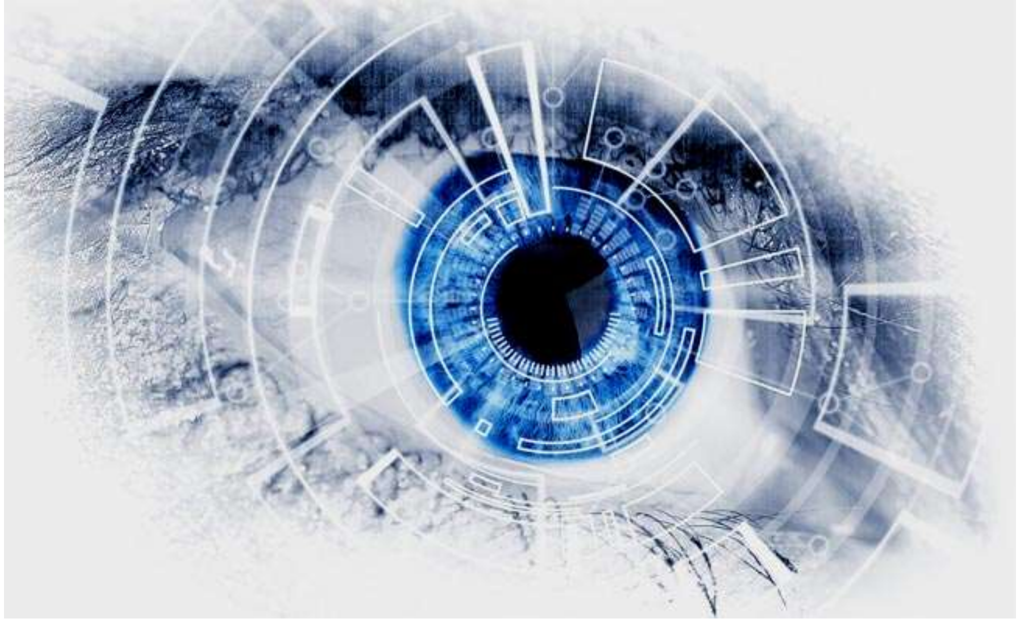
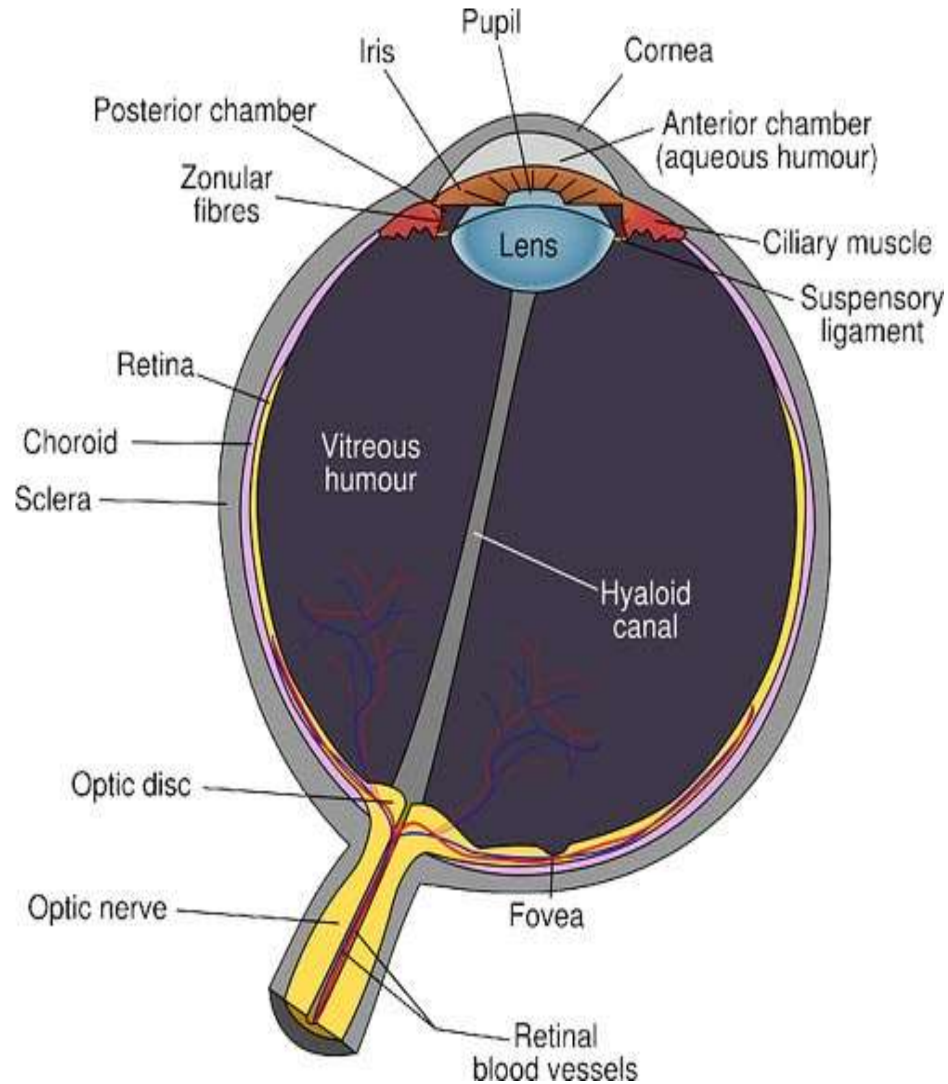
BIONIC EYE

