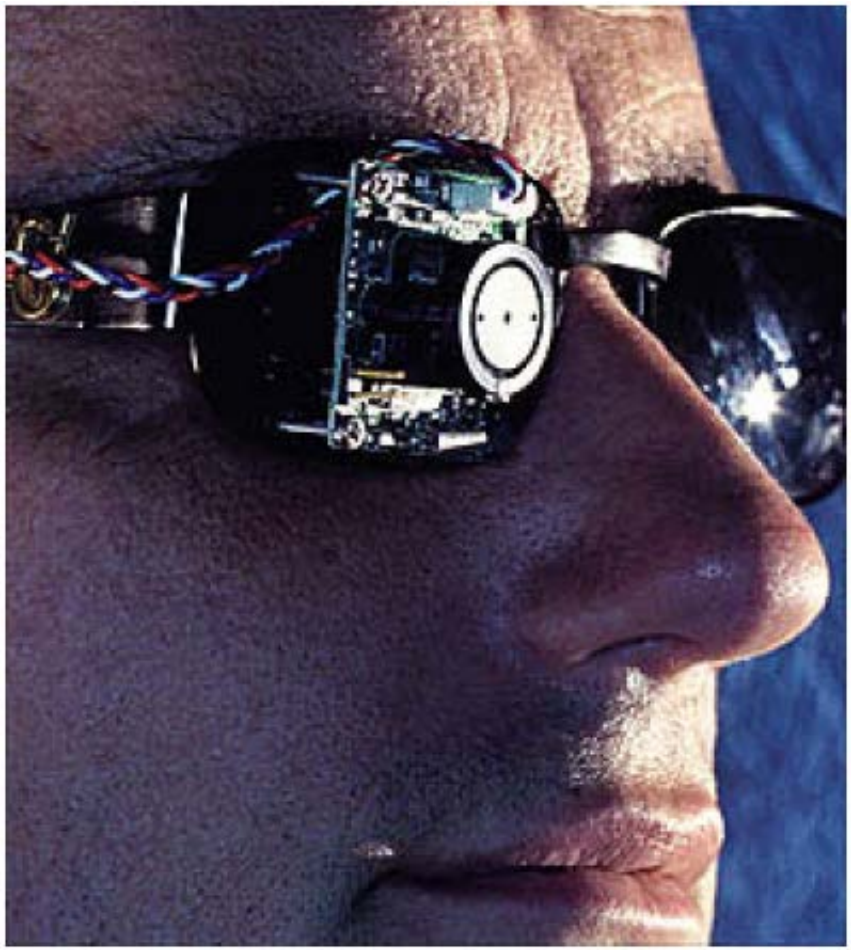
ELEC ENG 3BB3:

Cellular Bioelectricity

Notes for Lecture 31

Thursday, April 3, 2014

Advances in Vision (Artificial Retina)



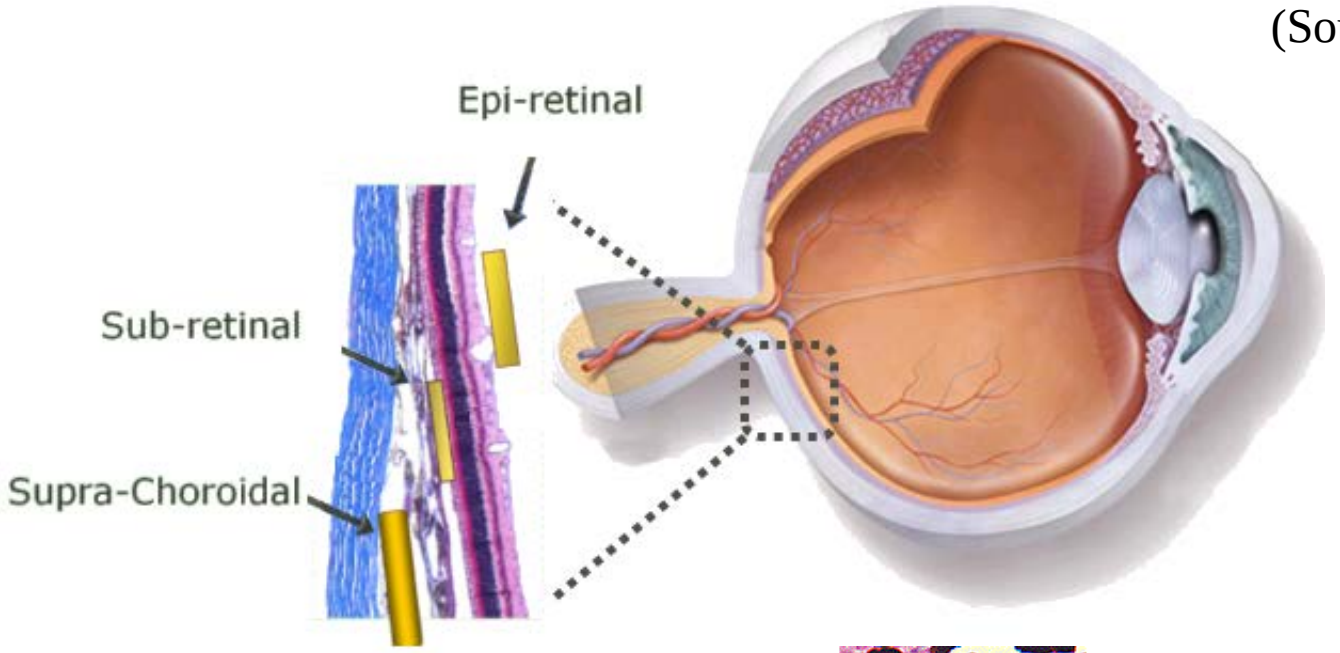
Advances in Vision (Brain Connection)

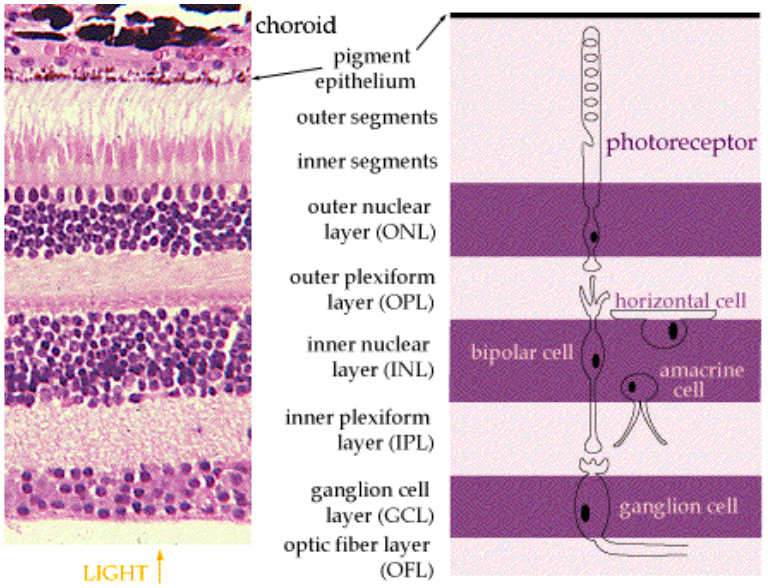
Retinal implants:

- Still in development; only one (low-res) device undergoing clinical trials so far
- First system approved by FDA recently
- Stimulate retinal cells (primarily the retinal ganglion cells, most likely)
- Low-density platinum electrode arrays → high-density silicon or diamond arrays
- Three different placement positions being considered:
  1. epi-retinal,
  2. sub-retinal, and
  3. supra-choroidal.

