Water Beads – Teacher Notes

By Louise Lopes

Introduction:

This investigation combines play with scientific discovery and learning. Water beads provide great tactile fun which makes them irresistible to touch, while also displaying interesting properties that encompass topics within Chemistry, Biochemistry and Physics. They are made up of a polymer which is superabsorbent, absorbing water up to 300 times their size!

The essence of scientific inquiry is to explore the world around us and solve mysteries that we uncover. This investigation allows students to do just that. It has been planned to be at an open inquiry level, in which students choose their own question, method and how to record and analyse their data. By doing this, students throughout grades 7 to 10 can develop their science inquiry skills.

The ability and grade level of students can determine the depth of study done within this investigation. Year 7 can benefit from learning more about solvents and solutes. Year 8 can identify whether chemical or physical changes are taking place, and they can learn about the solid-liquid state of gels and how scientists create new materials in the lab. Year 9 can learn the process of osmosis, which is an essential process for cell life, and how light refracts through lenses and other various mediums. Year 10 can learn how the molecular properties of water beads (a cross-linked polymer) create their interesting effects.

Water beads also have interesting real-life applications, such as in sustainable water management and design. They make great table top decorations when colours are added! Suggestions for discussion topics and extra guidance are provided throughout.

Question:

In order to engage students with play from the start, it is recommended that students are given the water beads already submerged in liquid. In this way, students are presented with what looks like a glass of water only. The very first question that students face is "**where are the balls**"? As they manipulate the glass with their hands, they will find that the water contains transparent slimy balls. The first mystery is solved!

Part A is a continuation of this initial exploratory phase. Students are given time to play with the water beads in order to discover any other interesting properties. Students are asked to write down as many observations as they can. These observations will serve as a basis for the formal investigation they are to conduct in Part B. It is recommended that a class discussion is held so that all students can contribute their findings and a master list is made on the board.

In Part B, students are required to come up with a question in which they can scientifically test for. They can be presented with an additional materials list in order to open up the scope of what they can test for. For extra guidance, or if teachers wish to guide students towards a particular discipline, the following list of questions has been provided:

INVESTIGATION QUESTIONS	
Chemistry	• Will the water beads absorb additives in the water, such as food colouring? • What type of water make the biggest balls (i.e. tap water, distilled water, mineral water, carbonated water, sea water or deionised water)? • What ways can water be extracted from the beads? (I.e. Can you squeeze the beads? Can you pop the beads? Can you “cut-open” the beads? Can you put salt on them? Can you put them in an acid or base solution?) • What happens when enlarged water beads are placed in a different type of solution? Do they shrink? Do they float?
Physics	• How does the water content of the beads relate to their bounce efficiency? • How much water do the beads need to absorb until they become “invisible” in water?
Maths Focus	• Calculate how much solution has been absorbed over a 24 hour period. • Calculate what proportion of the beads is made up of the polymer and which proportion is water. • Calculate how many times the water beads expand from their original size.
Biology	• Research the way that water beads absorb water and how this process is essential for life.
Environmental	• Research ways that water beads could be used in water management for agriculture and gardening.

In order to assist students with their question, they are asked to identify their variables. This will require that students focus on what components they are actually testing, which will greatly assist them when writing an Aim and Hypothesis.

Plan:

Water beads come in many different colours and sizes. It is recommended that students are given non-coloured balls as they display the most interesting properties.

Warning: While water beads are considered non-toxic, they are dangerous to consume. If this does happen, seek medical help immediately. Store beads away from children and pets.

Students are asked to describe the way that they plan to conduct their tests. Time may be allocated for student lab groups to construct a step by step method before commencing the experiment. Students can then present a list to the teacher of materials that are required. Alternatively, students may be allowed more freedom by getting access to additional materials at first and then developing a method as they go along. If this option is chosen, it is recommended that teachers facilitate this process by allocating a note-taker for each lab group.

Below is a comprehensive materials list that will allow students to test many different things:

- Completely dried out water beads
- Beakers or cups
- Kitchen scales or measuring cups
- Rulers, tape measure or calliper (if a calliper is not available, students can tape a toothpick to a ruler at zero and use a second toothpick to get the reading).
- Deionised water (works best), distilled water, tap water, seawater, etc.

