Bend a Carrot

Learning Objectives: *Students understand the process of osmosis, the net movement of water through a barrier.*

GRADE LEVEL

5–8

SCIENCE TOPICS

Atoms and Molecules
Techniques
Organic & Biochemistry

PROCESS SKILLS

Comparing/Contrasting
Describing/Defining
Controlling Variables
Explaining

GROUP SIZE

1–2

SNEAK PEAK inside …

ACTIVITY

Students observe changes in carrots exposed to salt.

STUDENT SUPPLIES

see next page for more supplies

carrots
sealing plastic bags (e.g., Ziploc™)
salt
plastic cups and spoons, etc.…

ADVANCE PREPARATION

see next page for more details

Fill student cups with salt
Put out carrots, etc.…

OPTIONAL EXTRAS

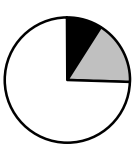
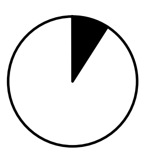
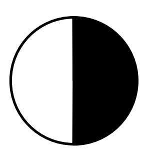
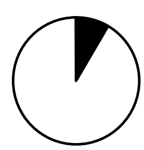
DEMONSTRATION

Super-Absorbent Diapers (p. C - 3)
Expanding Crocodiles (p. C - 5)

EXTENSIONS

Measuring Water Loss (p. C - 10)
Hypertonic and Hypotonic Solutions (p. C - 11)
Inquiry Opportunity—Test Variables (p. C - 12)

TIME REQUIRED

Advance Preparation	Set Up	Activity	Clean Up
			
5–15 minutes	**5 minutes**	**30 minutes**	**5 minutes**

SUPPLIES

Item	Amount Needed
carrots (purchase baby carrots or cut large carrots to 3" sticks)	4 per group
sealing plastic bags (e.g., Ziploc™)	2 per group
permanent markers (e.g., Sharpie™)	1 per group
salt	¼ cup per group
small plastic cups, 8 oz.	1 per group
plastic spoons	1 per group

For Extension or Demonstration supplies, see the corresponding section.

ADVANCE PREPARATION

Supplies Preparation

Carrots:

- ❑ Purchase peeled or unpeeled baby carrots.

OR

- ❑ Purchase large carrots and cut into 3" sticks.

Salt:

- ❑ Fill plastic cups with 2 spoonfuls of salt.
- ❑ Label the plastic cups "salt."

SETUP

For each group

- ❑ 4 carrots (or carrot pieces)
- ❑ 2 sealing plastic bags
- ❑ 1 permanent marker
- ❑ 2 spoonfuls salt in a plastic cup
- ❑ 1 plastic spoon

At a central location (or with the teacher)

- ❑ sponges and towels for clean up

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided primarily for the teacher's benefit.

Choose questions that are appropriate for your classroom.

In this activity, students will add salt to raw carrots and observe the water come out of the carrots.

Have you ever seen wilted plants? What makes plants wilt? What makes plants stand up straight?
A lack of water will make a plant wilt. Giving a plant water will help it stand up straight.

How does the water from the pot get into the plant?
Water moves from the soil into the roots. The water can then move through the plant.

If water moves into plants, can it move out of them? How does water usually leave a plant?
Students may say that water goes back into the soil, that it disappears, or that it evaporates as from a pan left on the countertop.

In this activity, students will have the opportunity to see how the water in plants and plant roots (carrots) responds to salt concentrations. They will see osmosis at work.

CAUTION: Never put lab supplies in your mouth. Even if lab supplies are foods, they may be contaminated by other items in the lab.

TEACHER DEMONSTRATION

Because the osmosis activity takes some time, you may wish to have the students start the activity first. Then do a demonstration while you are waiting for the osmosis to proceed.

Super Absorbent Diapers
Show how much water a diaper can absorb.

