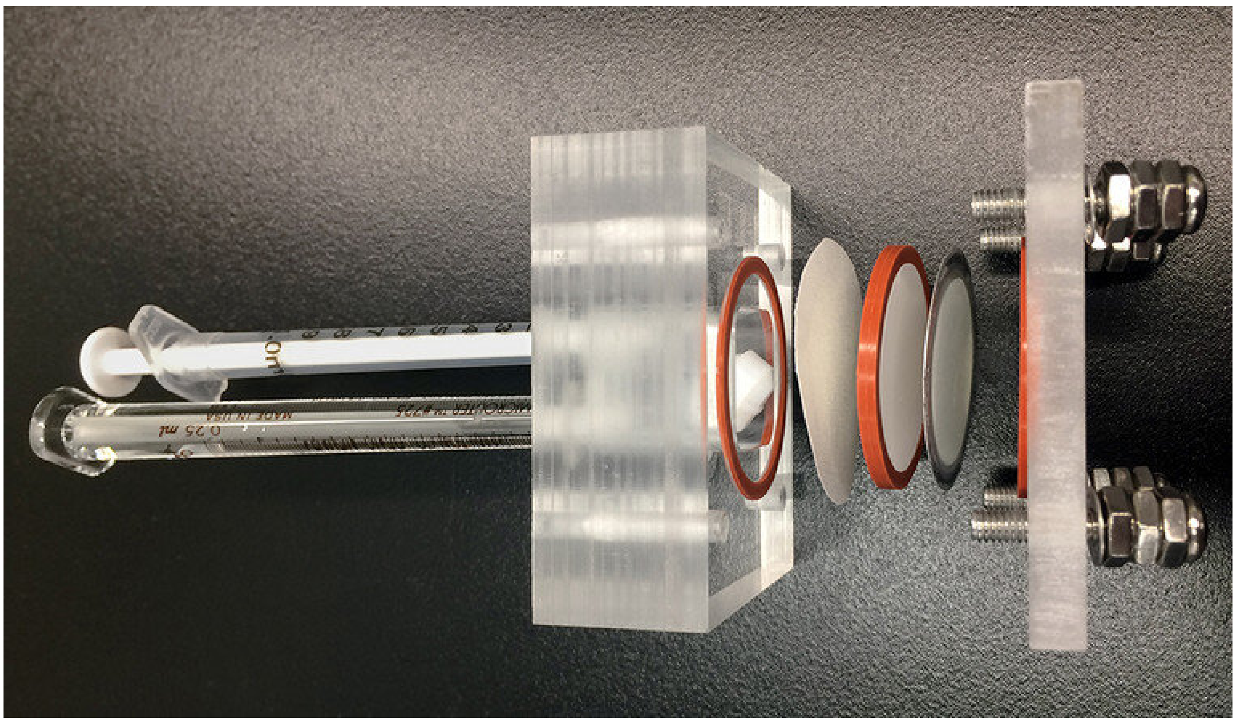
Device mimics the mangrove's water-purifying power

February 24 2020, by William Weir



The device up close, in the lab of Menachem Elimelech. Credit: Yale University

The mangrove tree survives in its subtropical habitat by efficiently converting the salty water of its environment into fresh water—an engineering feat that has long baffled scientists.

Now, a team of researchers in the lab of Yale engineering professor

Menachem Elimelech has developed a water-purifying device that mimics the mangrove. In addition to offering a better understanding of plants' plumbing systems, it could lead to new desalination technologies, his research team said. The results appeared Feb. 21 in *Science Advances*.

"We're showing the mechanism that's been proposed for how mangroves work," said co-author Jay Werber, a former graduate student in chemical and environmental engineering in Elimelech's lab. "We're not biologists, but we're coming at this from an engineering perspective."

Elimelech is Yale's Roberto C. Goizueta Professor of Chemical & Environmental Engineering.