- Salt, sugar, food colouring, vinegar (acid) or baking soda (base)
- pH paper
- Butter knife or scissors (for cutting the balls)
- Stop watch
- Time-lapse camera, high-speed camera

Conduct:

In Part A, students are advised to record qualitative results by writing down as many observations as they can make. This will assist students later when they are asked to apply scientific theories to explain the properties of water beads. For extra guidance with this activity, the teacher may offer starter questions such as: Do these balls bounce? What happens if you leave the balls outside water? How do the beads feel on skin before and after they have absorbed water? How do images from different distances appear when looking through the water balls? Describe what happens when you squeeze them tightly – do they burst or fall apart?

In Part B, students would have chosen a specific property to test. If they have chosen an effective plan and measuring techniques then they will be able to obtain meaningful quantitative data. It is expected that there will be a range of methods and number of tests conducted between student lab groups. If students are having difficulty with thinking of ways to test their specific question, the following guidance can be given:

INVESTIGATION PROCEDURES	
Absorbing additives	Test this by seeing if you can get the transparent balls to turn into different colours by putting food colouring in the water.
Finding best solution	Placing the balls in different solutions, and then measuring the circumference of the balls with a calliper or micrometre. Minimise time for soaking in order to get more noticeable differences between samples.
Floating water beads	Allow water beads to soak in a solution that has a relative low density (pure water), and then putting those beads into a solution with a higher density (salt solution).
Shrinking water beads	Place beads in a salt solution, or directly on salt. Any solution with a significant amount of electrolytes will do this.
Bounce efficiency	Calculate this by sticking a measuring tape up against a piece of furniture or the wall and bounce the ball from a specific height, then measure the tallest height it reaches after the first bounce.
Invisibility in water	Weigh the balls when they are dry. Put them in water and look out for when they become invisible (use a stop-watch to make assessments at certain increments of time, such as once per minute). Once you can no longer see them, take them out of the water and measure their weight/circumference.
Making calculations	Weigh the beads before and after they have been sitting in water over-night. **OR** Weigh cup of water. Put beads in over-night and place in a cool dark place (to minimise evaporation). Carefully remove beads with a straining ladle. Measure how much water remains. **OR** Measure the circumference of the beads before and after they have been sitting in water over-night. **OR** Do all three to compare!

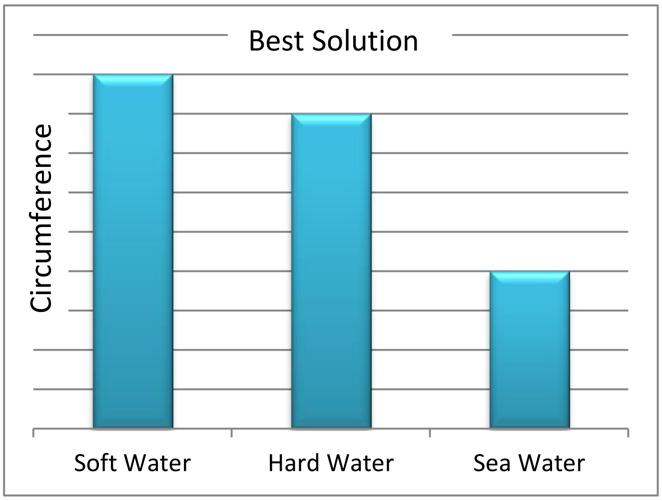
Students will have to record results for their independent and dependent variables. Teachers can guide students towards carefully constructing a table that displays all components that they are testing. Discuss with students the importance of taking multiple measurements and having duplicate specimens in order to find an average.

