Artificial Vision

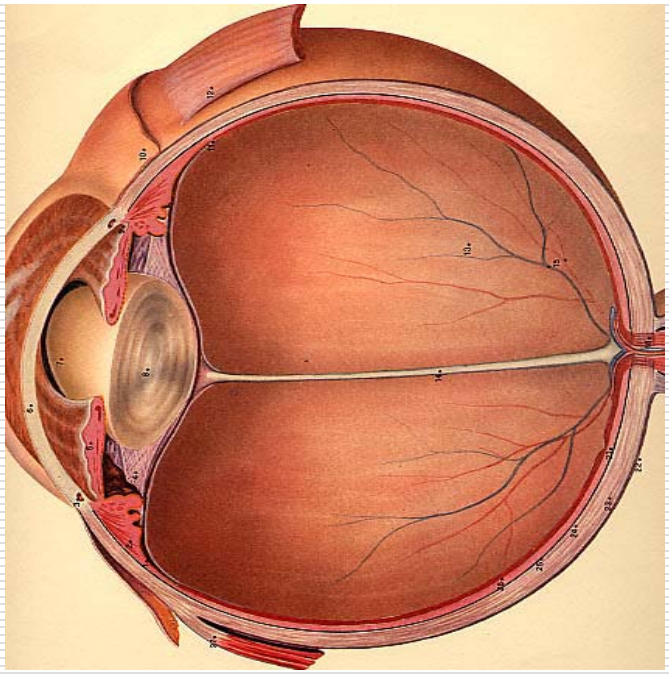
Causes of blindness in the adult

- The most common causes of blindness
  - Age-related Macular Degeneration, AMD(**나이관련황반변성**)
  - Diabetic Retinopathy(**당뇨망막병증**)

- The most serious cause of blindness
  - Retinitis Pigmentosa (**망막색소변성**)

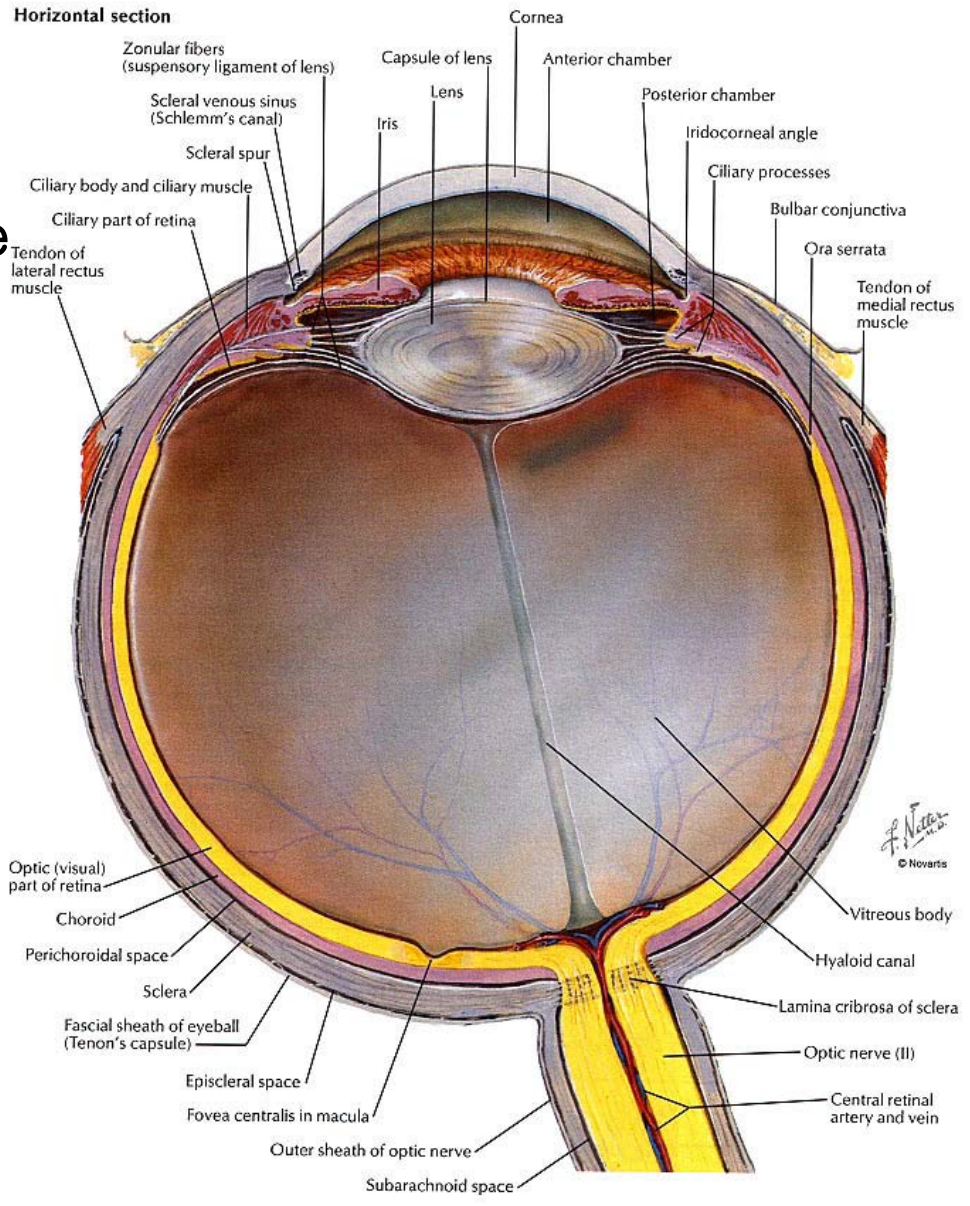
Blindness and Medical care

- visual disturbance :
  - 24%(**Uniocular**), 100%(**binocular**) loss of the function of the whole body
- 30% of blindness in the adult
  - Retinitis Pigmentosa; 1/4000(Normal)
  - AMD; 1/20(>aged 65)
- Artificial Organs in the eye :
  - Corneal clouding → Artificial Cornea
  - Lenticular opacity → Artificial Lens
  - Retina Damage→ Artificial Retina?



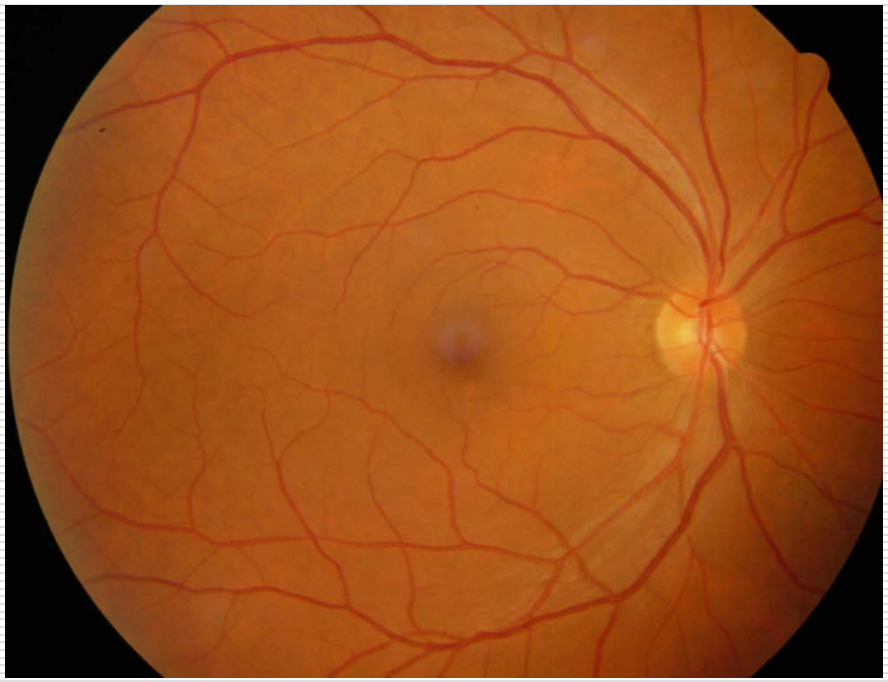
Structure of the eye

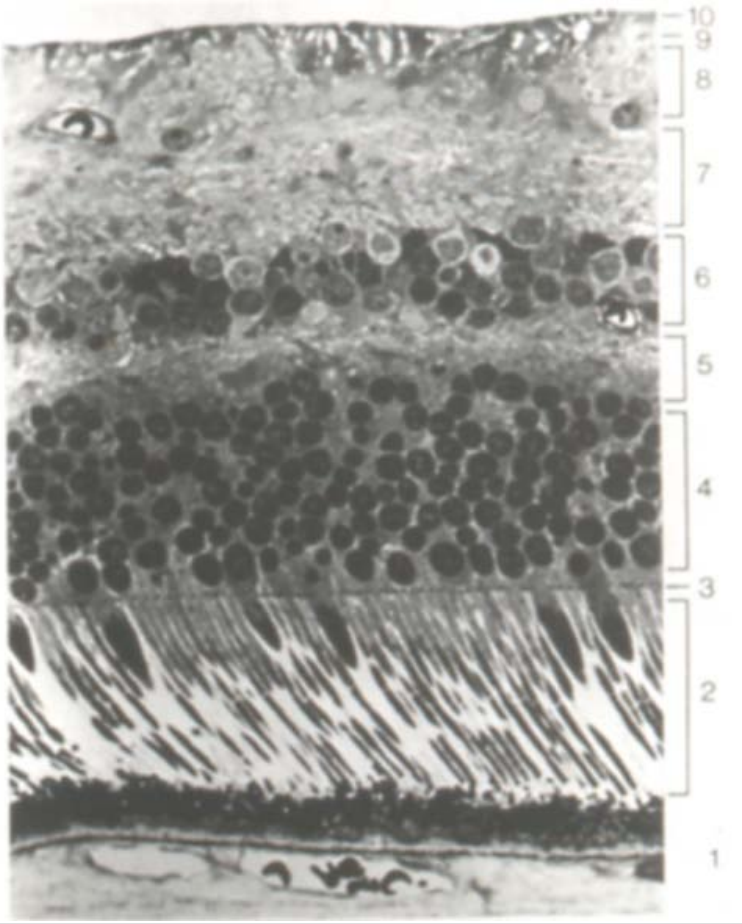
- **retina(망막):** nervous tissue
- **choroid(맥락막):** vascular tissue
- **sclera(공막):** connective tissue
- **optic nerve(시신경)**