Supplies
- ❑ overnight diaper
- ❑ scissors
- ❑ 1 gallon sealable plastic bag (e.g., Ziploc™)
- ❑ 2-L bottle filled with water
- ❑ 2 tablespoons of salt

Demonstration

- Holding the diaper in the bag, cut open the diaper. Inside the diaper, find the powder-filled absorbent pad. Leave the pad and powder in the bag and remove the rest of the diaper. (Keeping the pad and powder inside the bag keeps the powder from spreading.)
- Add water to the bag a little at a time, sealing and squishing the bag between each addition. Pass the bag around the classroom for students to squish as well. One large diaper will hold approximately
  2 liters of water in a spongy gel.
- Add 2 tablespoons of salt to the gel in the bag. Massage this thoroughly into the gel. All the water will come out of the gel and can be seen in the bag.

CAUTION: Although the powder and gel are non-toxic, it is best not to touch either. The powder or gel can be washed off of skin with soap and water.

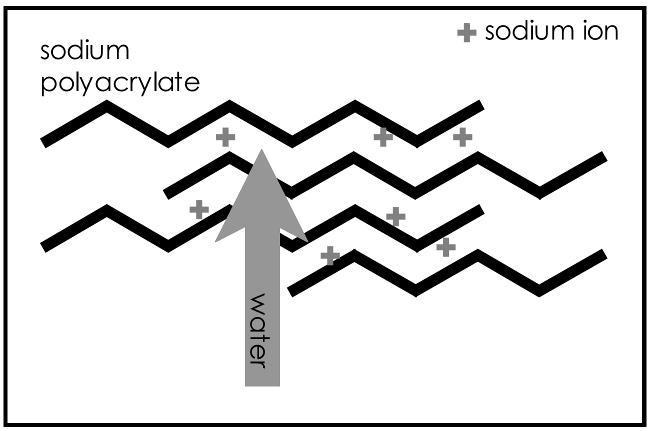


Figure 1 When sodium polyacrylate is surrounded by plain water, the concentration of sodium is less outside the net. In this case, water rushes into the network.

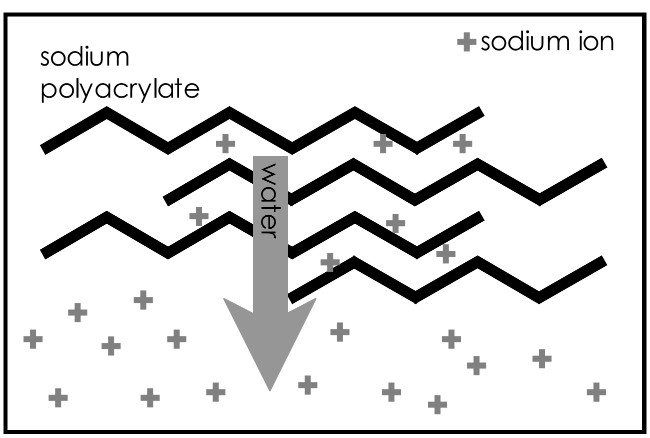


Figure 2. When sodium polyacrylate is surrounded by salt, the concentration of sodium is greater outside the net. In this case, water rushes out of the network.

Explanation

The powder in the diaper is a chemical called sodium polyacrylate. Sodium polyacrylate is amazingly absorbent. It can absorb 500 to 800 times its weight in pure water.

Sodium polyacrylate is made of long molecular chains connected in a large network (see Figure 1). This network is similar to a cell membrane in that it allows water to pass through. Trapped inside this network are charged particles of sodium called **ions**. When water is first added to the powder, the concentration of sodium ions inside the network is higher, so water rushes into the gel. The sodium polyacrylate network stays intact but swells to form a soft gel.

When salt is added, the water rushes out again. Table salt is a chemical called sodium chloride. Salt contains sodium ions, like the polyacrylate. When you add salt to the gel, the increased sodium ion concentration on the outside pulls the water out (see Figure 2). Diapers normally do not absorb as much urine as water because urine contains dissolved salts.

