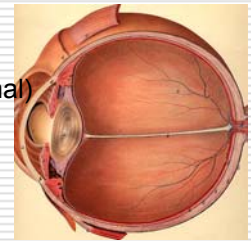
Artificial Vision

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**)

Care for Blindness

- visual impairment :
  - Legally considered percentage of lost body function: 24%(**Uniocular**) and 100%(**binocular**)
- 30% of blindness in the adult
  - Retinitis Pigmentosa**망막생소변성**; 1/4000(Normal)
  - AMD **나이관련황반변성**; 1/20(>aged 65)
- Artificial Organs in the eye :
  - Corneal clouding **각막혼탁** → Artificial Cornea
  - Lenticular opacity **수정체 혼탁**→ Artificial Lens
  - Retina Damage→ Artificial Retina?



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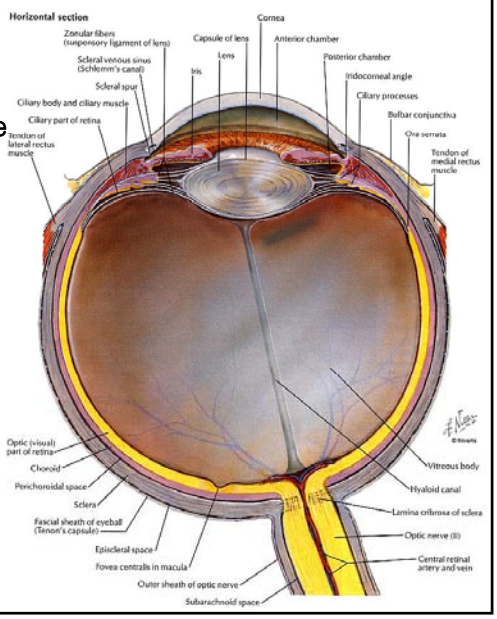
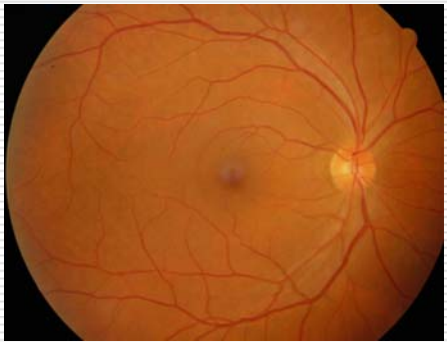
Structure of the eye

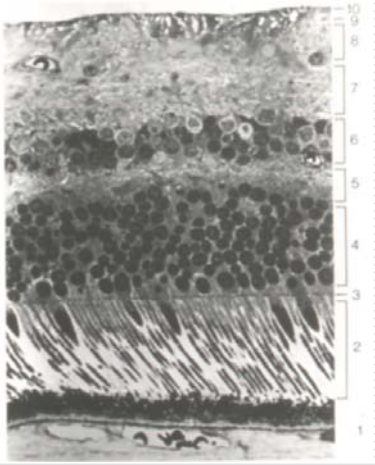
- **retina(망막):** nervous tissue
- **choroid(맥락막):** vascular tissue
- **sclera(공막):** connective tissue
- **optic nerve(시신경)**



Retina

- Recognizes image and transmits it to brain
- Can be compared to camera film





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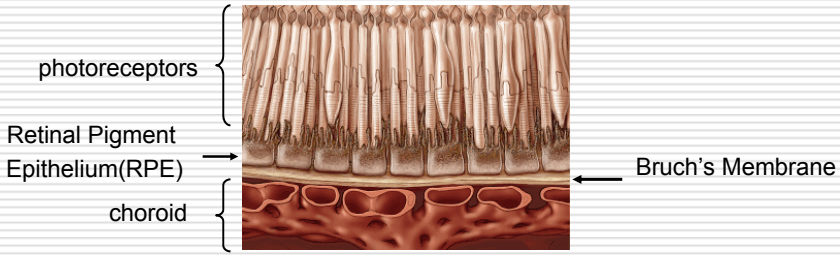
Structure of the Retina