Retina

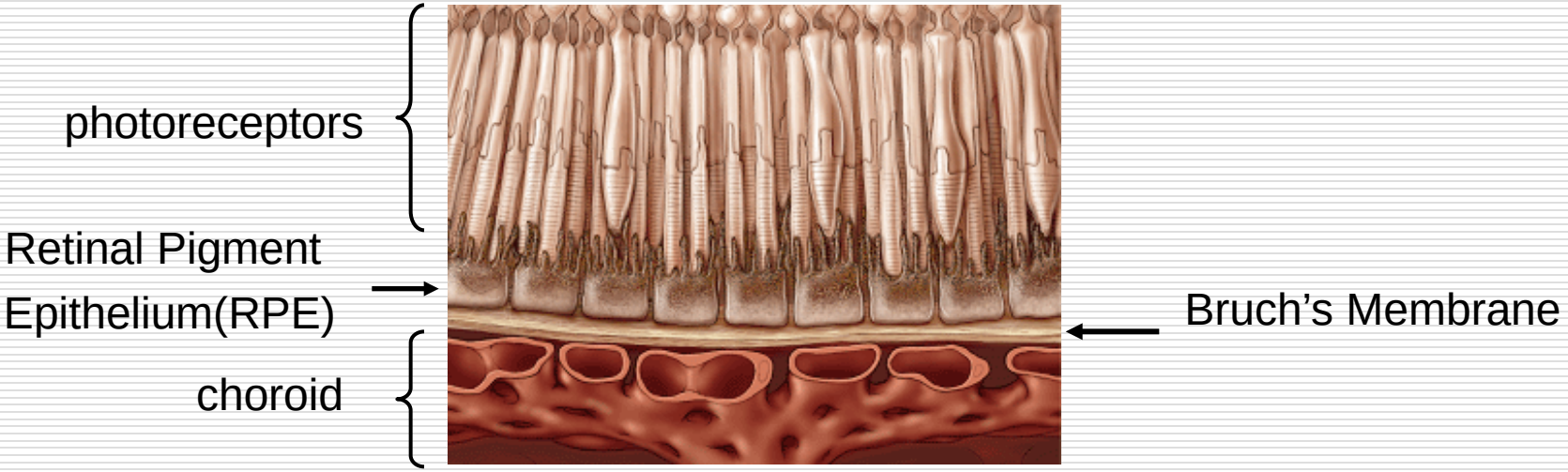
- Recognize image on the retina and transmit it to brain
- Compared with a film of a camera





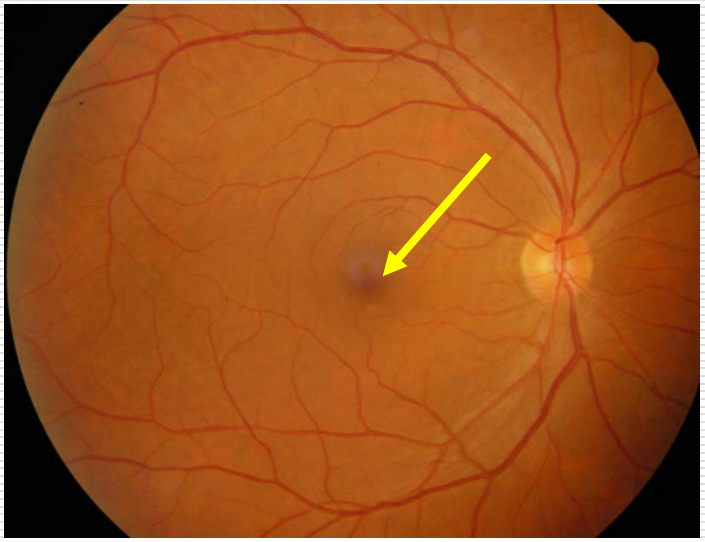
Structure of the Retina

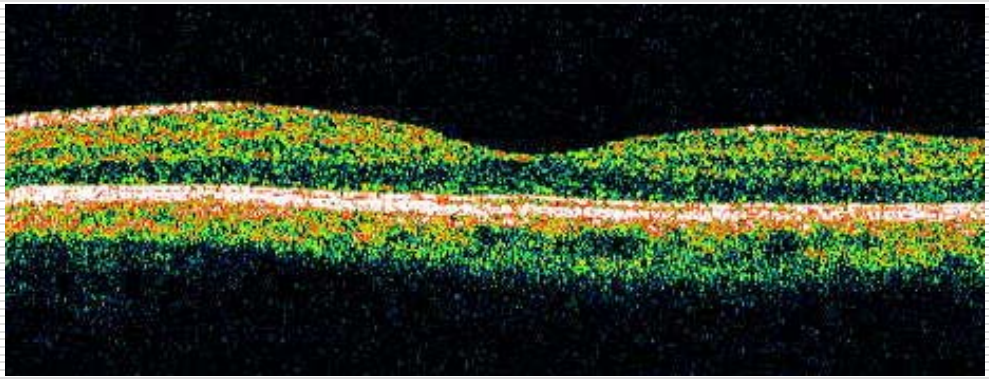
- photoreceptors(**시세포층**): Light Signal -> Elctrical Signal
- RPE(**망막색소상피 층**): Light absorption, Nutrition supply, Function of barrier
- Bruch's Membrane(**브루크막**) – Boundary tissue between retina and choroid



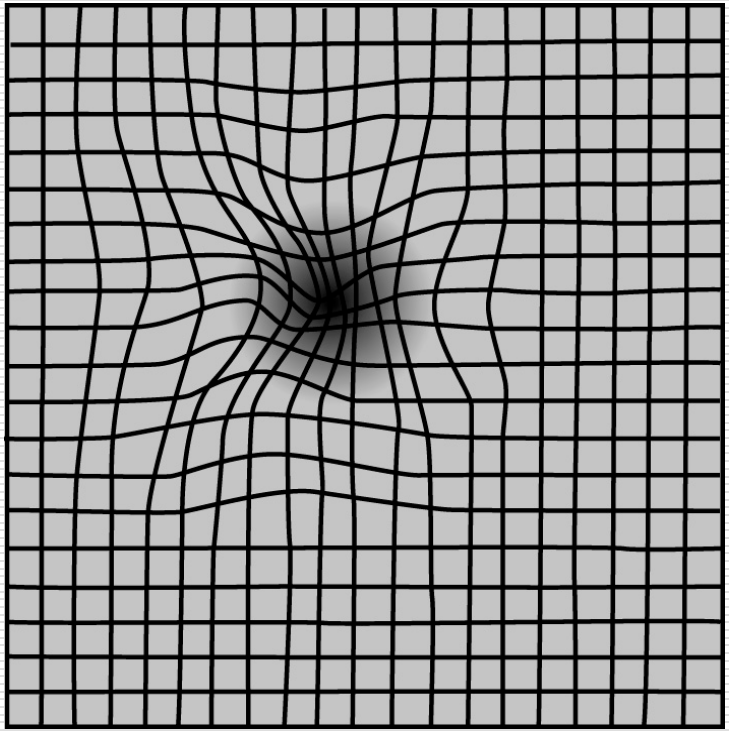
Macula (**황반,黃斑**)

- macula : the center of a retina with 5mm diameter, take charge of central vision
- tinted with yellow due to its rich Xantophyll(**엽황소**)



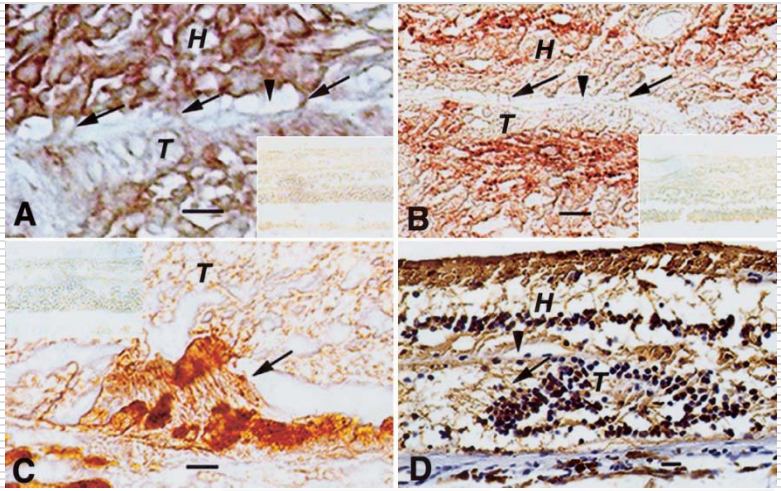


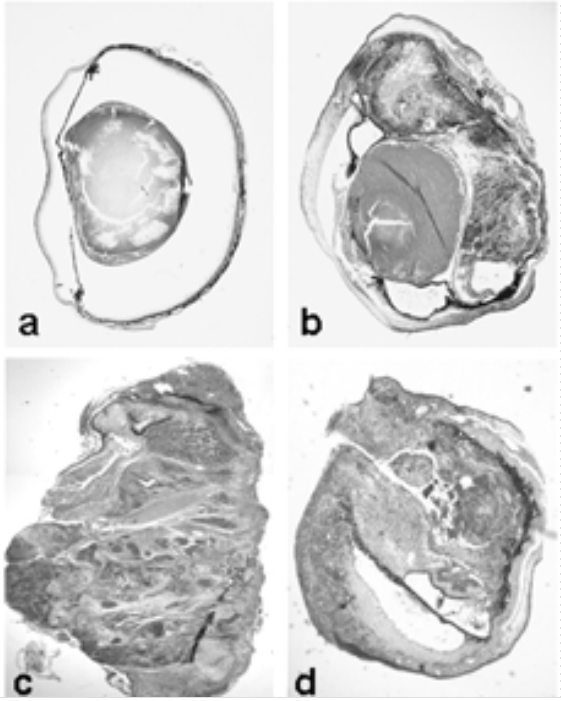
The world that patients with macular degeneration see



Study on visual recovery in retina damage state

- Drug treatment > Target Cell ?
- Stem Cell > Differentiation issue
- Transplantation of visual cells
  > Settlement issue
- Mimicking visual stimulation
  with electrical stimulation



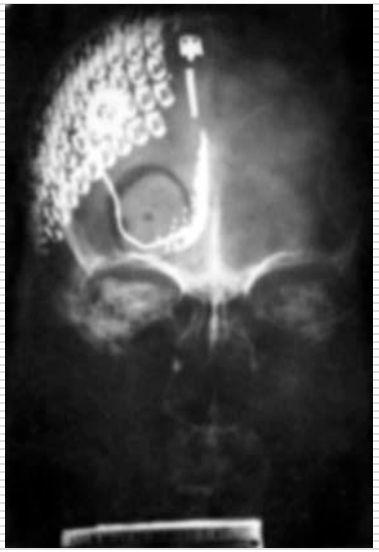


Why is artificial retina solution?

