Name: Tony DiMauro
Date: 08/01/10
Subject: Physics
Model Of Instruction: Direct Instruction
Time Required:~ 80 minutes

Yarn MicroFluidics

Baseline Information

Students already know about water pressure, density, force and area. Students have experienced Pascal's Law, Archimedes's Principle and Bernoulli's Principle.

California Standards

1. Recognize the usefulness and limitations of models and theories as scientific representations of reality.
2. Analyze situations and solve problems that require combining and applying concepts from more than one area of science.

1. Students will add, subtract, multiply, and divide rational expressions and functions.

Objective

Students will build a lab station, create a microfluidic network that demonstrates capillary action (wicking) and mixing of fluids and determine the Surface Tension of the yarn.

Anticipatory Set/Motivation/Hook

Activity

Nature plays trick on our senses!

Show the Youtube video of the gecko walking on water.[1]

http://www.youtube.com/watch?v=pimZMS-B4dQ&feature=player_embedded

Key Questions / Teacher Explanation

Explain that the gecko's skin is hydrophobic. Gravity is trying to sink the gecko. And, the cohesive forces between the water molecules and the adhesive forces between the gecko and the water are conspiring to keep the gecko afloat. Ask questions but don't give answers.

1. What does hydrophobic mean? What is the opposite to hydrophobic?
2. How is the floating gecko different than a floating surfboard?

Link to existing background knowledge

Activity

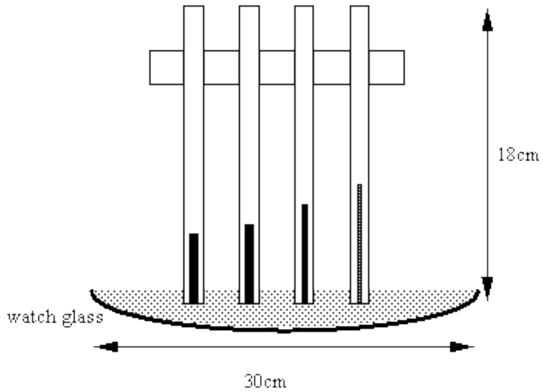
Teacher Explanation /Key Questions

Have students in small groups discuss other materials that are hydrophobic and hydrophyllic. Why do objects float or sink in water. (See Appendix A for more ideas.)

Demonstration

Activity

Teacher demonstrates capillary action with series of smaller diameter glass tubes.[2] First, draw the diagram below without the water. Explain capillary action and then ask questions.



Teacher Explanation /Key Questions

Explain that **capillary action** is a team effort between two intermolecular forces. Cohesive forces between the water molecules and adhesive forces between the glass tube and water molecules.
Surface tension (cohesive forces) can draw liquid up the tube if the tube is very narrow and the adhesion of the liquid to the walls of the tube is sufficiently strong. Ask

1. What will happen once you put the glass tubes into the colored water?
2. Why does the liquid only so far up in a tube?
3. What is the determining factor for the height of the water?
4. Is wicking a similar process?

Capillary action in any object is synonymous with 'wicking'.

Guided Practice

Activity

Students working in groups of four will experience different 'wicking' objects such as; paper towels, small glass tubes, clear straws and different thicknesses of yarn dipped in colored water. Have students place a drop of water on glass, waxed paper and plastic.

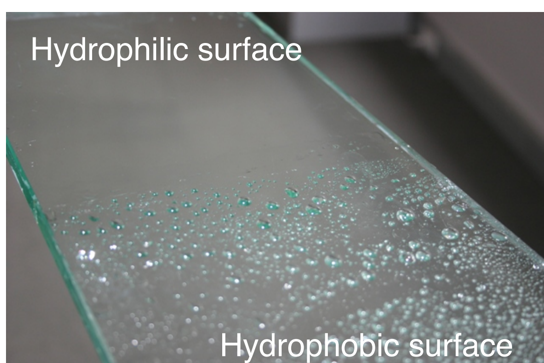
Materials: Glass Plates, Plastic plates, wax paper, rubber surfaces, water, alcohol, paper towels, straws, glass tubes

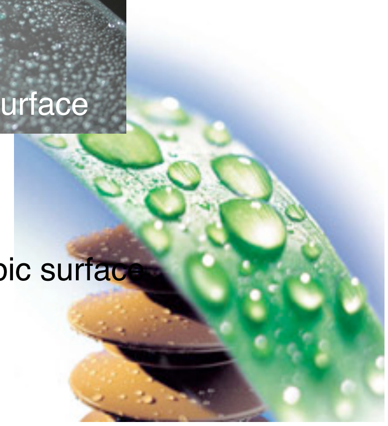
Teacher Explanation /Key Questions

Let students answer above questions in small groups.