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



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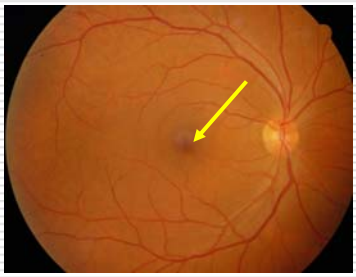
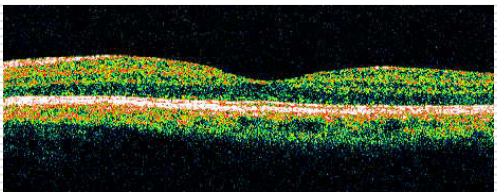
Macula (황반,黃斑)

- macula : center of retina, 5mm diameter, provides central vision
- Tinted yellow due to rich concentration of Xantophyll(엽황소)





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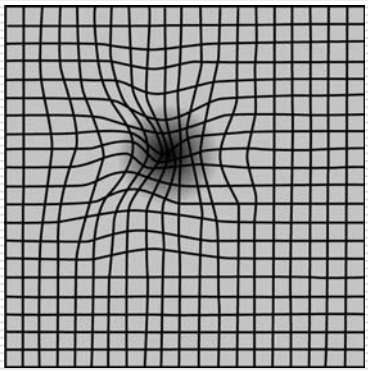
The world that patients with macular degeneration see



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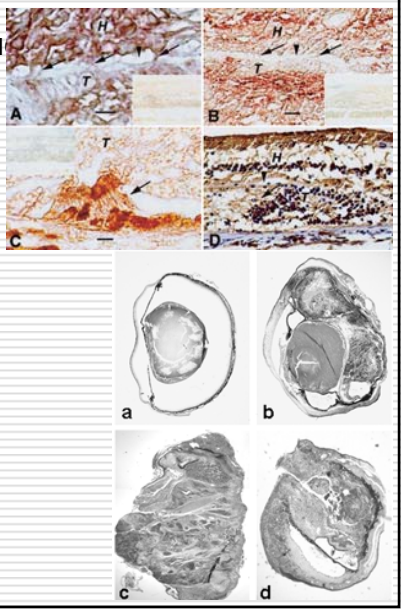
Recovery from retina damage

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



Why Artificial Retina?

- Progress for the last 20 years
  - Good preservation of the retina inner layers in the RP patients have become known.
  - success of cochlear implant
  - development in semiconductor technology
    → fabrication of a large-scale integrated circuit
  - AR research began in late 1980s

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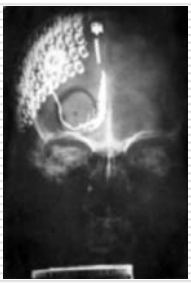
What happens when retina is electrically stimulated?

- Foerster (1929): patient saw a small spotlight on electrical stimulation of visual cortex - 'phosphene(인광)'
- Brindley & Lewin(1968)
  - Implant a visual cortex stimulator in a 52 years old patient
  - couldn't find conditions to obtain continuous images
- Dawson & Radtke (1977): electrical stimulation of retina
  → discovery of sense of phosphene



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Artificial vision

- Basic Concept:
  replace function of retina cells with an electrical device.
- Hypothesis :
  electrical stimulation can induce vision.
- Goal:
  implantation of microchip for evoking vision.

