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Artificial ion channels created using DNA origami

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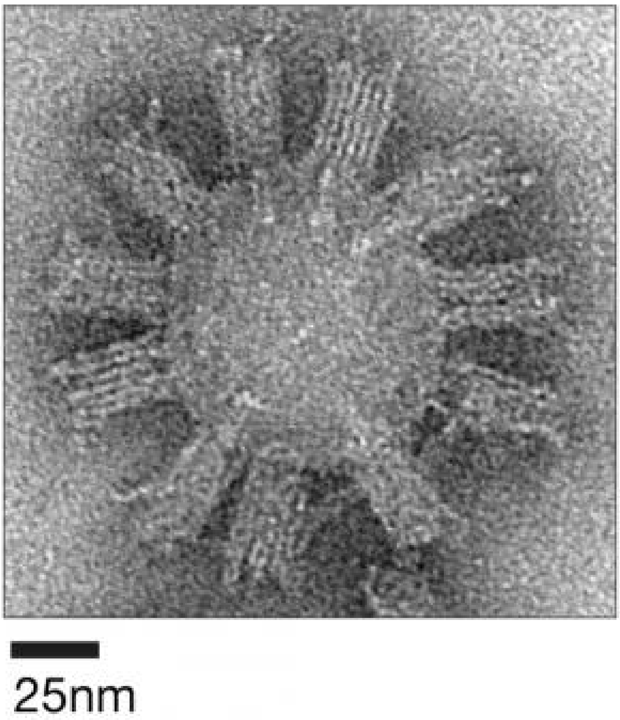
Scheme of a DNA-origami based ion channel. Credit: Technische Universität München

(Phys.org)—Researchers in Germany and the US have used scaffolded DNA origami techniques to create ion channels or pores that span and penetrate lipid membranes and mimic natural ion channels.

Prof. Dr. Friedrich Simmel and PhD student Martin Langecker of Technische Universität München (TUM) at Garching in Germany and their colleagues used a molecular self-assembly technique known as scaffolded DNA origami, in which strands of DNA are folded to create three-dimensional nanoscale structures. The strands are fixed in place by means of paired bases on short strands of DNA, and the base sequences determine exactly where the folds are fixed in place.

Scaffolding DNA origami has been used for several years and was described in this Phy.Org article. DNA origami has even been used to create nanoscale circuit boards, and has found application in cancer research.

Using this technique the team produced an artificial structure resembling a mushroom and comprising a 42-nanometer diameter stem and a barrel-shaped cap. The channel stem penetrated the lipid membrane while the cap was fixed to one side of the lipid membrane by attaching to 26 cholesterol groups within the synthetic membrane. The channels were subjected to electrochemical tests that showed the artificial channels allowed a current to flow, and could be exhibiting similar gating behavior to that found in natural ion channels.



TEM image of multiple DNA channels attached to a small lipid vesicle. Credit: Technische Universität München

Natural ion channels are basically proteins with holes down their middles, and they occur within the membranes enclosing all biological cells. The channels enable ions such as sodium, potassium, calcium and chloride to pass through what would otherwise be an impermeable lipid barrier, and can thus control the electrical current flow between the inside and outside of the cell. They are gated and can therefore be switched to open or closed, depending on the conditions and needs of the cell.

The researchers next made three versions of the artificial channel, with a short DNA strand protruding from the core of the channel in one of three different ways. These versions were then subjected to electrochemical testing. The tests revealed that the gating was more pronounced in the mutant versions, and the gating time was different for the three. These findings strongly suggest the gating is not an aberration produced by random thermal fluctuations, as might have been the case.

Possible applications for the artificial ion channels could include use in biosensors and in personalized medicine for delivering drugs directly to target cells. The paper was published in the journal *Science*.

More information: Synthetic Lipid Membrane Channels Formed by Designed DNA Nanostructures, *Science*, 16 November 2012: Vol. 338 no. 6109 pp. 932-936. DOI: 10.1126/science.1225624

ABSTRACT

We created nanometer-scale transmembrane channels in lipid bilayers by means of self-assembled DNA-based nanostructures. Scaffolded DNA origami was used to create a stem that penetrated and spanned a lipid membrane, as well as a barrel-shaped cap that adhered to the membrane, in part via 26 cholesterol moieties. In single-channel electrophysiological measurements, we found similarities to the response of natural ion channels, such as conductances on the order of 1 nanosiemens and channel gating. More pronounced gating was seen for mutations in which a single DNA strand of the stem protruded into the channel. Single-molecule translocation experiments show that the synthetic channels can be used to discriminate single DNA molecules.

Press release