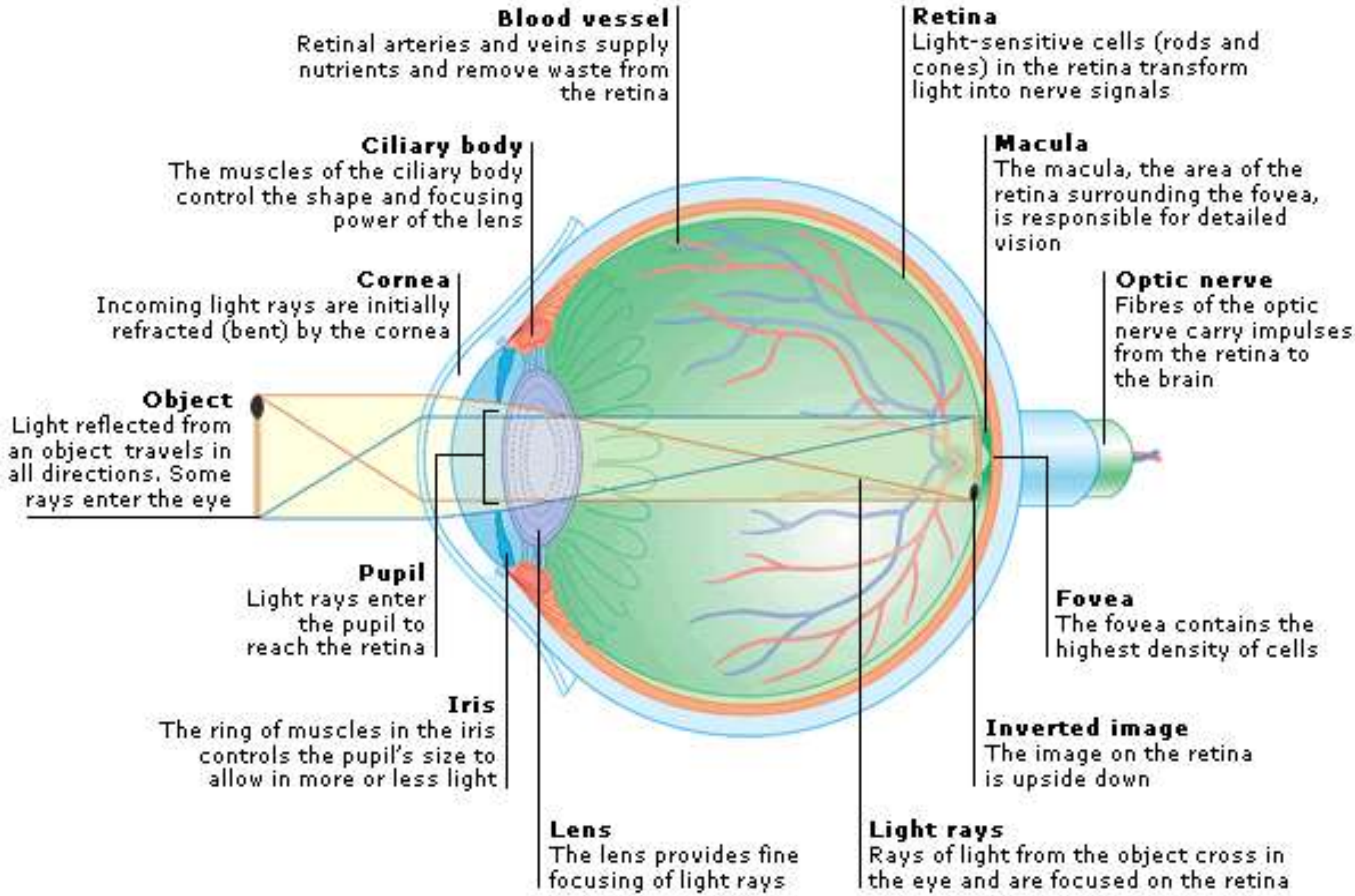


The Human Eye

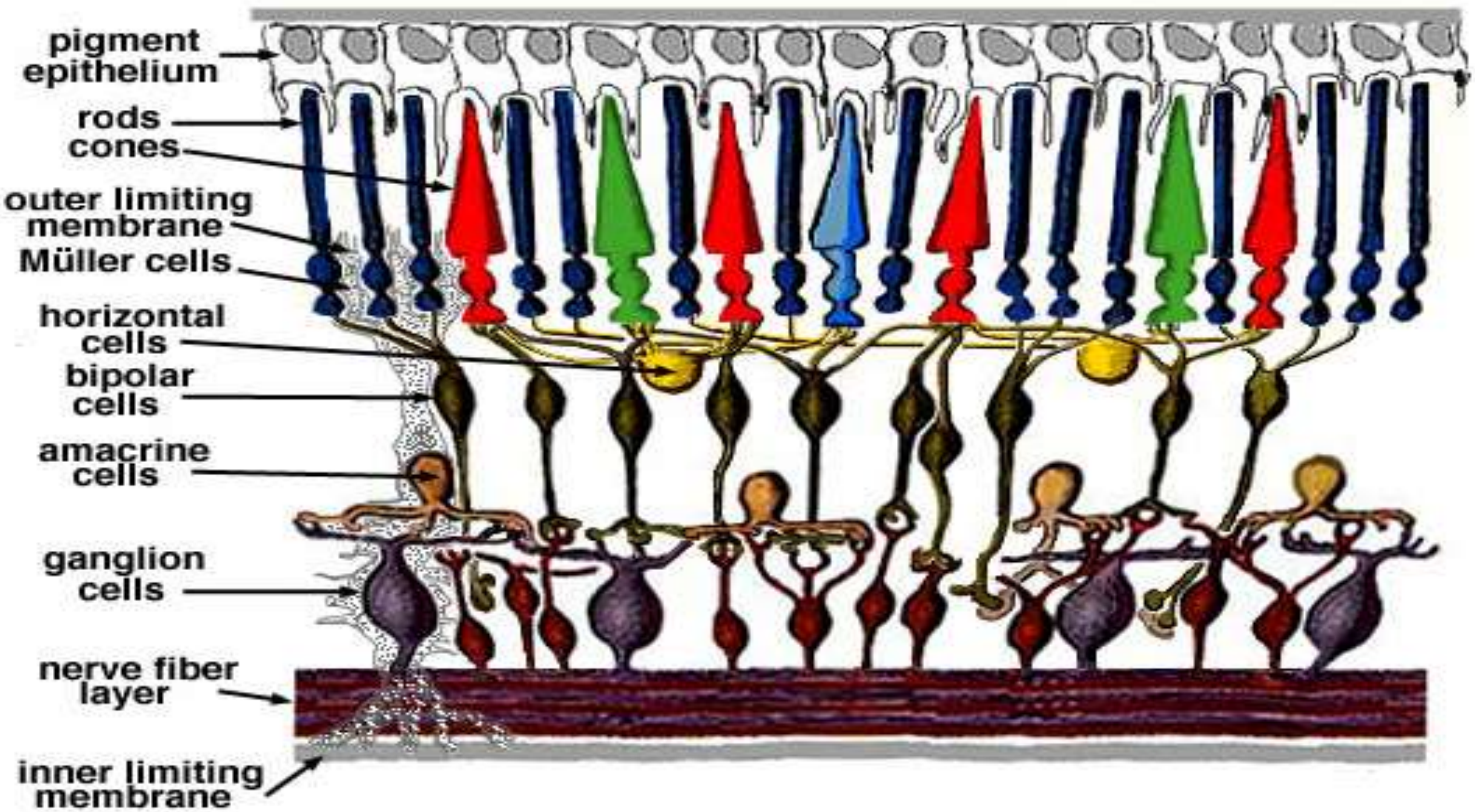
- Human vision is a complex physical process of visualizing something that involves simultaneous interaction of the eyes and the brain through a network of neurons, receptors, and other specialized cells.



Structure and function of the Eye

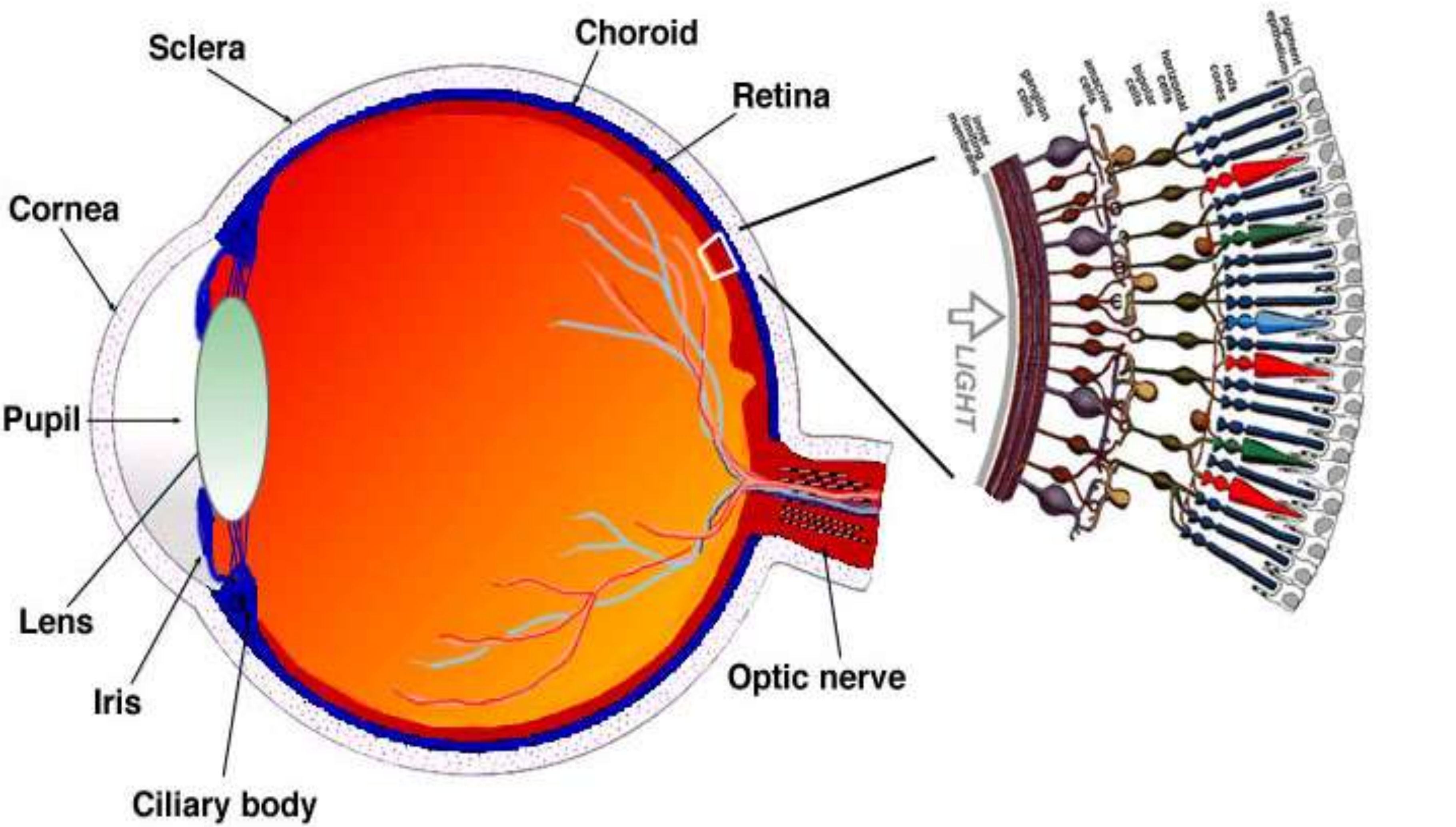


The Retina



pigment
epithelium
rods
cones
outer limiting
membrane
Müller cells
horizontal
cells
bipolar
cells
amacrine
cells
ganglion
cells
nerve fiber
layer
inner limiting
membrane

The Eye with Retina



- The human eye is equipped with a variety of optical elements including the cornea, iris, pupil, a variable-focus lens, and the retina.
- When an object is observed, it is first focused through the cornea and lens onto the retina, a multilayered membrane that contains millions of light-sensitive cells that detect the image and translate it into a series of electrical signals.
- These image capturing receptors of the retina are termed **rods** and **cones**, and are connected with the fibers of the optic nerve bundle through a series of specialized cells that coordinate the transmission of the electrical signals to the brain.

- In the brain, the optic nerves from both eyes join at the optic chiasma where information from their retinas is correlated.
- The visual information is then processed through several steps, eventually arriving at the visual cortex, which is located on the lower rear section of each half of the cerebrum.

- A particularly specialized component of the eye is the **fovea centralis**, which is located on the optical axis of the eye in an area near the center of the retina.
- This area exclusively contains high-density tightly packed cone cells and is the area of sharpest vision.
- The density level of cone cells decreases outside of the fovea centralis and the ratio of rod cells to cone cells gradually increases.

- At the periphery of the retina, the total number of both types of light receptors decreases substantially, causing a dramatic loss of visual sensitivity at the retinal borders.
- This is offset, however, by the fact that humans constantly scan objects in their field of view, usually resulting in a perceived image that is uniformly sharp

BLINDNESS

- 80% of blindness occurs in people over 50 years.
- Common causes :- macular degeneration, traumatic injuries , glaucoma etc.
- Less common causes :- vitamin A deficiency , retinitis pigmentosa etc.

The Problem with eye / vision

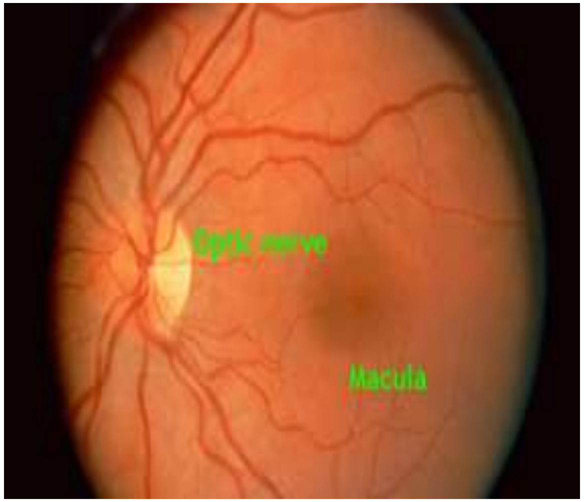
- **The Photoreceptor**
  - Photoreceptors signal the presence of light in the visual field.
  - Rods: Low light, no color detection.
  - Cones: Light required, three types of cones produce the perception of color when combined.

- **Degeneration**
  - Retinitis Pigmentosa: Loss of photoreceptors, both rods and cones, in the back of the eye.
  - Macular Degeneration: Age and genetic related.
    - Caused by atrophy of epithelial layer in retina or abnormal blood vessel growth.
    - Causes 30% of all eye-related problems ages 75 to 85.