- Progress for the last 20 years
  - it was known that internal layers of retina of patients with retinitis pigmentosa are maintained well
  - success of cochlear implant
  - development in semiconductor technology
    → fabrication of a large-scale integrated small circuit
  - start regular studyies since the latter half of the 1980s

망막에 전기 자극을 주면?

- Foerster (1929): patient saw a small spotlight on electrical stimulation of visual cortex - 'phosphene(**인광**)'
- Brindley & Lewin(1968)
  - insert indwelling type visual cortex stimulator in a patient aged 52 years
  - couldn't decide the appropriate stimulation frequency to get continuous images
- Dawson & Radtke (1977):
  electrical stimulation of retina
  → discovery of sense of phosphene



Artificial visual sense transmission device

- Basic Concept:

  replace function of visual cells with electrical device.

- Hypothesis :

  electrical stimulation can induce visual sense.

- Object:

  implantation of microchip for maintenance of visual sense.

How many electrodes are required?

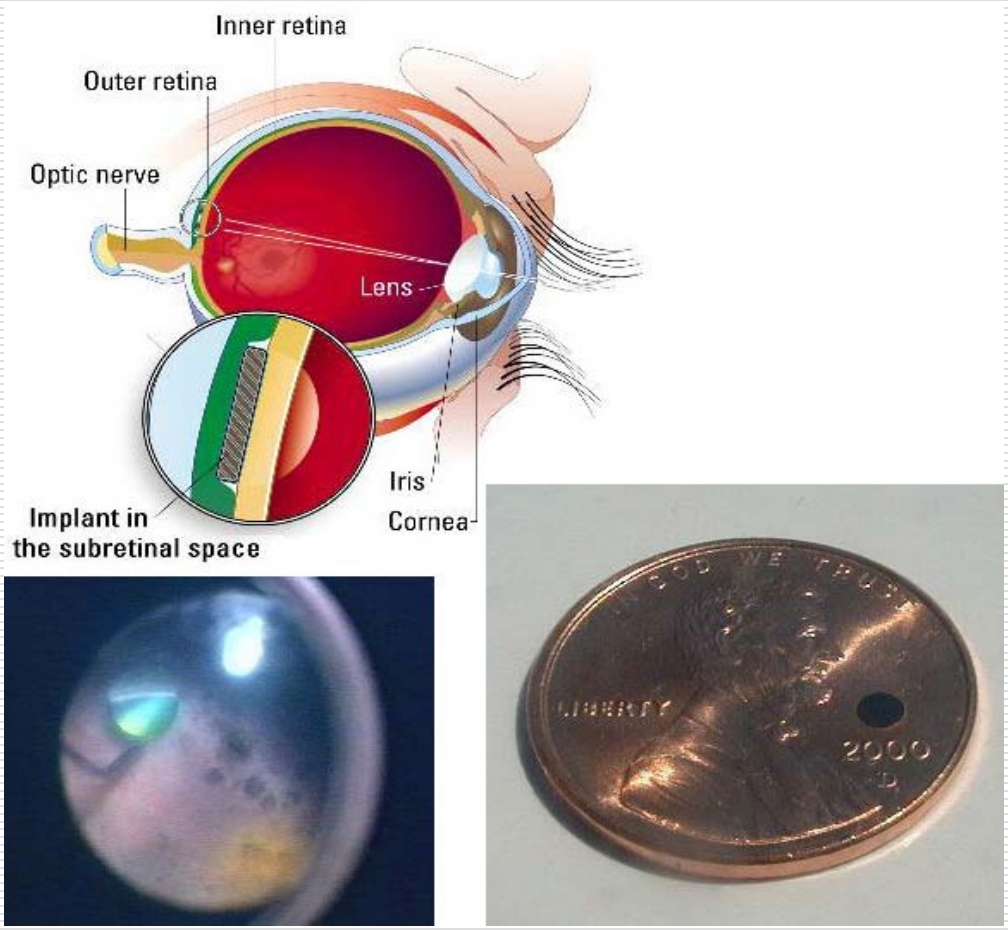
- Cochlear Implant
  - 6 electrodes **<<** 30,000 auditory ganglion cells
  - amazing adaptation of brain →
    can analyze new sensory information by training
- eyesight level based on reduced sensory information :
  project image divided into pixels onto the retina
  - **25 x 25** → independent movement
  - **32 x 32** → read book with subsidiary implements

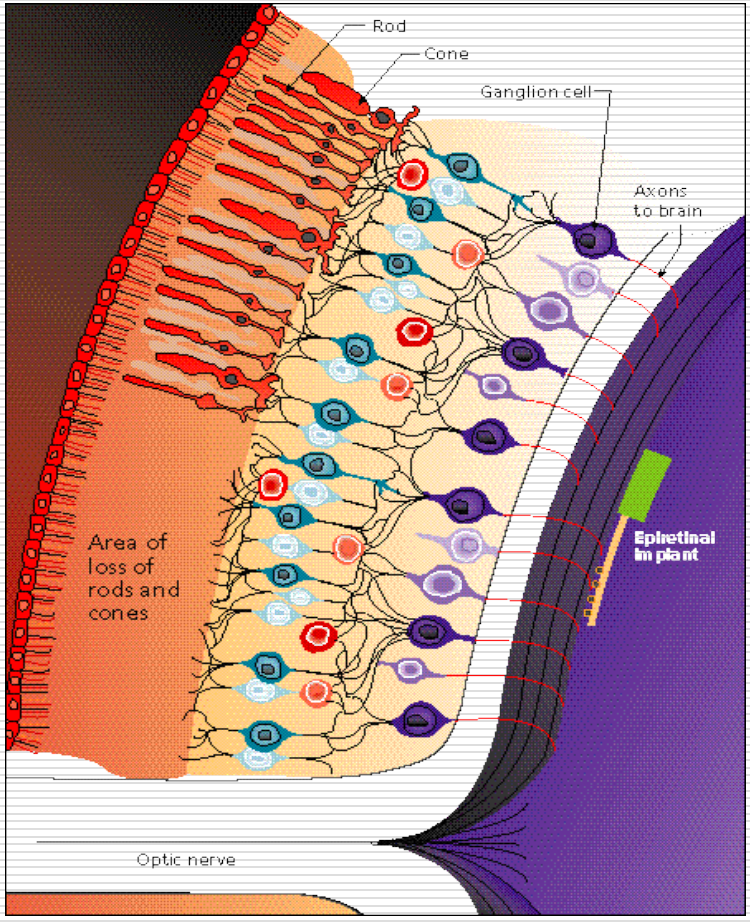
How many pixels are required?

8 x 8 32 x 32 320 x 320

- 100 pixel image (10 x 10)
- 625 pixel image (25 x 25) : enable mobility
- 1024 pixel image (32 x 32) : partially useful vision
- 10,000 electrodes (100 x 100) : ambitious goal

