Teacher's Preparatory Guide

Part 2: Properties of Fluids: Water in a Tube

Purpose: This lab is part 2 of 2 labs that explore the properties of water flow. Students will observe capillary action through the use of capillary glass tubes and colored water. The students will need to determine the best way to hold the glass tubes so that the water travels upward just like it does in plant stems. When things are very small, gravity may not seem to work. Students will come to the understanding that some forces can override gravity in certain cases. They will be introduced to a branch of nanotechnology called *microfluidics*, which uses microchannels to direct fluid flow. This lab connects with the Big Ideas in Nanoscale Science and Engineering (Stevens et al, 2009 NSTA Press); Big Idea – Forces and Interactions: All interactions can be described by multiple types of forces, but the relative impact of each type of force changes with scale. On the nanoscale, a range of electrical forces, with varying strengths, tech to dominate the interactions between objects.

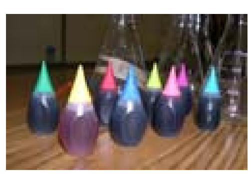
Level: Middle school or high school chemistry, physics, and physical science

Time required: 10–20 minutes

Teacher Background: When things are very small, gravity may not seem to work. *Capillary action* can cause water to travel upward. Capillary action occurs when the *adhesion force* of a substance is greater than the *cohesion force* of that substance.
One branch of nanotechnology called *microfluidics* uses microchannels to direct fluid flow. Microfluidics is used in lab-on-a-chip technology, DNA chip technology, cell sorting technologies, micropropulsion technologies, microthermal technologies, and micropneumatic technologies (which includes the development of inkjet printheads). The more there is a demand and a need for microscopically small technology, the larger the role of microfluidics will become

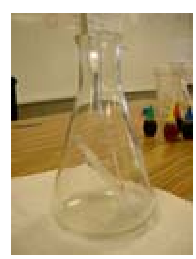
Materials for each group of 2 students

- clear reaction tray
- water
- food coloring
- 2 narrow capillary tubes
- Erlenmeyer flask (to contain capillary tubes)
- plastic metric ruler
- watch/clock with a second hand or a stop watch



food coloring

capillary tubes



Erlenmeyer flask

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Safety Information: Caution students that these narrow tubes are made of glass and can break easily. Broken tubes are a cutting hazard. Clean up broken glass fibers carefully for the glass splinters are difficult to see and can easily become attached to clothing and hands. You may consider having the students wear safety glasses in case of breakage.

Have a sharps container (a cardboard box) available in case a student drops and breaks a tube. It will also be used to dispose of used capillary tubes during cleanup.

Advance Preparation: Materials for the lab activity may be found here:

Source	Items
Fisher Scientific http://www.fishersci.com **(or other chemical or science education suppliers)**	(Part No. 22 260943) Capillary Tubes Blue Tip; 70 uL; 75 mm; 100/pk; VCAT: 40A22-260-943 OR (Part No. 22 260950) Capillary Tubes Heparinized Red Band; 75mm; 100/pk; VCAT: 40B22-260-950
any artists supply store	clear reaction tray

Teaching Strategies This activity works best in pairs. *Before* beginning the lab, review the terms and ask the students the questions in the *Guided Dialog* section.

Directions for the Activity

Name:______________________________Date:_______________Class:________________

Student Worksheet (with answers)

Part 2, Properties of Fluids: Water in a Tube

Safety

Glass tubes may break. Broken tubes are a cutting hazard. Clean up all broken fibers carefully for the splinters are difficult to see and can easily become attached to clothing and hands.

Materials for each group of 2 students

- clear reaction tray
- water
- food coloring
- 2 narrow capillary tubes
- Erlenmeyer flask
  (to contain capillary tubes)
- plastic metric ruler
- watch/clock with a second hand or a stop watch

Procedure

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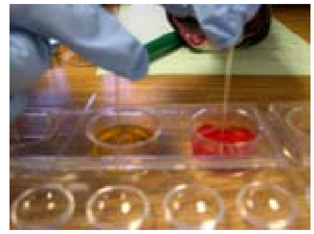
1. Take the clear tray and fill each well halfway with water.
2. Add one drop of food coloring to each well of water.
3. Place a narrow tube with one end in the colored water. What is the best way to hold the glass tube so that the water travels upward just like it does in plant stems? Observe what happens.



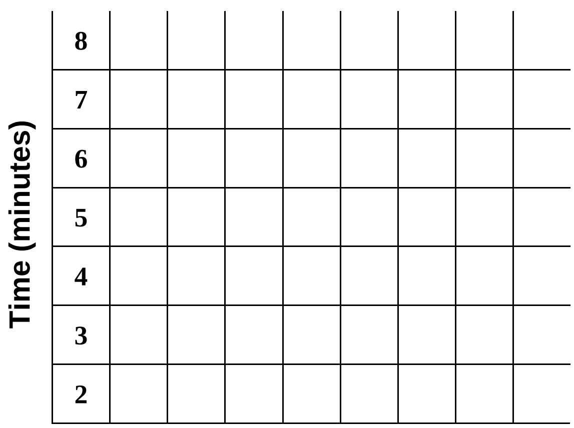
4. Without taking the tube out of the fluid, once every minute for 5 minutes measure (in millimeters) how far up the tube the fluid moves. Measure from the surface of the liquid to the meniscus inside the tube. Record these measurements in the table in the *Record Your Observations* section on the next page.