Retinitis Pigmentosa

- Hereditary Genetic Disease
- Peripheral Rods degenerate
- Gradually progresses towards center of eye
- Tunnel vision results

Opthalmoscope View

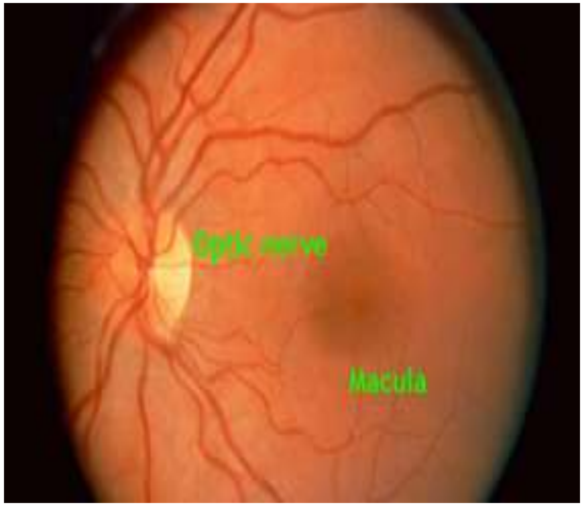


NORMAL EYE

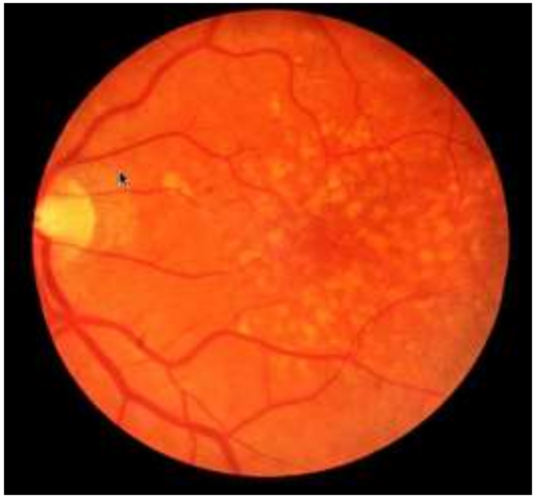
DEFECTIVE EYE

Macular Degeration

- Genetically Related
- Cones in Macula region degenerate
- Loss or damage of central vision
- Peripheral Retina spared
- Common among old people



NORMAL EYE



DEFECTIVE EYE

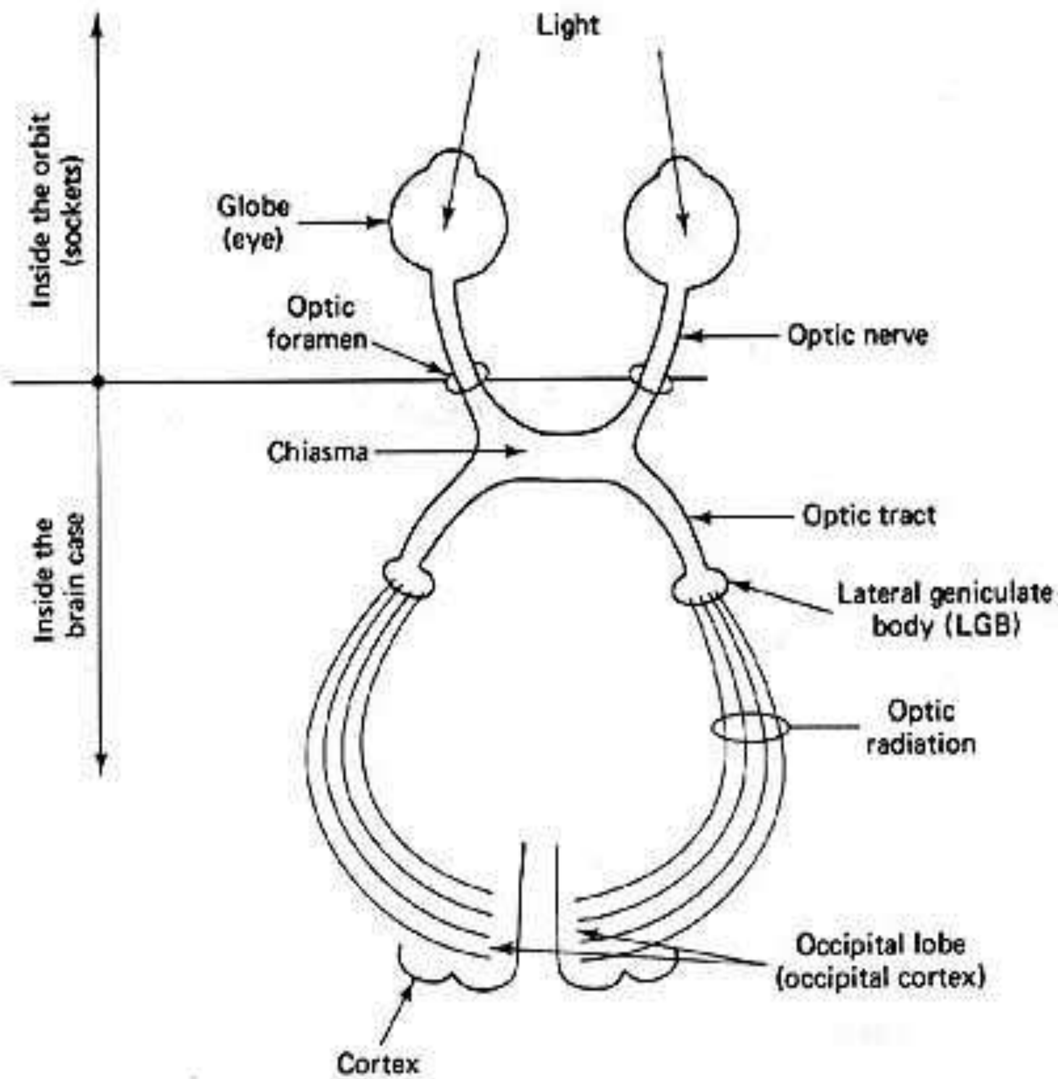
The Bionic Eye

- It is an **artificial eye** which provide visual sensations to the brain.
- Bionic eye refers to bioelectronic eye.
- The electronic device which replaces functionality of a part or whole of the eye.
- It consist of electronic systems having image sensors, microprocessors, receivers, radio transmitters and retinal chips. Technology provided by this help the blind people to get vision again.
- Bionic Eye Inventor: **Dr. Mark Humayun**

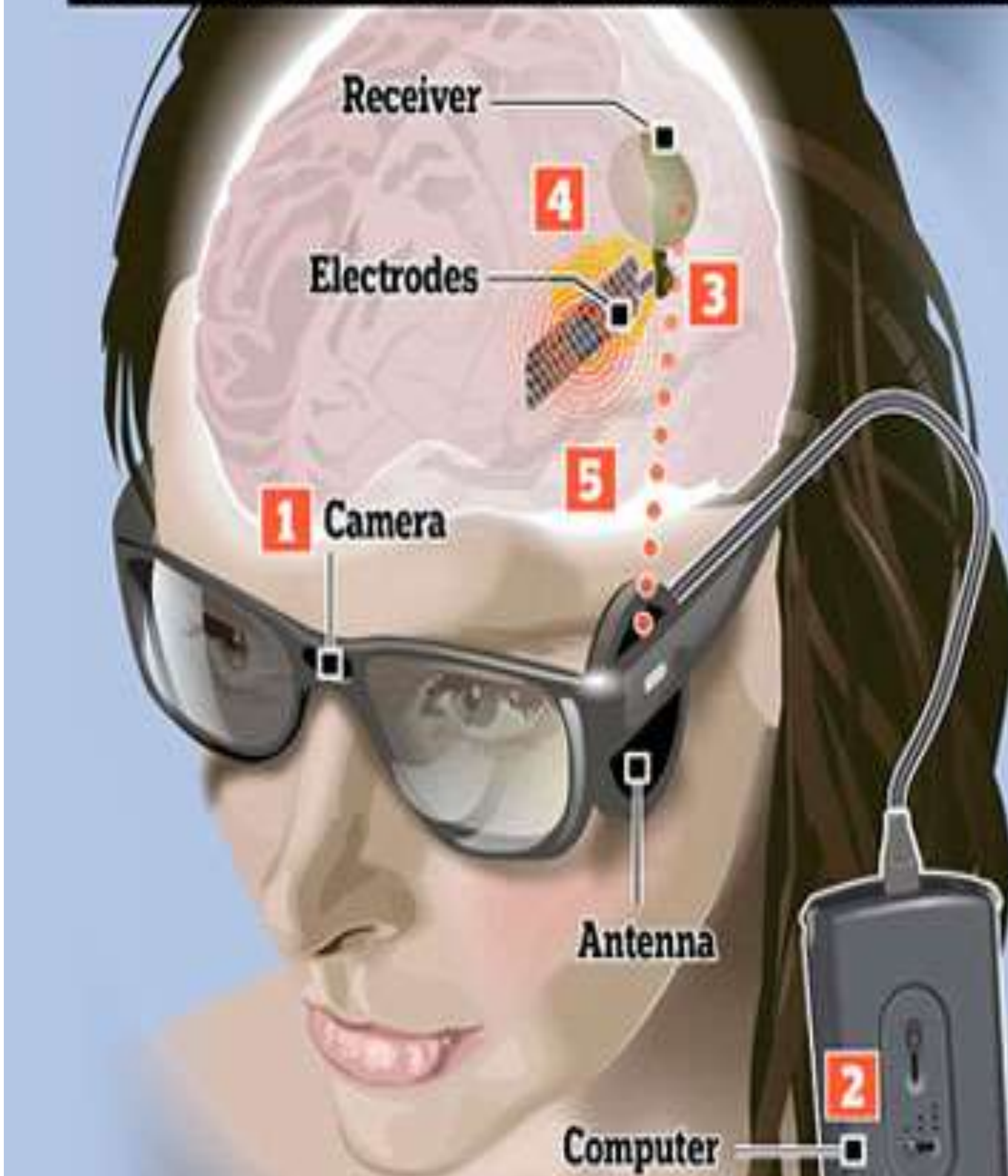
- It consist of a computer chip which is kept in the back of effected person eye and linked with a mini video camera built into glasses that they wear.
- Then an image captured by the camera are focused to the chip which converts it into electronic signal that brain can interpret.
- The images produced by Bionic eye were not perfect but they were clear enough for recognition
- The implant bypasses the diseased cells in the retina and go through the remaining possible cells.