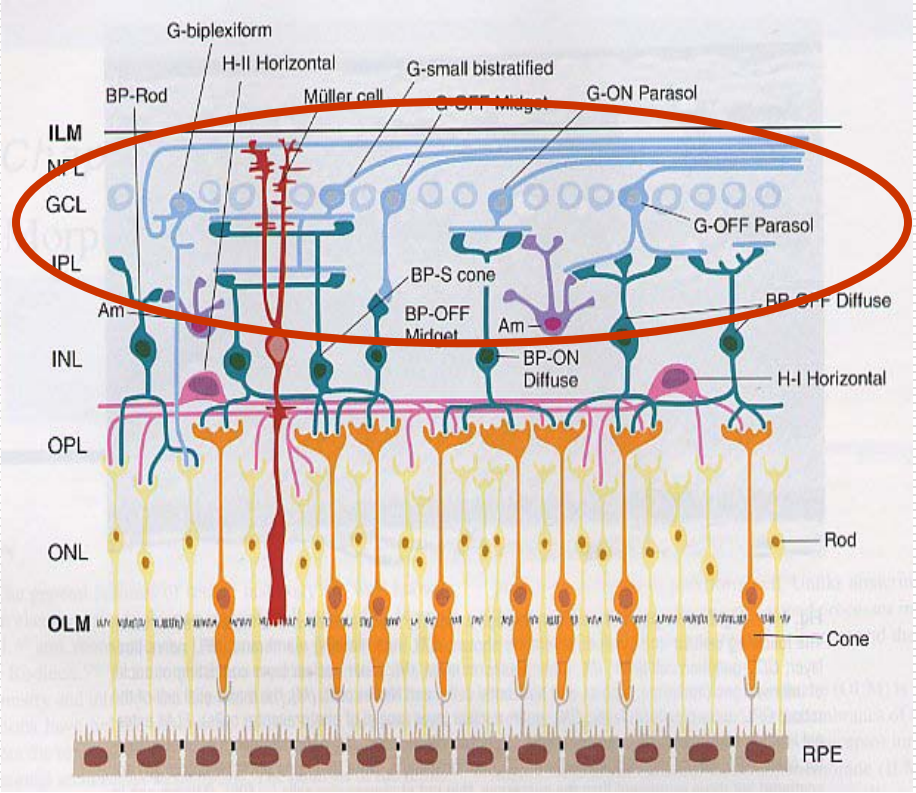
Subretinal vs. Epiretinal





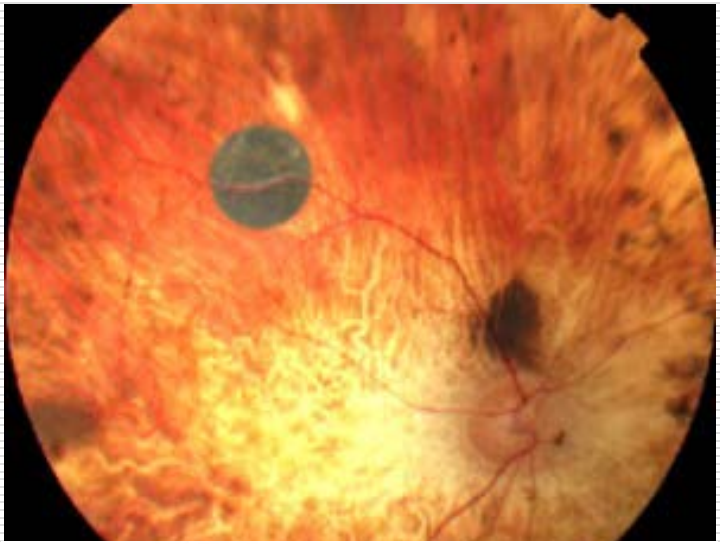
Subretinal stimulator

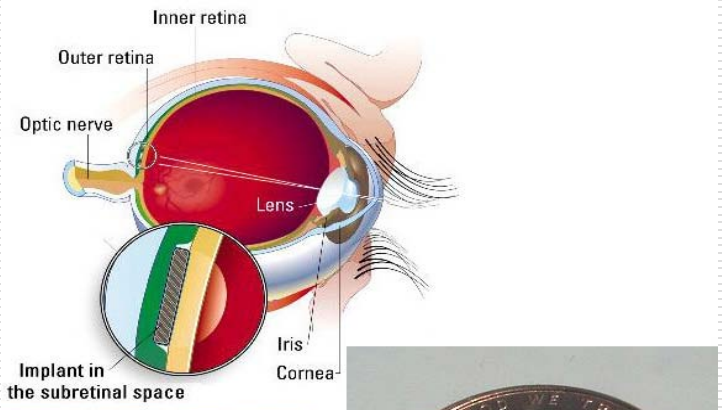
- Advantage
  - use intraretinal neural network
  - Stimulation level : bipolar cell



Optobionics

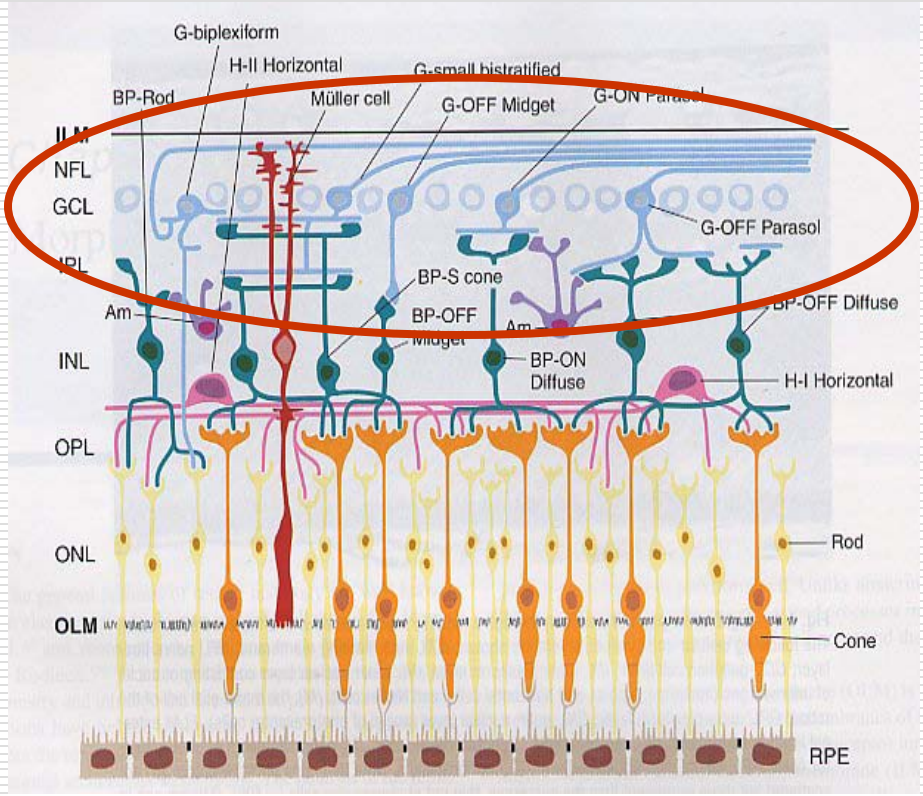
- **Use Photodiode**, Simple Design: light recognition and neural stimulation with one chip
- Disadvantage
  - Natural light is not enough to generate electrical power at this stage.
- Experiments under FDA permission on ‘in vivo biocompatibility’
- Operation on 12 patients with RP, from 45 to 76, in 2000.
- No ERG response by daylight stimuli on ASR™, but active ERG by direct IR laser stimuli on it.





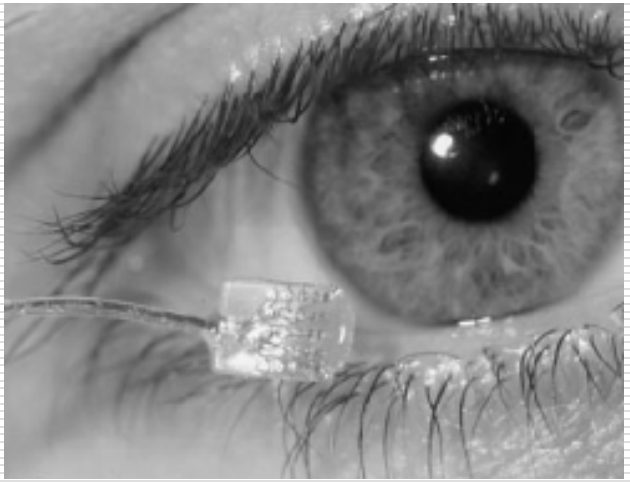
Epiretinal stimulator

- Stimulation level : Retinal ganglion cell
- Doheny / NCSU / SecondSight



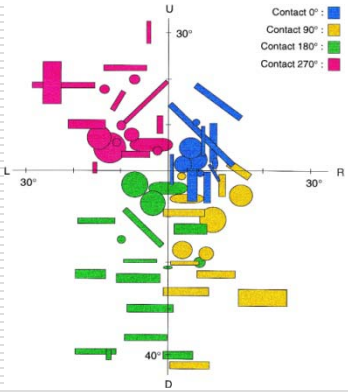
Doheny / Second Sight

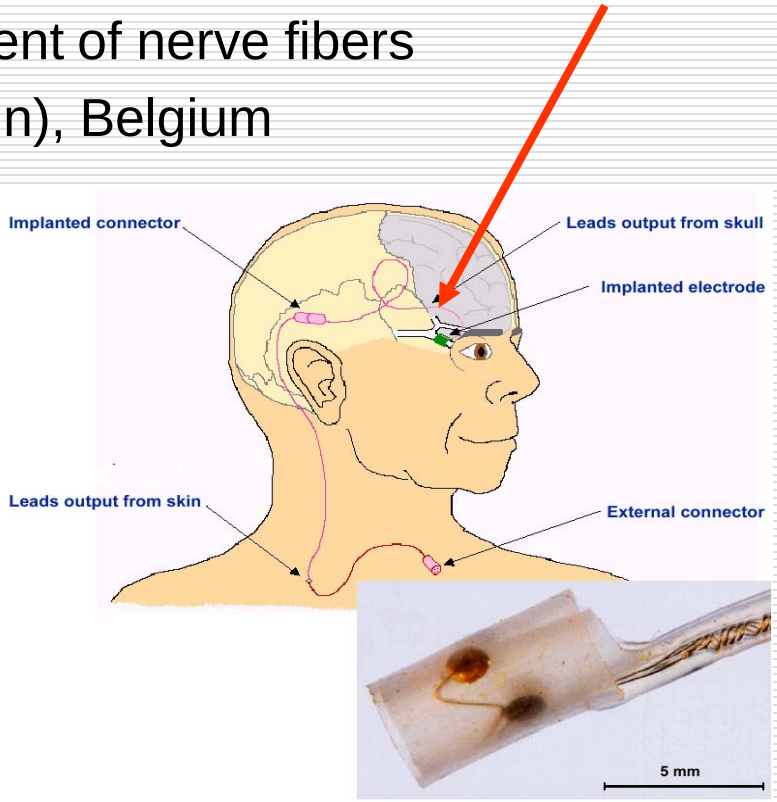
- 4 x 4 Pt electrode
- powered by Clarion® cochlear implant system
- Experiment results from 3 patients after December, 2001
  - Detect light direction : 90-100%
  - Orientation of “L” : 75%
  - Location of white object on black background : 80%



Optic nerve stimulator

- Stimulation level : Optic nerve
- Disadvantage
  - High density of axons (1.2million/2mm diameter) with tough dura
  - Specialized topological arrangement of nerve fibers
- UCL (Universite Catholique de Louvain), Belgium
- First human trial in April, 1998
  - spiral cuff electrode (Au-Ti) with 4 electrodes
- Second human trial in 2003
  - 8 electrodes



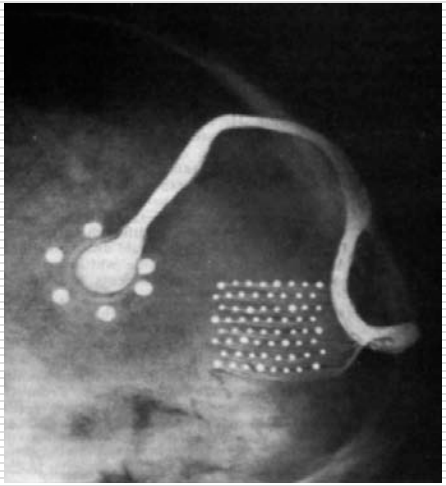


Visual cortex stimulator

- stimulation level : visual cortex
- Advantage
  - Therapeutic potential is greatest.
- Disadvantage
  - More complex topology of neurons.
  - Stimulation at a large area of visual cortex
    → Epileptogenic
- Utah, Dobelle Inst., Kresge

Visual cortex stimulator

- Dobelle (1976):
  - **64 Pt electrode**, 8 x 8 array on 3 mm centers in Teflon ribbon cable matrix
  - use only 6 electrodes among them.
  - connection with the outside through penrose drainage
- Dobelle (2002):
  - insist that a operated patient drive and sense color



