained from seawater.

5. The membranes required were expensive and tended to wear out quickly. Recently, sturdier and less expensive membranes have been developed.

Urine: Your Own Chemistry

1. Urine is a water solution containing a variety of different salts and several organic chemicals. It normally has a pH of about 6, but can vary from around 4.8 to 7.5, depending on a person’s personal biochemistry and what they have been eating and drinking. It is yellow because it contains a yellowish-brown compound called urochrome.

2. Three other nonionic compounds are urea, uric acid and creatinine. Urea is formed when proteins are broken down in the body. Uric acid is formed when nucleic acids (DNA and RNA) are broken down. Creatinine is produced as a waste product formed from the chemical reactions that are involved in muscle function.

3. Although the idea may be repugnant to most people, urine from a healthy person can be safely drunk because it is bacteria free.

4. Asparagus contains two sulfur-containing compounds. When asparagus is digested, these compounds are broken down into smaller molecules that cause the characteristic odor. But heredity seems to be involved. Not everyone produces the same compounds, and some people are incapable of detecting the odor.

5. Urinalysis is the chemical analysis of urine. By measuring the amounts of various chemicals present in a person’s urine, useful information can be obtained about the status of their health. For example, if a person’s urine has too high or low of a concentration of creatinine, it can be an indication that a person’s kidneys are not functioning properly. The presence of sugars or ketones may indicate the presence of diabetes.

CONTENT READING MATERIALS

Anticipation Guides help engage students by activating prior knowledge and stimulating student interest. If class time permits, discuss their responses to each statement before reading each article. Students should read each selection and look for evidence supporting or refuting their initial responses.

Directions for all Anticipation Guides: In the first column, write "yes" or "no" indicating your agreement with each statement. As you read, compare your opinions with information from the article. Cite information from the article that supports or refutes your original ideas.

Antibacterials—Fighting Infection Where it Lives

Me	Text	Statement and Information from Article
		1. People have known since ancient times that hand washing helps prevent many illnesses and infections.
		2. Your desk at school probably harbors more bacteria than a toilet seat in the school restroom.
		3. When you use hand sanitizers containing alcohol, the bacteria you encounter for the next 2 hours will be killed.
		4. Most scientists agree that we should stop using antibacterial soaps because they contribute to antibiotic resistance.

Tapping Salt Water for a Thirsty World

Me	Text	Statement and Information from Article
		1. Most of the world's desalination plants are in the Middle East.
		2. Reverse osmosis plants use less energy than desalination plants to produce fresh water.

		3. Reverse osmosis membranes work much like cell membranes to regulate ion concentration.
		4. Most of the fresh water on Earth is unavailable for human use.

Urine: Your Own Chemistry

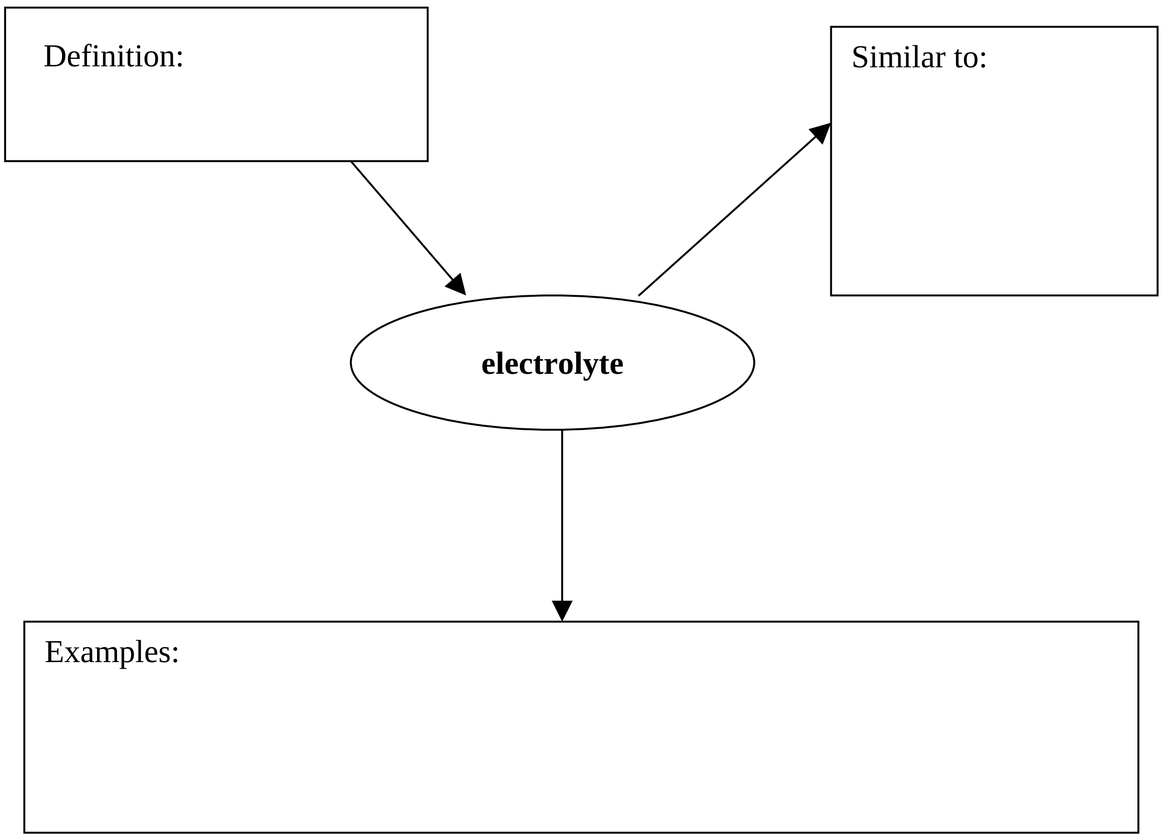
Me	Text	Statement and Information from Article
		1. Healthy people have pale yellow urine.
		2. Urine is normally full of bacteria.
		3. Urea, uric acid, and creatinine are composed of only carbon, hydrogen, nitrogen, and oxygen.
		4. Heredity and what you eat and drink affect your urine.