Regions of Implantation

- Retina
- Optic Nerve
- Lateral geniculate body
- Visual Cortex



TECHNOLOGY TO BEAT BLINDNESS



1 A tiny video camera in the bridge of the glasses captures moving images and sends them via a wire to a computer

2 The computer unit, carried in a pocket, transforms the images into electrical signals and sends them back to an antenna on the glasses

3 The signals are then transferred wirelessly to a receiver implanted on the back of the skull

4 They are sent on to electrodes placed on the surface of the brain

5 The electrodes stimulate the neural cells in the visual cortex – enabling the wearer to see

TECHNOLOGIES APPLIED IN BIONIC EYE

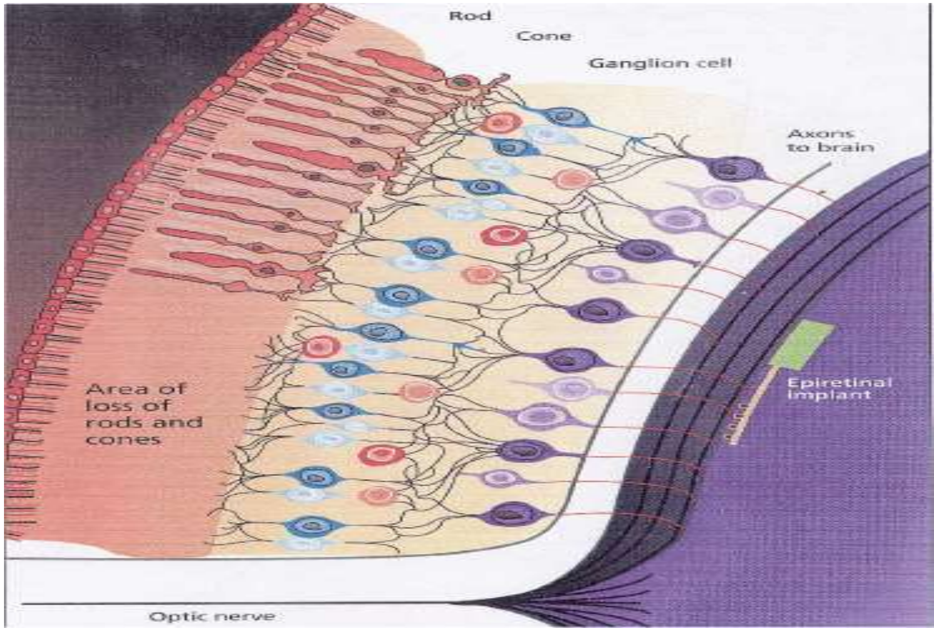
- **MIT – HARVARD DEVICE**
- **ASR (ARTIFICIAL SILICON RETINA)**
- **MARC (Multiple Unit Artificial Retina Chipset)**
- **ARGUS II**
- **HOLOGRAPHIC TECHNOLOGY**
- **ALPHA IMS**

MIT-Harvard device

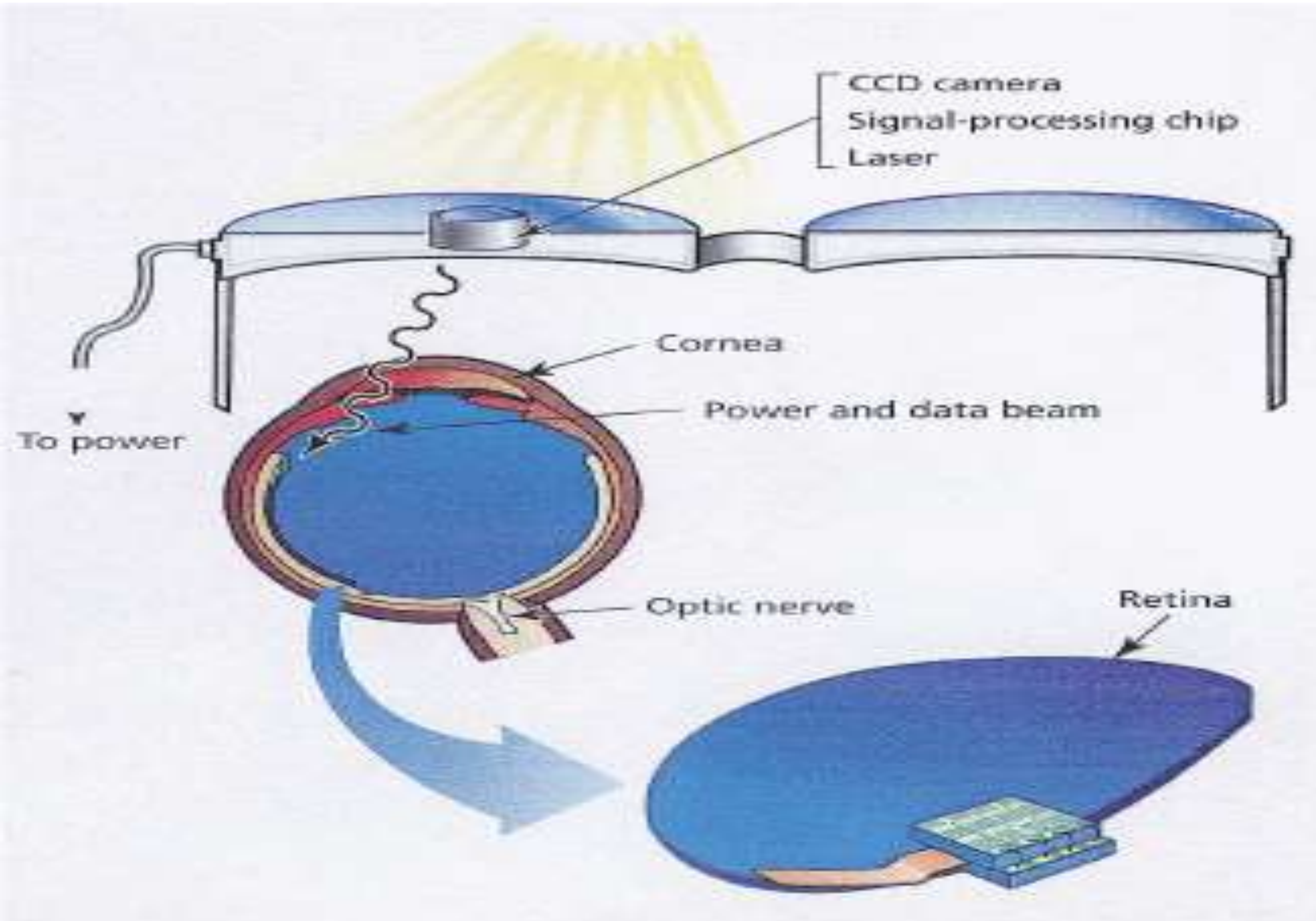
Features

- Epi-Retinal Approach
- Microelectrode array replaces damaged photoreceptors
- Power source – Laser(820nm wavelength)
- Image Acquisition - Using CCD Camera
- Patient’s spectacles holds the camera and power source

Site of Implant



The Whole Picture



Implant Structure

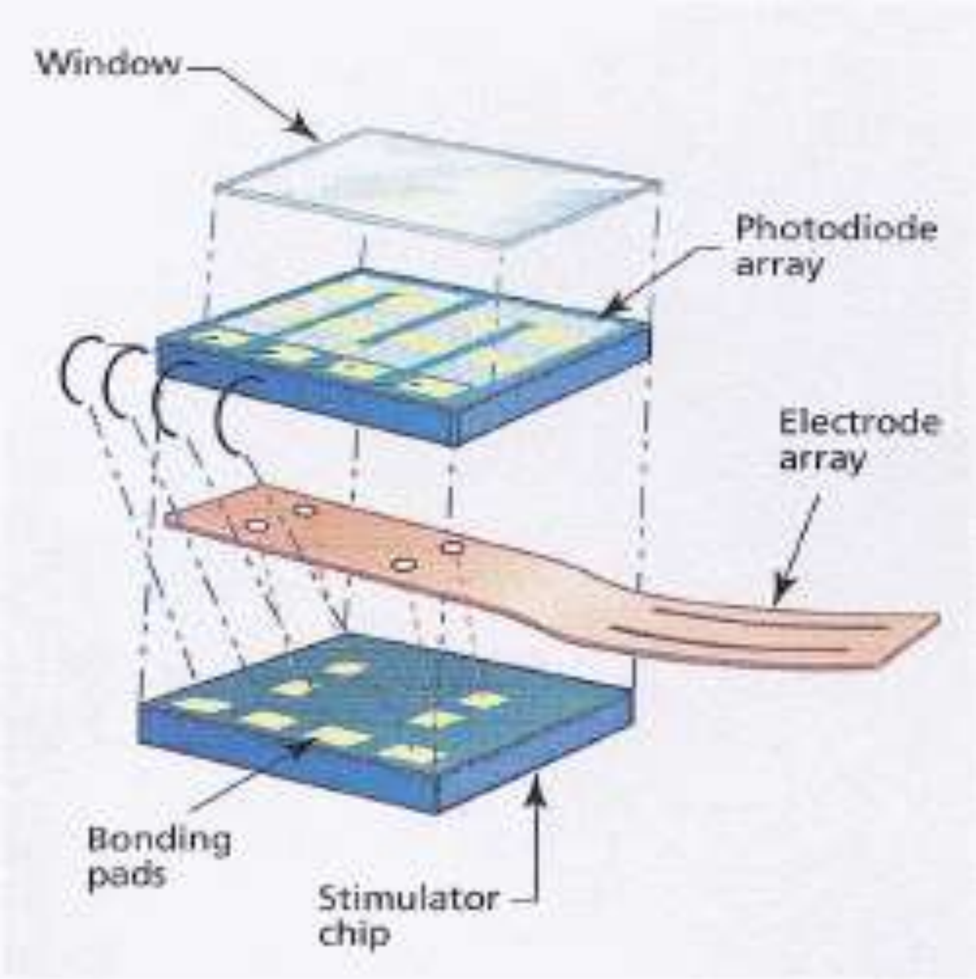
- Layers

  1- Photodiode Array

  2- Polyimide strip

  3- Stimulator chip

- Electrodes on other end of Polyimide strip



Working of the System

- CCD camera input – External light intensity
- CCD output amplitude-modulates laser source
- This hits photodiode array of implant
- This in turn powers stimulator chip (SC)
- SC drives current to electrodes facing retina
- This excites the ganglionic cells > axons > optic nerve > visual cortex in occipital lobe of brain
- Brain helps in perceiving an image

Advantages

- Very Early in the visual pathway
- No Batteries implanted within body
- No complicated surgical procedure
- Power Requirement – ¼ of milliwatt

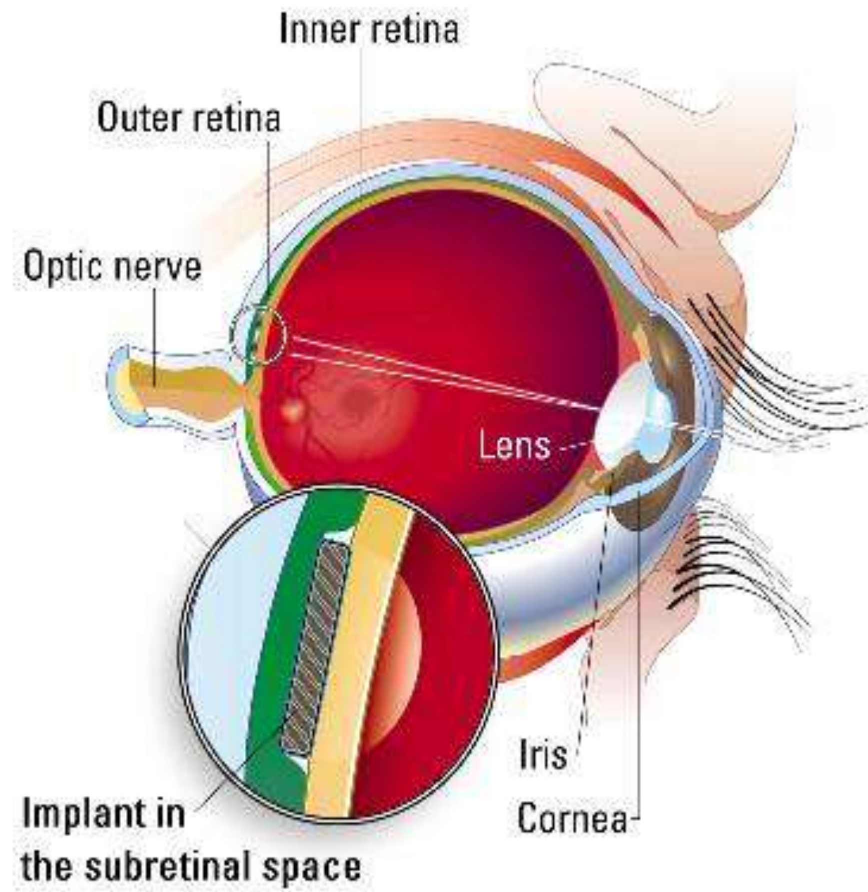
Disadvantages

- Axons b/w electrodes and ganglionic cells
- Other axons get excited – unwanted perception of large blur
- Extra circuitry required for downstream electrical input

Artificial Retina Prosthesis using ASR

(Artificial Silicon Retina)

- Macula is comprised of multiple layers of cells which process the initial analog” light energy entering the eye into “digital” electrochemical impulses.
- Human eye has nearly 100 million photoreceptors.