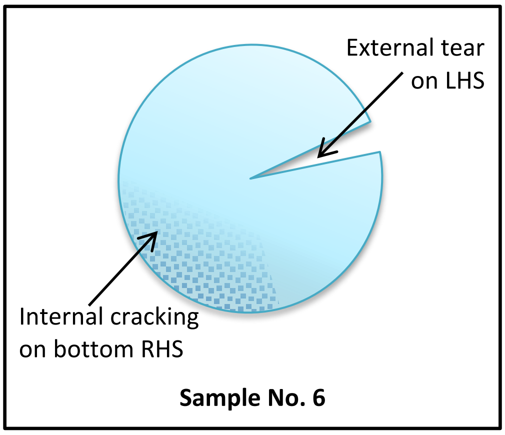
Below is just one example of a results table that could be used:

Best Solution to Enlarge Water Beads (for 20 minutes)				
Solution	Circumference (mm)			
	1st Test	2nd Test	3rd Test	Average
Sea Water				
Coconut Water				
Distilled Water				
Tap Water				
De-Ionised Water				

<u>Analysis:</u>

In this section students are asked reflect on their results and choose a way to best represent their data visually. For example, a student that was testing what type of water made the best solution can draw a bar graph in order to make relationships between solutions more clear. Another student may instead choose to make detailed drawings of the water beads after they were placed on a pile of salt. As the water beads tend to crack and break, the student may carefully sketch and label these points of failure in the material. This could provide a map of what forces are at play which will aid students during the problem-solving stage.





Students who have chosen the Maths Focus questions can use this space to work out their calculations. The volume of a sphere (round water bead) is calculated by the equation,

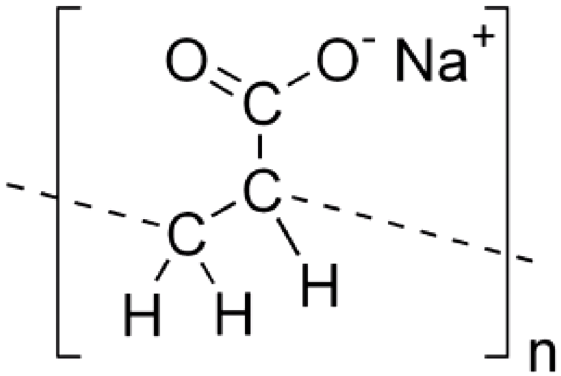
$$V = 4/3\pi r^3,$$

where V = volume and r=radius. Ensure students remember that radius is ½ of the diameter. Ask students whether they measured mm or cm. If finding for mL, then convert to cm as **cm³ = mL**. Students who have chosen multiple ways of calculating the expansion of water beads can also now compare their answers for each case.

Problem-Solving:

Evaluate: At this stage students can evaluate whether their experimental design was satisfactory. Did they test the correct things in order to obtain an answer to their question? Did they conduct a fair-test? Did students identify the main control variables, and were they able to implement strategies to keep them consistent throughout? Where there any forms of human error? Discuss these issues with students as they assess the reliability of their results.

What is a water bead made of? Water beads are made up of a polymer, which is a word to describe a material made up of very long chain molecules. Water beads have cross-linked polymers, meaning there are bonds from one polymer chain to another. This is what gives the water bead its consistent shape. The polymer used is a superabsorbent polymer because it can absorb large quantities of water, up to 300 times its weight. The most common water beads are made of sodium polyacrylate polymer.



Sodium Polyacrylate

Is a hydrated water bead a solid or a liquid? Water beads are classed as a hydro-gel, a type of non-Newtonian fluid, which behaves as a liquid and a solid under different conditions, such as when stress and force are applied. Even though hydro-gels are mostly liquid by weight, their polymerisation makes them behave like a solid.

How do water beads absorb water? The polymers in water beads contain salt that attracts water molecules. This attraction is the same force that allows salt to dissolve in water. It is due to the charge of ions being attracted to parts of the water molecule which have the opposite pole, causing them to "stick together" at a molecular level.

