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| Creating a Bionic Eye |
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**Loughborough University**

Biophotonics Engineering 14ELC014

December 12, 2014

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Creating a Bionic Eye

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# Introduction

Human beings are able to see when light bounces of an object and enters the pupil which creates an inverted image of the object that the person is looking at. This report aims to analyze current methods for recovering eye sight to the possibility of creating the first super eye (Bionic eye). This report will go into a look at the basic biological functioning of the eye to give a foundation in understanding the methods used to correct vision. The report will also identify key methods and advancements in this field and critically compare and analyze the different methods.

# The Human Eye

## Basic Biology

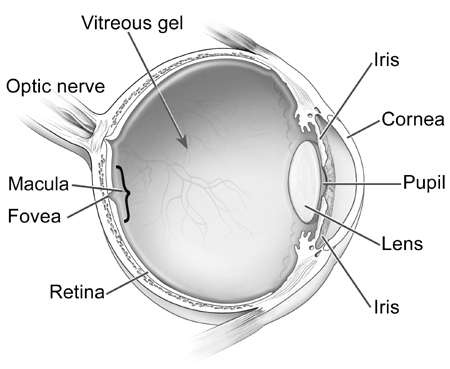


Figure 1: Image courtesy of the (National Eye Institute)

Let’s look at how a human being sees and object. In this scenario its daylight and there is a ball in the middle of a field that can be clearly seen. This happens because in order for human beings to see anything there must first be light, either natural or manmade. The light source in this case is the sun; the sun gives of light particles or photons that travel and hits the ball. As the light photons hit the ball it bounces of (this is known as reflection) and the photon then makes its way into the eye through the pupil.

The pupil is the opening in the iris controlled by the iris to regulate the flow of light into the eye to prevent damage hence in low lighting conditions the pupils appear larger and dilated, this is too let more light photons through. While during the day or periods of bright light the pupil appears small and contracted. The changing is notably felt when moving from a bright environment to a dark environment as initially squinting might be required to discern objects but after a short time the vision gets adjusted. Same is true for the reverse.

The lens, located just behind the pupils, is used to direct the light to a focused point on the retina which is located at the back of the eye. The retina holds the photoreceptor cells (nodes and cones) that sense color and black and white, hue depth etc. The signal is then sent to the brain via the optic nerve.

## Common Disorders

**Macular degeneration:** this forms when the macula cannot function effectively [6].

**Dry Age-Related Macular degeneration (AMD)**: the less serious form of AMD. It forms when the cells in the macula is destroyed by waste build up. The loss of vision in this case is gradual and can take many years to be fully blind. However there is a possibility to get wet AMD [6].

**Wet Age-Related Macular degeneration (AMD):** this is the serious form of AMD and vision can be lost “within days”. This is caused when abnormal blood vessel form and damage the cells in the macular. Also known neovascular AMD [6].

**Retinitis Pigmentosa (RP)**: This is an inherited eye disorder which causes partial loss of some aspect of vision these changes are permanent and can include loss of peripheral vision or loss of sight in dim lighting conditions. RP cause blindness similar to dry AMD over a couple of years, with some patients still being able to see partially into their old age.

**Dystrophies**: dystrophies are also inherited eye disorders cause by faulty genes. These lead to the loss of the central vision only but not complete loss of vision as there is still the peripheral vision (side vision) [4].

# Current Solutions

A lot of current attempts to create the human bionic eye consist of mainly a camera to capture images of the real world and sending a signal to the brain using transmitters and receivers. Most of the current prototypes are based on rectifying sight degeneration.

Most of the methods discussed in this make use of retinal implants. There are two types of retinal implants:

**Epiretinal Implants**: These implants are located on the Retina and require an external video source to obtain images.an external transmitter provides power to the implant by using either radio-frequency induction coils or by using infrared lasers. [8]

Advantages: For this to work the ganglion cells are the only cells required and thus can be effective if more than just photoreceptive cells are damaged. Implants can be smaller as most of the electronics can be placed externally. The implant can be cooled by the liquid in the eye and gives doctors more control over the image processing of the implant. [8]

Disadvantages: external components can become o bother to wear and in order to pan vision the user is required to tilt their head to get the view the want which makes it less natural. [8]

**Subretinal Implants:** These implants are located on the outer surface of the retina and rely on the inner and middle layers of the retina to work. This means that it can be stimulated by the light directly. [8]

Advantages: it has a simpler design than the Epiretinal Implant. If used with an array of micro photodiodes no external camera or processing unit will be required. To pan the view can be done natural by the turn of the eyeballs. [8]

Disadvantages: the light that hits it is not enough to create sufficient current so an external power source is required to boost the light hitting the implant. Damage to the retina can be observed due to heating. [8]

## Argus 2

The Argus 2 an epiretinal implant that is designed mainly to treat people suffering from retinitis pigmentosa (a degenerative eye disease). The Argus two is made up of a small camera mounted into the frame of a pair of glasses connected to a hip mounted signal processor, a retinal implant that consist of an electrode array with 60 electrodes, an electronics case and an antenna.