Working system

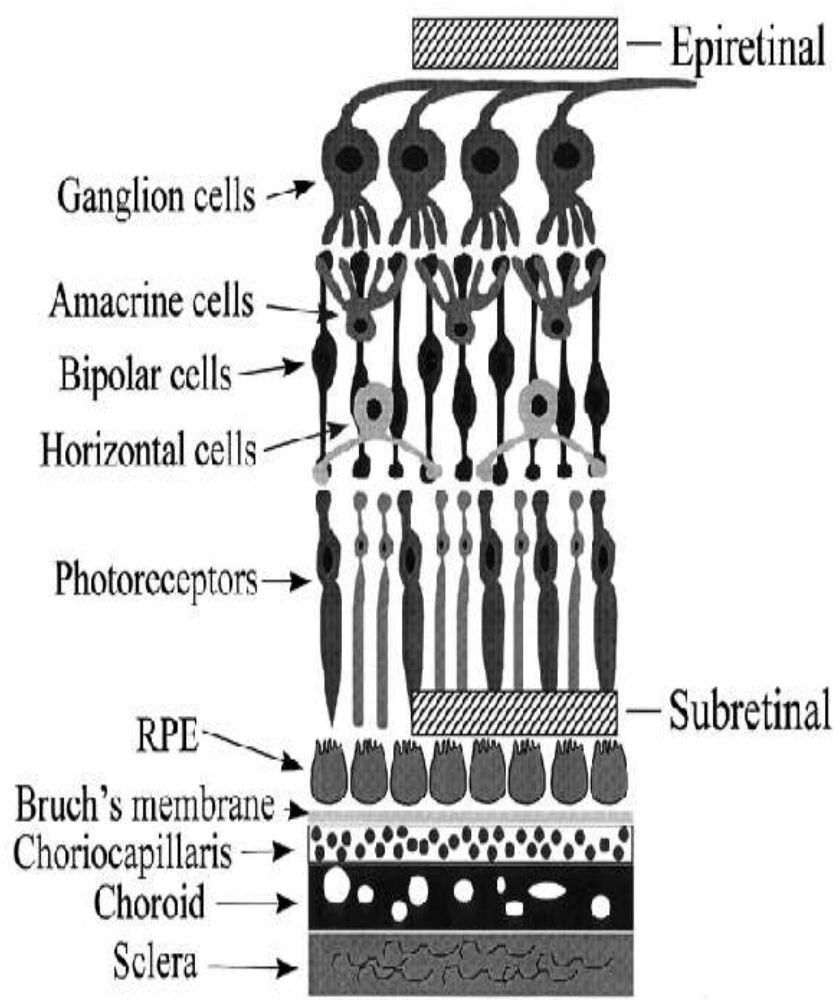
- ASR is a solid state biocompatible chip which contains an array of photo receptors ,and is implanted to replace the functionality of the defective photoreceptors .
- Current generated by the device in response to light stimulation will alter the membrane potential of the overlying neurons and thereby activate the visual system.

- Visual sensations or “phosphenes” can be evoked by electrical stimulation of the different levels of the visual pathway.
- Phosphenes are evoked by the stimulation of the eyeball or the visual cortex.
- Artificial vision created by the controlled electric stimulation of the retina has color.

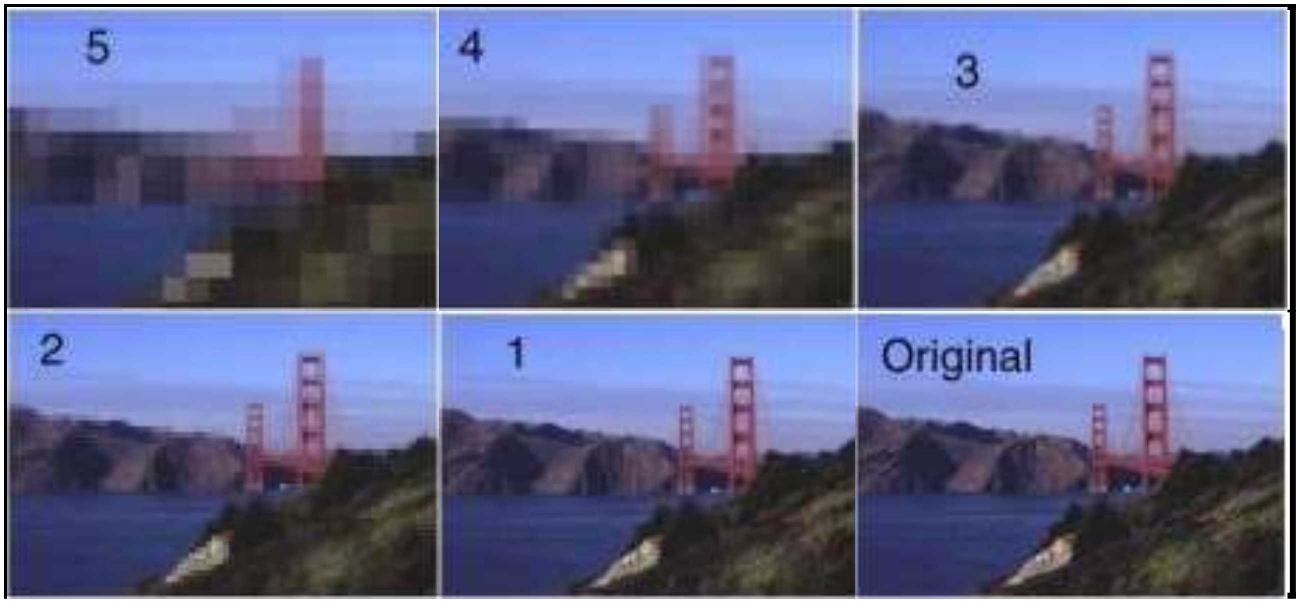
Approaches Towards Retinal Prosthetic Implantation

- **Epiretinal Approach** involves a semiconductor based device positioned on the surface of the retina to try to simulate the remaining overlying cells of the retina.

- **Subretinal Approach** involves implanting the ASR chip behind the retina to simulate the remaining viable cells.



Enhancement of the image quality using the ASR



Disadvantages

- ASR can be applied only when the photoreceptor cellular layer of the retina is damaged but the remaining cellular layers are still functional.
- ASR can be effectively applied to RP and AMD.
- Conditions amenable to treatment with ASR’s include some forms of long-term retinal detachment, Usher’s syndrome, Cone- Rod Dystrophy.

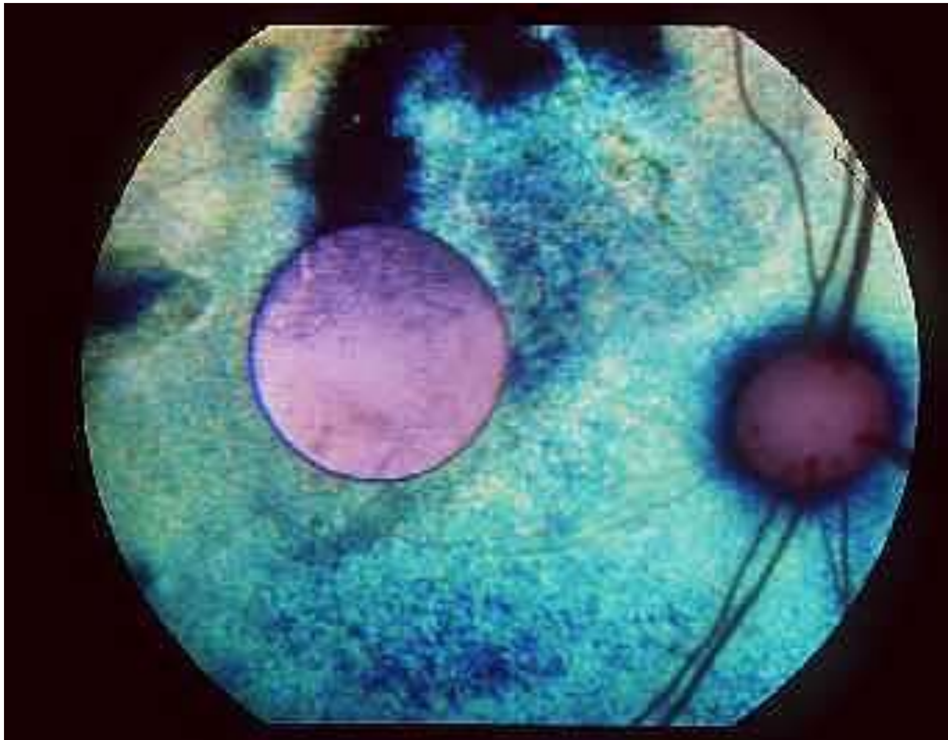
Sub-Retinal Approach

- The basic idea-”Alter the membrane potential”