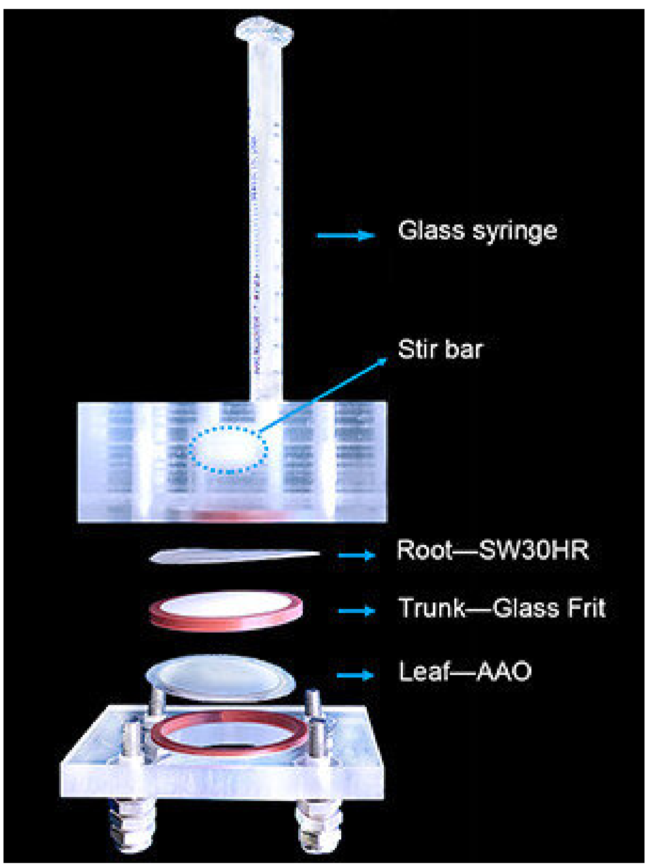
The device, which the researchers call an artificial mangrove, combines the desalinating effects of the mangrove's root, the capillary pumping of the leaves, and the water-conducting capability of the stem. Key to its success is its ability to generate a high level of negative pressure, similar to what you create when drinking through a straw. In the synthetic mangrove, evaporation from specially designed membranes—acting as "leaves"—creates a large negative pressure, which drives desalination of salty water through a semi-permeable membrane "root."

Trees need negative pressure—generated when water is evaporated through the leaves—to take in enough water. Mangroves, which can be found in Florida and are particularly abundant in such countries as Indonesia, Brazil, and Malaysia, perform a doubly impressive trick, researchers said: They need to produce greater negative pressure than the typical tree to drink up the salty water of their environment. Plus, they desalinate this water with their roots, in a process called reverse osmosis.

Particularly impressive, the researchers note, is the way trees minimize the formation of air bubbles inside their system of water tubes, known as the xylem. Water tends to form bubbles under high negative pressures, which would disrupt the flow of water in the plant's xylem.

Co-author Yunkun Wang, a postdoctoral researcher, said that the researchers' device manages a similar feat by minimizing the formation of air pockets, due in part to a porous silica structure known as a frit that's positioned in the middle of the device.

In addition to solving some longstanding mysteries about tree hydraulics, Werber said, the researchers' work could potentially lead to the creation of small-scale devices for separating solutions. "Typically, you have an expensive pump that creates really high pressure to separate those things," he said. "With the mangrove device, you can use the evaporation to drive that completely passively."



Credit: Yale University

The researchers said the device would be particularly useful in situations where electricity isn't readily available.

Not only did the researchers' device mimic the natural process, it generated much greater negative pressure than what the mangrove tree generates and could desalinate water with a salt concentration nearly 10-fold that of seawater. Elimelech said this means it could lead to ways of desalinating very salty water, such as the water produced through hydrofracking.

More immediately, though, he said the device provides a window into a process that had long been unclear.

"We were just curious about how nature does some things, and it's such an amazing thing that we were able to describe it with physics," Elimelech said. "We showed that the tree follows physical principles, and that we can mimic them in a microfluidic device."

Co-author Jongho Lee, a postdoctoral researcher, said the device also has the potential to be used for flood reduction by incorporating it into "sponge cities"—that is, urban areas designed to absorb and catch rainwater and quickly remove it. "Buildings could be designed to work as mangrove trees: Their outside walls would work as leaves and the foundations would act as roots filtering out contaminants," he said.

More information: Yunkun Wang et al. Capillary-driven desalination in a synthetic mangrove, *Science Advances* (2020). DOI: 10.1126/sciadv.aax5253. advances.sciencemag.org/content/6/8/eaax5253