Expanding Crocodile

Watch a toy grow as it absorbs water over several days.

Supplies

- 3 toy expanding crocodiles (available at toy stores, the OMSI Science Store, 503-797-4626, or Flinn Scientific, www.flinnsci.com)
- 2-L bottle filled with water
- 2-L bottle filled with salt water (3 tablespoon of salt to 2 liters of water)

Demonstration

- Put one toy crocodile into the bottle filled with water.
- Put one toy crocodile into the bottle filled with saltwater.
- Save the third crocodile for comparison.
- Allow the bottles to sit for at least 48 hours.
- Compare the sizes of the crocodiles in the bottles to the dry crocodile.

Explanation

The toy crocodiles are made from two polymers—starch and polyacrylonitrile—and glycerin to form a plastic gel that can be molded into a toy. These polymers work in a similar way as the sodium polyacrylate in disposable diapers. The plastic gel in these toys can absorb up to 400 times its mass in water.

The crocodile in the salt water will not grow as much as the one in plain water. This is because there are sodium ions in the water outside the crocodile as well as in the crocodile.

If you remove the crocodiles from the water, they will dry and return to their original size.

CLASSROOM ACTIVITY

Have students follow the Scientific Procedure on page C - 14, working in groups of 1–2. Below are suggestions to help the teacher facilitate the activity.

NOTES

Bend a Carrot

This handout is on p. C - 14.

SCIENTIFIC PROCEDURE

1. Label your bags.
   - Label one bag "Salt" and the other bag "No Salt."
2. In the bag labeled "Salt" add 1 spoonful of salt.
3. Add two carrots to each bag.
   - Shake the bag to mix the carrots and the salt.
   - Wait about 30 minutes.
4. Observe your carrots.
   - How have the carrots changed?

Running Suggestions

- Because the osmosis activity takes 15–30 minutes, you may wish to start the activity with students first. Then do a demonstration while you are waiting for the osmosis to proceed.
- You may choose to have students keep their bags of carrots in the classroom overnight. After 24 hours, even more water will move out of the carrots.

Ongoing Assessment

- Circulate around the room and ask students for their observations. Encourage them to touch the carrots through the bags.
- How are the carrots the same in each bag? How are they different?
- Is there new material appearing? Where is it coming from?

Misconception alert: When students see the water come out of the carrots in this experiment, they may think the salt is melting, since the source of the water is not clear, and since the amount of salt seems to decrease as it dissolves in the water from the carrots.

Safety and Disposal Information

- All materials may be thrown away.

CAUTION: Never put lab supplies in your mouth. Even if lab supplies are foods, they may be contaminated by other items in the lab.

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

How do the carrots look after being in the bags? How are they the same? How are they different?
The carrots from the bag with salt bend easily. There is a lot of water in the bag with the salt. The carrots in the bag without salt look the same as when they started.

What would happen if we left them in for a longer time?
The carrots would lose more water; other students might believe they have already lost all their water.

How is this similar to what happens in plant roots?
When the soil is dry, water moves out of the roots into the soil. Alternatively, when the soil is salty and wet, water also moves out of the plant roots into the soil.

Does this only happen with salt or would it happen with other chemicals as well?
Yes, it happens with all particles. Soil has no salt, but when the soil around plant roots is dry, the water will leave the roots. Maybe we should do the same experiment with something else to test.

Students should understand that through osmosis, the water moved from the carrots to the salt. Salt contains sodium ions in higher concentration than that in the carrot, so the water moves out of the carrot.

EXPLANATION

This background information is for teachers. Modify and communicate to students as necessary.

This experiment investigates the movement of water into and out of cells. The movement of water in and out of cells depends on the amounts of dissolved chemicals (like sugar or salt) inside and outside of cells. Plants rely on the water in their cells to help them stand up straight—they wilt when they don't have enough water in their cells.