The Search for Martian Water

Me	Text	Statement and Information from Article
		1. Scientists have analyzed water samples from Mars.
		2. The presence of water on Mars is a certain indication that life has existed there.

Vocabulary Maps

Two important terms students need to know to understand the October 2002 articles are **electrolyte** and **spectrometry**. Vocabulary maps help make the meanings clear:



Structured note-taking helps students take notes effectively in a visual framework that helps them learn. The graphic organizers provided can help students learn how to organize information as they read.

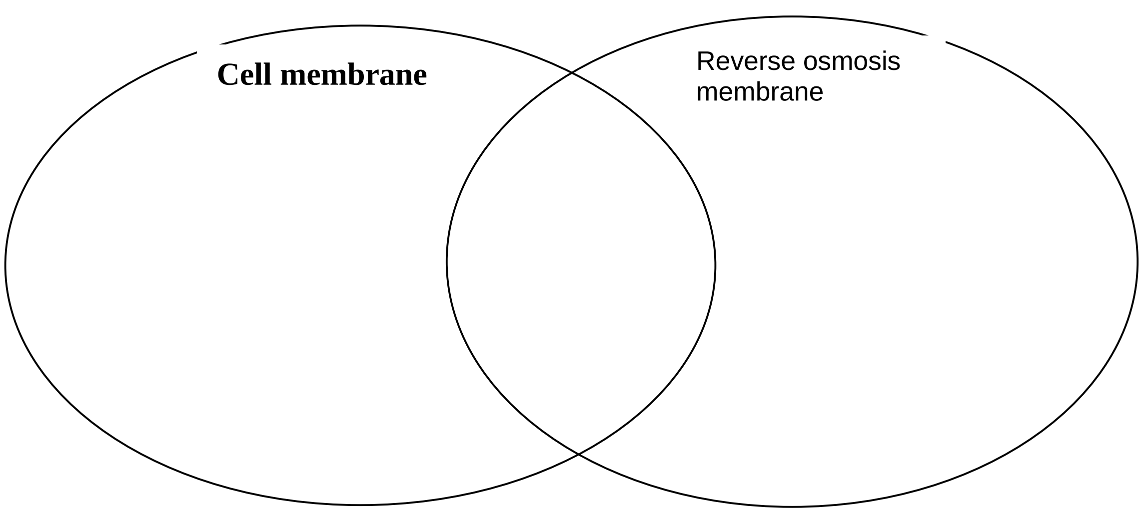
Antibacterials—Fighting Infection Where it Lives

As you read, look for support for using antibacterials and reasons not to use them. Include scientists who support each side. When you finish reading, write a paragraph expressing your opinion on the use of antibacterials.

Antibacterial Products	
Pro	**Con**

Tapping Salt Water for a Thirsty World

A **Venn diagram** comparing cell membranes with reverse osmosis membranes can help you visualize important differences between the two. List how they are different in the outside circles and their similarities where the circles overlap.



Use the following table for finding connections between the October 2002 articles and the **National Science Education Content Standards** for grades 9–12.

✓ = Strong connection

National Science Education Content Standard Addressed As a result of activities in grades 9-12, all students should develop understanding	**Anti-bacterials**	**Tapping Salt Water**	**Urine**	**Martian Water**
Science as Inquiry Standard A: about scientific inquiry.	✓			✓
Physical Science Standard B: of the structure and properties of matter.	✓	✓	✓	✓
Physical Science Standard B: of chemical reactions.			✓	
Physical Science Standard B: of interactions of energy and matter.				✓
Life Science Standard C: of the cell.		✓	✓	
Life Science Standard C: of biological evolution.	✓			
Life Science Standard C: of the interdependence of organisms.	✓			
Earth and Space Science Standard D: of geochemical cycles.		✓		
Earth and Space Science Standard D: of the origin and evolution of the universe				✓
Science and Technology Standard E: about science and technology.		✓	✓	✓
Science in Personal and Social Perspectives Standard F: of personal and community health.	✓	✓	✓	
Science in Personal and Social Perspectives Standard F: of natural resources.		✓		
Science in Personal and Social Perspectives Standard F: of environmental quality.	✓	✓		
Science in Personal and Social Perspectives Standard F: of science and technology in local, national, and global challenges.	✓	✓	✓	✓

History and Nature of Science Standard G: of science as a human endeavor.	✓			
History and Nature of Science Standard G: of the nature of scientific knowledge.	✓			✓
History and Nature of Science Standard G: of historical perspectives.	✓			✓