A Biomimetic Device to Restore Lost Vision to the Blind

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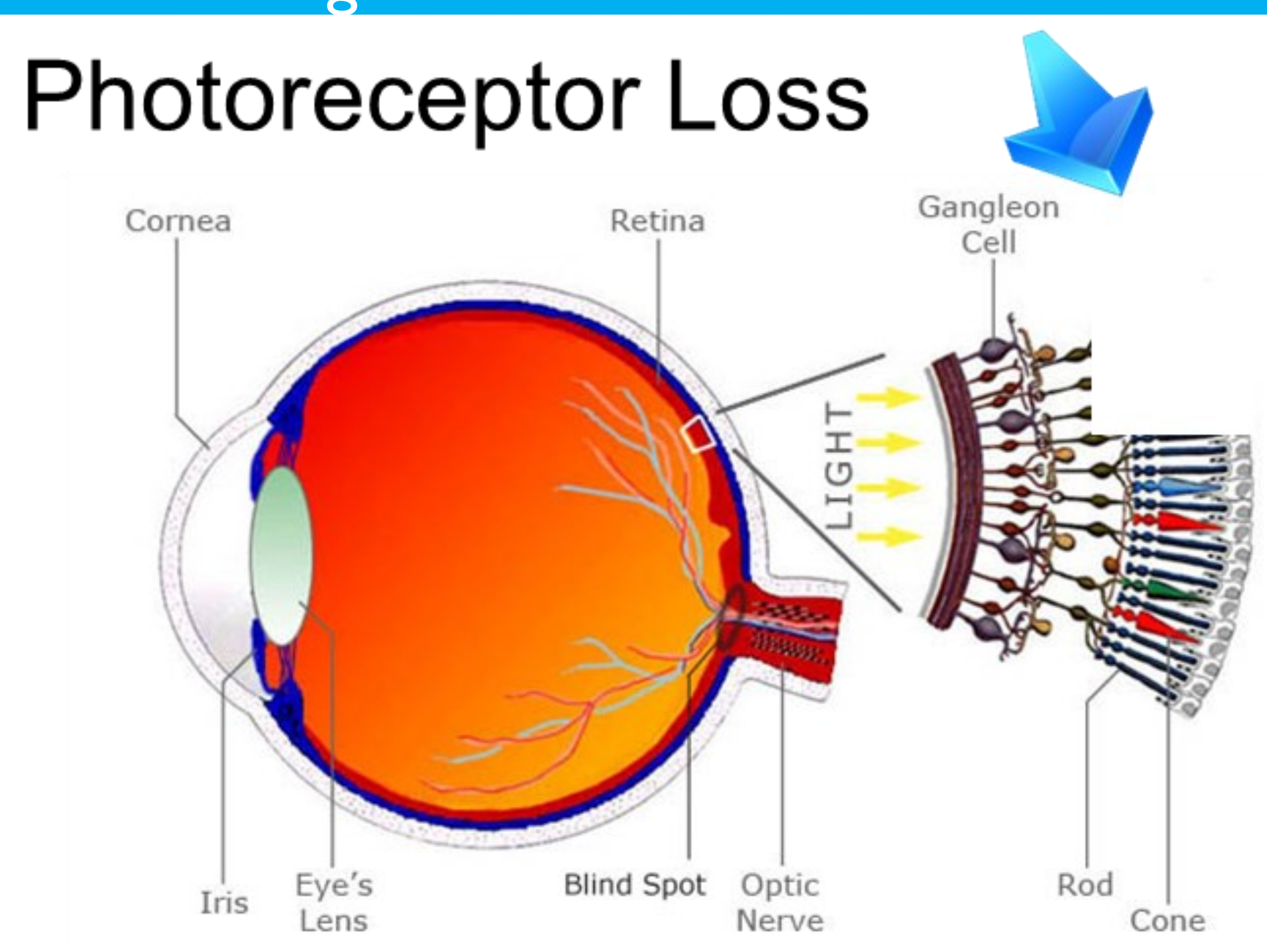
Abstract