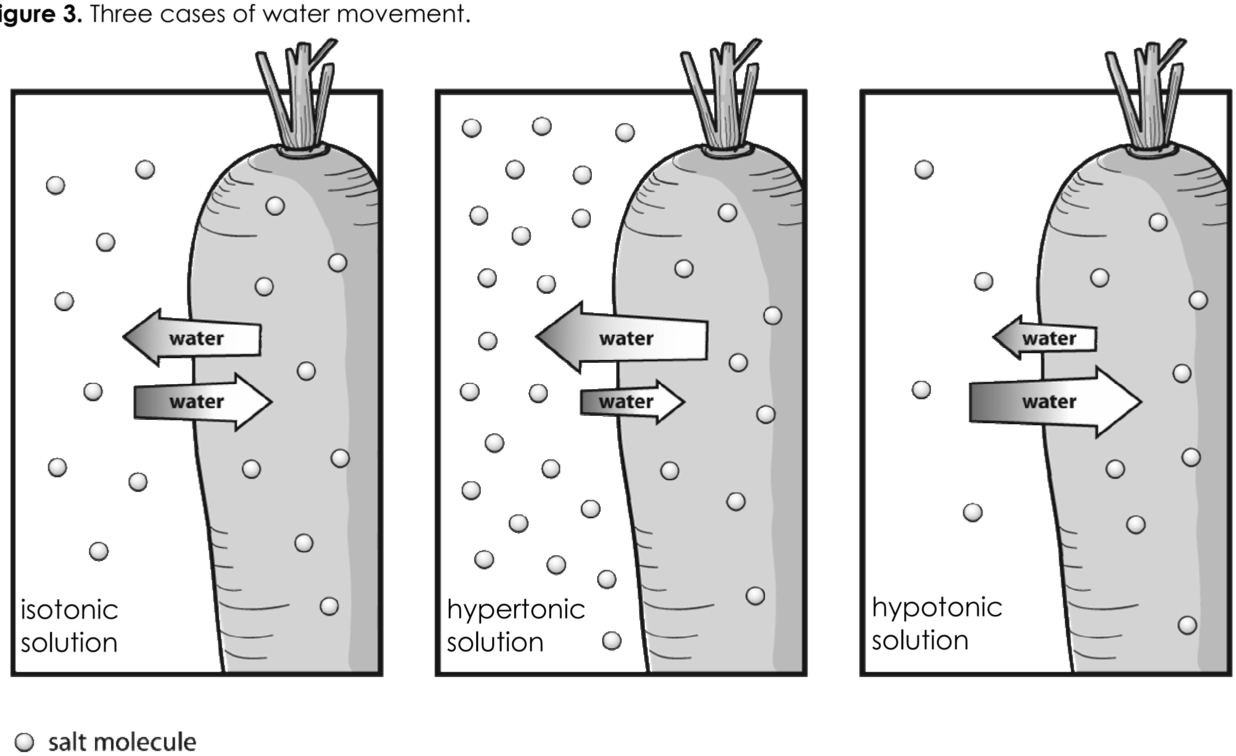
Movement of Water

All cells are surrounded by a barrier called a **cell membrane**. The cell membrane controls the movement of most chemicals into and out of the cell. One exception to this is water. Cell membranes allow water to move into and out of the cell. When water moves across a cell membrane in a particular direction (see Figure 3), it is called **osmosis**.

The direction water moves across the membrane depends on the **concentration** of particles (e.g., the amount of dissolved salt, sugars, starch, etc.) inside and outside the cell.

ISOTONIC: When the concentration of particles inside and outside the cells is the same, the solutions are **isotonic** (*iso-* means *same* and *–tonic* means *solution*). In this case, water moves equally into the cell and out of the cell.

Figure 3. Three cases of water movement.