1. What will happen once you put the 'wick' into the colored water?
2. Why does the liquid only so far up in a 'wick'?
3. What is the determining factor for the height of the water in the 'wick'?
4. Is wicking a similar process?
5. Which surfaces are hydrophobic? Hydrophilic?

Wicking or Capillary Action





Hydrophobic surface

Independent Practice

Activity

Students will determine which yarns work the best fastest for a microfluidic network. Then, they will mix different solutions to see the reaction. They will build a lab station of popsicle sticks and hot glue to use in this effort. They will then determine the surface tension of the yarn from the derived equation.

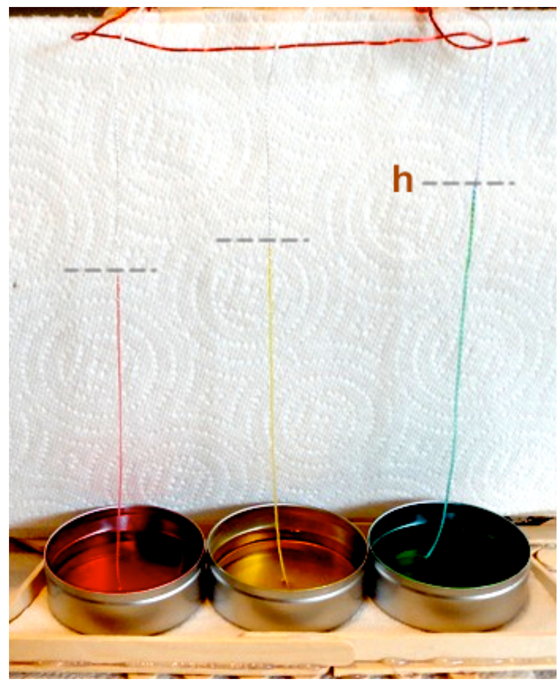
Materials: Popsicle sticks, hot glue, yarns, paraffin, small containers, food coloring and water.

Teacher Explanation /Key Questions

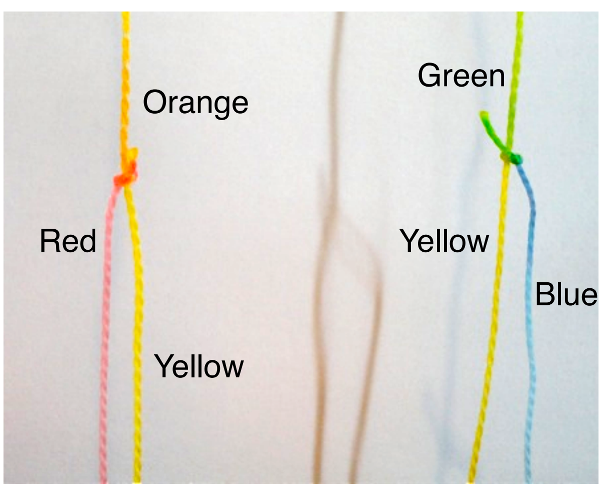
1. Teacher derives the equation that students will use in this activity.
2. Students should experience setting up a lab station to perform their experiments.
3. Students will experiment with different yarns.
4. Students will demonstrate mixing.