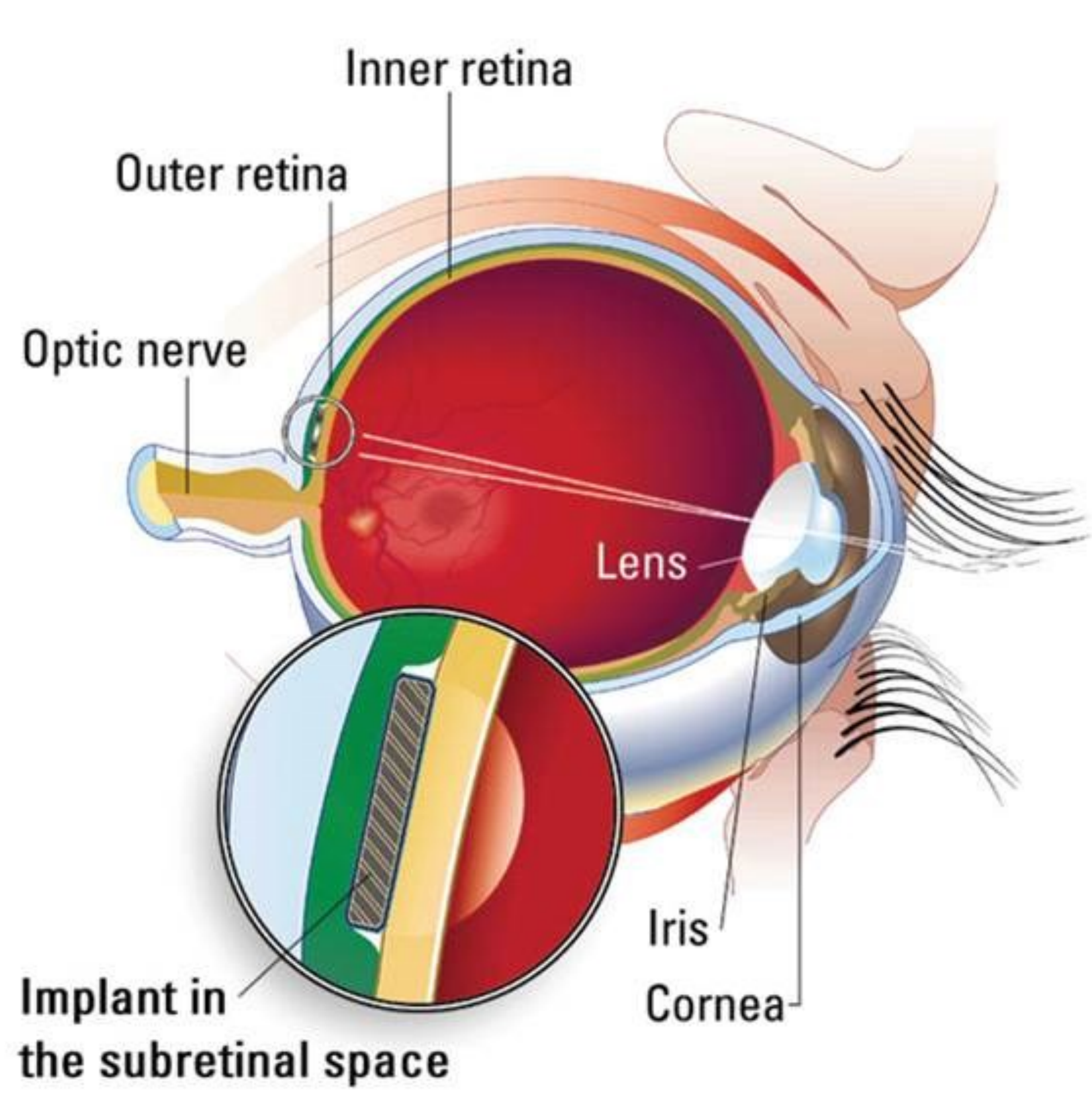
In nature, nanopores play an essential role in a number of biological functions. The malfunctioning of these biological channels can therefore have devastating effects on the well being of their host. Synthetic nanopores have emerged as a powerful tool to better understand biological nanopores and could potentially restore lost functionality to such systems. The key to unlocking this immense potential of synthetic nanopores is the ability to functionalize the nanopore with any desired molecule, such as ligands, proteins, crown ethers, etc. By developing a methodology to attach any molecule of choice, we will be able to quickly explore potential candidates to achieve similar functionality as biological channels. One particular biological system of interest is the retinal system, gaining popularity with the recent success of cochlear implants. Several recent attempts have restored partial functionality to vision, but have limitations due to power constraints and non-renewable sources of stimulation. It was recently established that a small increase in the extracellular potassium ion concentration can effectively stimulate neural tissue. Dr. Theogarajan has proposed a novel synthetic ion pump that will function by sequestering local potassium ions from extracellular fluid, ultimately leading to a renewable and low power device. We report here on potential candidates for a potassium selective channel, with measurements on single nanopores in Silicon Nitride and Aluminum Oxide and nanopore arrays in Polycarbonate.