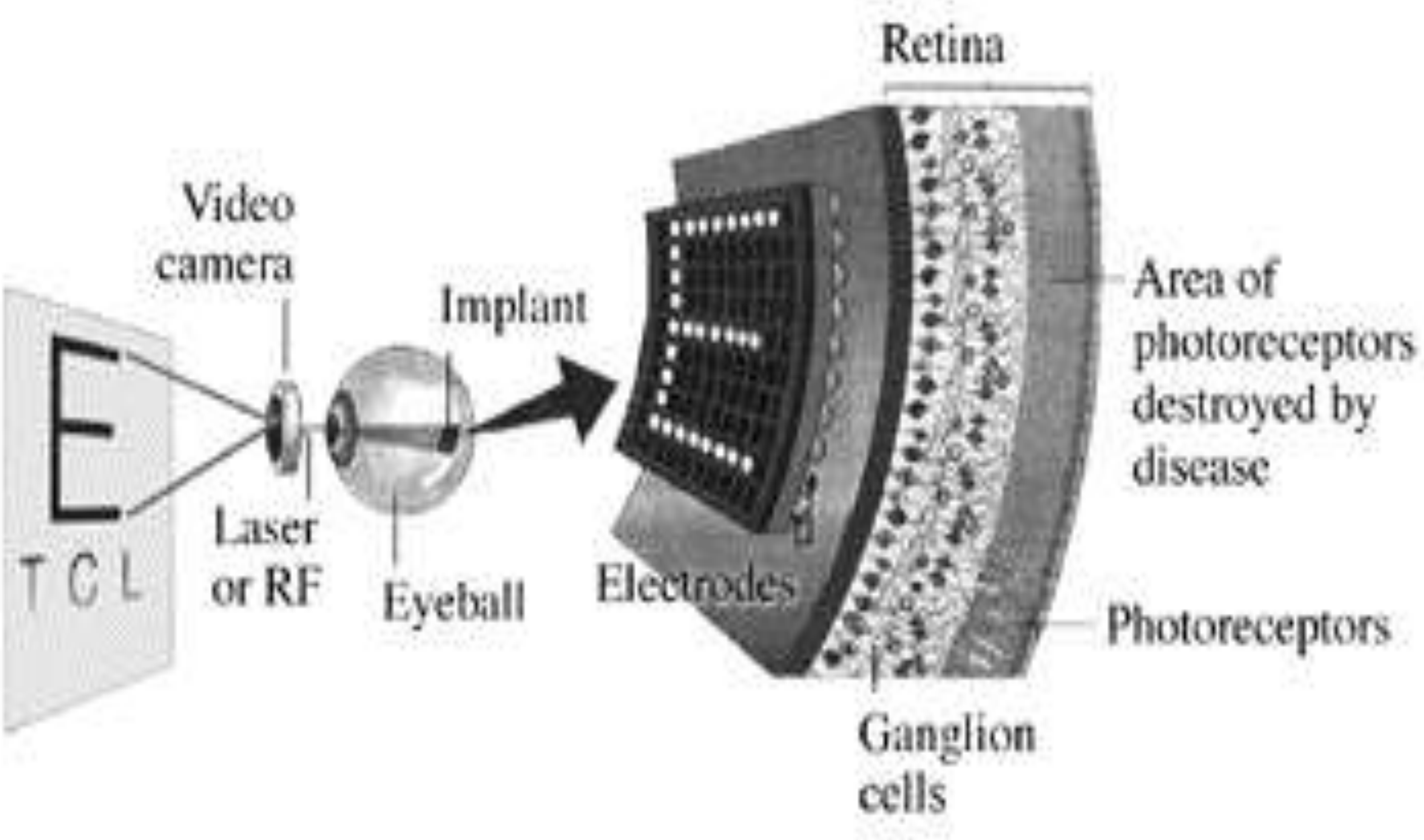
- **IMPLANT DESIGN**
  - Primitive devices
    - Single photosensitive pixel(3mm in diameter)
  - Neo devices
    - The current micro photodiode array (MPA) is comprised of a regular array of individual photodiode subunits, each approximately 20×20-µm square and separated by 10-µm channel stops (37). The resulting micro photodiode density is approximately $1,100/m^2$.

IMPLANT features

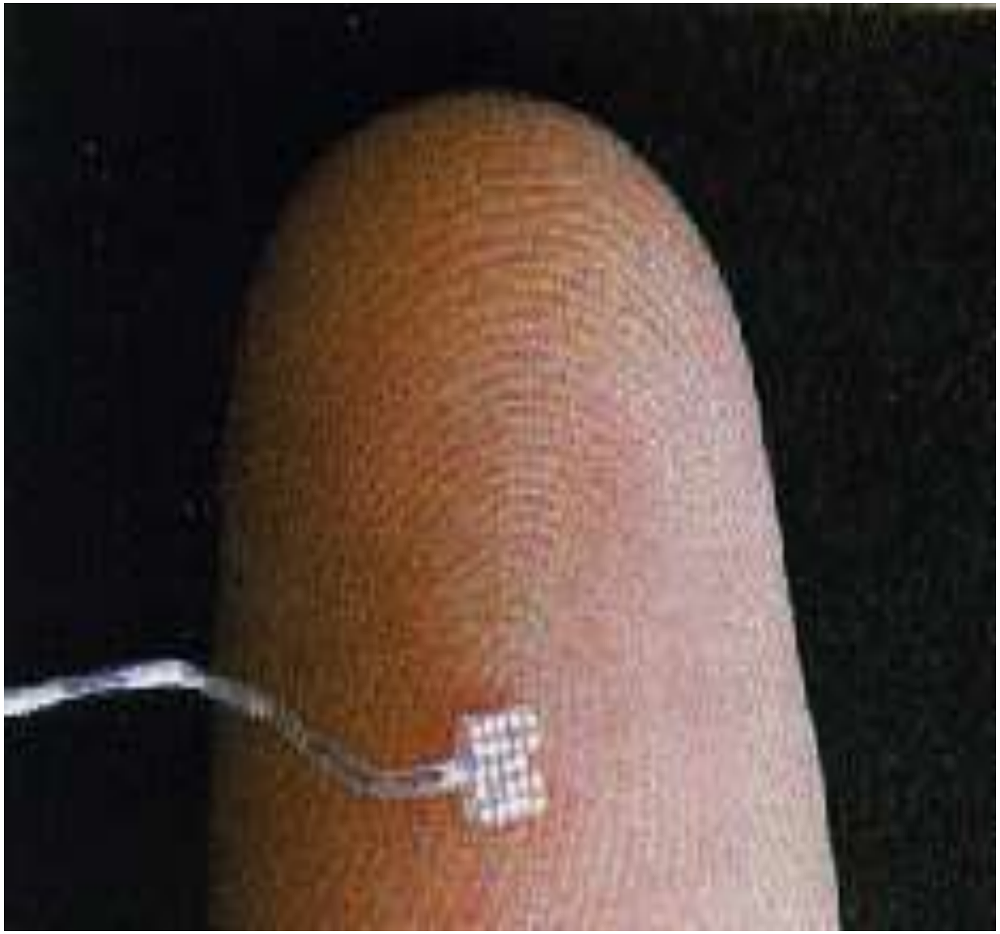
- The size has decreased from 250um to 50um
- No external power supply
- 500nm to 1100nm wavelength response



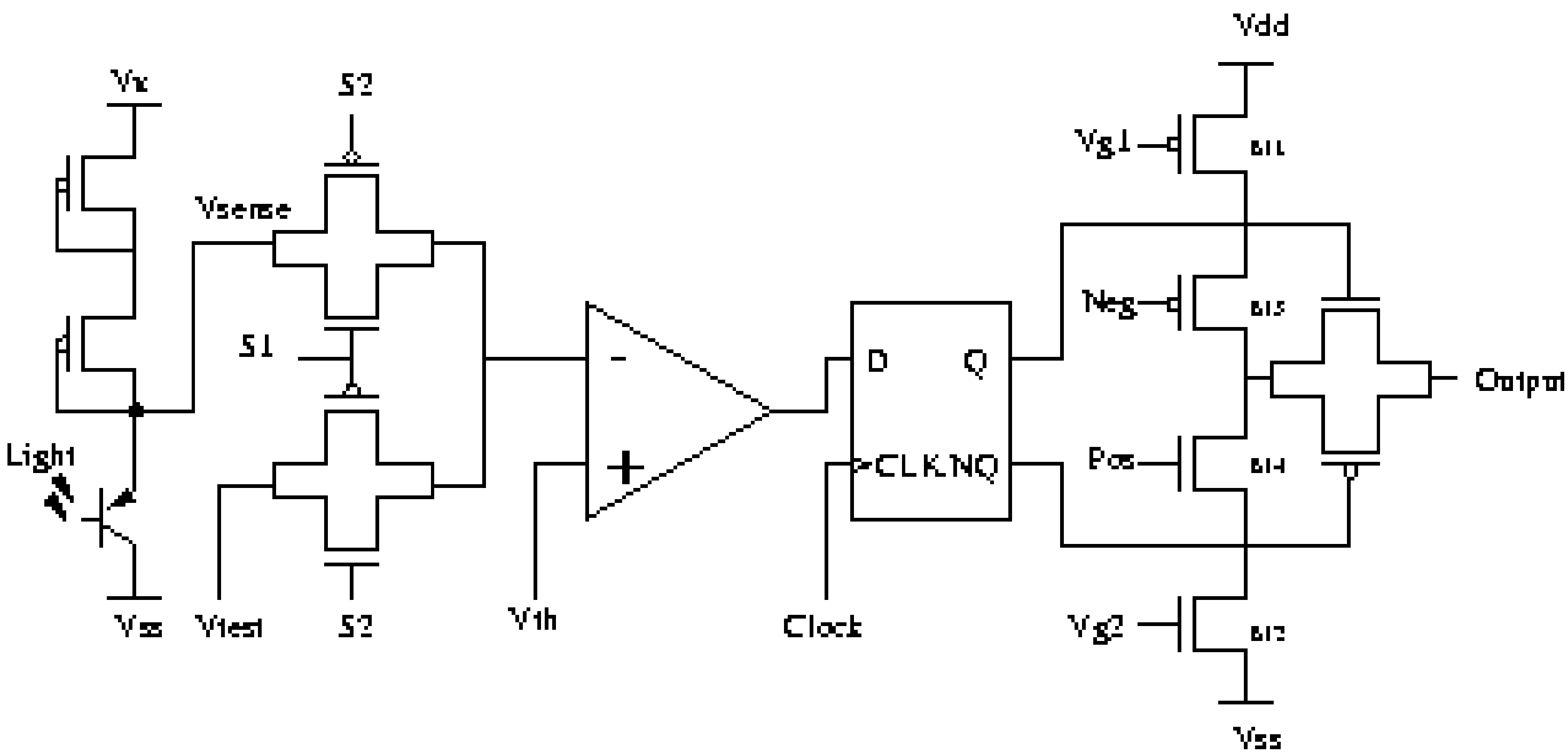
Multiple Unit Artificial Retina Chipset (MARC)