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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
- Mimimum resolution:
  project image divided into pixels onto normal retina
  - **25 x 25** → can detect movement
  - **32 x 32** → can read books with some help

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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

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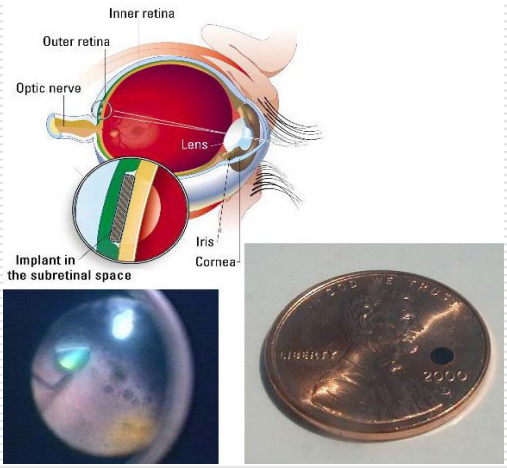
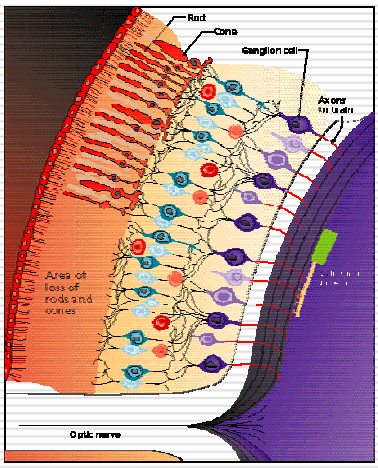
Subretinal vs. Epiretinal





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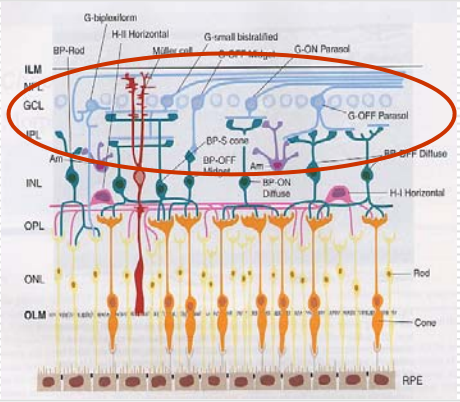
Subretinal stimulator

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



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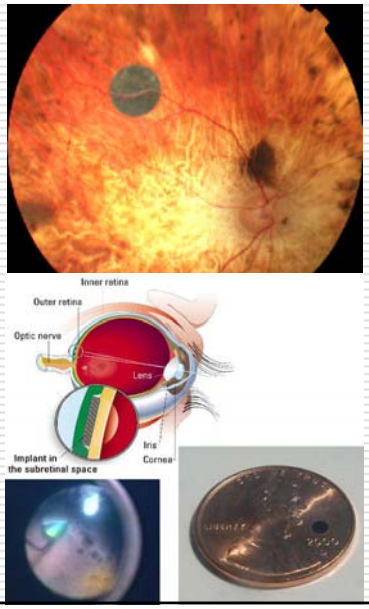
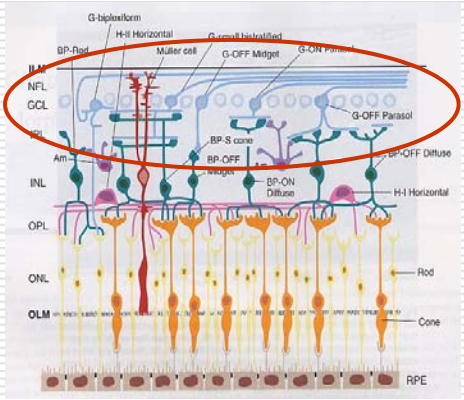
Optobionics Design

- **Used a simple photodiode array chip, no biasing, photovoltaic mode**
- Natural light is not strong enough to generate electrical power necessary.
- Experiments under FDA permission on 'in vivo biocompatibility'
- Operation on 12 patients with RP, from 45 to 76, in 2000.
- Nevertheless, some improvement of vision is reported in all patients.