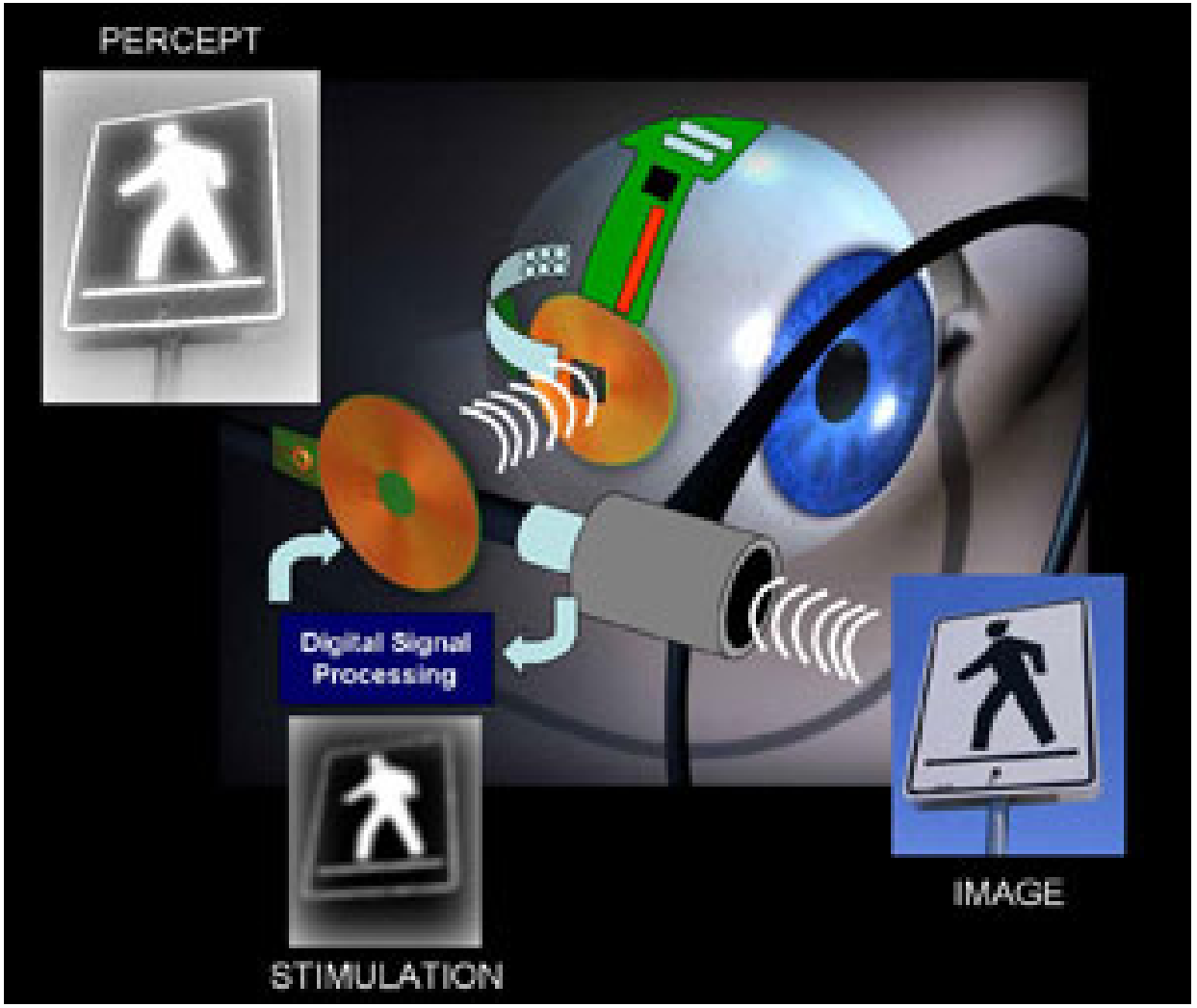
Retinal implants (cont.):

(Source: BEI)