Lab Station

Capillary Action Only Side



Mixing of Solutions

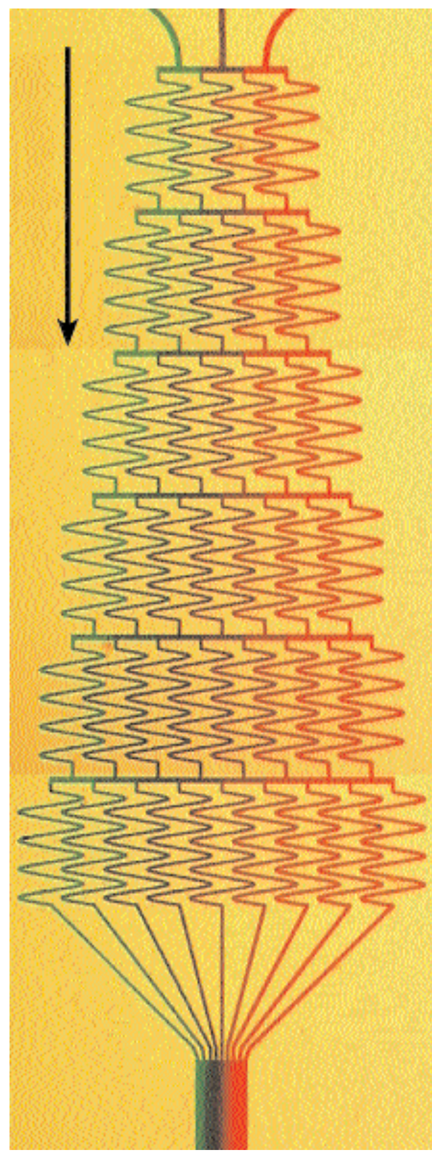


Closure/Evaluation

Activity

Teacher Explanation /Key Questions

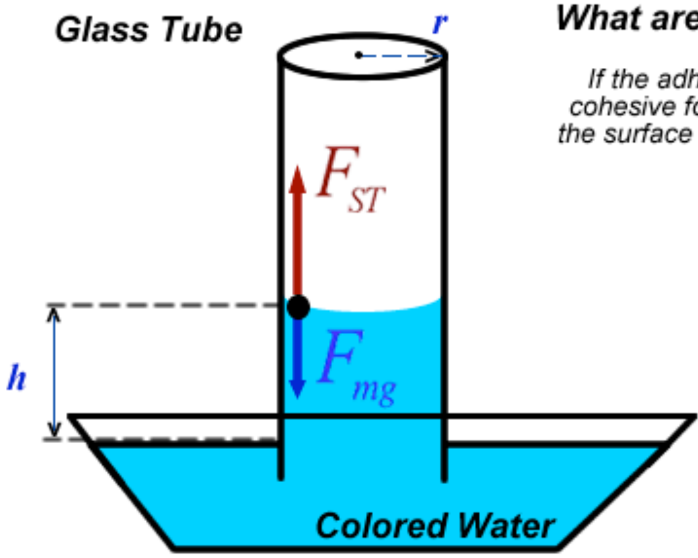
1. Students will read a current MicroFluidic article together in their respective groups.
2. Students will explain the application of the MicroFluidic Device.
3. Students will determine the science involved with this Midrofluidic device.



The Physics of Capillary Action

Derivation of the Capillary Force Equation

Surface Tension pulls the liquid column up until there is a sufficient mass of liquid for gravitational forces to overcome the intermolecular forces.



What are these forces on the water?

If the adhesive force between the liquid and solid is greater than the cohesive force within the liquid, the liquid is said to wet the surface and the surface of the liquid near the edge of the container will curve upward.

The Forces in the Upward direction = The Forces in the Downward direction

Surface Tension (F_{ST}) between the water and the glass tube = The Force of Gravity or the weight of the water

When the water stops rising the net forces cancel and the system is in equilibrium.