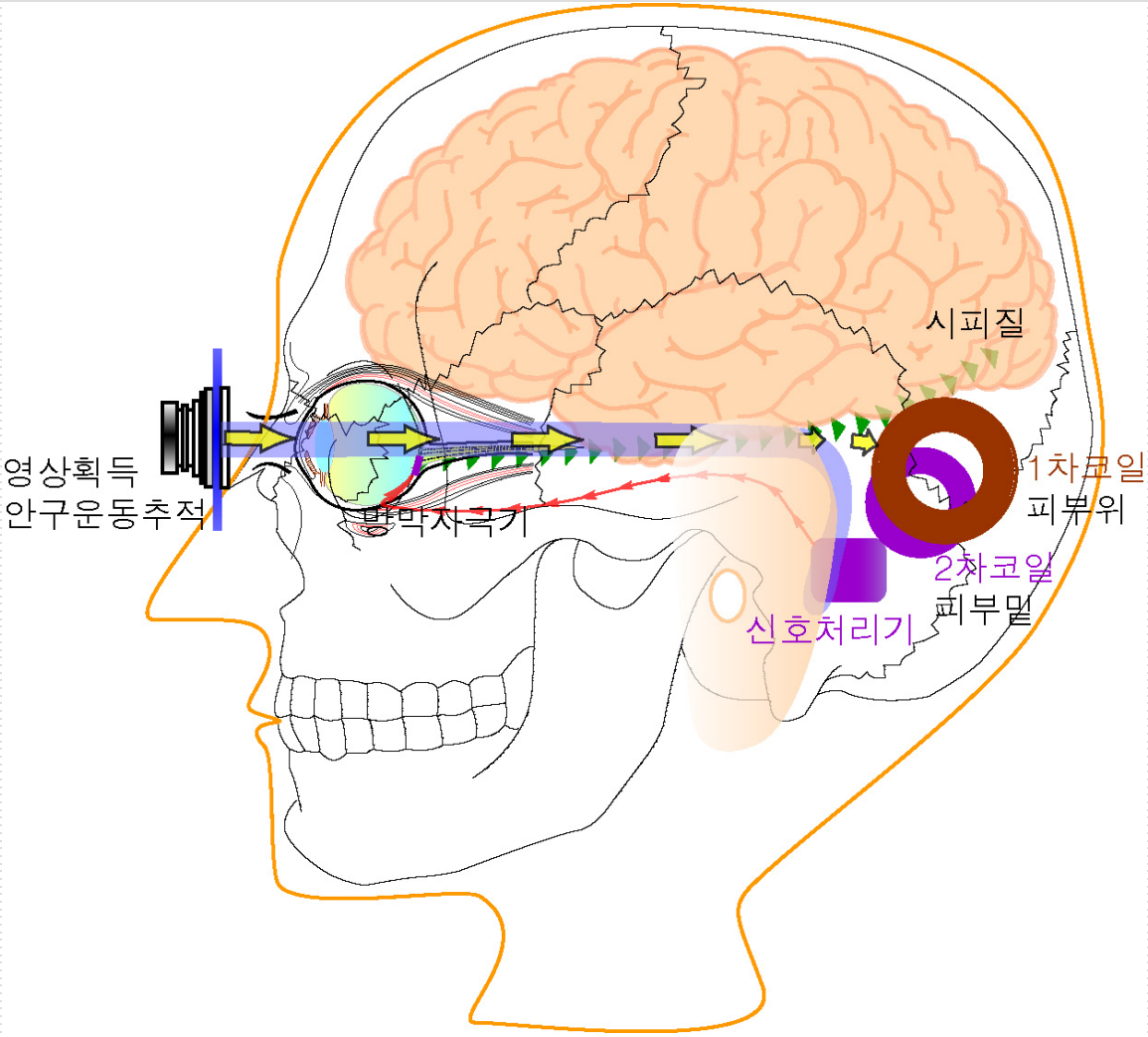
Artificial retina：problems to be solved

- where should a stimulator be implanted?
- How can visual information be transmitted to the stimulator?
- How can energy be supplied to the stimulator?
- What is the optimal stimulation form of the stimulator?
- How can the eternal and best stimulator be made?

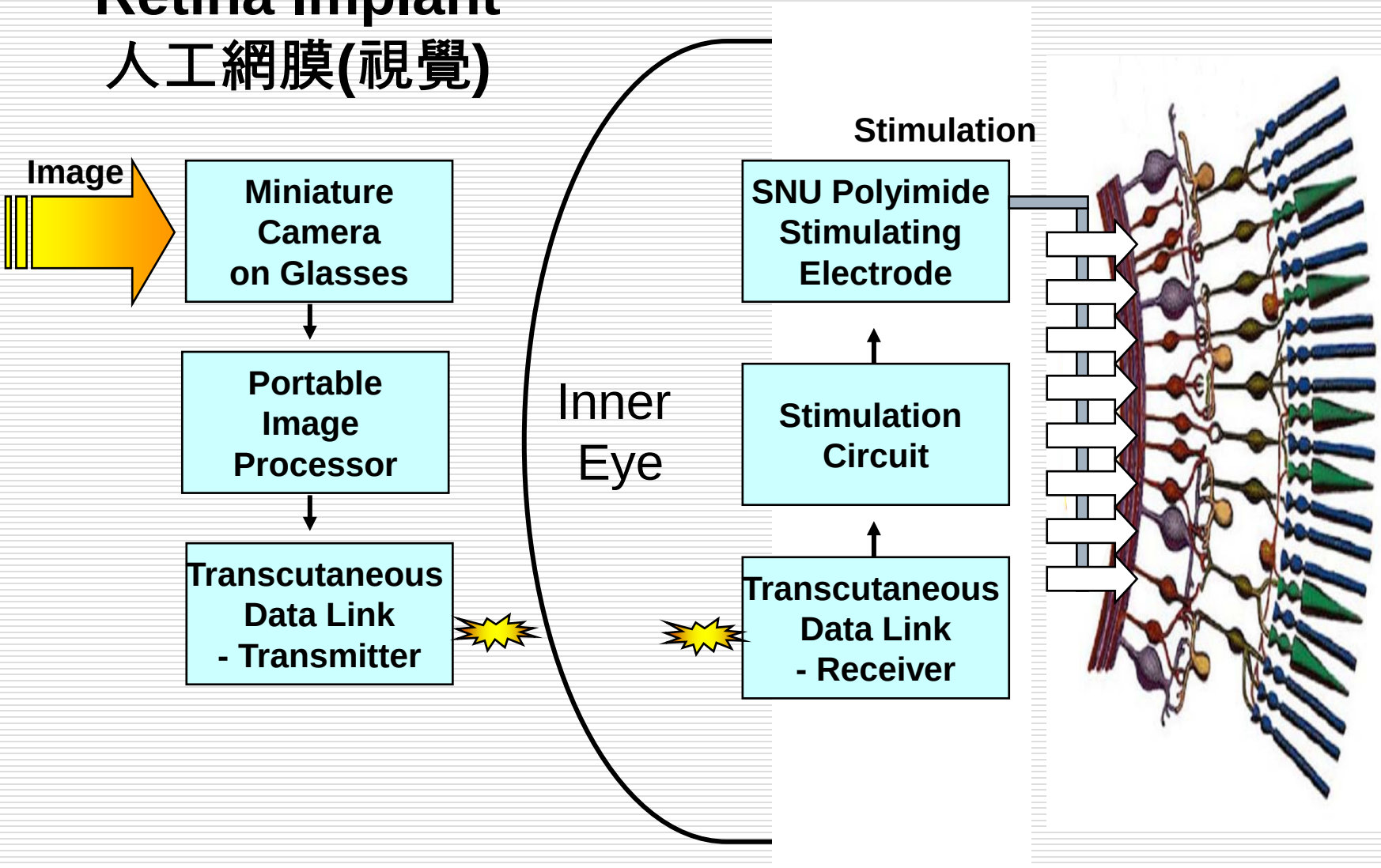
SNU artificial retina

- Nano-bio system research center (for 9 years, 3 main subjects)
  - supported by KOSEF(KOREA SCIENCE AND ENGINEERING FOUNDATION)
  - development of electrode for retina stimulation as a subject in Neural chip/MEMS
- Nano artificial vision research center (for 6 years)
  - supported by Minister for Health, Welfare and Family Affairs
  - development of SNU artificial retina system and application to a human body
- Organization
  - ophthalmology
  - physiology
  - Electrical Engineering & Computer Science
  - biomedical engineering

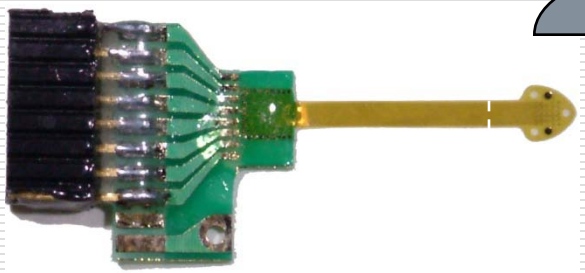
SNU artificial retina

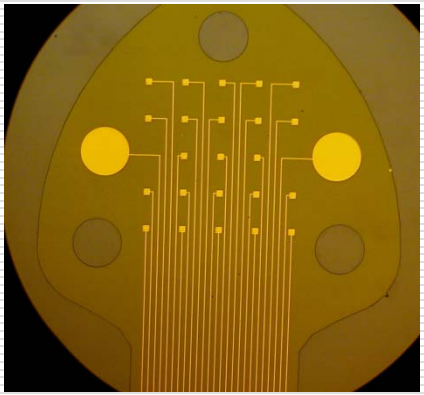


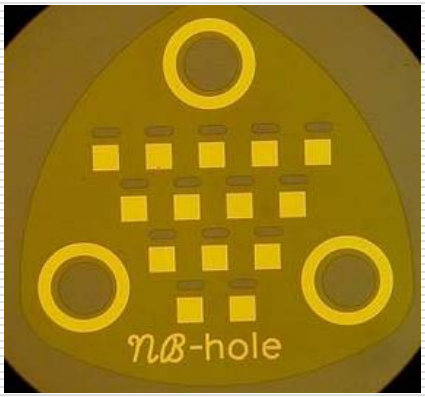
Retina Implant
人工網膜(視覺)



Polyimide-based Retinal Prosthesis







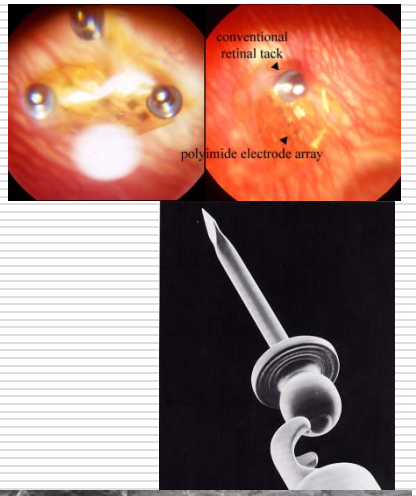
Electrode spec.