HYPERTONIC: When the concentration of particles outside the cell is greater than the concentration inside, the outside is called **hypertonic** (*hyper-* means *more*). In this case, more water will move out of the cell. As water leaves the cell, the cell starts to shrivel and shrink.

HYPOTONIC: When the concentration of particles outside the cell is less than the concentration inside, the outside is called **hypotonic** (*hypo-* means *less*). In this case, more water will move into the cell than out.

In other words, osmosis is the spontaneous, net movement of water to an area of higher concentration of particles.

Plants and Osmosis

When plant cells are placed in solutions of low concentration, they have a strong advantage over animal cells. Living cells are full of sugars, salts, and other chemicals. This means there is usually a higher concentration of particles inside the cell, and water will move into cells.

So much water can move into animal cells in this way that they might eventually **lyse** (break open). This is similar to inflating a balloon until it pops. Plant cells have an advantage because they have an extra barrier around the cell membrane called a **cell wall** (see Figure 4). The rigid cell wall provides extra structural support, helping plant cells to not break open as easily.

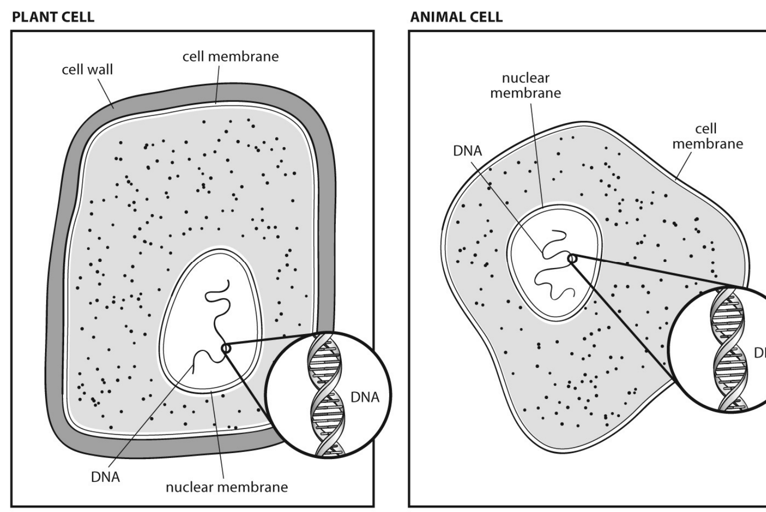


Figure 4. Structure of plant cells and animal cells. The rigid cell walls in plant cells keep the cell from bursting when water enters.

When a plant's cells are filled with water (or **turgid**) they become physically strong enough to hold up the weight of the plant.

When the soil around the roots of a plant is dry, the concentration of particles outside the plant is now greater. Plant cells lose water, the cells shrivel, shrink, and the plant wilts.

Water Regulation is the Key to Cell Function

Many forms of life, including fish, use a special technique (called **osmoregulation**) to control the flow of water into and out of their cells. For example, saltwater fish must keep the water in their cells from flowing out into the salty water around them, because that water has a higher concentration of dissolved particles. On the other hand, fish swimming in freshwater need to prevent freshwater from flowing into their bodies, because their cells have a higher concentration of particles.

Misconception Alert: Even though all the examples in this explanation refer to the concentration of salt solutions, osmosis is not limited to salt. Starch, sugar, and other minerals also dissolve to increase concentrations and cause water to move into and out of cells.

EXTENSIONS

Extension A: Measure Water Loss

Measure the mass of the carrots before and after the activity.

Extra Supplies

- balance or scale that can measure in grams or fractions of ounces

Extra Instructions

- Mark or arrange the carrots in some way to tell them apart.
- Record the mass of each carrot before the activity.
- After the activity, rinse and dry all carrots.
- Record the mass of each carrot after the activity.