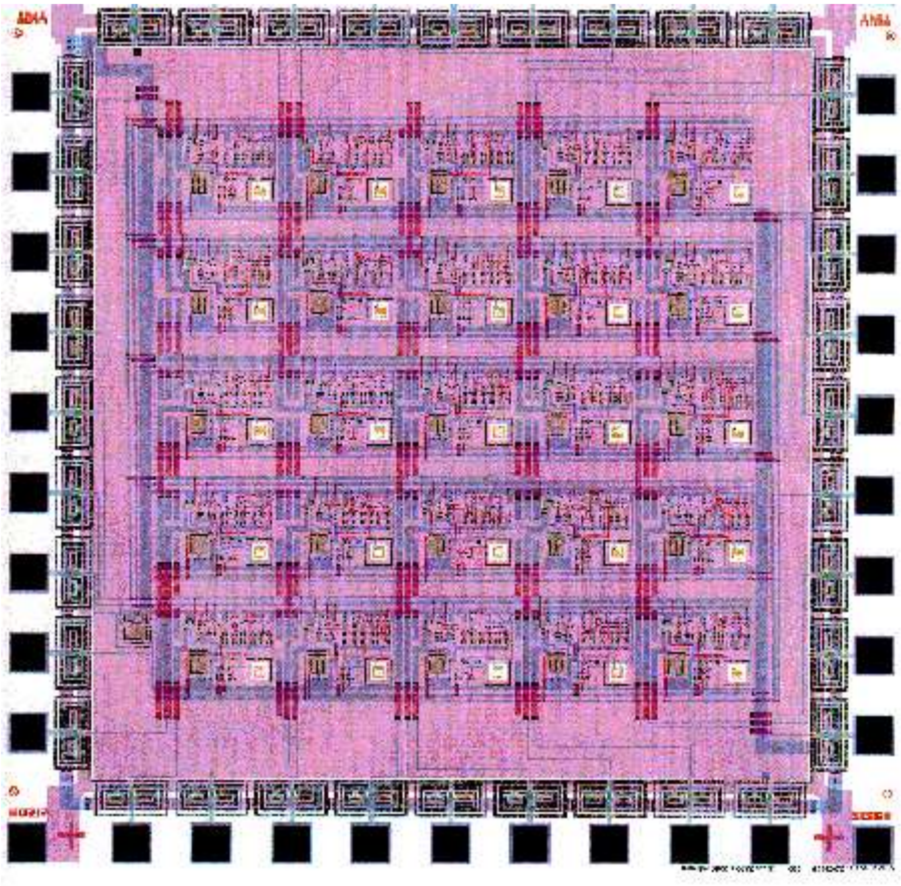
Platinum on Silicone Rubber Electrode Array



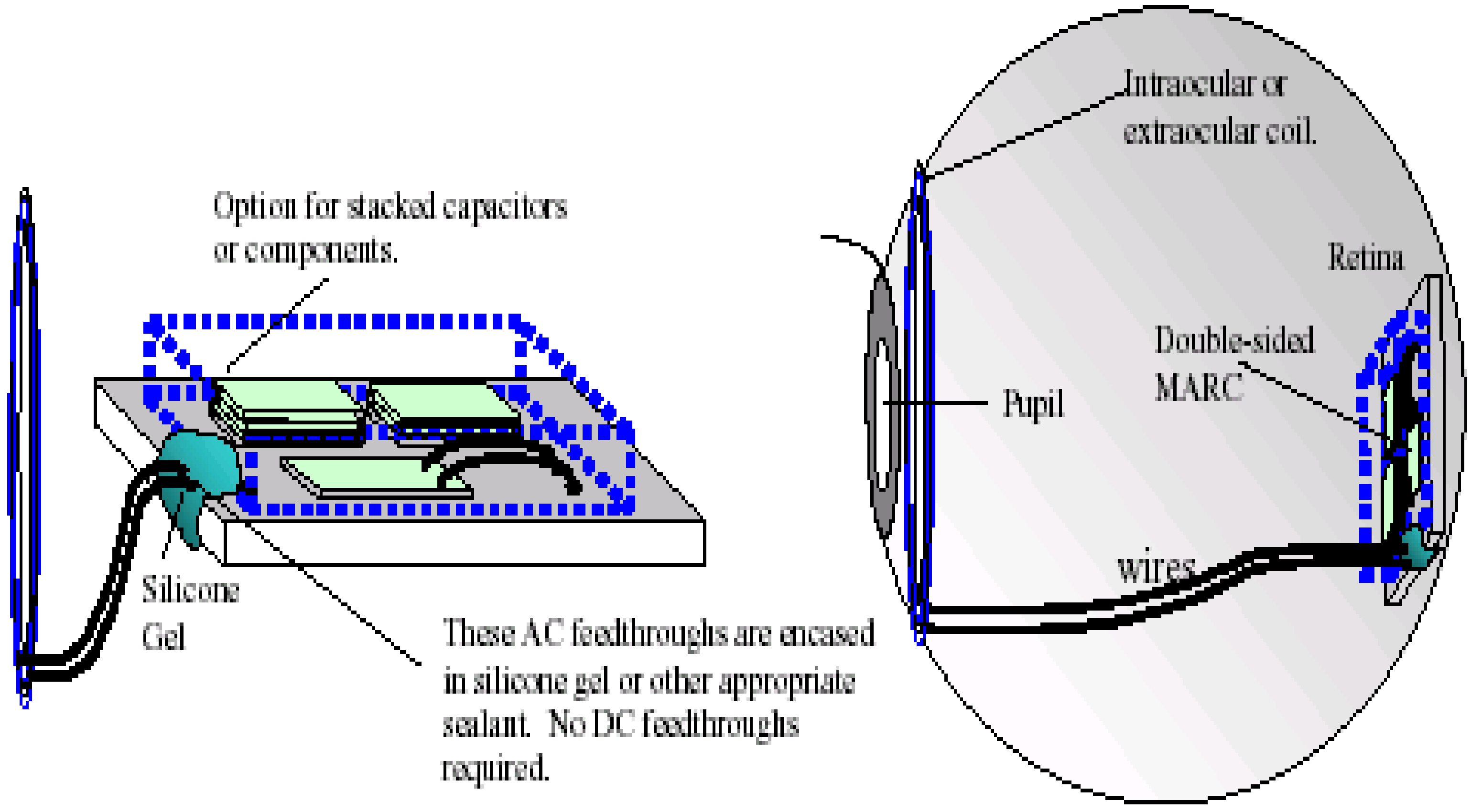
MARC Photoreceptor and Stimulating Pixel

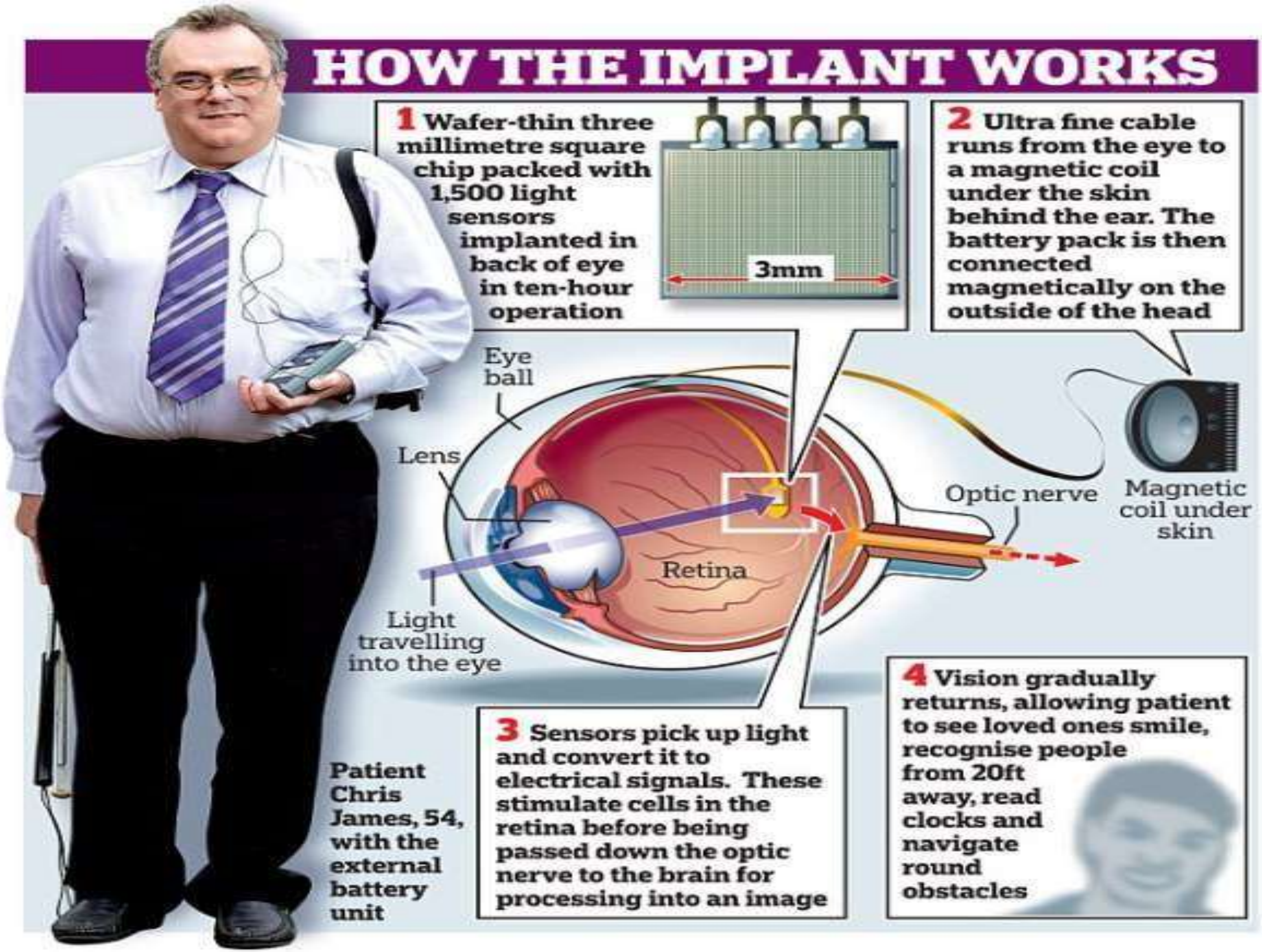


Photograph of MARC Chip



MARC Hermetic Sealing and Positioning




HOW THE IMPLANT WORKS
1 Wafer-thin three millimetre square chip packed with 1,500 light sensors implanted in back of eye in ten-hour operation
3mm
2 Ultra fine cable runs from the eye to a magnetic coil under the skin behind the ear. The battery pack is then connected magnetically on the outside of the head
Eye ball
Lens
Retina
Optic nerve
Magnetic coil under skin
Light travelling into the eye
3 Sensors pick up light and convert it to electrical signals. These stimulate cells in the retina before being passed down the optic nerve to the brain for processing into an image
4 Vision gradually returns, allowing patient to see loved ones smile, recognise people from 20ft away, read clocks and navigate round obstacles
Patient Chris James, 54, with the external battery unit