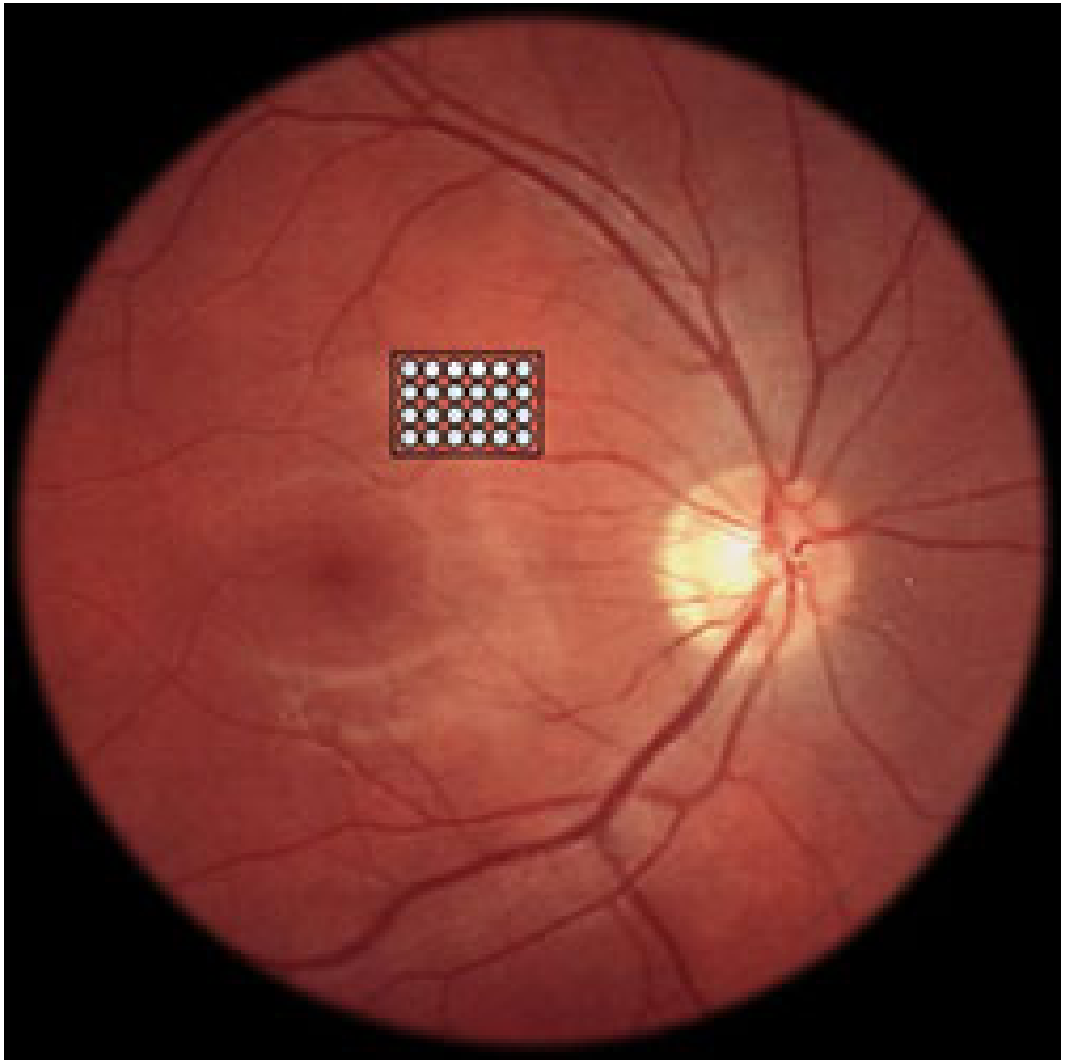




Advances in Vision (Retinal Stimulation)

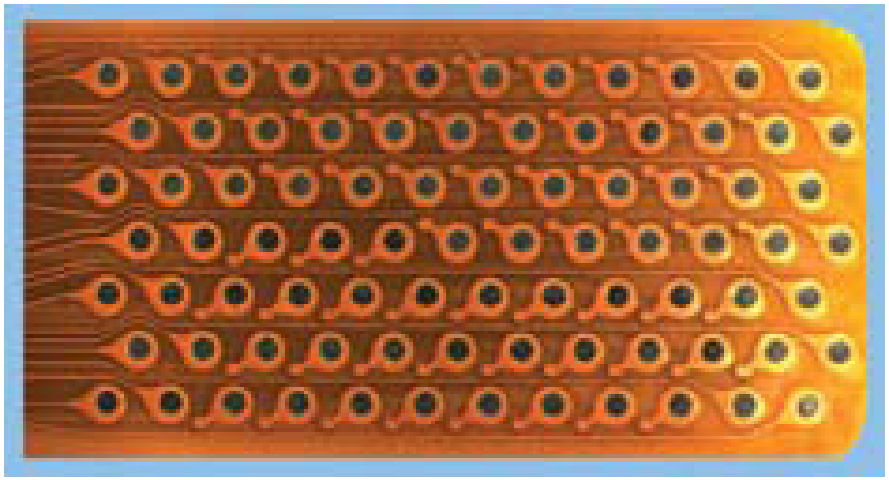


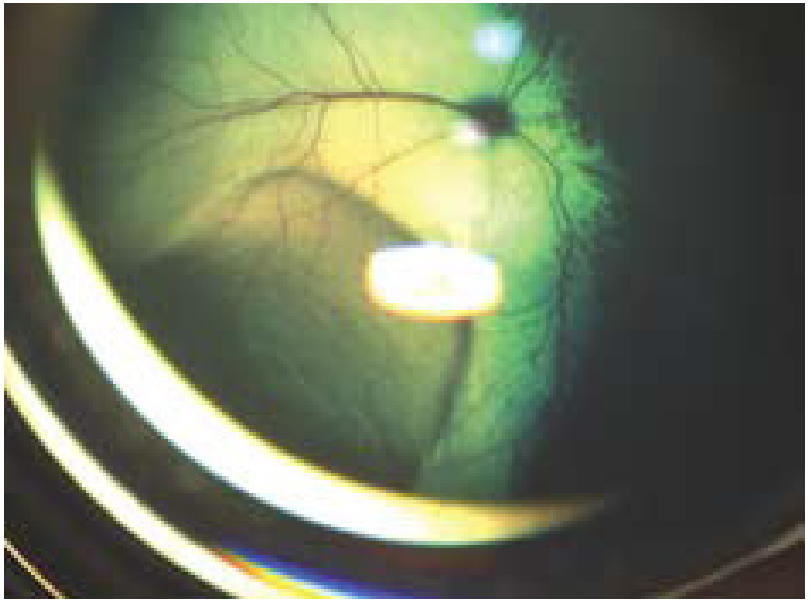
Advances in Vision (Retinal Implant)



Retinal implants (cont.):

Low-density supra-choroidal array:

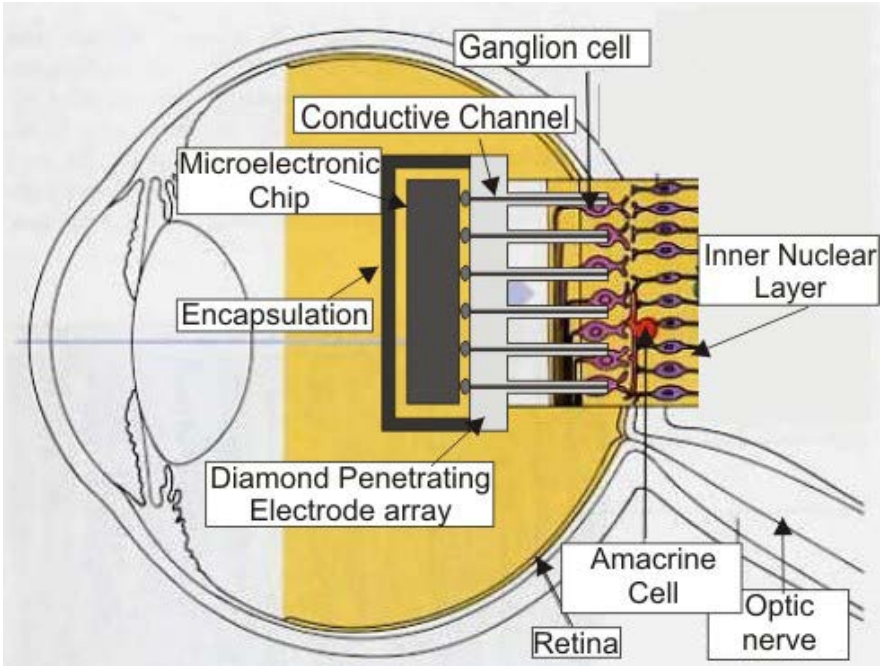


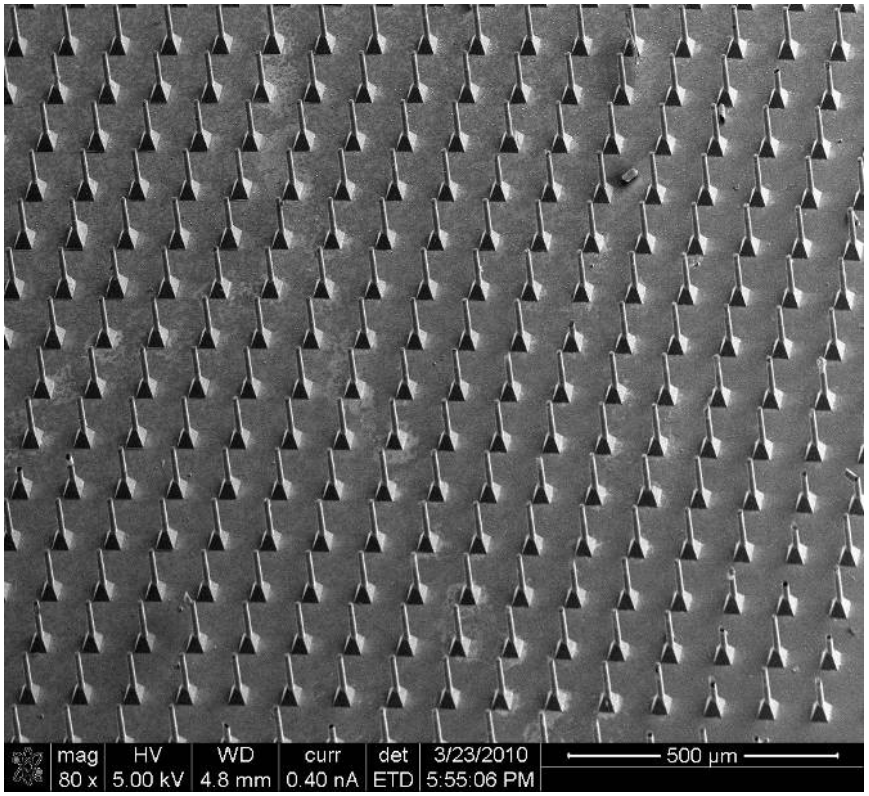


(Source: BEI)

Retinal implants (cont.):

High-density epi-retinal array:





(Ganesan et al., IEEE EMBS 2010)

Retinal implants (cont.):

The bionic eye - how it works

First prototype: Wide-view neurostimulator

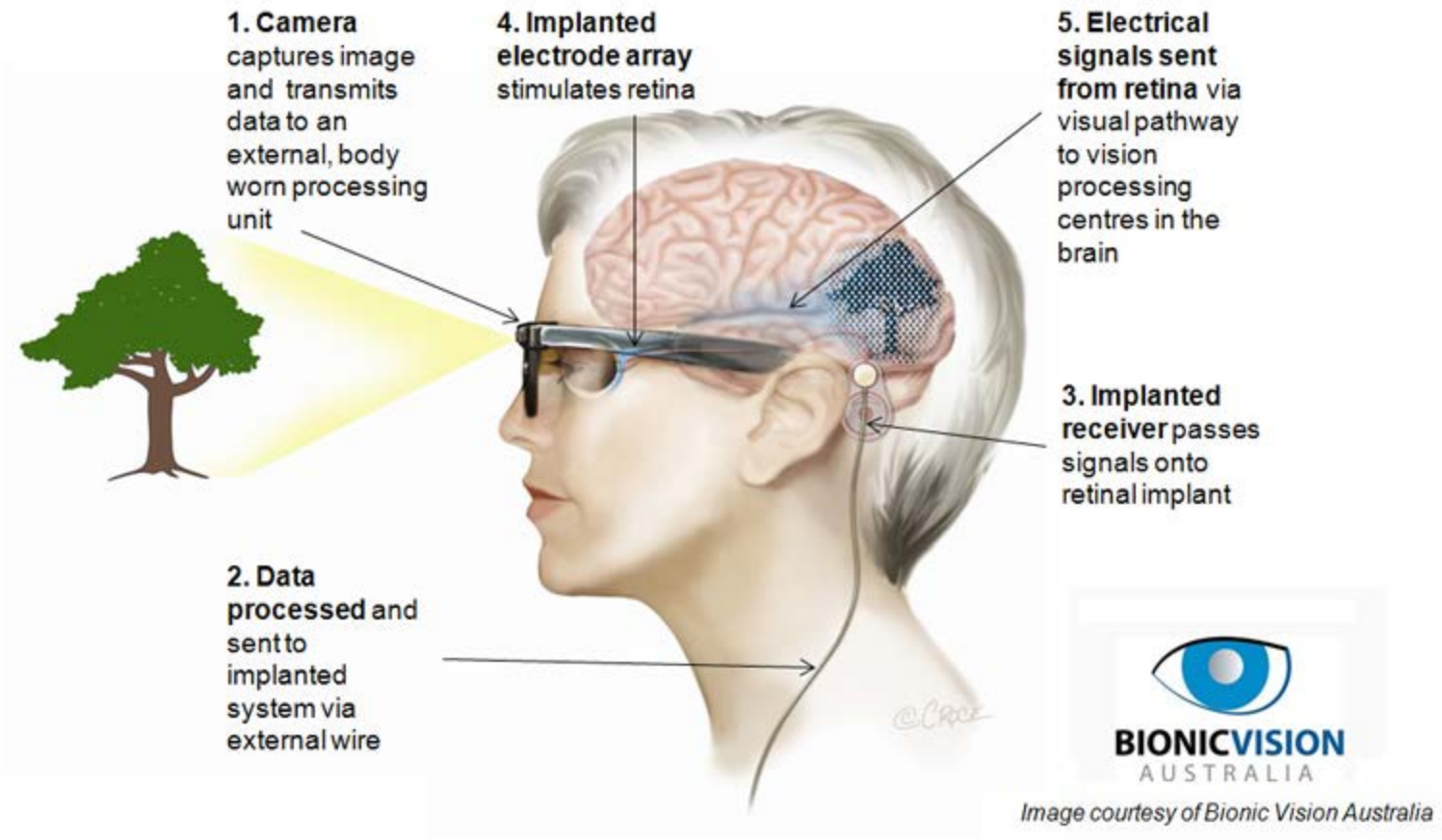
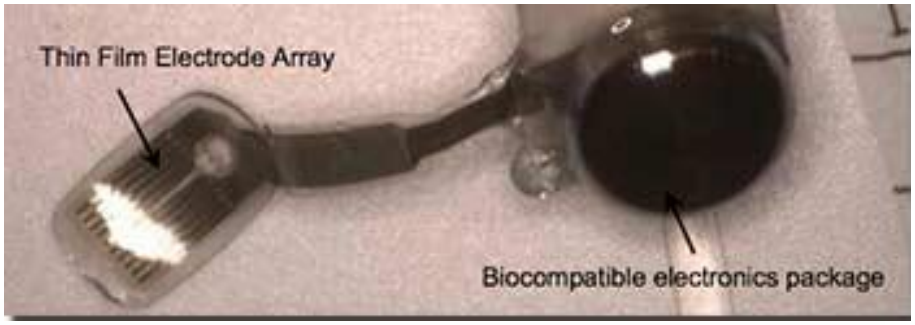


Image courtesy of Bionic Vision Australia

Retinal implants (cont.):