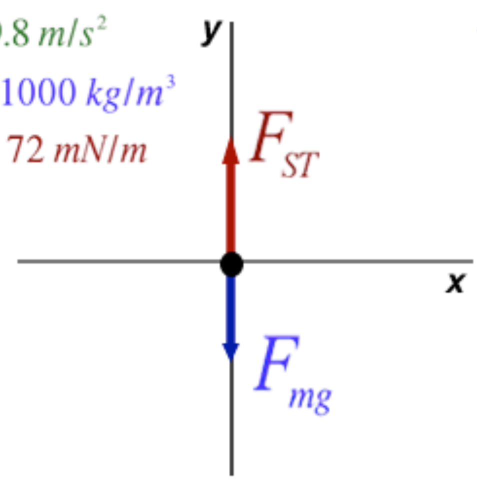
$$F_{ST}(2\pi r) = m_w g$$

Freebody Diagram

$g = 9.8\ m/s^2$

$\rho_w = 1000\ kg/m^3$

$F_{ST} = 72\ mN/m$



$mass = (density)(Volume) = \rho V$ $\quad$ $Volume_{cyl} = (\pi r^2 h)$

$$F_{ST}(2\pi r) = \rho_w V g = \rho_w(\pi r^2 h) g$$

Solve for the final height of the column of water in the glass tube.

$$\boxed{h = \frac{F_{ST}(2\pi r)}{\rho_w(\pi r^2) g} = \frac{2F_{ST}}{\rho_w r g}}$$

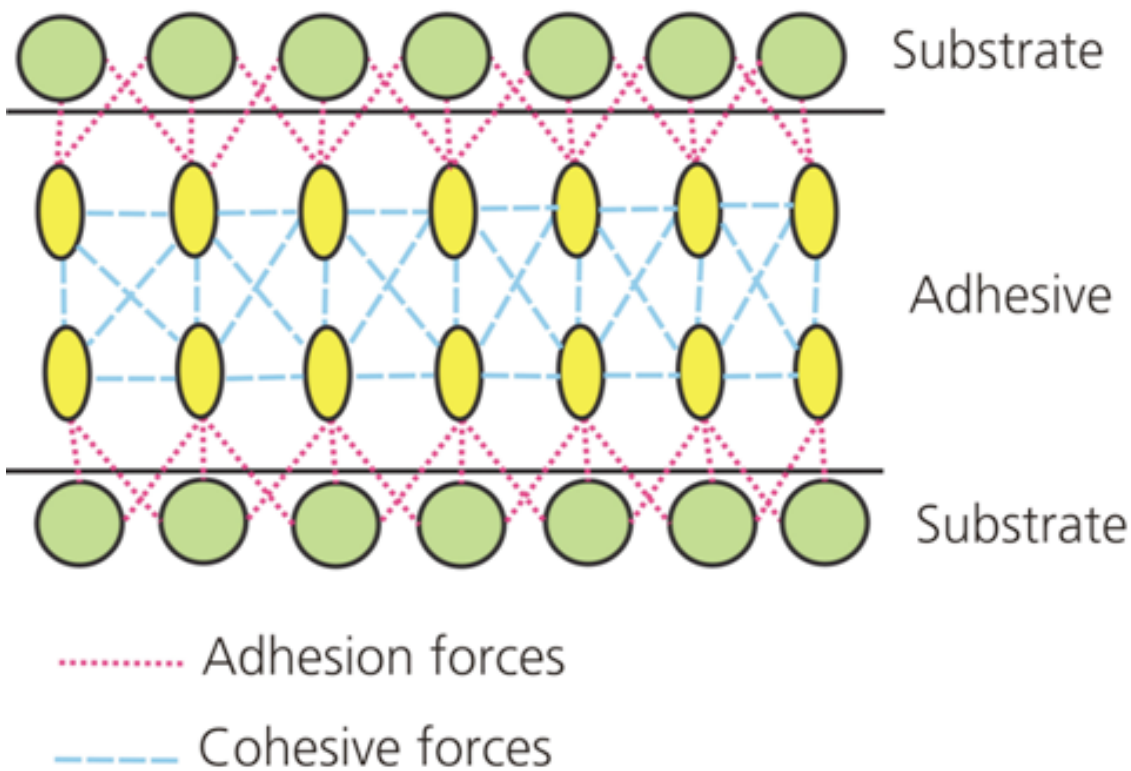
The height the water will travel up the tube is indirectly porportional to the radius of the tube.