Leading Cause of Blindness in U.S



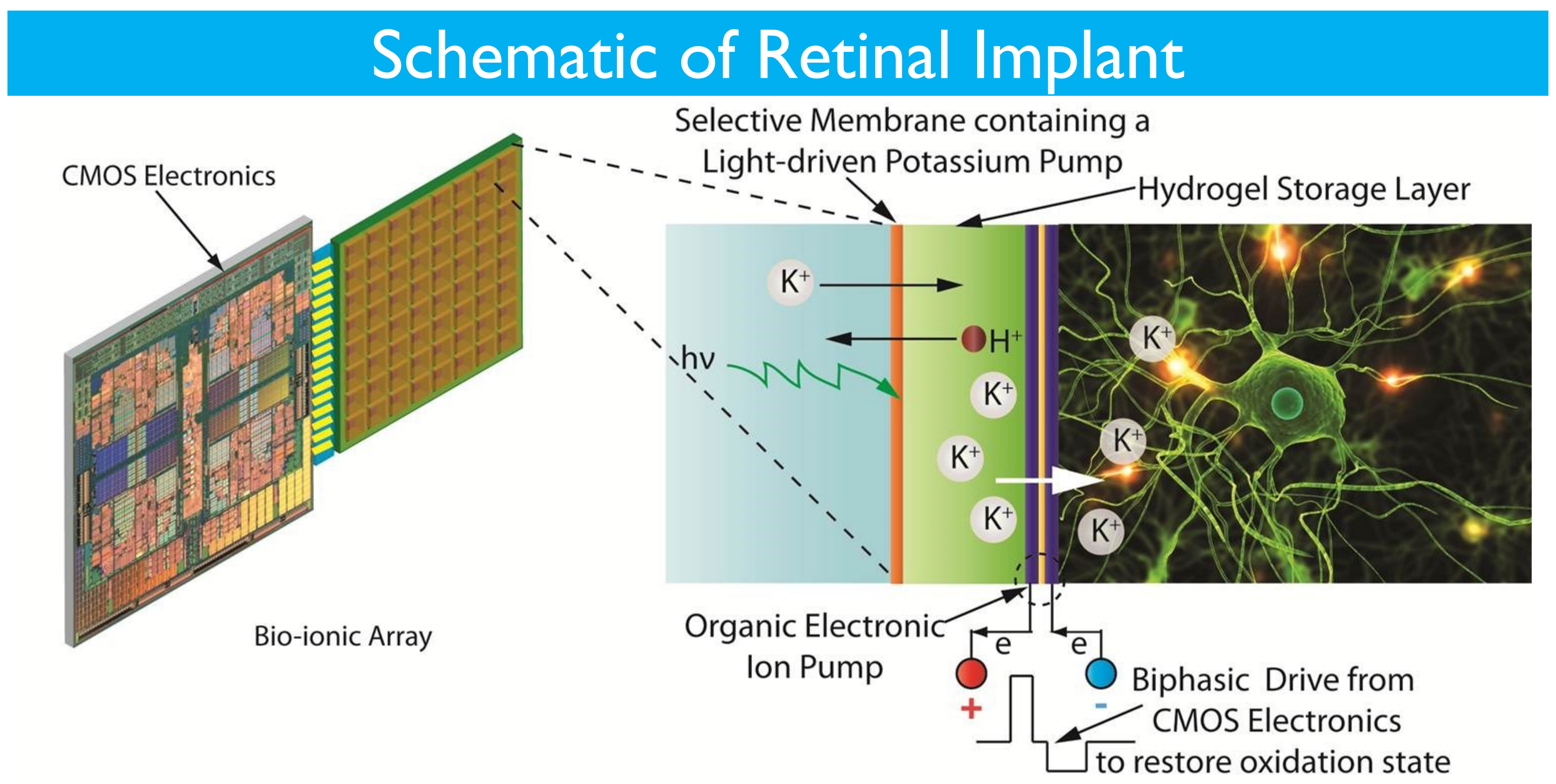
The deterioration of photoreceptor cells causes the loss of sight.