Whole structure size : 3mm x 17.8mm x 16um
Size of each site : 50um x 50um
Number of sites : 25
Site spacing : 300 um
Insulation layer : Polyimide (PI2525)
Shape of head : Rectangular, Triangular
Head size: 3mm x 3mm

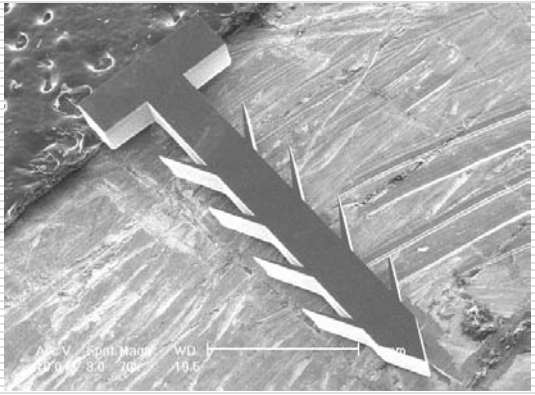
Acute stimulation

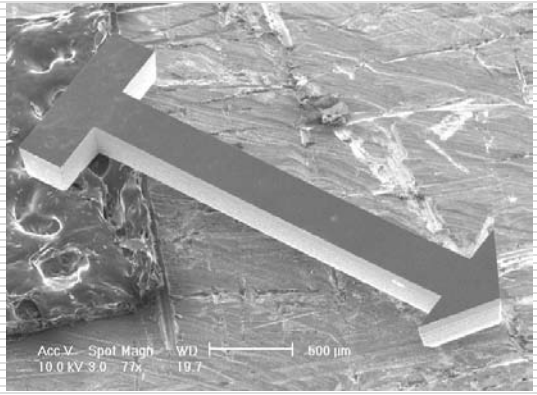
Experiment (rabbit)

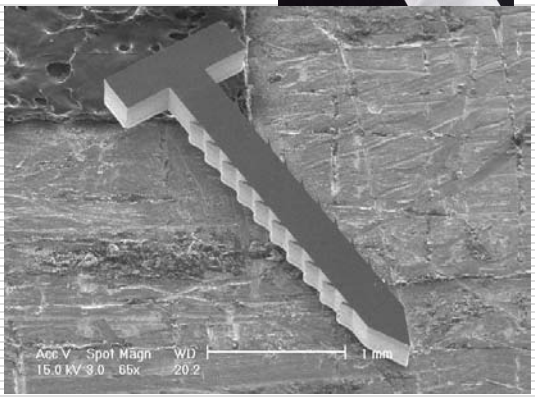
Micromachined Silicon Tacks

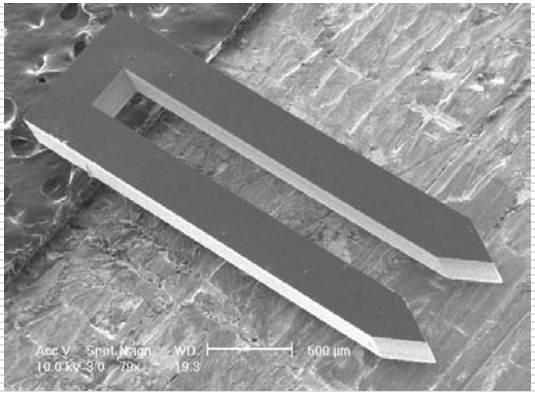


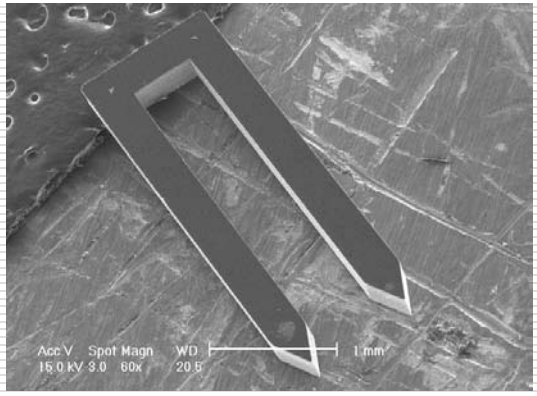
- Fabrication
  - material: silicon, oxide on silicon, parylene on silicon
  - full scale dimensions: length 3 mm, width 300 μm, height 300 μm
  - half scale dimensions; length 1.5 mm, width 150 μm, height 150 μm

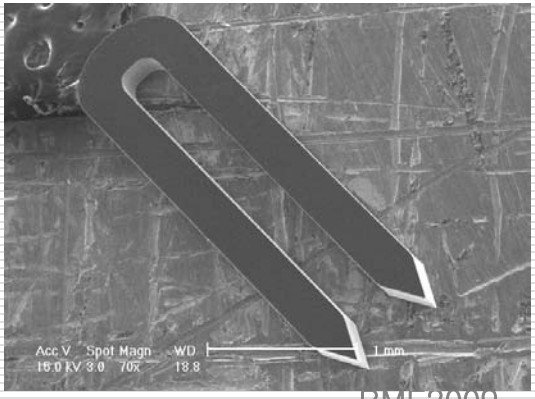






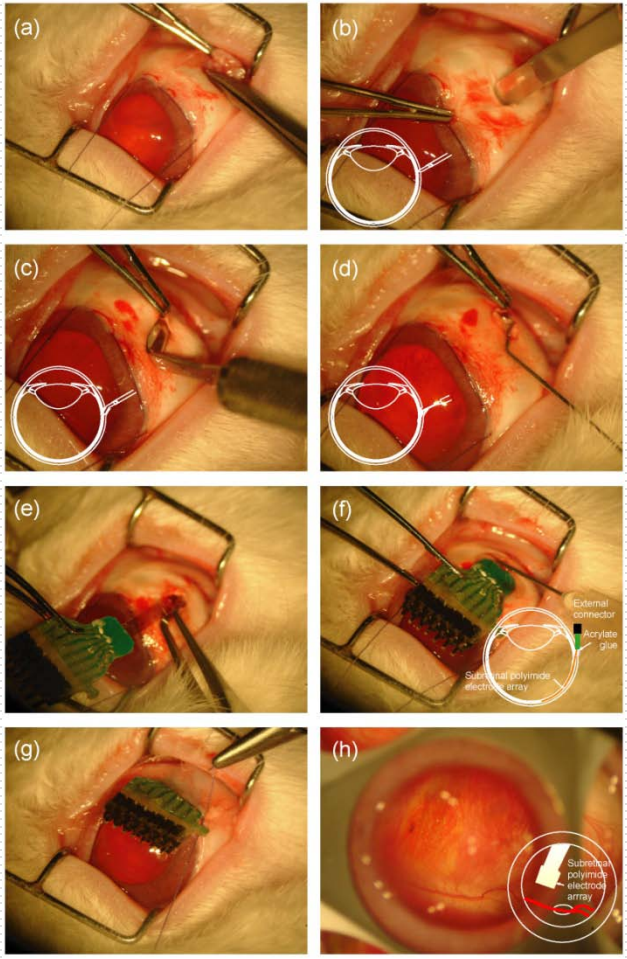




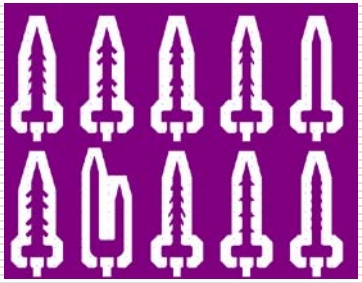


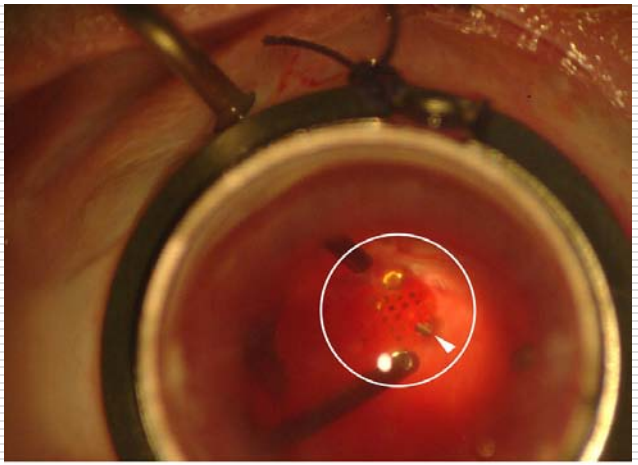
Study on operation methods of a electrode for retinal stimulation