Appendix A
Courtesy of HyperPhysics

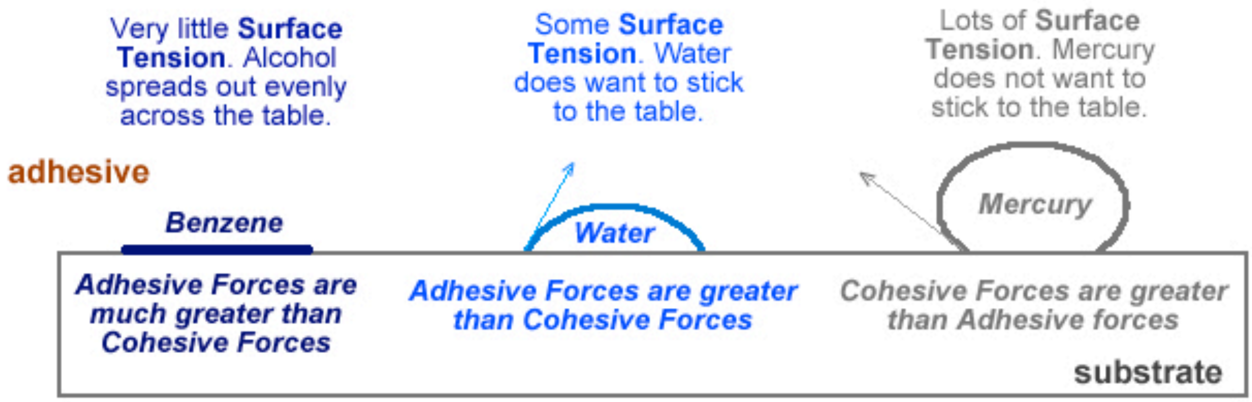
Walking on water	Floating a needle
Small insects such as the water strider can walk on water because their weight is not enough to penetrate the surface.	If carefully placed on the surface, a small needle can be made to float on the surface of water even though it is several times as dense as water. If the surface is agitated to break up the surface tension, then needle will quickly sink.
Don't touch the tent!	**Soaps and detergents**
Common tent materials are somewhat rainproof in that the surface tension of water will bridge the pores in the finely woven material. But if you touch the tent material with your finger, you break the surface tension and the rain will drip through.	help the cleaning of clothes by lowering the surface tension of the water so that it more readily soaks into pores and soiled areas.
Clinical test for jaundice	**Washing with cold water**
Normal urine has a surface tension of about 66 dynes/cm but if bile is present (a test for jaundice), it drops to about 55. In the Hay test, powdered sulfur is sprinkled on the urine surface. It will float on normal urine, but sink if the S.T. is lowered by the bile.	The major reason for using hot water for washing is that its surface tension is lower and it is a better wetting agent. But if the detergent lowers the surface tension, the heating may be unneccessary.
Surface tension disinfectants	Can you think of another?
Disinfectants are usually solutions of low surface tension. This allow them to spread out on the cell walls of bacteria and disrupt them. One such disinfectant, S.T.37, has a name which points to its low surface tension compared to the 72 dynes/cm for water.	

Adhesion and Cohesion

Cohesion is defined as the internal strength of an adhesive as a result of a variety of interactions within the adhesive. Adhesion is the bonding of one material to another, namely an adhesive to a substrate, due to a variety of possible interactions. The figure below illustrates adhesion and cohesion forces present within an adhesive and between an adhesive and substrate.



Adhesive and Cohesive Forces and Surface Tension



The smaller the contact angle and the smaller the surface tension, the greater the degree of adhesion.

Effective wetting requires the surface tension of the adhesive to be less than or equal to that of the substrate.