Bioionic Neural Interface



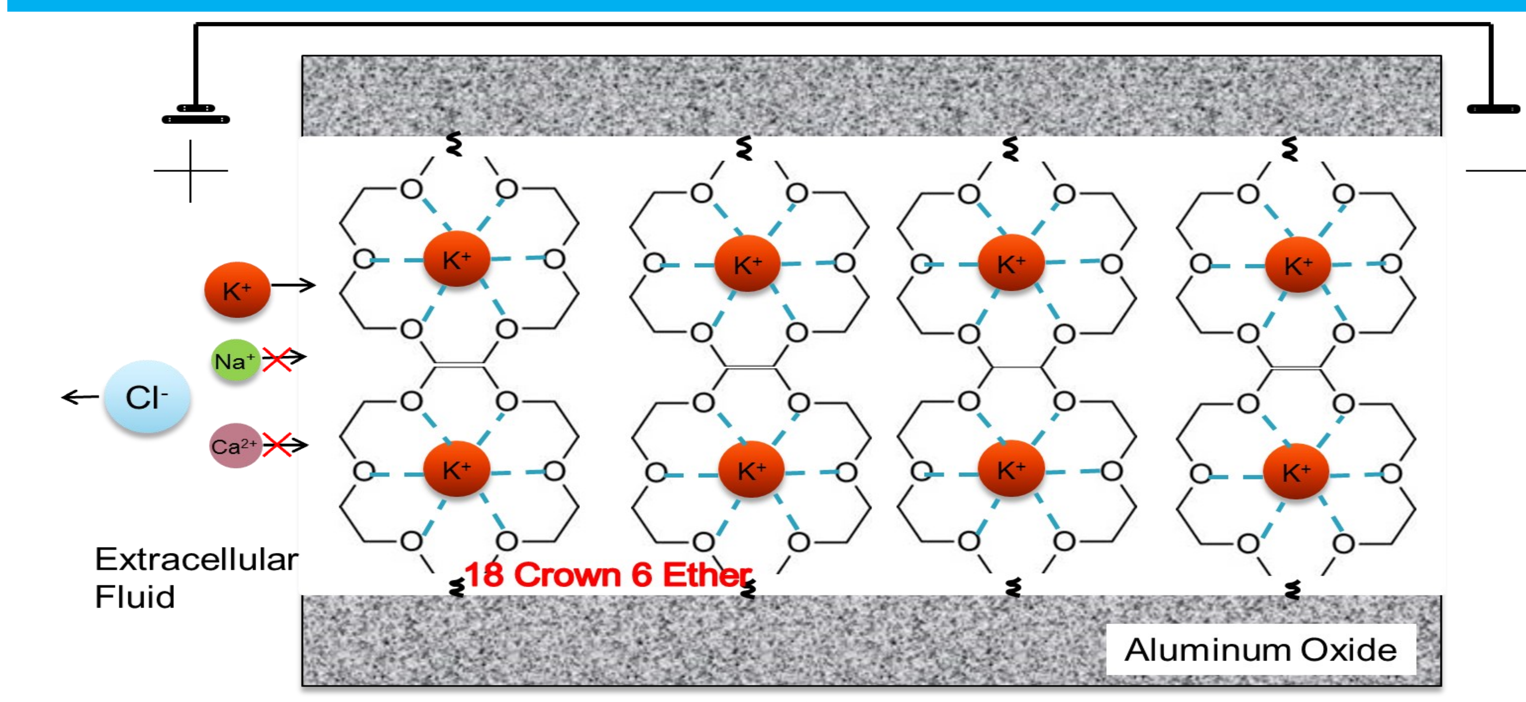
This implant will be effective, low powered, renewable and organic.