Explanation

The change in mass of the carrots is:

mass of water lost = initial mass of dry carrot – final mass of dry carrot

Students can assume the change in mass is due to the mass of water lost, either through evaporation or osmosis. Additionally, since the density of water is about 1 gram per
1 milliliter, students can find the **volume** of water lost by the relation

1 g water = 1 milliliter water

Extension B: Hypertonic vs. Hypotonic (Grades 7–8)
Place carrots into different kinds of salt solution to see what happens to them. Students should predict what direction osmosis will occur and then test their predictions.

Extra Supplies

- plastic cups, 6 oz. or larger
- salt
- measuring spoons, ½ teaspoon and 1teaspoon
- pop-top squeeze bottles (e.g., water or sports drink) filled with water

Extra Instructions

- There is an additional Scientific Procedure sheet on p. C - 15.
- Label the cups #1, #2, #3, and #4, or with the salt amounts. (An example range is shown; other ranges of salt concentration will also work.)
  - #1: none
  - #2: ½ teaspoon
  - #3: 1 teaspoon
  - #4: 2 teaspoons
- Add the above amounts of salt to the corresponding cup.
- Add water to each of the 4 plastic cups for the same total volume.
- Leave carrots in the solutions overnight.

Explanation

The water inside carrots contains all the sugars, salts, proteins, and DNA of the carrots. Pure water is hypotonic to (less concentrated than) this solution. When carrots are placed in pure water, the water moves into the carrot through osmosis, causing them to swell and become stiff; some carrots may crack open due to the pressure.

Each salty water solution used in this extension may be more or less concentrated than the solution inside carrots. If the solution is more salty (i.e., hypertonic) than the carrots, the carrots will become squishy and may shrink, just as in the regular activity.

Extension C: Inquiry Opportunity—Test Variables
There are many possible variables to change in this experiment.

Additional materials
- different vegetables (e.g., celery, potatoes, cucumbers)
- different solids (e.g., sugar, baking soda, Epsom salt, detergent, calcium chloride)
- different liquids (e.g., vinegar, oil, corn syrup)
- pop-top squeeze bottles (e.g., water or sports drink) to contain different liquids

For more information about experimental design, see the section **Science Inquiry** in the beginning of the Guide.

Explanation

Younger students can design a simple experiment using the standard directions. Older students should use techniques learned in Extensions A and B to design a scientific investigation. Students should predict the direction of osmosis, test, and explain their results.

CROSS-CURRICULAR CONNECTIONS

MATHEMATICS — **Graphing Change**

After doing Extension A, students can make a bar graph comparing the change in mass of carrots mixed with salt to those without.

SOCIAL STUDIES — **Research Report**

Carrots have a long history. From their humble beginnings as a white or purple root in Afghanistan, to their current value as a modern source of vitamins and antioxidants, there is much to be learned about this amazing vegetable. A good start is the link to the Carrot Museum listed in Resources.

RESOURCES

Web – http://jchemed.chem.wisc.edu/HS/classAct/ClassActsList.html
The Journal of Chemical Education publishes online lesson plans for high school students on multiple topics. Under the topic, Biochemistry, the lesson by Bertoluzzo, et al. investigates osmosis. The first half of the investigation requires advanced technique and chemicals. The second investigation is appropriate for younger students. Students observe onionskin under a microscope as water and saltwater solutions are added.

Web – http://www.tvdsb.on.ca/westmin/science/sbi3a1/cells/osmosis.htm
Good graphics about the process of osmosis in hypertonic, hypotonic, and isotonic solutions.

Web – http://www.carrotmuseum.co.uk
An extensive site about carrots, their history, their cultivation, nutritional value, and literary references. Contains many links to external sites as well as detailed information on the site.