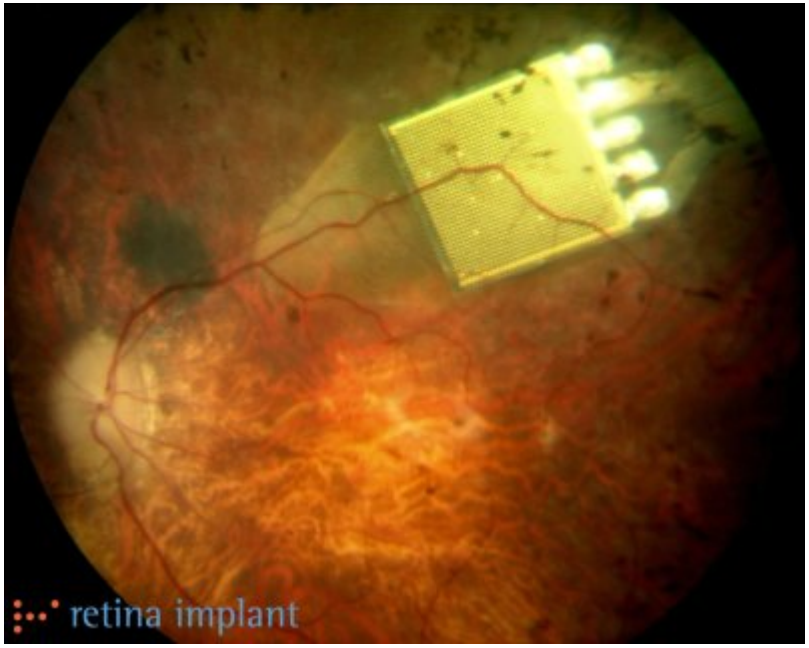
Second Sight Inc.

Argus Implant:

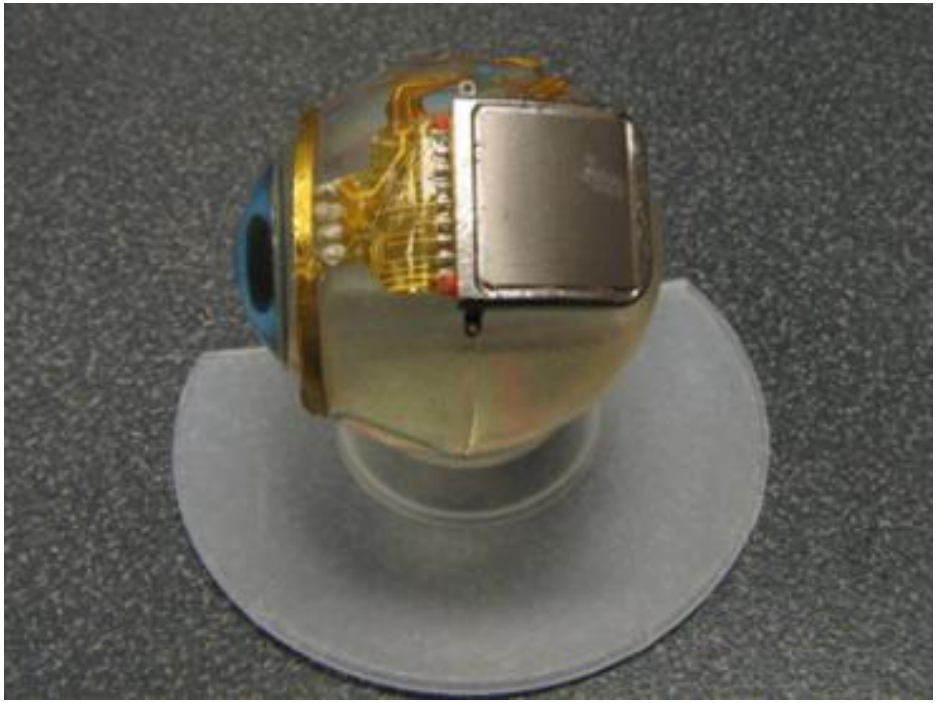


Retinal implants (cont.):

Retina Implant AG sub-retinal implant:



MIT sub-retinal implant:



Therapeutic Brain Stimulation

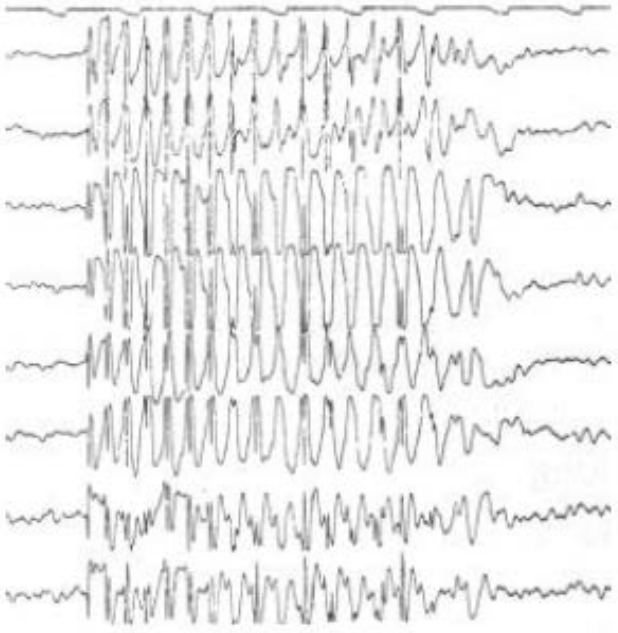
- Intracranial cortical stimulation (e.g. epilepsy)
- ECT (transcranial electrical stimulation e.g. depression)
- Deep brain stimulation (e.g. Parkinsonism)
- Vagal stimulation (epilepsy, depression)*
- Transcranial magnetic stimulation (depression, schizophrenia)*

Problems Encountered

- Complexity of Brain (anatomical, neurophysiological) especially of frontal lobes
- Treatment mechanisms little understood (animal research suggests some mechanisms but human mostly hypotheses)
- Hardware well developed and flexible but treatment protocols either too rigid or too flexible
- Patient selection