Schematic of Retinal Implant



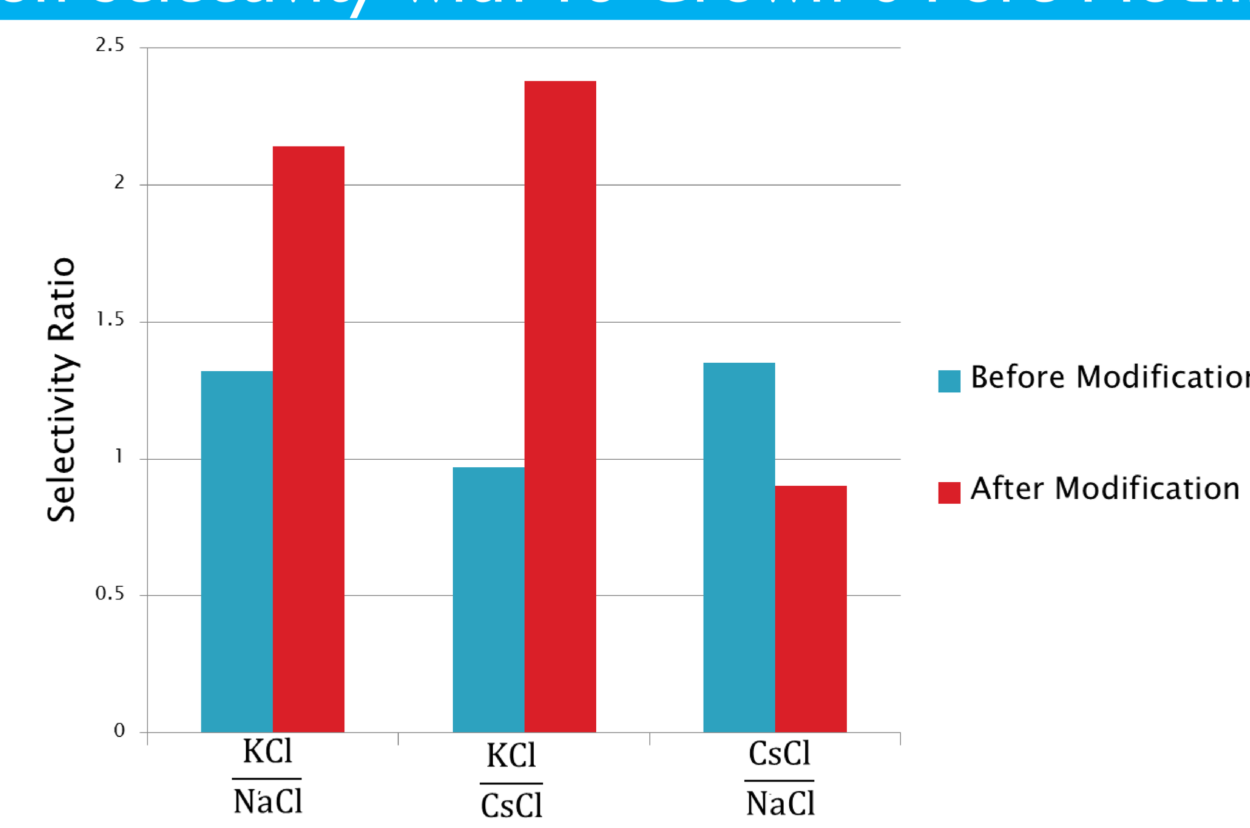
This interface is powered by the energy of light. Once light (hv) comes in and hits our potassium selective membrane, it will allow potassium from the outside fluid to come into the hydrogel storage layer. The potassium will then diffuse into the cell on its own and cause neurons to fire.