Advantages

- Compact Size – 6x6 mm
- Diagnostic Capability
- Reduction of stress upon retina

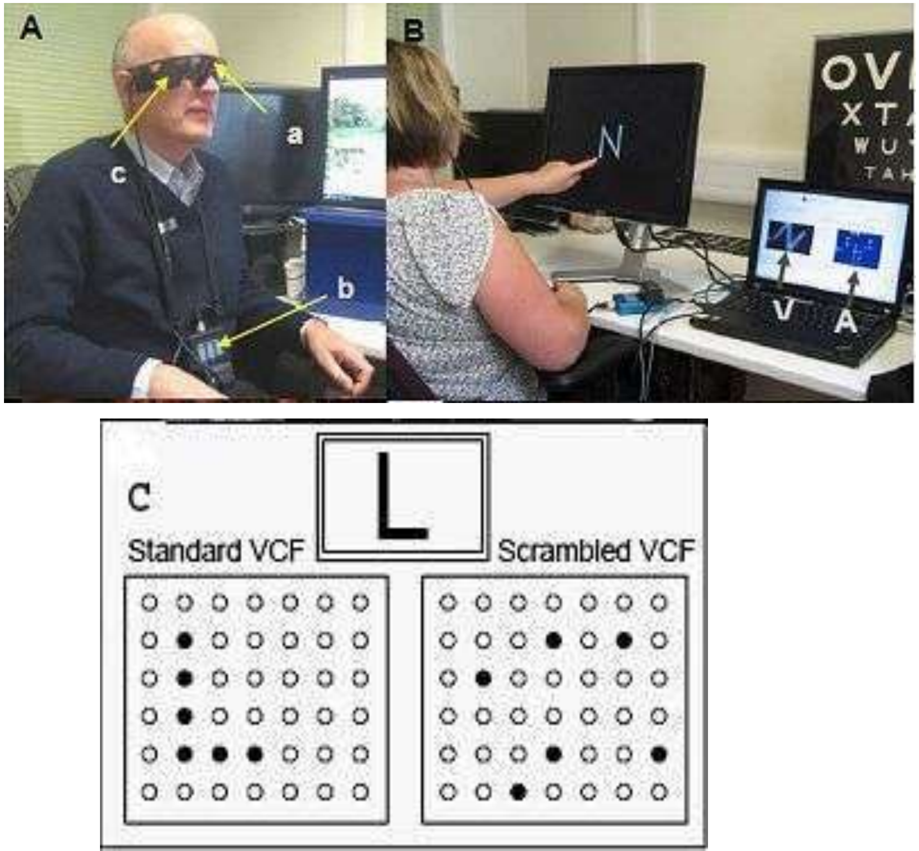
Disadvantages

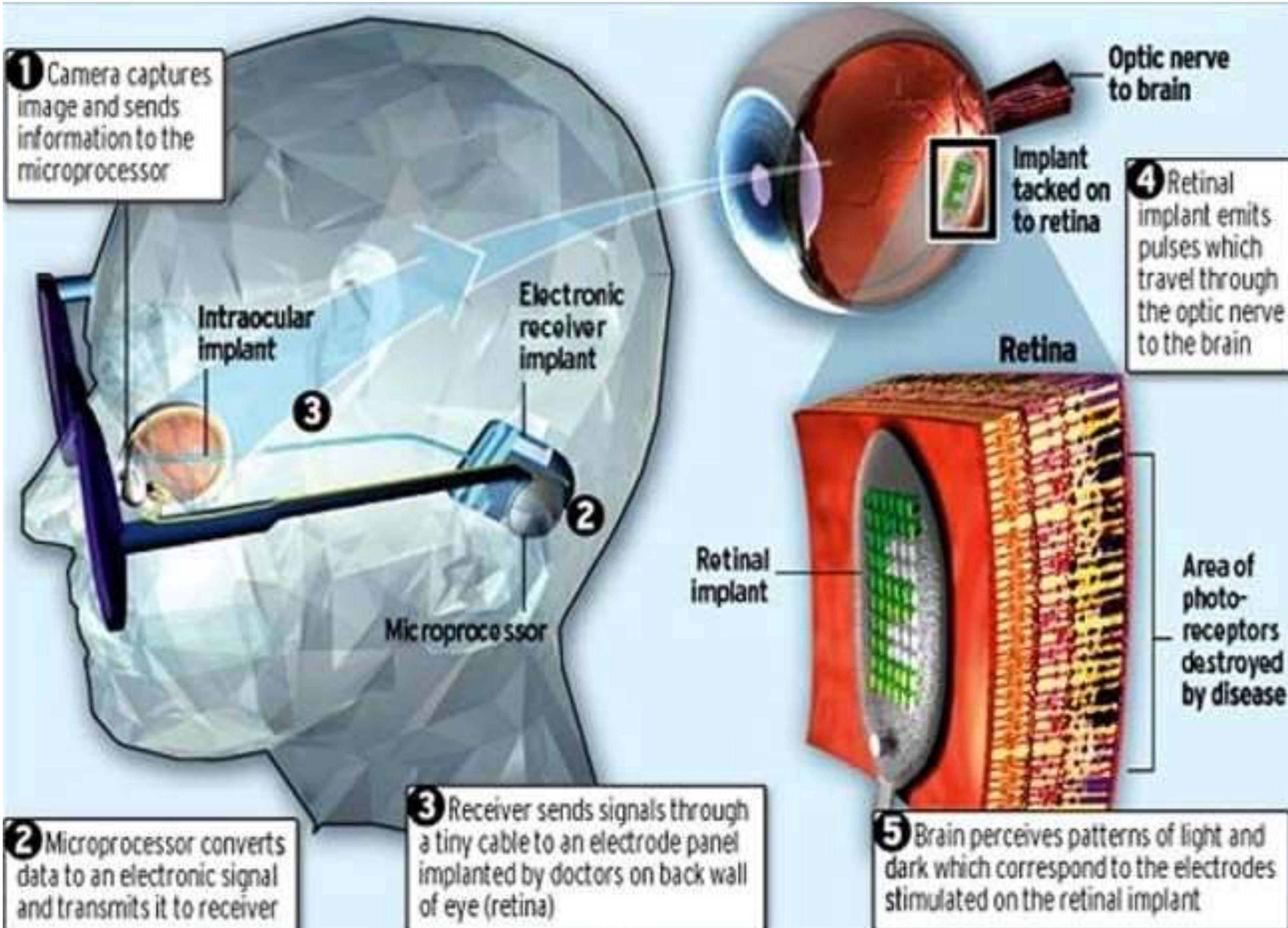
- Costly
- If a single part of the chip is damaged the total technique will be meaningless.

ARGUS II

- Uses external components to “amplify” what it seen, has a camera.
- The Argus II epiretinal prosthesis system allows letter and word reading and long-term function in patients with profound vision loss.

- Test I: letter identification
- Test II: letter size reduction
- Test III: word recognition





1 Camera captures image and sends information to the microprocessor
Optic nerve to brain
Implant tacked on to retina
4 Retinal implant emits pulses which travel through the optic nerve to the brain
Intraocular implant
Electronic receiver implant
3
Retina
2
Retinal implant
Area of photo-receptors destroyed by disease
Microprocessor
2 Microprocessor converts data to an electronic signal and transmits it to receiver
3 Receiver sends signals through a tiny cable to an electrode panel implanted by doctors on back wall of eye (retina)
5 Brain perceives patterns of light and dark which correspond to the electrodes stimulated on the retinal implant

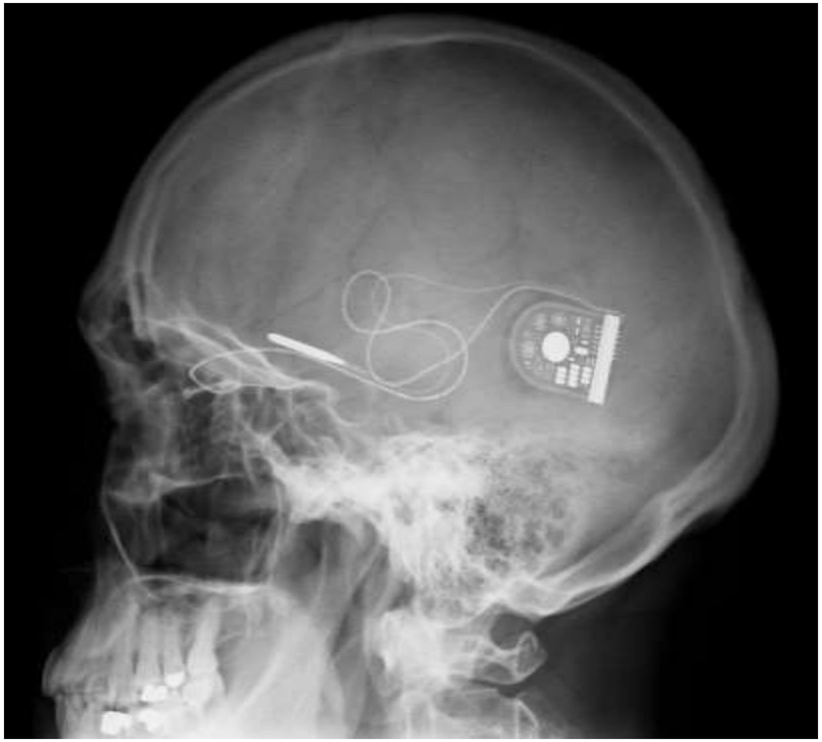
Holographic Technology

- Computer-generated holography, could be used in conjunction with a technique called optogenetics, which uses gene therapy to deliver light-sensitive proteins to damaged retinal nerve cells.

- “The basic idea of optogenetics is to take a light-sensitive protein from another organism, typically from algae or bacteria, and insert it into a target cell, and that photosensitizes the cell,”

Alpha IMS

– Uses implants in brain to bypass retina and hook into optical nerve.



The Alpha IMS

- Extremely new technology.
- No external components besides the battery.
- No camera is used, unlike the Argus II.
  - 3x3m microchip in retina captures a visual resolution of 1500 pixels.
  - Microchip bypasses damaged photoreceptors, uses natural eye to "see"
  - Placement of microchip allows the middle layer of the retina to do it's processing of input.
  - Allows movement of eye to look around, rather than the entire head.
- Allows users to see black and white details.
  - The brighter the object, the more it shows up.
  - Cars and water, when reflected upon by the sun, was the most visible to those participating.