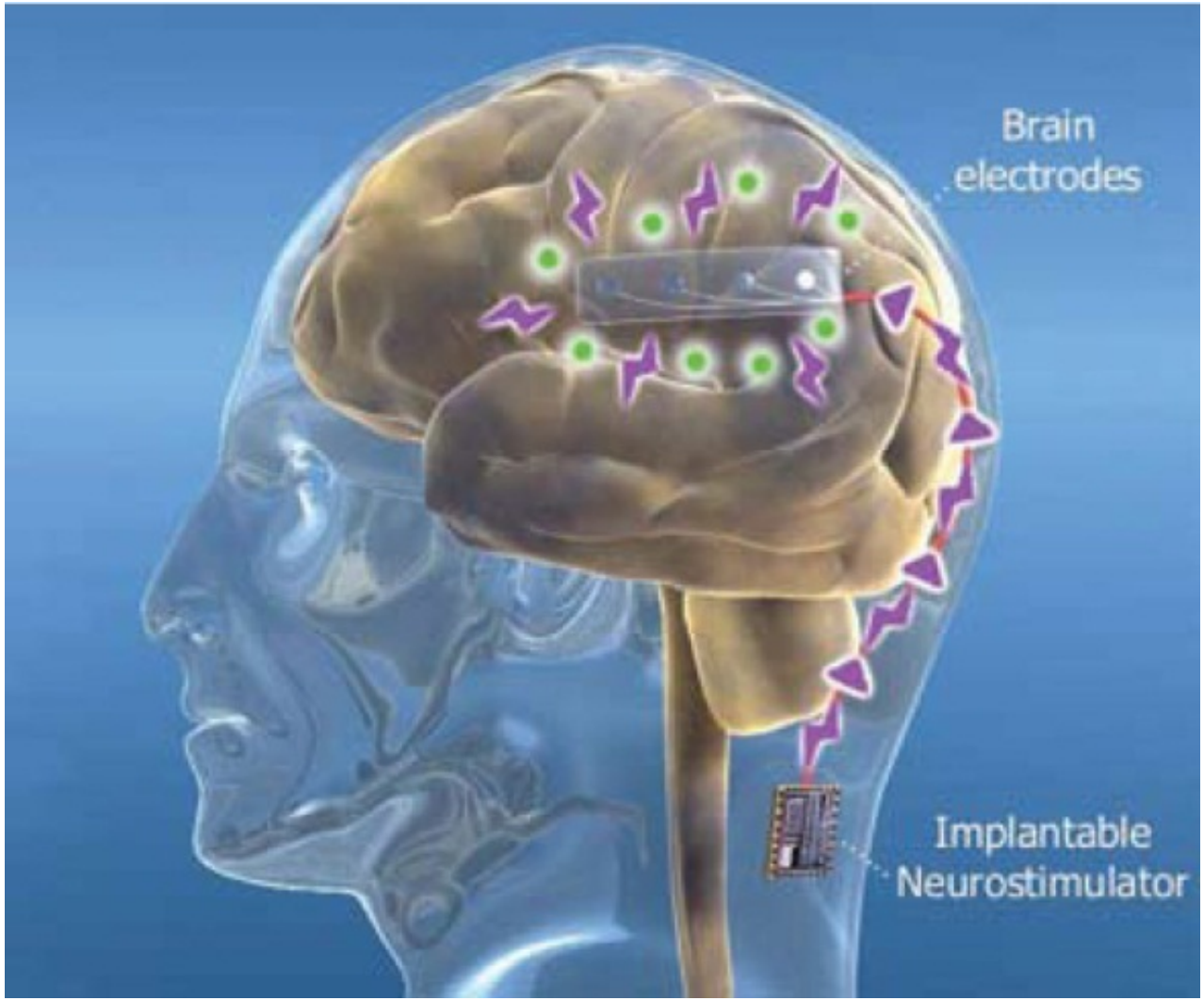
Epilepsy EEG Signal

- Spikes
  - response to stimuli
  - Epileptic seizures
  - higher frequency content
  - Up to 100 Hz



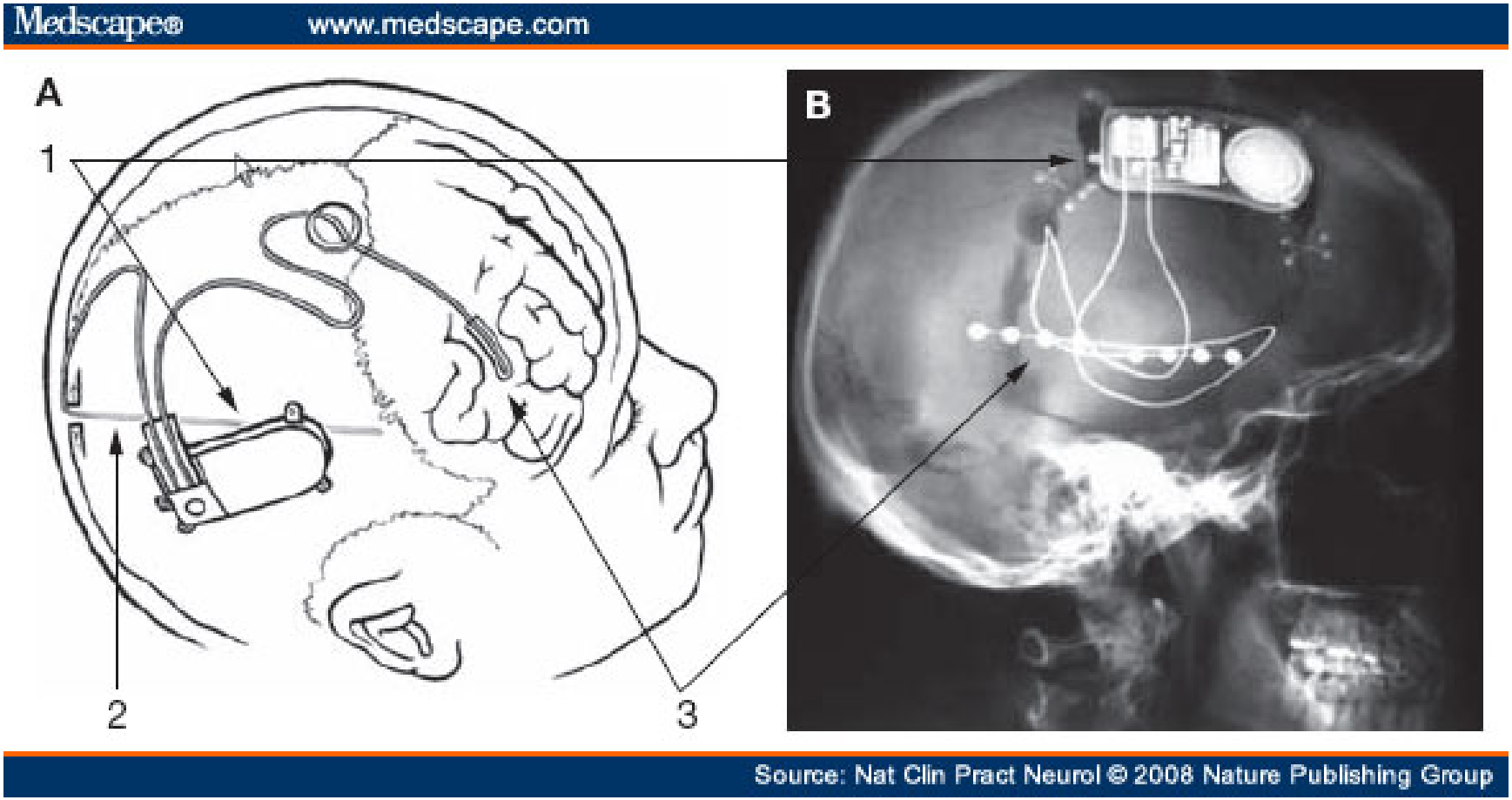
Epilepsy detection and suppression:

- Example system



(Source: BEI)

