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Osmosis: Everything you know about it is (probably) wrong

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Osmosis – the flow of a solvent across a semipermeable membrane from a region of lower to higher solute concentration – is a well-developed concept in physics and biophysics. The problem is that, even though the concept is important to plant and human physiology, osmosis is understood in biology and chemistry in a much simpler – and often incorrect – way.

"A range of surprising misconceptions about osmosis continue to appear in papers, web sites and textbooks," says Eric Kramer, professor of physics at Bard College at Simon's Rock in Great Barrington, Mass. "Wrong ideas about osmosis are especially common in educational materials aimed at students of chemistry and biology. Once learned, these errors influence the thinking of professionals throughout their careers."

The thermodynamic theory of osmosis was published by J.W. Gibbs in 1897, and during the next half-century dozens of other scientists published explanations for it in terms of interactions between the solute and solvent molecules. "Many of the greatest scientists of the 20th century took a turn at it," says Kramer, "A textbook in 1951 offered the first coherent telling of the whole theory."

Though physicists have had this complete and correct explanation since the 50s, chemistry and biology never caught up. Why? One reason is because the incorrect theory is much easier. "The thermodynamic explanation can be pretty dense, and features entropy, which can be scary for people," he says. "The correct theory would be harder to teach at an introductory level, although I'm working with a textbook author who plans to spread the word."

Reach back into your memory for your first science lesson on osmosis. It probably involved a demonstration with a bag of sugar with holes poked in it. When dunked into water, the water rushed into the bag. Using this example of osmosis, Kramer lays out the common misconceptions:

- "The first misconception is that osmosis is limited to liquids," he says. "But it works just fine for gases, too."
- "Another misconception that osmosis requires an attractive force," he says. "It doesn't. When water fills the bag of sugar, it's not because the sugar is pulling the water in. That's not part of the explanation."
- "A misconception is that osmosis always happens down a concentration gradient," he says. "When you dissolve something in water, the water doesn't necessarily get more diluted. Depending on the substance, it can get more concentrated."
- "Anther misconception is that you don't need to invoke a force to explain why the water flows into the bag. It's thought that, like diffusion, it's a spontaneous process," he says. "But, in fact, there is a force. It's complicated how it happens, but it turns out that the membrane – or the bag, in the familiar lab demonstration – exerts a force that pushes the water in."

"These misconceptions are surprisingly robust," says Kramer. "Nearly all have been discussed by other authors during the long history of osmotic research, and yet they continue to find believers in each generation of professionals. While authors in physics and biophysics have generally settled on the correct understanding of osmosis, these ideas have not penetrated into the fields of chemistry and biology. It's very surprising that, in 60 years, no physicist talked to a chemist long enough to figure this out."

Kramer is co-author, with colleague and chemist David Myers, of the article, "Osmosis is not driven by water dilution," in the April issue of *Trends in Plant Science*. They have authored a previous article, "Five popular misconceptions about osmosis," in the *American Journal of Physics* (August, 2012).

Provided by Dick Jones Communications