Ferroelectric switching seen in biological tissues

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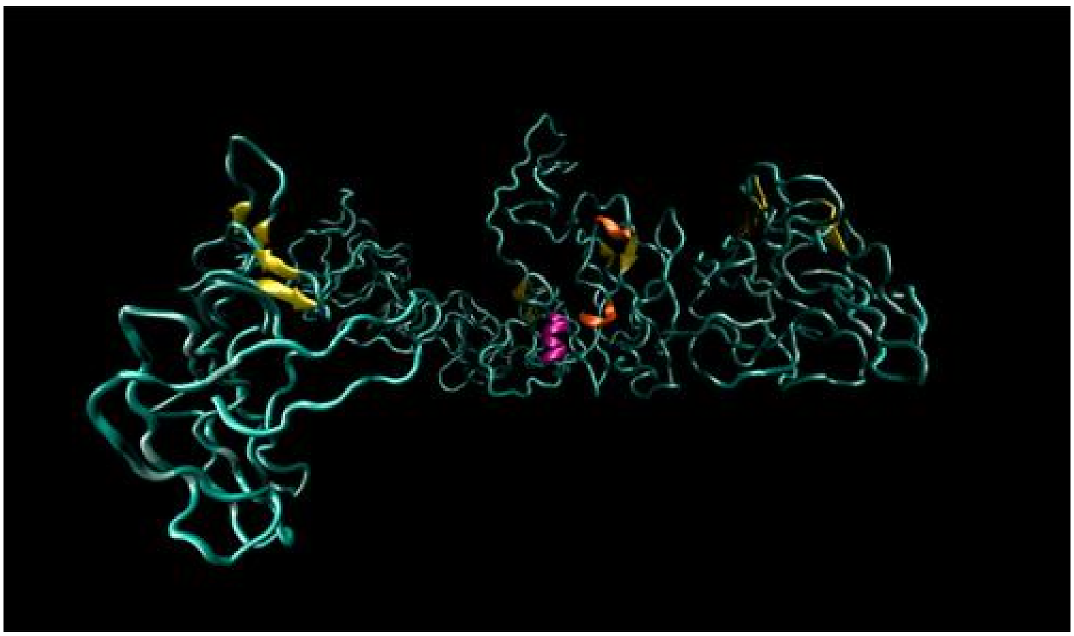

This is an illustration of the molecular structure of tropoelastin, the smallest unit of the protein elastin. Credit: Matthew Zelisko, University of Houston

Measurements taken at the molecular scale have for the first time confirmed a key property that could improve our knowledge of how the heart and lungs function.

University of Washington researchers have shown that a favorable electrical property is present in a type of protein found in organs that repeatedly stretch and retract, such as the lungs, heart and arteries. These findings are the first that clearly track this phenomenon, called ferroelectricity, occurring at the molecular level in biological tissues.

The researchers published their findings online June 23 in the *Proceedings of the National Academy of Sciences*.

"We wanted to bring in different experimental techniques, evidence and theoretical understanding of ferroelectricity in biological functions," said Jiangyu Li, a UW professor of mechanical engineering and corresponding author of the paper. "We certainly have much more confidence now in the phenomenon itself."

Ferroelectricity is a response to an electric field in which a molecule switches from having a positive to a negative charge. This switching process in synthetic materials serves as a way to power computer memory chips, display screens and sensors. This property only recently has been discovered in animal tissues and researchers think it may help build and support healthy connective tissues in mammals.

A research team led by Li first discovered ferroelectric properties in biological tissues in 2012, then in 2013 found that glucose can suppress this property in the body's connective tissues, wherever the protein elastin is present. But while ferroelectricity is a proven entity in synthetic materials and has long been thought to be important in biological functions, its actual existence in biology hasn't been firmly established.

This study proves that ferroelectric switching happens in the biological protein elastin. When the researchers looked at the base structures within the protein, they saw similar behavior to the unit cells of solid-state materials, where ferroelectricity is well understood.

"When we looked at the smallest structural unit of the biological tissue and how it was organized into a larger protein fiber, we then were able to see similarities to the classic ferroelectric model found in solids," Li said.

The researchers wanted to establish a more concrete, precise way of verifying ferroelectricity in biological tissues. They used small samples of elastin taken from a pig's aorta and poled the tissues using an electric field at high temperatures. They then measured the current with the poling field removed and found that the current switched direction when the poling electric field was switched, a sign of ferroelectricity.

They did the same thing at room temperature using a laser as the heat source, and the current also switched directions.

Then, the researchers tested for this behavior on the smallest-possible unit of elastin, called tropoelastin, and again observed the phenomenon. They concluded that this switching property is "intrinsic" to the molecular make-up of elastin.

The next step is to understand the biological and physiological significance of this property, Li said. One hypothesis is that if ferroelectricity helps elastin stay flexible and functional in the body, a lack of it could directly affect the hardening of arteries.

"We may be able to use this as a very sensitive technique to detect the initiation of the hardening process at a very early stage when no other imaging technique will be able to see it," Li said.

The team also is looking at whether this property plays a role in normal biological functions, perhaps in regulating the growth of tissue.

More information: Ferroelectric switching of elastin, *PNAS*, www.pnas.org/cgi/doi/10.1073/pnas.1402909111

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