Closed Loop Epilepsy Treatment

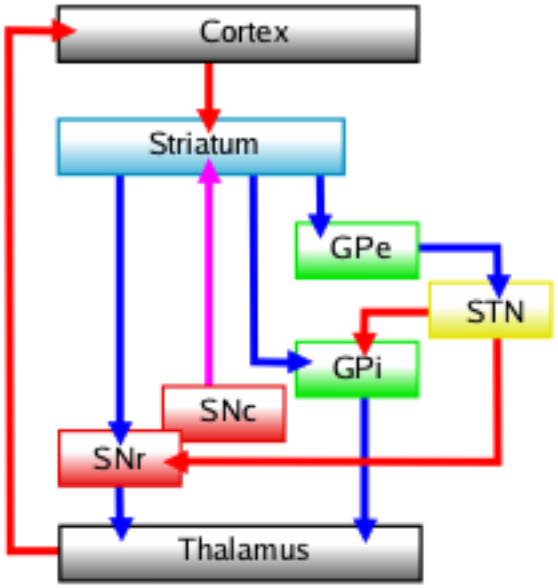


Movement Disorders
(Parkinsonism)

- Resulting from loss of neurons in substantia nigra (SNc) which produces dopamine
- Treated with dopamine agonist (short lived), monoamine oxidase inhibitor (less effective), dopamine precursor L-DOPA (gold standard)
- Biggest challenge is dose regulation (half-life of L-DOPA is 90 min)
- Less and less effective as deterioration of substantia nigra continues

Deep brain stimulation (cont.):

- Typical targets include nuclei in the thalamus or the basal ganglia, particularly the subthalamic nucleus (STN)



Connectivity Diagram showing glutamatergic pathways as red, dopaminergic as magenta and GABA pathways as blue.

Basal Ganglia

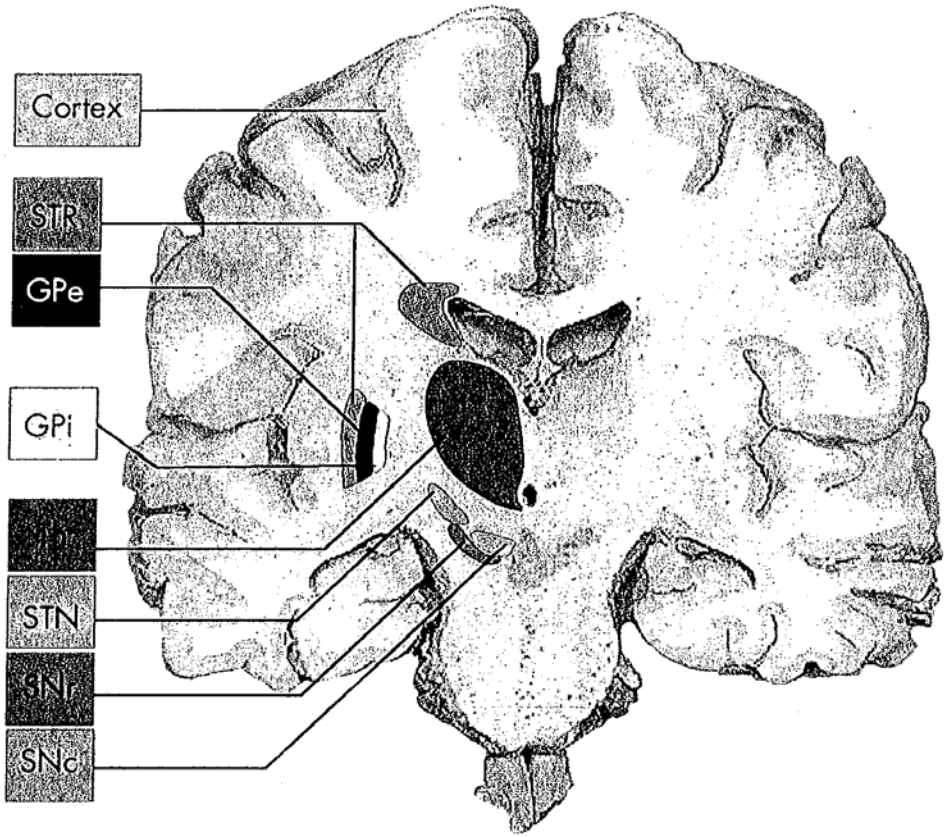


Figure 1 - Coronal (frontal) section of the brain showing the different structures in the basal ganglia. STR, striatum; GPe, globus pallidus pars externa; GPi, globus pallidus pars interna; Th, thalamus; STN, subthalamic nucleus; SNc, substantia nigra pars compacta; SNr, substantia nigra pars reticulata[14].

Deep brain stimulation (cont.):

