Restoring Vision with Nanowires

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Curing blindness has been a human fascination throughout most of recorded history, in every form from the mystical to the proto-scientific. Today, with a modern understanding of the eye and its functions, we may be closer to such a cure than ever before, at least for some forms of blindness. Like many other conditions, blindness is not a single disease that can be universally cured, but rather a symptom of many varied diseases that must be addressed individually.

One such disease, or more precisely a collection of them, is *retinitis pigmentosa* (RP). RP is a collection of genetic diseases that result in the death of the light-sensitive cells (commonly known as rods and cones) in the human eye while leaving the remainder of the retina relatively intact. These light-sensitive cells, typically called photoreceptors, are particularly fragile due to the complex chemical mechanism they use to detect light and translate it into an electrochemical signal that can be passed on to other cells in the retina.

The retina itself is roughly organized into three layers, and is built up in a reverse order, meaning that light passes all the way through the retina before being detected at the deepest area. This outermost brain-facing layer of the eye is dominated by the photoreceptors as well as the retinal pigment epithelium, a layer of support cells that maintain the photoreceptors. This layer is where the damage due to RP happens - typically the disease is the result of any of a number of mutations that slowly disrupts the maintenance process for photoreceptors, resulting in cell death. The middle layer primarily consists of bipolar cells, which form complex networks that provide the first layer of signal processing of visual information. This layer then connects to the innermost layer, which primarily consists of retinal ganglion cells (RGCs) which gather information for transmission to the brain. The axons of the RGCs are what make up the optic nerve.

Since the transmission of information in the retina is electrochemical, applying electrical current to the retina can stimulate it and produce a signal similar to that produced by light. As a result, an obvious approach to try to restore vision in a patient lacking photoreceptors due to RP or another condition is to electrically stimulate the middle layer of the retina in a manner similar to that produced by light. Some implants that do this already exist, although they use comparatively large electrodes, and as a result vision is very limited in resolution (around 60 pixels total for one current clinical implant, the Argus II). These implants also require a source of power, which in turn either requires hard-to-replace batteries under the skin or wires going through the skin (which tends to result in infection).

An approach to both minimize the size of the electrodes and to eliminate the external power requirement is to use photovoltaic nanowires. These are wires with a diameter in the 100s of nm and a length in 100s to 1000s of nm - significantly smaller than individual cells. Their photovoltaic properties allow them to produce electricity when hit by light, in the same way as solar panels (in fact, the nanowires used in this project were originally developed for use in solar cells). As a result, arrays of

these nanowires hold the promise of implants granting significantly better vision.

In order to test the properties of these nanowires, experiments were done on mice retina, dissected out of the eye and placed on a microscope slide. A flexible array of microelectrodes was then placed against the retina to measure signals from the RGCs and record them, and the resulting data analyzed to detect and characterize responses to light. Both wild-type(normal, healthy mice) and rd1(a disease model for RP) were used. The intent was to place the retinas on top of nanowire arrays and measure, but due to the COVID-19 pandemic only experiments with retinas alone were carried out. As a result, there were no major new findings as a result of this project, only refinements to the experimental techniques used. As a result, there were no major new findings as a result of this project, only refinements to the experimental techniques used.