The Camera in the eye glass captures the area around the user. The hip worn processing unit then processes the images from the glasses and sends the processed information back to the glasses which is then sent wirelessly to the retinal implant. The electrodes in the retinal implant then gives off electrical impulses which stimulate the remaining photoreceptors and a signal is then sent through the optic nerve to the brain. [7]

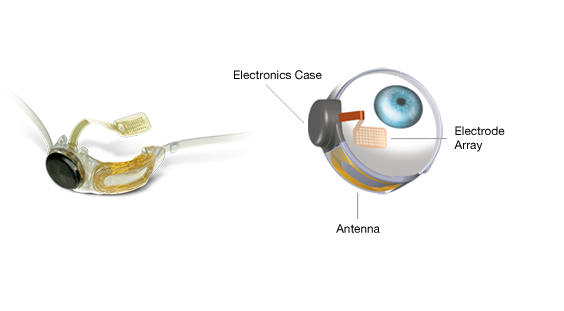


Figure 3: Retinal Implant (Second Sight)

Figure 2: External Electronics (Second Sight)

Advantages to this method include the fact that there is only one implant which is located on the eye and the data is transferred wirelessly to the electrode array. Having the video processing unit external means the implant is smaller and also being epiretinal has a higher thermal capacity.

Disadvantages include the fact that in order to pan the view around a tilt of the head is required as opposed to the repositioning of the eyeballs. The glasses and video processing unit must be worn at all times and a low resolution image is created of just sixty pixels.

## Smart Lens

The “Smart lens” by google, licensed out to Novartis, does not exactly rectify vision but acts as a diabetes diagnosis. The lens is made up of a wireless receiver and miniature glucose sensor. There is a tiny pinhole that allows tear fluid to flow in so as to analyze it and send the collected data wirelessly to be processed. This technology is currently just being developed but the possibilities are endless. This could bring the current google glass to the contact lens. However users for this smart lens will need to already be able to see in order to use them as they do not attempt to rectify vision except for possibly allowing users that struggle to focus by helping the eye focus on objects. [3]

## Wide View

Created by Australia’s Bionic Vision Australia is the cheaper priced model allowing its users to avoid large objects like buildings, cars etc. It consists of the same components as the US Argus 2. It has a camera mounted unto the frame of glasses that captures and transfers data to an external processing unit which is worn on the person similar to the hip placement of the Argus 2. The processed data from the external processing unit is then passed by a wire to an implanted receiver in the back of the head which then sends the signal to the retinal implant. . It also consist of an implanted electrode array placed on the retina to stimulate the dead photoreceptor cells, this is formed of 98 electrodes which is more than that of the Argus 2. When the dead photoreceptor cells are stimulated they then send a signal through the optic nerve to the brain. The image below is a diagram of the Wide-View Device. The image obtained will be slightly better than the image created by that of the Argus 2 due to the fact that it contains more electrodes and so more pixels can be viewed. An eye tracker is also a feature which allows the camera to pan based on the positioning of the pupil. [1]

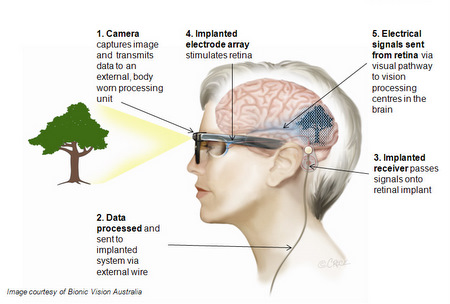


Figure 4: Wide View Device (Bionic Vision Australia)

Advantages to this method include the fact that the view can be panned based on the movement of the eyeballs. At ninety-eight electrodes it has a higher resolution image than that of the Argus 2. The implant is placed in the choroid (vascular tissue) located behind the retina to this prevents damage to the retina during implanting and can help to keep the implant fixed in its position

Disadvantages to this method include the fact that there are 2 implants required, the receiver and the electrode array and a wire is used to send the signal from the processor to the implanted receiver. It can also get uncomfortable to wear as the external electronics, mainly the eye tracker, may be seen as intrusive and uncomfortable.