Epiretinal stimulator

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



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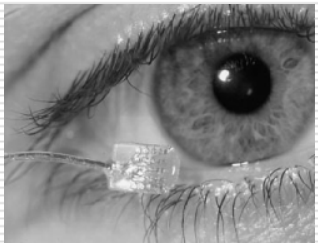
Doheny / Second Sight

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



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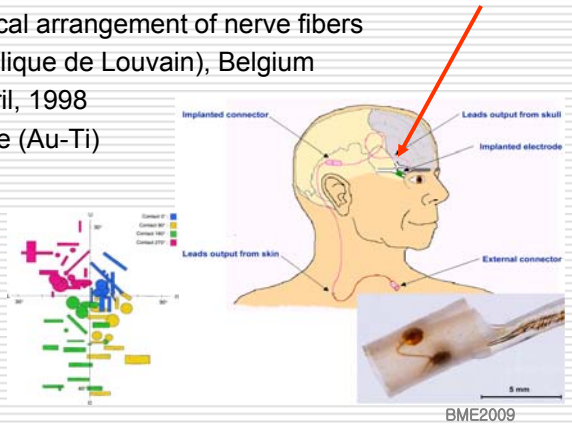
Optic nerve stimulator

- Stimulation target : Optic nerve
- Disadvantage
  - High density of axons (1.2million/2mm diameter) with tough dura
  - Uncertain 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



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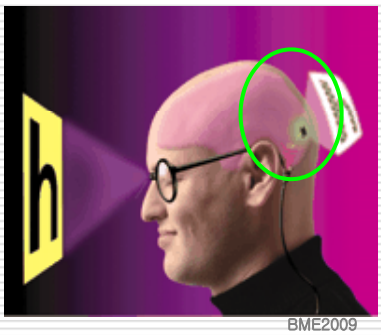
Visual cortex stimulator

- stimulation target : visual cortex
- Advantage
  - Broad applicability.
- Disadvantage
  - Complex topology of neurons.
  - Stimulation at a large area of visual cortex
    → Epileptogenic (**간질발생**)
- Utah, Dobelle Inst., Kresge



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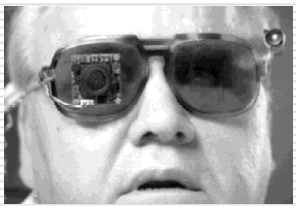
Visual cortex stimulator

- 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):
  - Insisted that a operated patient drive and sense color



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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 strategy?
- How can the eternal and best stimulator be made?

BME2009

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
- Collaborators
  - ophthalmology
  - physiology
  - Electrical Engineering & Computer Science
  - biomedical engineering

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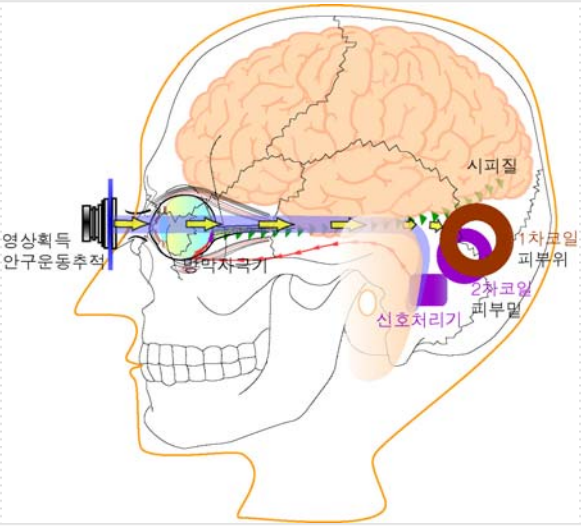
SNU artificial retina