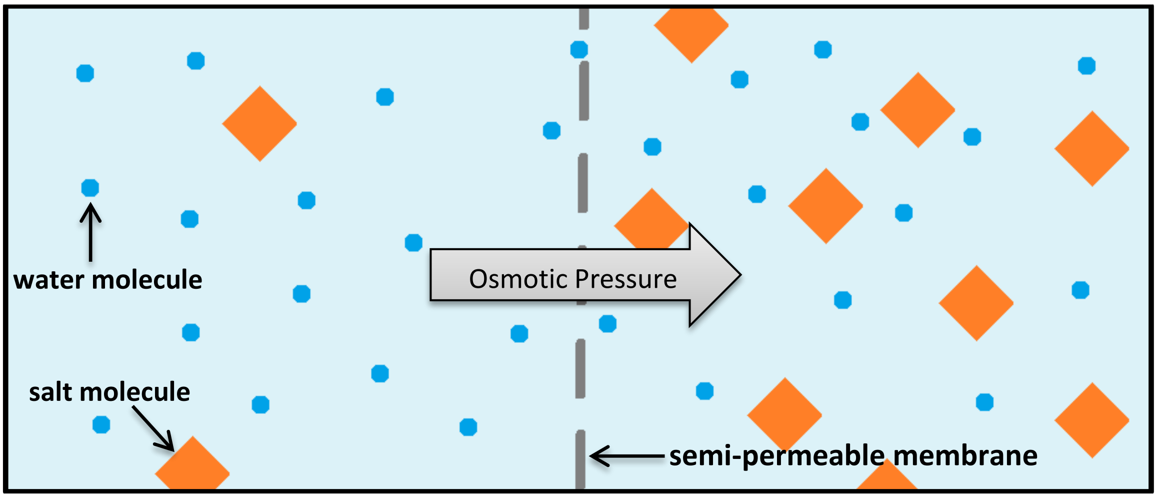
Looking at this in more depth, sodium ions (Na^+) in the polymer form a hydrogen bond with water molecules, drawing them into the gel. These sodium ions are trapped within the polymer, and therefore do not flow back out into the water. Once the water moves into the water bead, the polymer chains begin to straighten up and expand. This is not just due to extra mass, but also because of repulsive forces acting between negatively charged ions (carboxylate ions) in the polymer. This action also allows more water to move in as the surface area expands.

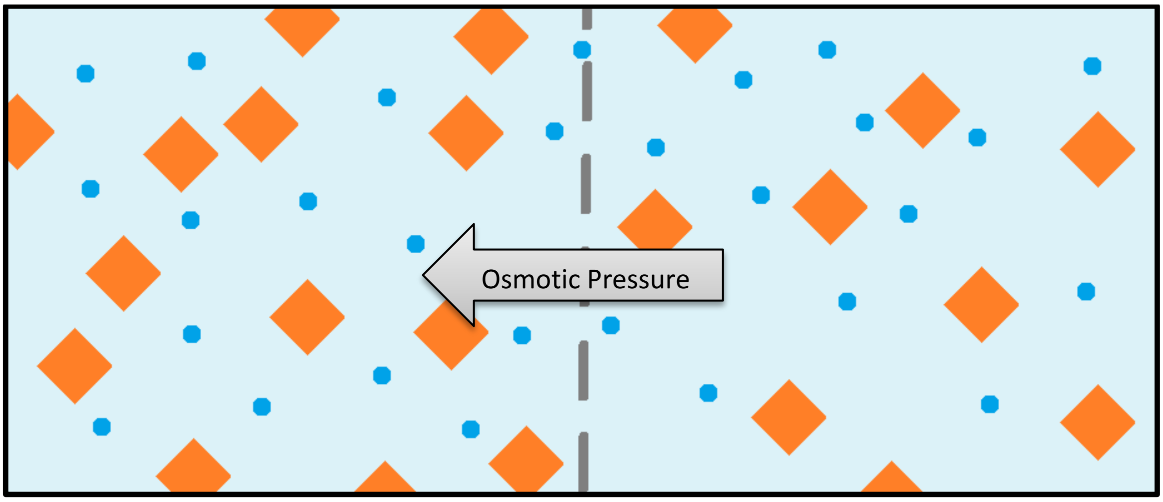
Why does deionised water work best? If many water beads are put into the same container, you will see that the water beads will still swell when they are sitting above the water line. How is it possible that water moves in a way that seems to defy gravity? This is due to the process of **Osmosis**.

Superabsorbent polymers act like semi-permeable membranes. This means that some things can pass through, while other things cannot. It also means that some things are more likely to pass through the membrane in one direction than in the opposite direction. Because of the higher salt concentration in the polymers, the water moves into the water bead, but not back out. This action is referred to as osmotic pressure.