## High-acuity

Created by Australia’s Bionic Vision Australia the high-acuity bionic eye is its high performance version of the bionic eye allowing for facial recognition and reading of large prints from book, computer screens etc. the high-acuity device is made up of three main components: The camera, mounted unto a pair of glasses, which takes the photos and sends signals wirelessly. Retinal Implant and Processor, placed on the retina, receives signals from the camera and processes it. The Retinal implant will consist of 256 electrodes which will allow for a 256 pixel vision making vision appear clearer. Diamond materials are being used for the implants and the electrode arrays as it is very biocompatible and is rarely rejected by the body making it safer and is very durable.

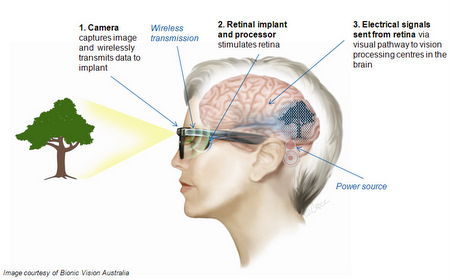


Figure 5: WIDE VIEW DEVICE (BIONIC VISION AUSTRALIA)

Advantages include the fact that this method makes use mainly wireless technology and the processor is now located in the implant so the amount of electronics required to carry around is drastically reduced. There is a much higher resolution of 256 pixels making allowing for facial recognition and reading of large text.

Disadvantages include the fact that it requires on stimulating cells in the eyes.

## Alpha-IMS

The Alpha-IMS consists of a chip which is placed beneath the fovea in the eye and instead of using electrodes as the previous methods utilized it makes use of microphotodiode-amplifier-electrodes and contains 1500 pixels. This method also has a wire running from the chip to a sub dermal coil behind the ear which powers and sends signals to the chip in the eye. There is also a battery pack that powers the external coil. This method uses transdermal electric induction to provide power. [9]

This method is a Subretinal implant and thus does not require the use of an external camera.

Advantages are that most components are internal and no need to wear glasses with cameras as it relies on the light already entering the eye so is much less intrusive than the other methods discussed above. It also creates a higher resolution image for the user.

Disadvantage: can only be used for blindness cause by only degenerated photoreceptor cells as it only by passes those cells and none other.

# Expected Difficulties and Possible Solution

Current research relies on stimulating the cells that are in the retina that have not been affected by degeneration. This is done by using one form of an electrode. This stimulation is currently limited to only representing shapes and objects using light and dark or grey scale. Vision currently relies on the signal being processed by the eye and sent via the optic nerve. Each electrode stimulates a single cell in the retina below the photoreceptors as seen by all the methods above. These methods are only useful for rectifying vision problem with patients who have suffered from either retinitis pigmentosa or macular degeneration. And will not work for people with the destruction of their retina. Another limit is color as none of the methods and trials stated above attempt to represent any information in color.

The main challenge facing the super human bionic eye however will be space in the human eye for the electronics required. Having these systems external will feel like using a google glass, having a bulky attachment on someone’s face will be quite uncomfortable. Eventually scientist will need to bypass the optic nerve to get information to the brain to process images or at the very least to simulate the signal into optic nerve without stimulating the retina. This way signals from cameras can be directly converted into impulses the optic nerve can transfer to create an image in the brain from a camera or directly from the microphotodiodes.

It is important to know that in cases of blindness seen in this report that the eye is completely intact and functions properly apart from the degenerated cells (Rods and Cones) retinal implants currently act as cones because only an electric signal is passed from the electrode to the inner layers of the retina. Color vision can be achieved once the signal the cones give off can be replicated artificially. By including a second camera with a variable band filter that only allows a select light frequency through at any point allowing it to pass specific color signals to the brain through the optic nerve. Another challenge would be pinpointing the exact position of that particular color which can be achieved by using the format of a simple radar system by letting only a tiny area of light in at a time and letting out a signal that gets reflected of the object at the point. This will enable blind people to regain their color vision. A simpler way would be to have the color processor in the subretinal implant allowing for a less bulky implementation.

# Conclusion

In conclusion the field of vision has come a long way and with the introduction of the Argus 2 into commercial service scientist are now able to rectify blindness and give people their sight back in the form of object recognition and light detection. There is currently more research being done into making the images generated from these methods higher in resolution so the patients can recognize more. Eventually research will start looking into adding color to the mix to bring people back their site. At this point will scientist be closer to creating the “Super Human Eye”.

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