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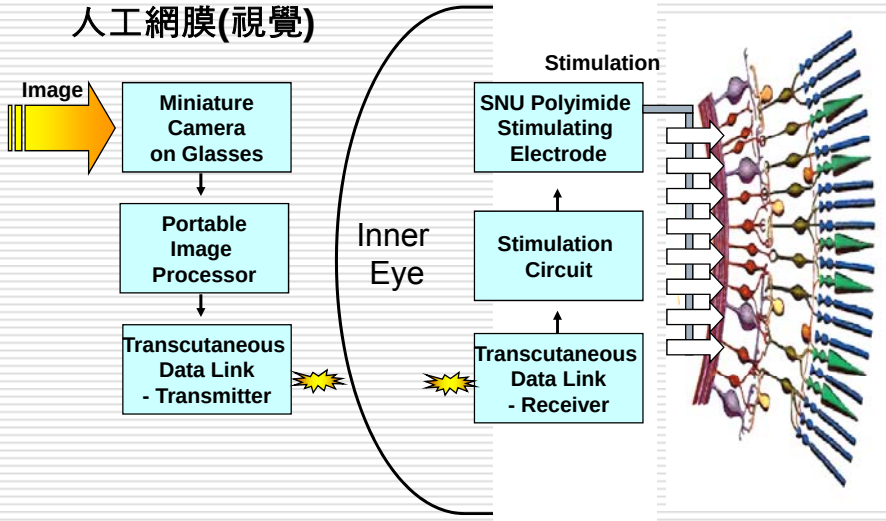
Retina Implant
人工網膜(視覺)



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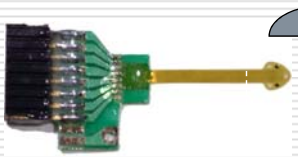
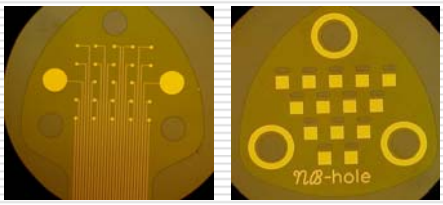
Polyimide-based Retinal Prosthesis





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)

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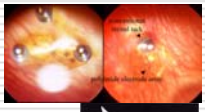
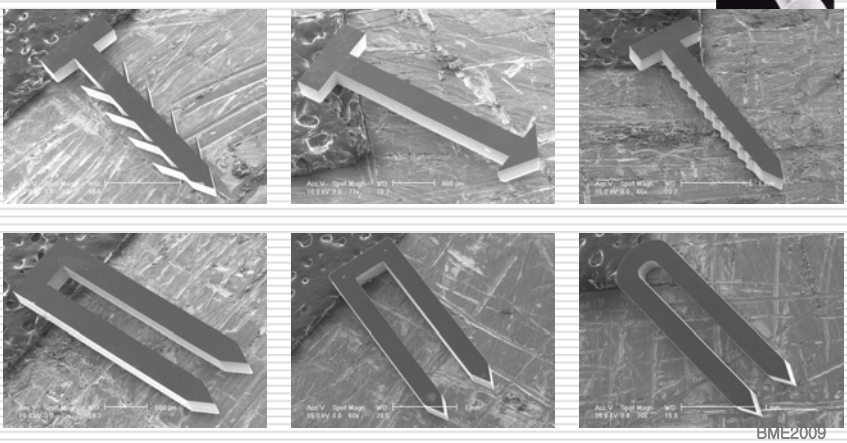
Micromachined Silicon Tacks



- 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



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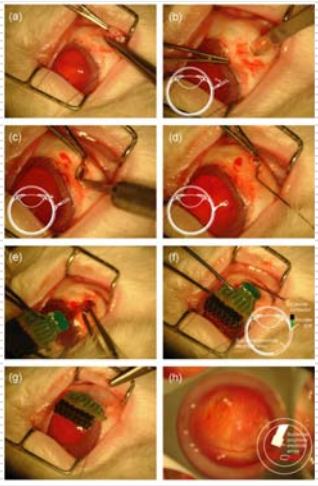
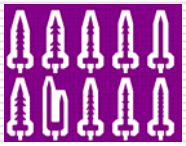
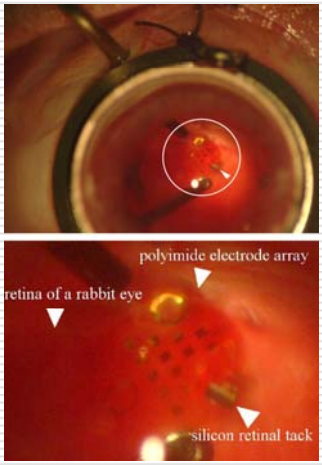
Surgical methods