Potassium Selective Membrane Channel



Aluminum oxide represents the membrane. Ions in the extracellular fluid create a charge and want to go in different directions. The way only potassium will go through is by functionalizing the pore with 18-Crown-6 ether which prefers potassium over the other ions. This will allow potassium to go through the pore and later on cause neurons to fire.

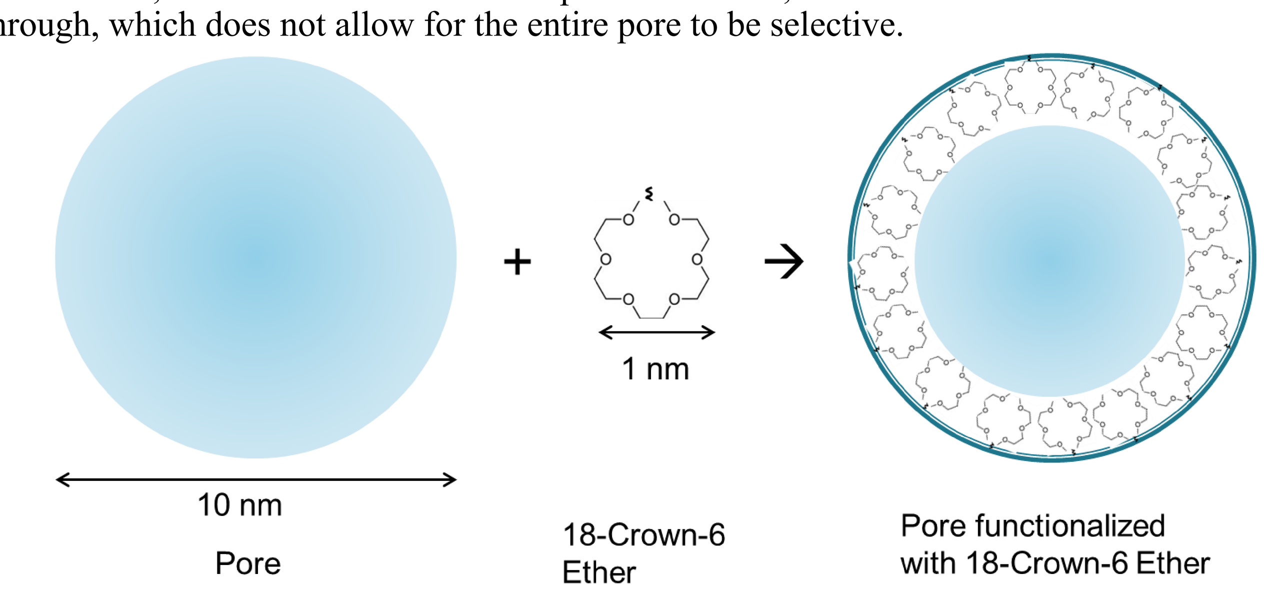
Ion Selectivity with 18-Crown-6 Pore Modified