Deionised water has had its mineral ions (salts) removed. Because it has the lowest particle concentration, it readily moves into the water beads. The osmotic pressure to move into the bead is at its highest.

Why does salt make the water beads shrink? This is for the same reason that deionised water works best to expand the water beads. Because the particle concentration is higher in salt water than in normal water, the osmotic pressure for water molecules to move into the gel decreases and can reverse. When water beads are placed directly on salt, they can crack and tear because the osmotic pressure is so strong that the material contacting the salt rapidly contracts and tears away from the rest of the bead.





Why do the water beads absorb the colouring? Additives in the water may lessen the osmotic pressure of water entering the gel, but that does not mean that some water won't make its way through. If the water has dissolved substances, then those substances will pass into the gel as well.

Why doesn't water spill out of water beads when they are cut? This is because water beads are not balloons with an external film structure that holds water within it. Water is absorbed at a molecular level.

Why do the water beads display strange shapes as they are getting larger, but then end up as a ball? The osmosis process in water beads is not uniform across its surface. It occurs with random movement of particles interacting with other particles. Different shapes occur as the water beads hydrate, such as 'berry' and 'brain' shapes. Until the material is pushed to its limits, it will stretch into to a uniform shape it had when dry. It also takes longer for the water to absorb into the inner layers of the polymer. If water beads are cut in the early stages of hydration, you will see that they are hard in the middle and squishy on the outside.

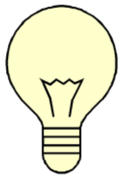
Why do water beads have the texture that they do? Hydrogels are squishy because of their significant water content. This is similar to natural tissue, giving them an organic feel. Moreover, we usually have salt on our hands from sweat; this causes the water beads to perspire in our hands, giving it an extra wet feeling.

Why do water beads that were sitting in pure water float when they are put into salt water? This is because salt water has a higher density than pure water. It is the same reason that air-filled pool toys float.

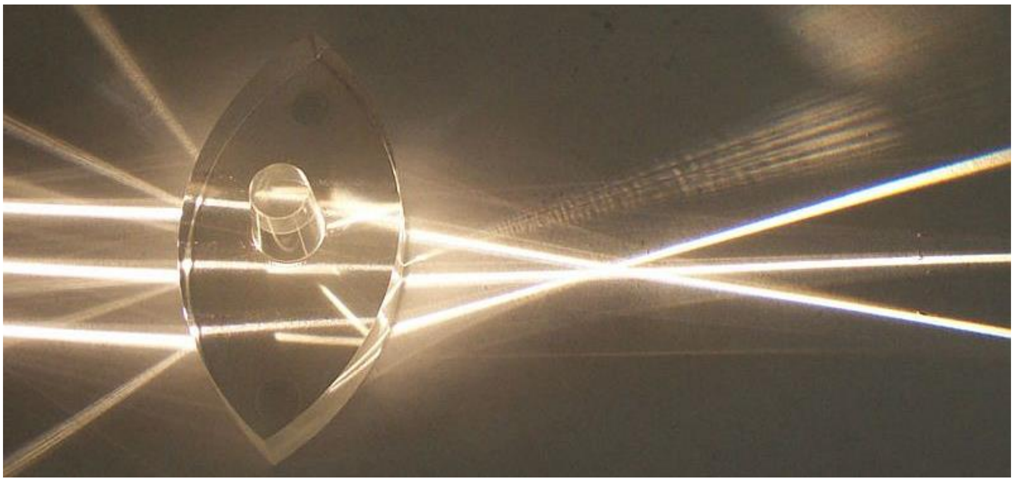
Why do the water beads appear clear in the water? This is due to the way that light travels through different mediums. The denser an object is, the slower that light travels through it. This can be observed through light refraction, which is the bending of a light beam as it hits a new medium. The degree to which light refracts in a medium is referred to as the object's refractive index.

Although water is transparent, our eyes can still see it because it refracts and reflects light that hits it. When water beads are dried out and small, they can be seen in water. However, when they absorb water (up to 99%) they start to refract light in the exact same way. When water beads take on the same refractive index as the water they are sitting in, they become invisible in the glass.