- subretinal insertion



- epiretinal insertion





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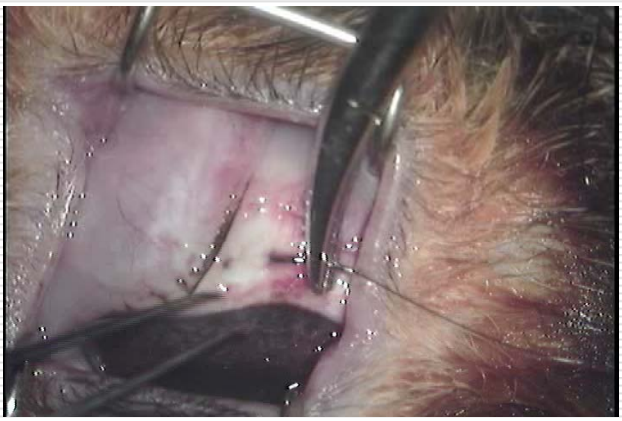
Epi-retina implant using Polyimide electrode and Micromachined Tacks



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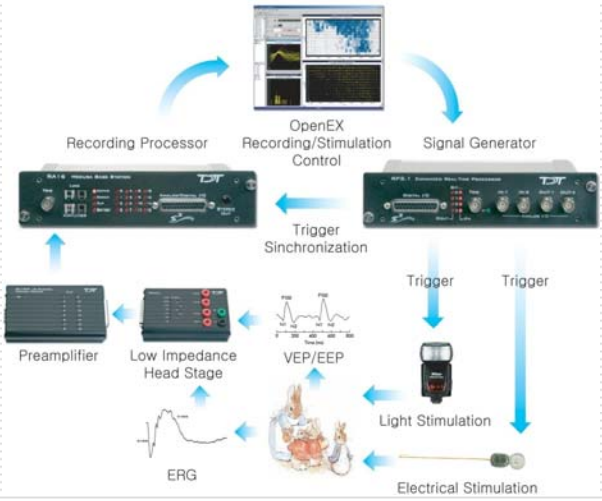
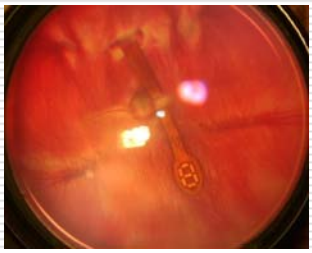
Setup for stimulation and recording





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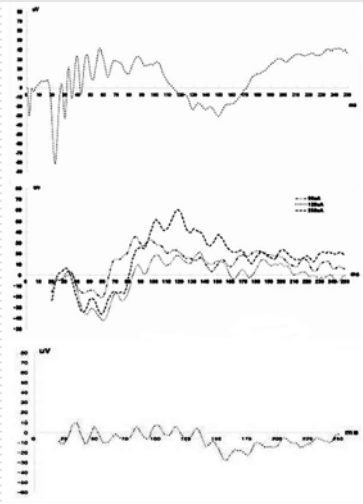
Electrophysiological recording after insertion of retina stimulator



Visual evoked Cortical potential (VECP)

Electrically evoked cortical potential
(EECP)