5. On the graph in the *Analyze the Results* section, plot the data you recorded from your observations. Is the graph linear or nonlinear? Why do you think this is so? Answer these questions in the *Draw Conclusions* section.
6. Take the narrow tube out of the fluid. What happens to the fluid in the tube? Why do you think this happens? Answer these questions in the *Draw Conclusions* section as well.

Record Your Observations

Time (minutes)	Height (millimeters)
1	
2	
3	
4	
5	

Analyze the Results



National Nanotechnology Infrastructure Network *www.nnin.org*

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1								
0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**

Height (millimeters)

Draw Conclusions

1. What is the best way to hold the glass tube so that the water travels upwards?

   *Example answer: vertically; straight up and down*____________________________________

2. Is the graph linear or nonlinear? Why do you think this is so?

   *Example answer: nonlinear; the more water that rises inside the tube, the greater the weight of the water that the capillary action must fight against slowing the action down*__________

   ____

3. What happens to the fluid in the tube when you remove the tube from the fluid? Why do you think this happens?

   ____

   ____

   ____

Guided Dialog *Before* beginning the lab, review the meaning of the following terms:

Adhesion force *the attraction of a substance to a different substance*
Cohesion force *the attraction of the substance to itself*
Capillary action *occurs when the adhesion force of a substance (the attraction of the colored water to the glass tube) is greater than it's cohesion force (the attraction of the colored water to itself)*

Ask students the following questions to provoke thought and review what they already know:

1. What are some examples of fluid moving through small tubes? *capillary tubes, veins*
2. What is the U-shaped surface formed by the water inside of a tube called? *meniscus*

Post Lab Activity: *After* the lab activity, relay the following information to the students:

> *A tree's trunk is made up of millions of xylem—tiny cellulose tubes. Water is carried all the way up from the roots to the top of the tree through these tubes using capillary action. The world's largest tree is a Redwood tree on the west coast of the United States that is approximately 379 ft. tall. The very top of that tree receives it's water through capillary action.*

Now inform the students that there is a branch of nanotechnology called microfluidics and ask if anyone can explain the term: microfluidics. *Microfluidics is the directing and controlling of fluid flow using microchannels; these microchannels are measured at the micrometer level and the fluids are measured in nanoliters and picoliters.* Microfluidics is used in many technologies including: lab-on-a-chip, DNA chip, cell sorting, and in the development of inkjet printheads.

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The more there is a demand and a need for microscopically small technology, the larger the role of microfluidics will become.

Cleanup: Dispose of colored water down a sink. Capillary tubes can be used one time only. Dispose of them in the sharps container. Wipe trays clean with paper towel and put in storage bin.

Going Further: Students who have a good grasp of the content of the lab can be further challenged by repeating the lab activity using a clear soda straw or larger glass tubes. Have students compare their observations using this wider diameter tube versus the very narrow capillary tube. Then ask: "Why does the water not go up the soda straw as high as it does in the capillary tube?" *Capillary action is actually a result of both adhesion and surface tension. As adhesion forces the outer edges of the meniscus to turn upwards, surface tension keeps the surface intact so the whole water surface is pulled upward with the edges of the meniscus. The height to which capillary action will cause the water to go depends on the weight of water that the surface tension will lift. The smaller the diameter of the tube, the less water, and therefore the less weight of water inside the tube, allowing the water to rise higher inside a narrower tube.* To go even further, then ask: "What stops the water from going all the way up and out of the tube?" *The more water that rises inside the tube, the greater the weight of the water that the capillary action must fight against until eventually the effects of the capillary action equal the effects of gravity. Even if the water made it to the top edge of the tube, it would not flow out because there is no longer any glass there to allow capillary action to force water up further.*

Assessment:
Each student will turn in their completed worksheet so the teacher can assess the student's understanding of capillary action. Points can be given for correctly:

- completing the activity and recording observations during the activity
- completing the graph
- providing reasonable conclusions

Resources: Background information and inspiration for this lab can be found at the following websites:

- Classic Encyclopedia: Capillary action http://www.1911encyclopedia.org/Capillary_action
- Trees & Capillary Action http://www.davidlnelson.md/Cazadero/Trees&CapillaryAction.htm
- Plant Transport Mechanisms http://home.earthlink.net/~dayvdanls/plant_transport.html#Movement%20of%20Water
- Microfluidics http://en.wikipedia.org/wiki/Microfluidics http://www.kirbyresearch.com/
- Lab on a chip http://en.wikipedia.org/wiki/Lab-on-a-chip

National Science Education Standards (Grades 5–8)
Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science

- Properties and changes of properties in matter
- Motions and forces

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Content Standard E: Science and Technology

- Abilities of technological design
- Understandings about science and technology

National Science Education Standards (Grades 9–12)

Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science

- Structure and properties of matter
- Motions and forces

Content Standard E: Science and Technology

- Abilities of technological design
- Understandings about science and technology

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