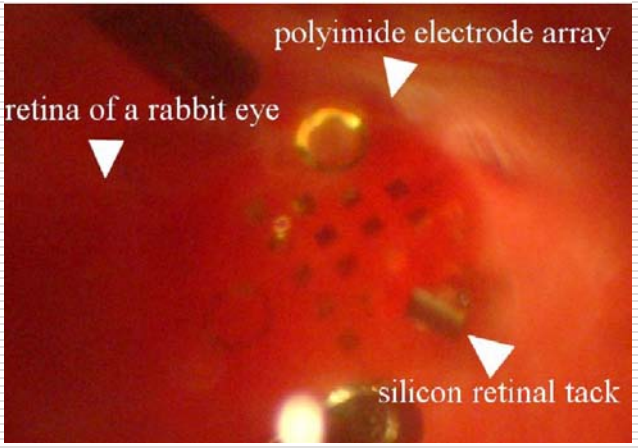
- subretinal insertion



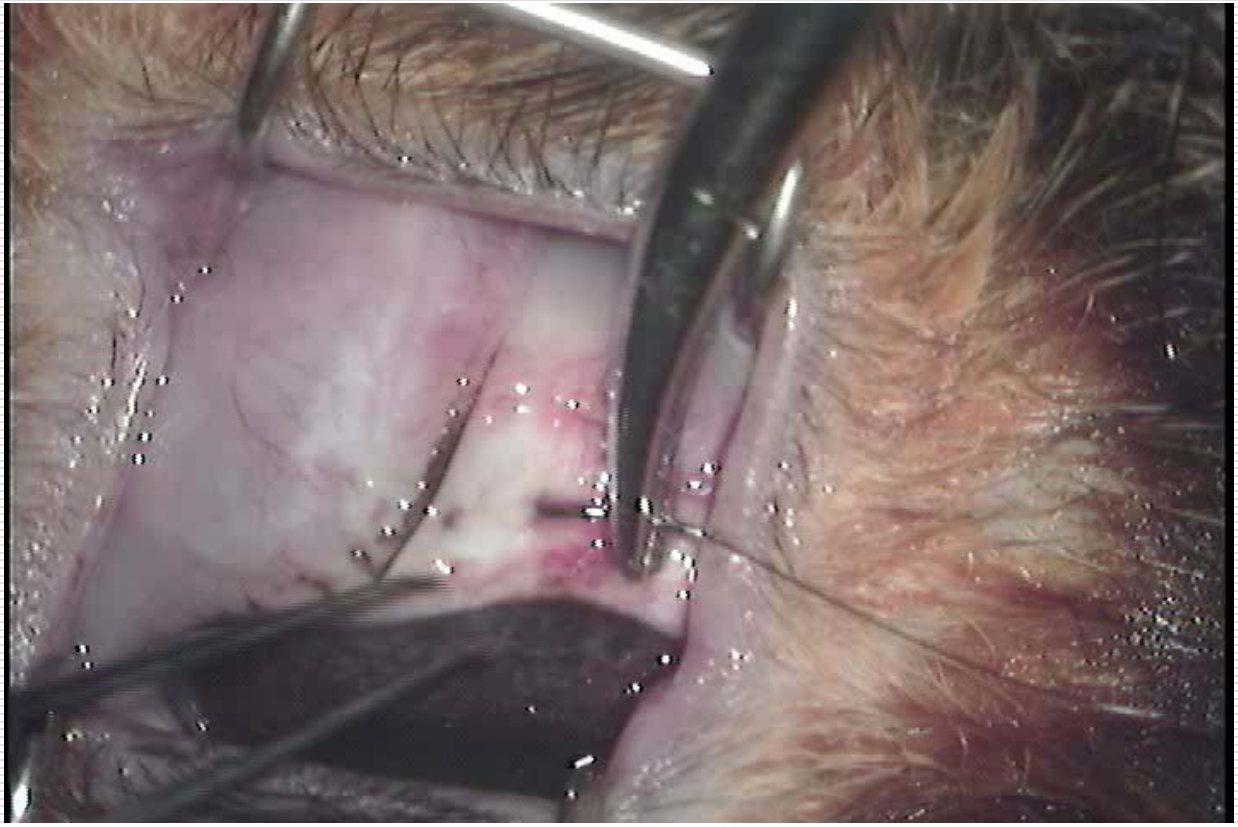
- epiretinal insertion



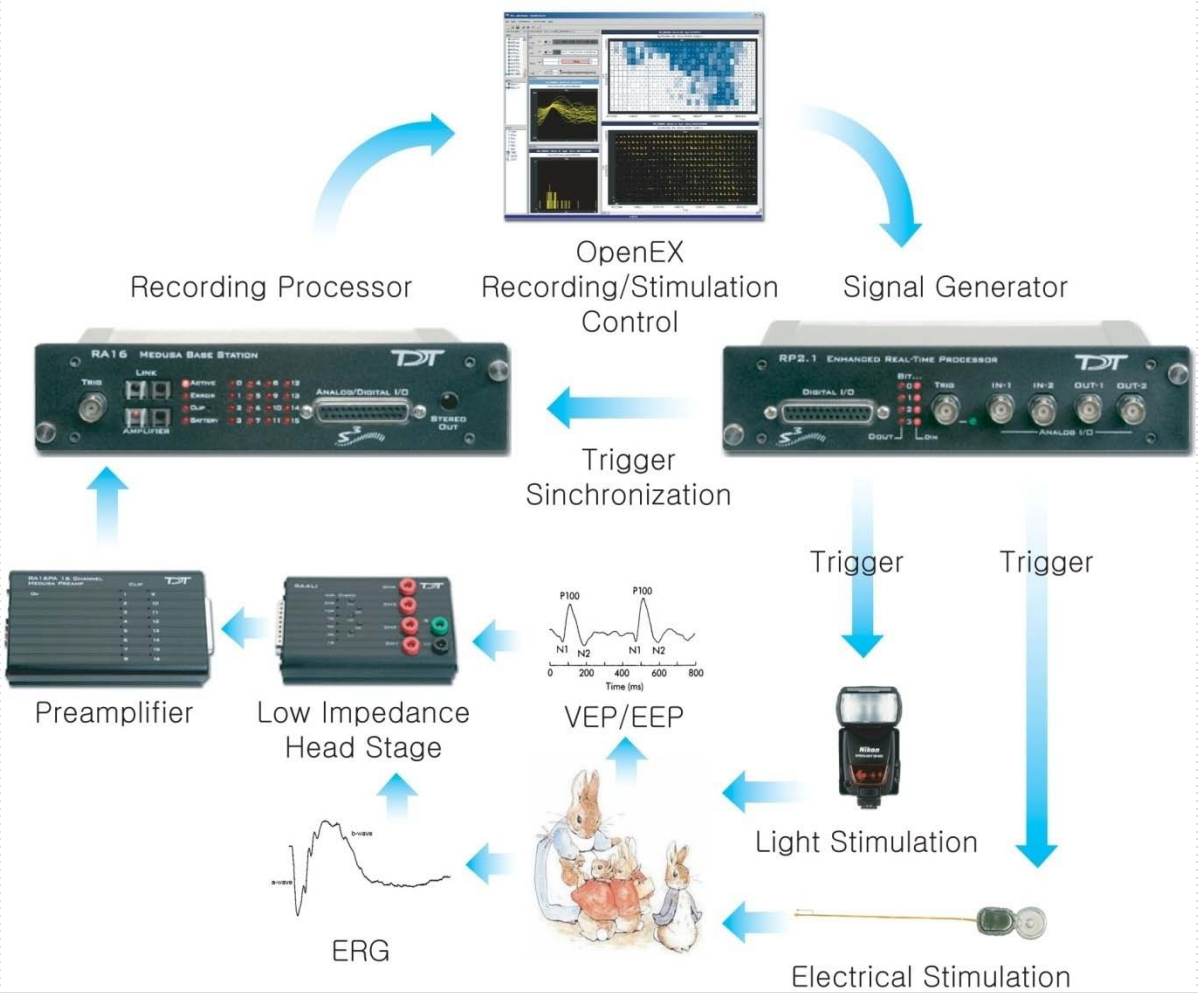


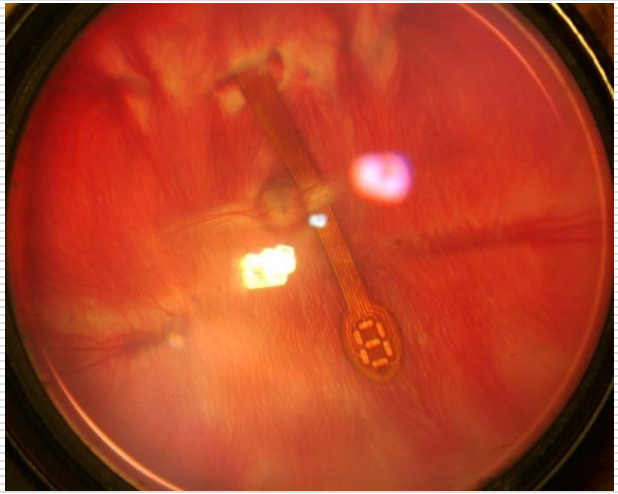


Epi-retina implant using Polyimide electrode and Micromachined Tacks

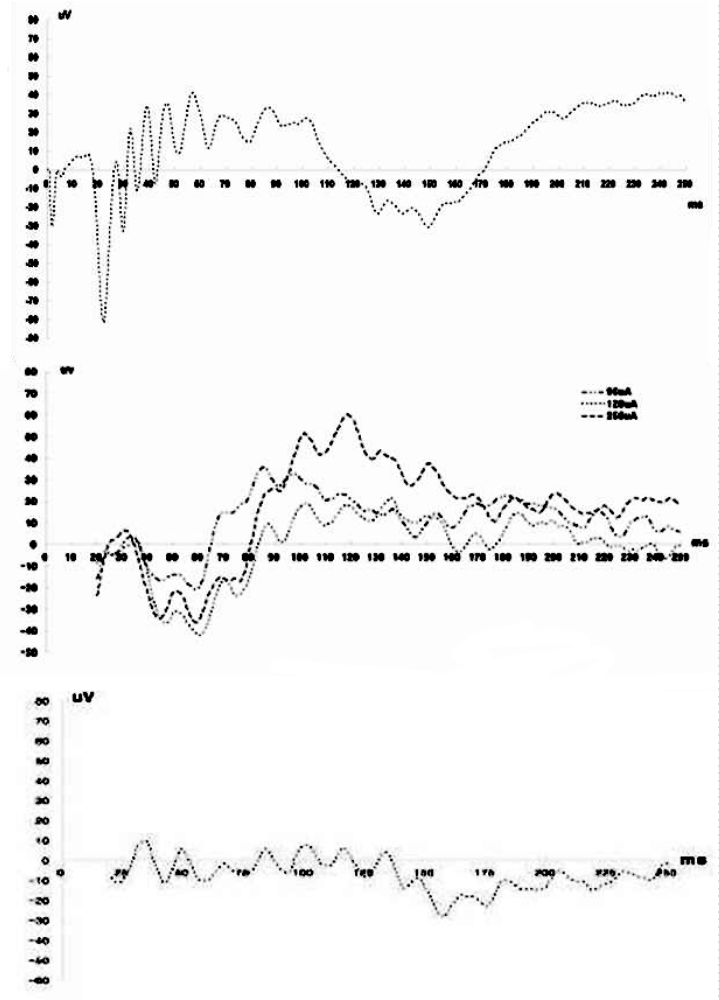


Setup for stimulation study using electrodes and a system





Electrophysiological recording after insertion of retina stimulator

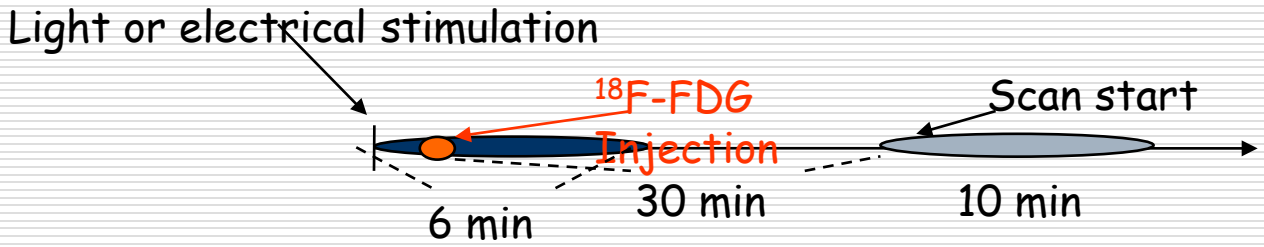


Visual evoked Cortical potential (VECP)