After optic nerve cutting

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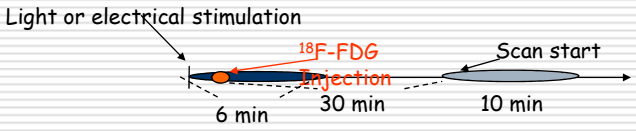
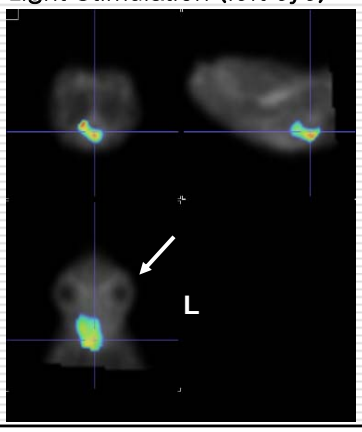
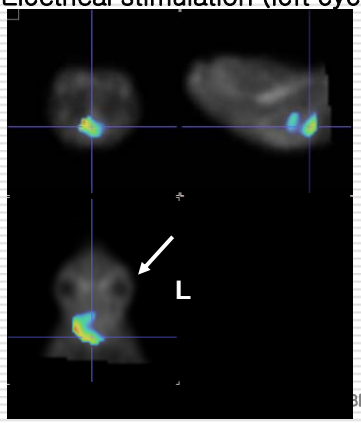
Range of increase in glycometabolism of visual cortex (PET image)



Light Stimulation (left eye)



Electrical stimulation (left eye)



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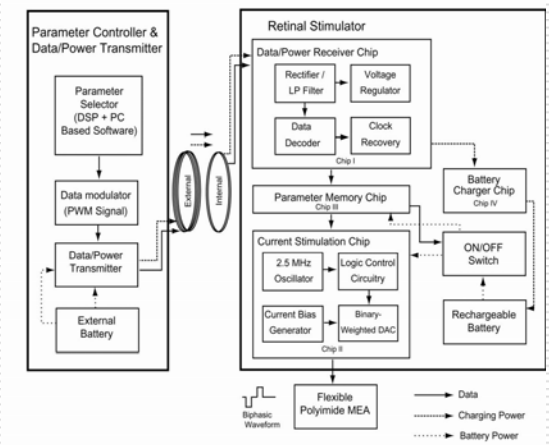
Artificial Retina System for Animal Study

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



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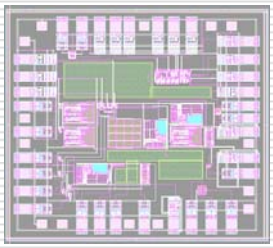
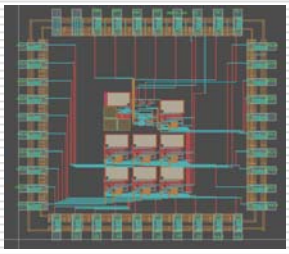
Fabricated ICs



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

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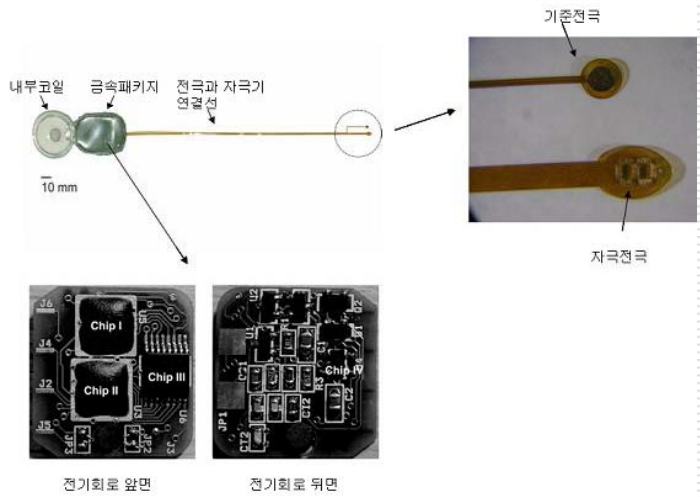
Fabricated Artificial Retina System for Animal Study



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