VOCABULARY

cell membrane: a thin barrier that surrounds the contents of plant and animal cells, controlling the passage of water and other chemicals both into and out of the cell

cell wall: the rigid outermost cell layer found in all plants and some algae, bacteria, and fungi; absent from all animal cells

concentration: the ratio of the amount of a chemical in a solution to the volume of the solution

hypertonic: having a higher concentration of particles in solution; *hyper* means *more*

hypotonic: having a lower concentration of particles in solution; *hypo* means *less*

ions: an electrically charged atom or group of atoms

isotonic: having the same concentration of particles in solution; *iso* means *same*

lyse: to break open or split

osmoregulation: the process whereby living cells control the flow of water across their cell membranes

osmosis: the movement of water molecules across a barrier; water spontaneously moves from a region of low particle concentration to a region of high particle concentration

turgid: so full of water as to be stiff and rigid

Bend a Carrot

SCIENTIFIC PROCEDURE

1. Label your bags.
    - Label one bag "Salt" and the other bag "No Salt."
2. In the bag labeled "Salt" add 1 spoonful of salt.
3. Add two carrots to each bag.
    - Shake the bag to mix the carrots and the salt.
    - Wait about 30 minutes.
4. Observe your carrots.
    - How have the carrots changed?
    - How are the carrots different in each bag?
    - How do the carrots feel when you bend them?
5. Clean up your area.
    - Follow your teacher's directions.

Bend a Carrot

SCIENTIFIC PROCEDURE—Extension B

1. Label your cups.
   - Write your name(s) on all cups.
   - Label the cups: "water," "½ teaspoon salt," "1 teaspoon salt," and "2 teaspoons salt."

2. Add salt and water to your cups.
   - Carefully add the correct amount of salt to each labeled cup

3. Add water to the cups so that each has the same total amount of liquid. The amount is not important, except that it be the same.
   - Stir the solutions in each cup.

4. Add two carrots to each cup. Leave the cups overnight.

5. The next day, observe your carrots.
   - Which solutions were hypotonic (less salt) compared to the carrot?
   - Explain how you know.

   - Which solutions were hypertonic (more salt) compared to the carrot?
   - Explain how you know.

   - Which solution was isotonic (equal salt) compared to the carrot?
   - Explain how you know.

6. Clean up your area.
   - Follow your teacher's directions.

This worksheet is available online at **www.omsi.edu/k8chemistry**.