- Example electrode placement

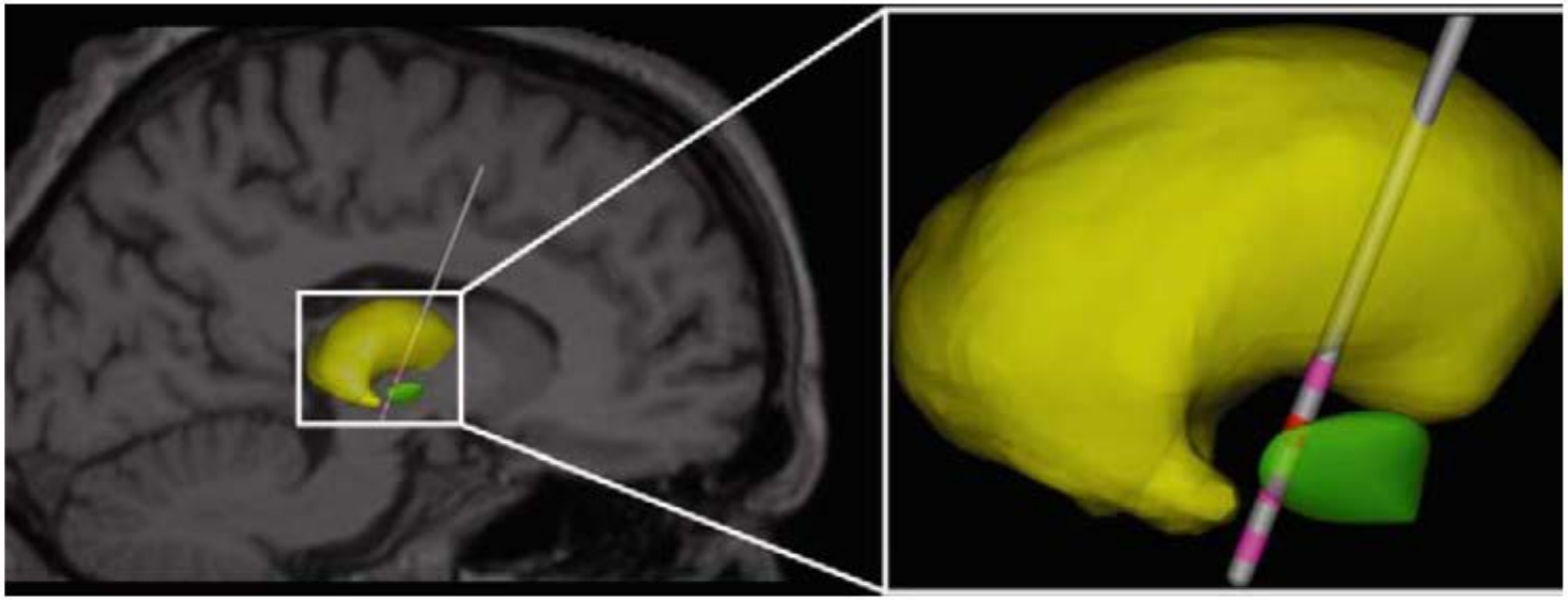


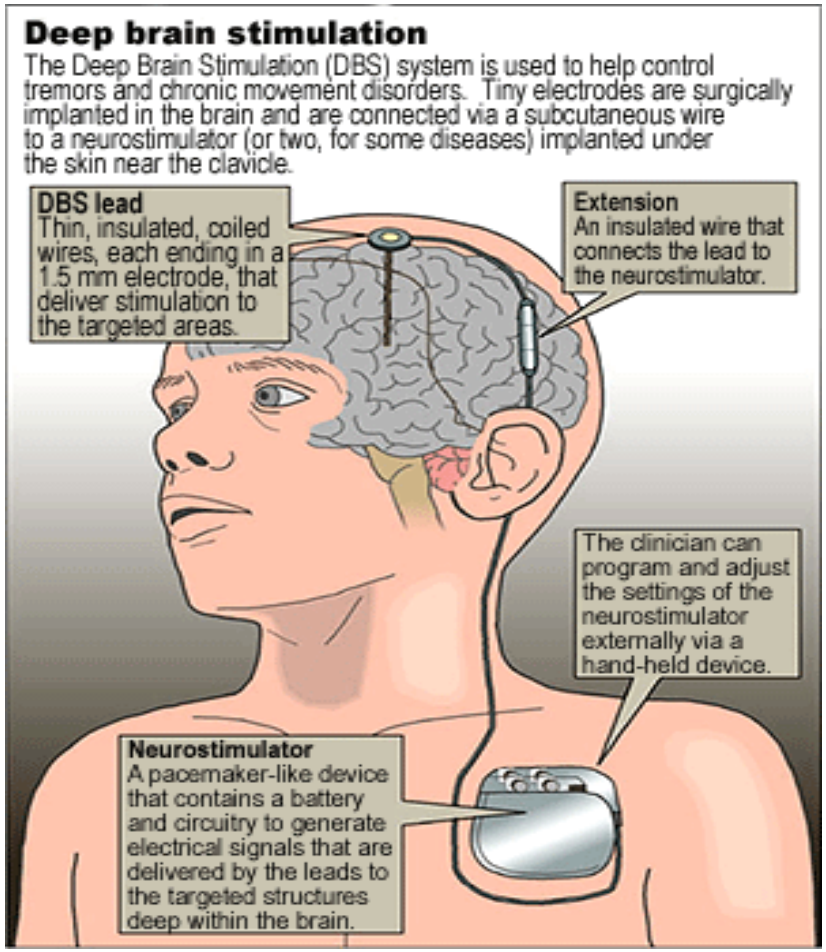
Fig. 1. Patient MRI scan with a 3D brain atlas warped to fit the thalamus (yellow) and STN (green). Right panel shows the position of the surgically implanted DBS electrode relative to the anatomical nuclei.

Deep Brain Stimulation

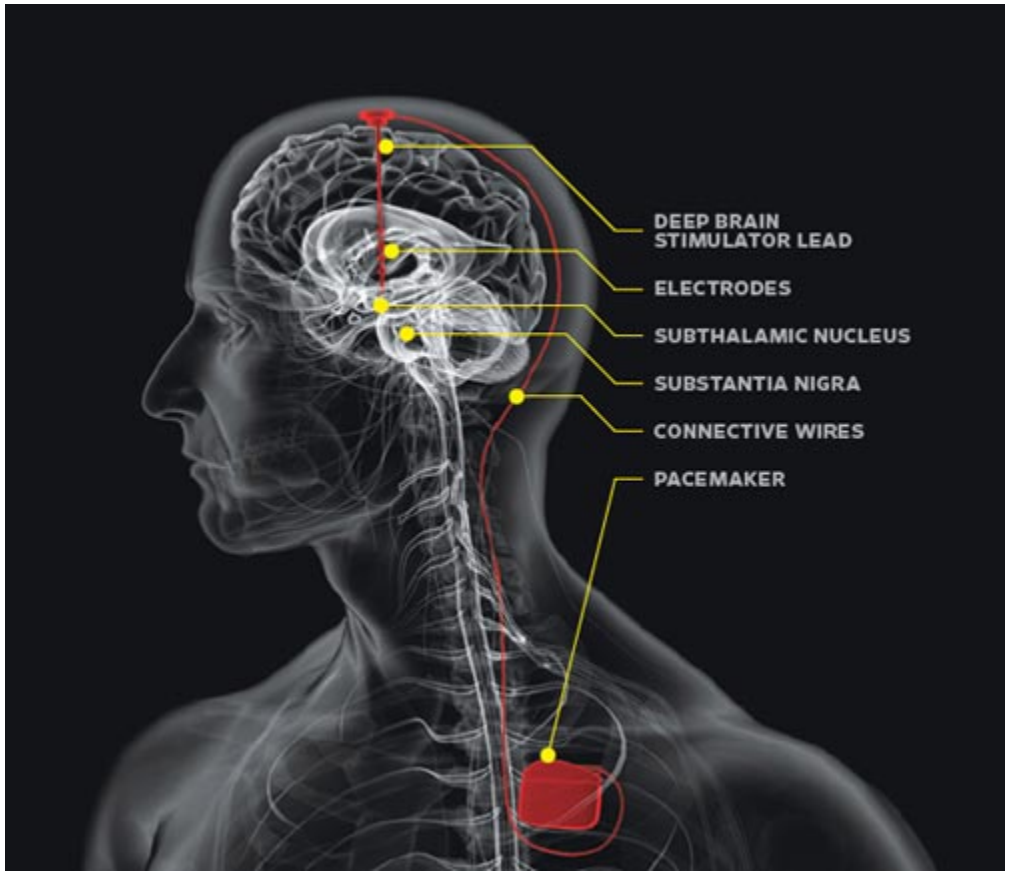
- Instead of ablation (to relieve tremor)
- First reported in 1987 with thalamus stimulation
- Globus pallidus next site with some success
- Subthalamic nucleus (1998) most successful with immediate relief of symptoms when stimulator turned on
- Stimulation of 60–200 μs pulses at >100 Hz
- Hypothesized result is inhibition, same as ablation

Deep brain stimulation:

- Example DBS system



System to Control Movement Disorders



Basic Stimulator

- Medtronic Kinetra Stimulator
- Treat Parkinson or other Movement Disorders

Electrode Insertion