Why do water beads reverse the image of objects that are far away? Water beads are a double convex due to their sphere shape. Parallel rays of light hitting a convex lens will exit the lens at an angle which causes them to converge (move towards each other). The beams of light are no longer parallel, and therefore eventually meet at what is called a focal point. The beams of light cross over each other and shoot out in a flipped direction. This is what causes the image to be reversed once it hits our eyes.

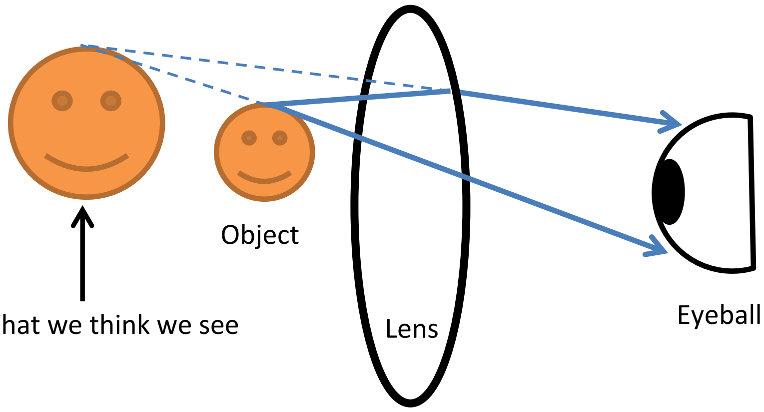


Extension: Students can be asked to work out the focal length of the water beads. The focal length is the distance between the focal point and the centre of the lens. Use a light box with slits in a darkened room for this activity.

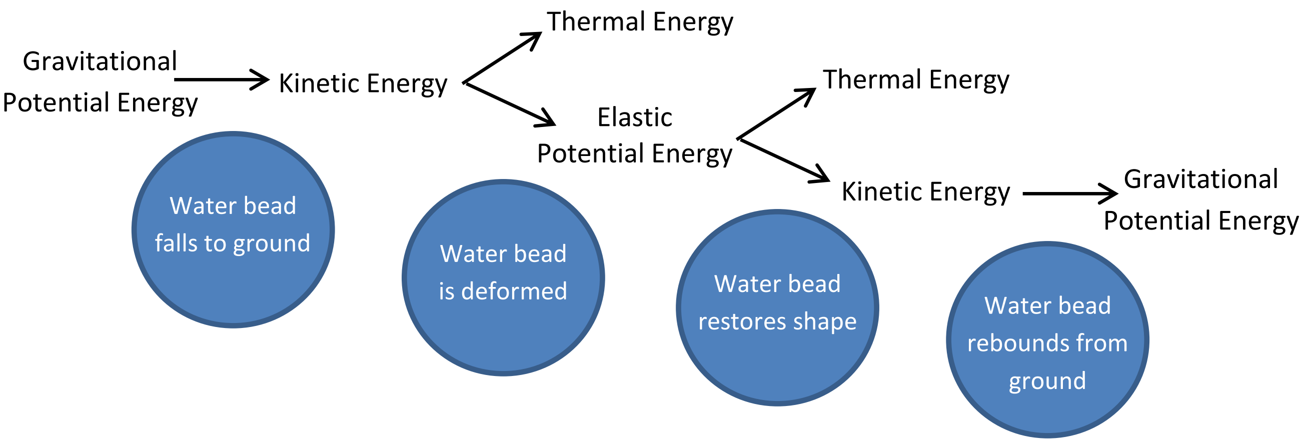


The eyeball is a great example of a convex lens. In fact, our eyes see everything upside down. It is our brain which then reverses the image back upright.

Why do the water beads magnify images that are up close? Objects that are sitting closer to a convex lens than where its focal length is will appear right way up and magnified. This is because the light rays from the object which passes through the convex lens spread out. This causes the object to look as though it has been enlarged.

