Answer #359

The answer is (d): the water level will be lowest in 1 and highest in 4, due to the phenomena of capillary action. The reasoning of (c) is incorrect.

Alternate high-res version.

Trees know all about capillary action -- for it is what allows water in the soil to "wick" upwards yards and yards into the tiny branches at the top!

Capillary action is the result of *adhesion* and *cohesion* of the water molecules. Adhesion describes the tendency for molecules to stick to *other* objects (like the water sticking to the walls of the tube), whereas cohesion describes the tendency for like molecules to to stick to each other (the water sticking to itself). The interplay of these two forces gives rise to the phenomena of capillary action.

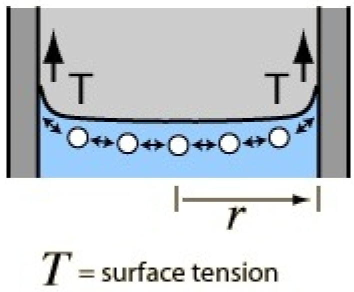

Diagram courtesy of Hyperphysics.

Since the shape of the water inside the tube is a meniscus, the outer edges are slightly higher than the middle. The water on the outer edges cling to the tube's walls since they adhere to the other surface. However, since water molecules like to stick together (cohesion), those below in the center try to "pull themselves" upwards against the force of gravity, to be in line with the outer edges. The outer edges can then creep upwards to reform the meniscus shape, and the process repeats again, until a balance between the adhesion and cohesion is reached.

By this reasoning, it should be evident why the maximum height occurs with a smaller tube: since cohesion must battle the force of gravity, larger tubes have a greater force downward in the center than would a thinner tube, by virtue of the greater volume of water in the center. Gravity wins over cohesion in the wider tube, and therefore wicking process is not as great. (The same effect can be accomplished by changing the density of the liquid: a denser liquid will not rise as high by capillary action.) This works nicely for nature too, since smaller veins in trees would correspond to newer branches that would require more nutrients to grow.

Another, perhaps more colloquial example of adhesion and cohesion at play, is a glass filled with some beverage nearly to the brim -- the liquid looks like it should overflow, but doesn't't! Adhesion of the liquid to the walls of the rim helps keep the outer edges from overflowing, and cohesion keeps the water in the middle sticking to its outer edge brethren despite their being higher than the glass, preventing the glass from overflowing.

[Question of the Week]

[Outreach Index Page]

[Lecture-Demonstration Home Page]

For questions and comments regarding the *Question of the Week* contact
Dr. Richard E. Berg by e-mail or using phone number or regular mail address
given on the Lecture-Demonstration Home Page.