1 M salt solutions buffered at pH8.

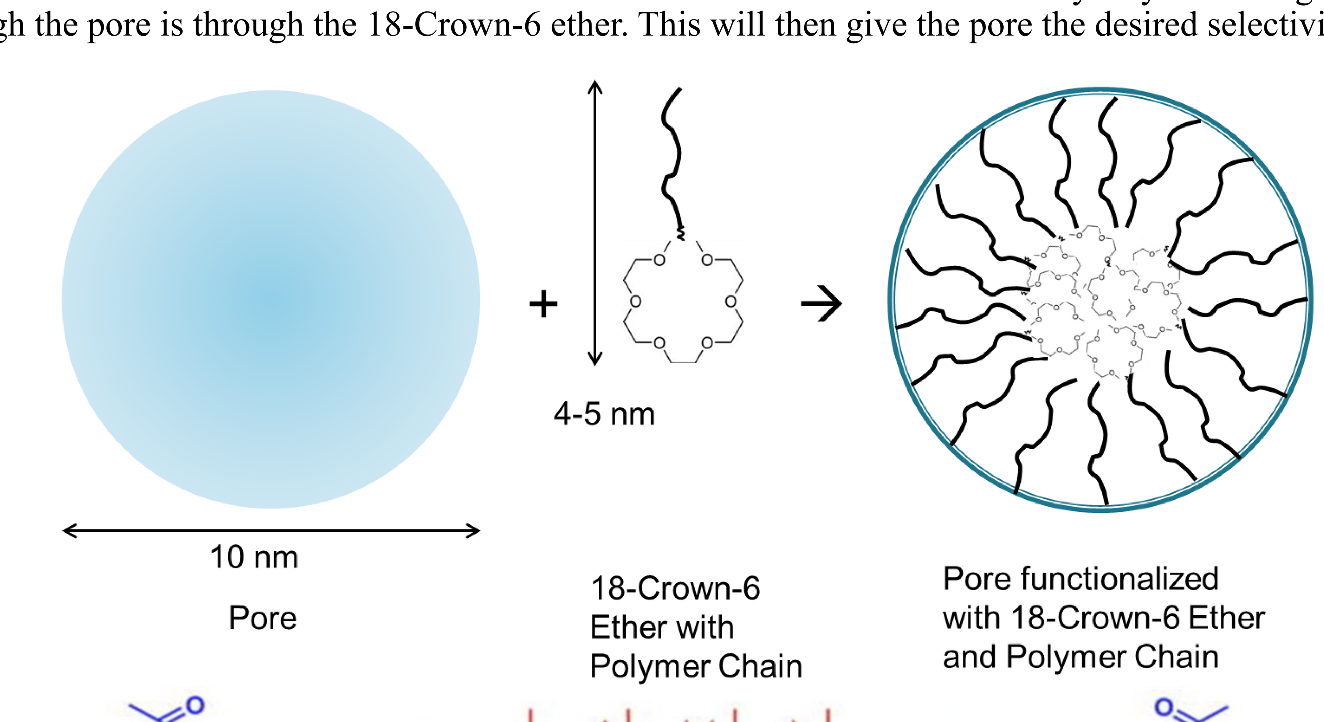
Pore Modified with Only 18-Crown-6 Ether

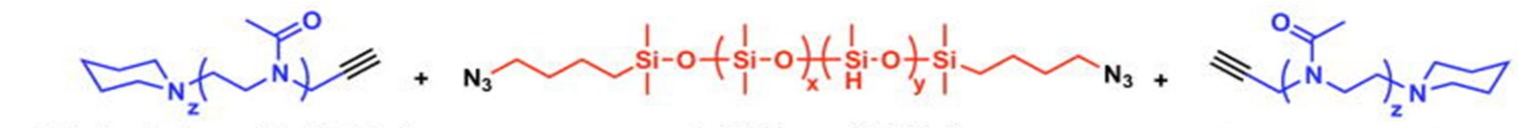
The reason why the pore was not fully selective above is because when the pore was modified with only 18-Crown-6 ether, it does not cover the entire pore. Therefore, the area in the blue still allows for any ions to go through, which does not allow for the entire pore to be selective.



Combine 18-Crown-6 Selectivity & Polymer Blockage

The way the issue above will be targeted, is by attaching a polymer to the 18-Crown-6 ether. This polymer does not interact with the ions which will then act as a blocker. Therefore the only way ions can go through the pore is through the 18-Crown-6 ether. This will then give the pore the desired selectivity.





Materials and Methods

Aluminum Oxide windows were prepared by Sukru Yemenicioglu, and nanopores were drilled via a Transmission Electron Microscope at the Materials Research Laboratory (MRL) at UCSB. The MRL Shared Experimental Facilities are supported by the MRSEC Program of the NSF under Award No. DMR 1121053; a member of the NSF-funded Materials Research Facilities Network(www.mrfn.org)." Preparation of Crown Ethers for attachment to nanopores was performed by Dr. Weibin Cui. Measurements were performed on an EPC 10 by HEKA Elektronik.

Acknowledgements

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