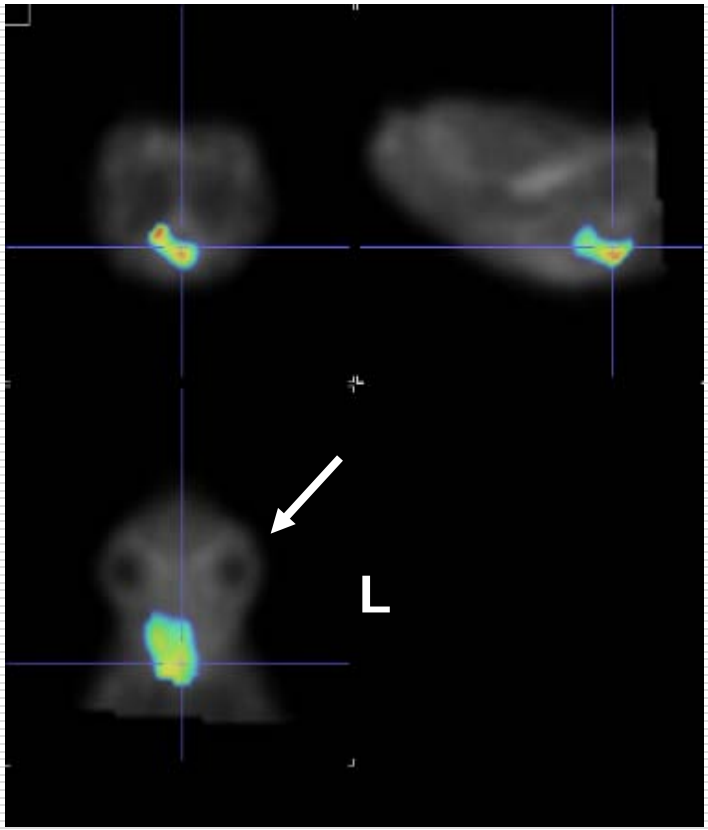
Electrically evoked cortical potential
(EECP)

After optic nerve cutting

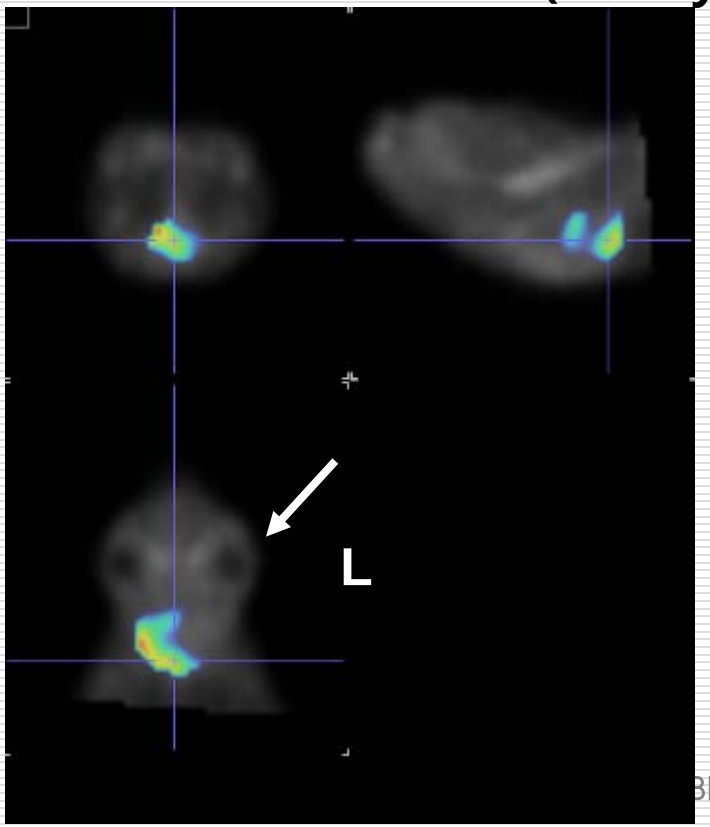
Range of increase in glycometabolism of visual cortex (PET image)



Light Stimulation (left eye)

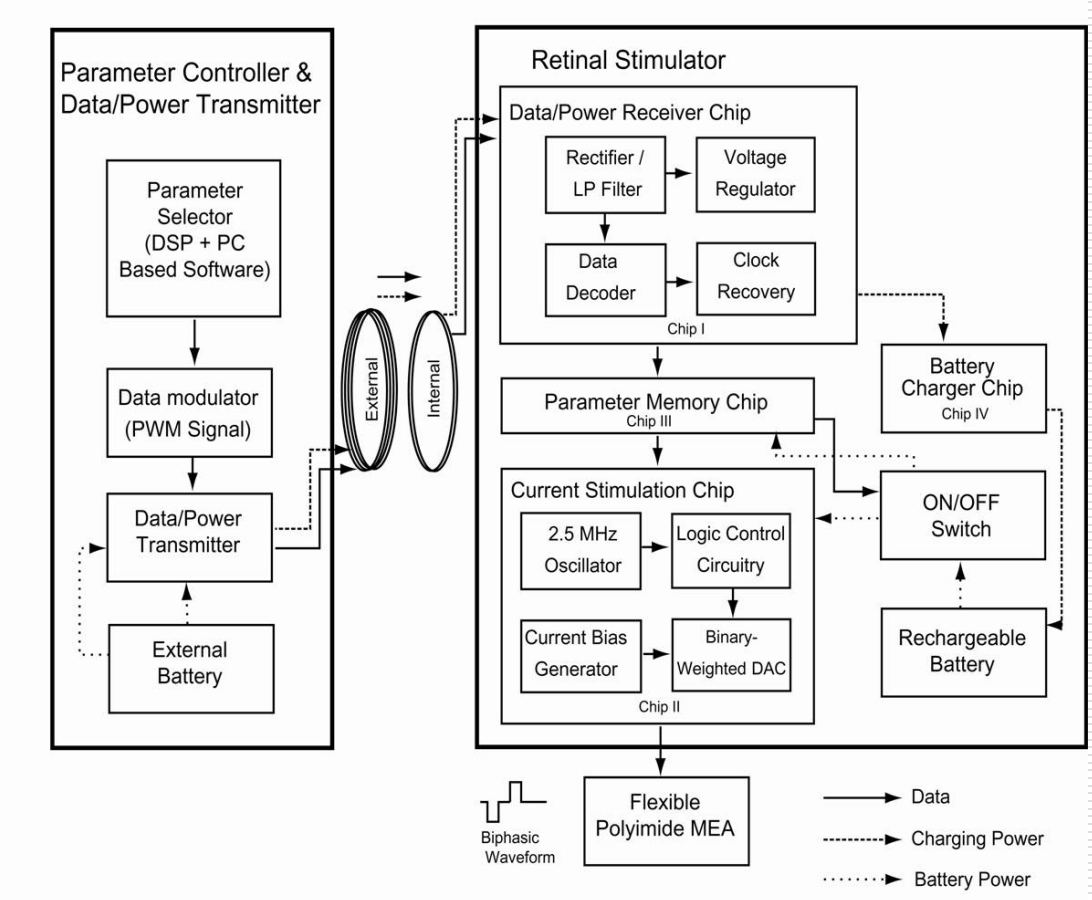


Electrical stimulation (left eye)

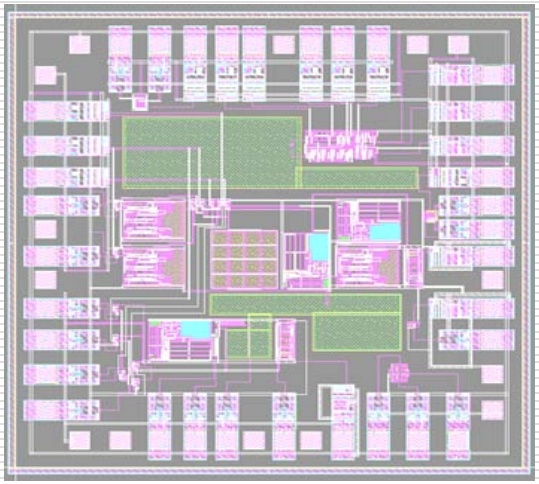


Artificial Retina System for Animal Study

- Simultaneous Wireless Transmission of Data for Stimulation and Power (Class-E amplifier)

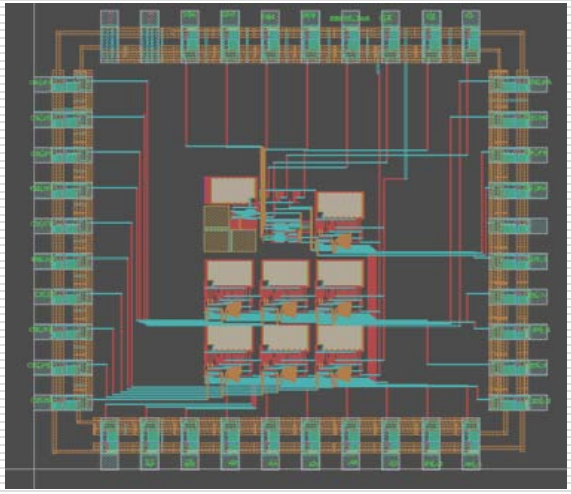


Fabricated ICs



Data/Power Receiver Chip

- Rectifier/Amplifier
- Data Decoder (125Kbps)
- Voltage Regulator (5V)
- Internal Clock Generator(125KHz)



Current Stimulator Chip

- Current Source (7 channel)
- Biphasic Wave Form Generator

Fabricated Artificial Retina System for Animal Study