Bend a Carrot

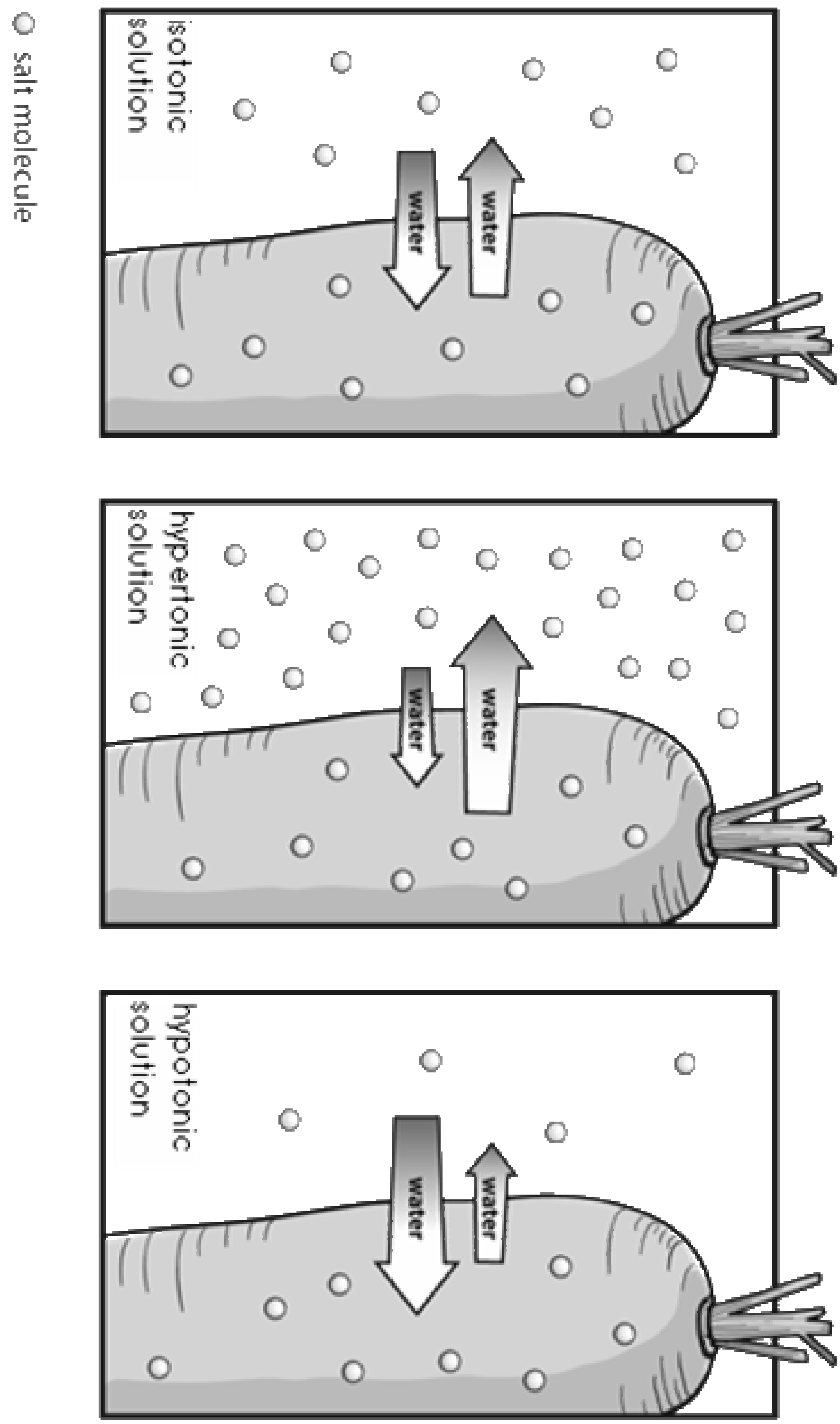
Recommended group size: 1–2

Number of Students: ☐ Number of Groups: ☐

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
carrots (baby carrots or cut large carrots to 3" sticks)	4 per group		
sealable plastic bags (e.g., Ziploc™)	2 per group		
permanent markers (e.g., Sharpie™)	1 per group		
salt	¼ cup per group		
small plastic cups, any size	1 per group		
small spoons (e.g., teaspoons)	1 per group		
masking tape	1 roll per class		
Extension A			
balance or scale	1 per group or a few for class to share		
Extension B			
plastic cups, 6 oz. or larger	4 per group		
additional salt	¼ cup per group		
measuring spoons, ½ teaspoon and 1 teaspoon	1 each per group		
pop-top squeeze bottles (e.g., water or sports drink) filled with water	1 per group		
Extension C			
different vegetables—for example, celery, potatoes, cucumbers cut to 3" sticks	4 pieces of each vegetable per group		
different solids—for example, salt, sugar, baking soda, Epsom salt, detergent	¼ cup per group		
different liquids—for example, vinegar, oil, ammonia, corn syrup	1 cup per group		
pop-top squeeze bottles (e.g., water or sports drink) to contain different liquids	2–3 for each liquid		

Supply Worksheet continues on next page.

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
Teacher Demonstration			
Super Absorbent Diaper			
overnight diaper	1 per class		
scissors	1 pair for class		
1 gallon sealable plastic bag (e.g., Ziploc)	1 for class		
2-L bottle filled with water	1 for class		
salt	2 tablespoons		
Expanding Crocodile			
toy expanding crocodiles (available at toy stores, the OMSI Science Store, 503-797-4626, or Flinn Scientific, www.flinnsci.com)	3 per class		
2-liter bottles	2 per class		
salt	3 tablespoons		


salt molecule
isotonic solution
water
water
hypertonic solution
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