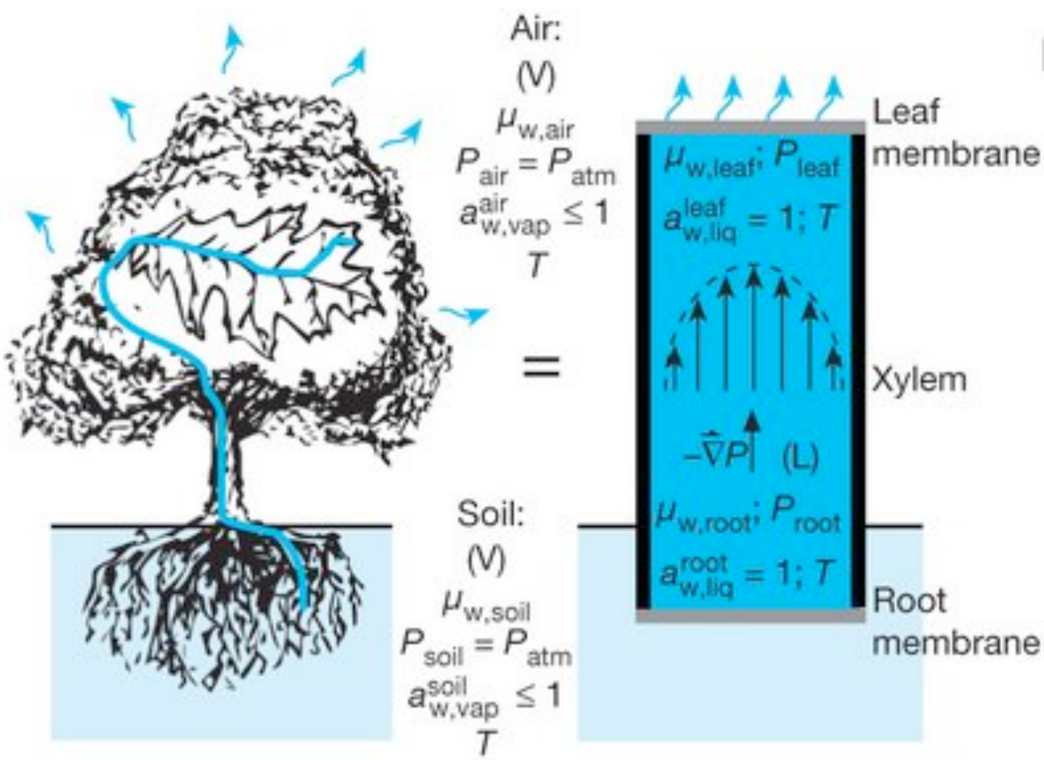
Liquid	Surface Tension (dyne/cm)
Water	73
Glycerol	63
Ethylene Glycol	48
Nitrobenzene	44
Epoxy Resin	43
Petroleum Lubricating Oil	29
Benzene	29
Silicone Oil	21
n-Hexane	18

Solid	Critical Surface Tension (dyne/cm)
Copper	~ 1000
Aluminum	~ 500
Glass	290
Acetal	47
Polyamide	46
Polycarbonate	46
Polyethylene Terephthalate	43
Cured Epoxy Resin	43
Polyimide	40
Polyvinyl Chloride	39
Polystyrene	33
Polyethylene	31
Silicone	21
Polytetrafluoroethylene	18

Transpiration in Leaves

Plants don't have hearts to pump fluids throughout their systems, so how do they generate the pressure to move water against the force of gravity from their roots to their shoots (leaves)? Capillary action (the tendency of a fluid to move through small spaces due to it's molecular constituents cohesive properties or surface tension) can explain the movement of water over small distances, but it cannot account for the large scale movement of water from the bases to the tips of tall trees like the Giant Sequoia of Redwood Forest.

Instead, it has long been thought that evaporation of water at the leaves draws water up in a long continuous column from the root, a process known as transpiration. This hypothesis was recently verified in the form of an artificial model[1]. Abraham Stroock and his graduate student at Cornell University built a small (10 cm) proof-of-concept tree model with artificial membranes representing roots and leaves and small "microfluidic" channels connecting them. Though small, this device demonstrates the functional capacity of the evaporation/water-column idea, and might eventually be used to test failures of this model (such as when air-bubbles intervene in the column) and to draw small amounts of water out of hard to reach places.



Water is constantly lost by transpiration in the leaf. When one water molecule is lost another is pulled along by the processes of cohesion and adhesion. Transpiration pull, utilizing capillary action and the inherent surface tension of water, is the primary mechanism of water movement in plants. However, it is not the only mechanism involved. Any use of water in leaves will force water to move into them.

A capillary calendar