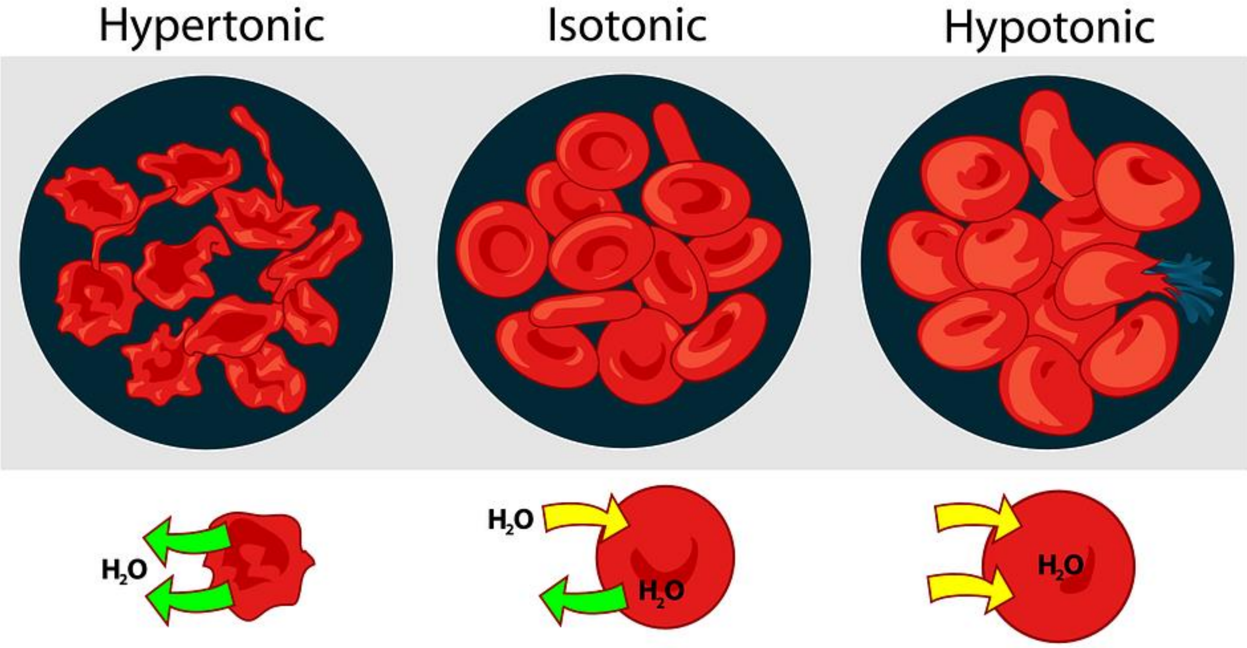


Why do dried water beads not bounce while engorged beads do? Things bounce because of their molecular structure. When water is occupied in the water bead, the long polymer chains get stretched out. When they are squished together, they act like springs by pushing back out from the pressure. This is elastic energy. When a ball hits the floor it squishes due to the force of gravity. This gravitational energy is converted to kinetic and then elastic energy within the water bead. The elastic energy then "springs" the ball back to its original shape. Energy transforms back to kinetic energy as the water bead bounces in the opposite direction.

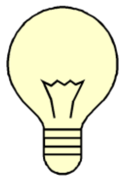


Biology Application: Cells have semi-permeable membranes, which also use the process of osmosis to regulate hydration levels. The levels of salt in the blood stream are highly regulated by the kidneys and the adrenal gland, which produces hormones (such as aldosterone) to signal the amount of sodium to retain and expend.

It is common to put salt on a leech in order to detach it from a person. The leech's skin is also a semi-permeable membrane. When salt is added, the leech dehydrates and dies. This can happen to all living cells, and is the reason why a solution with a high salt concentration can be a disinfectant.



Environmental Application: Water beads are considered biodegradable. UV light will degrade the polymer over time. They are considered useful in agriculture as a water retainer. Irrigation needs for modern farming are intense, and any way to lessen the load on the water supply is valuable.



Extension: Students are to conduct a research project on how water retainers help with water management at the same time as trying to grow a pot plant using water beads as its only water source. Compare this with a more traditional way of maintaining a pot plant.

Conclusion:

In this section students will be able to answer their initial question, making a short statement about what their overall findings were.

Were students successful in answering their question? How many groups were able to show that their hypothesis was correct?

References

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