BiomimeticMicroElectronicSystems

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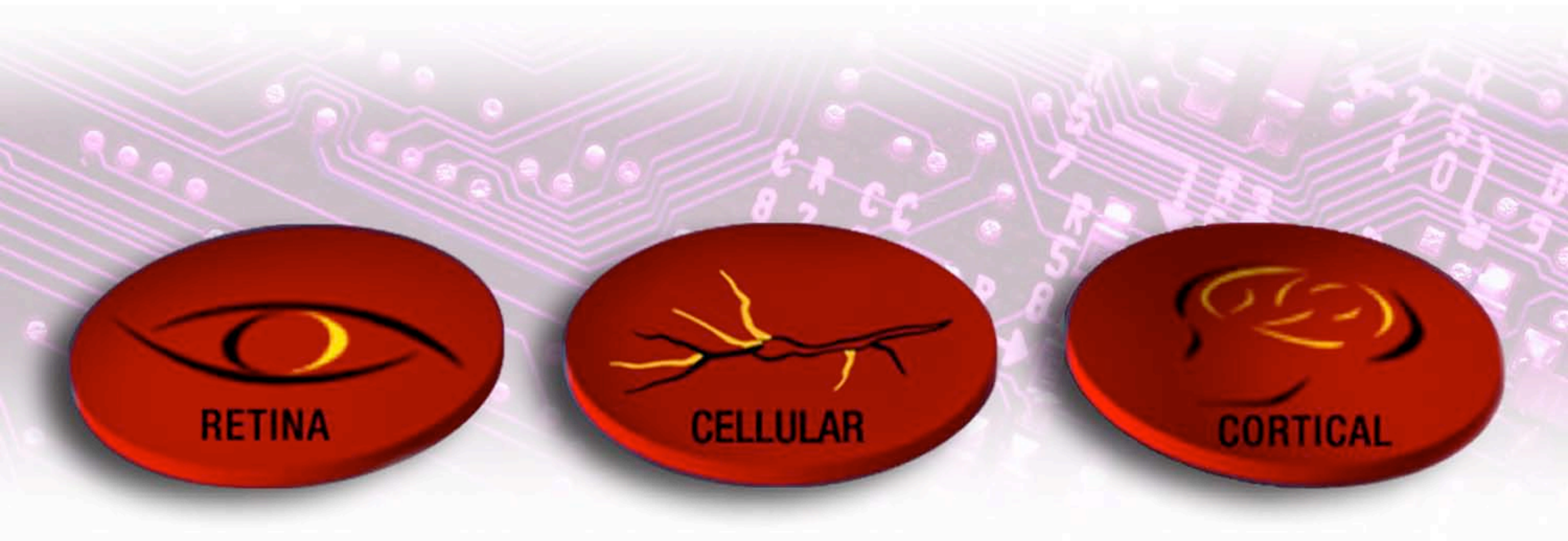
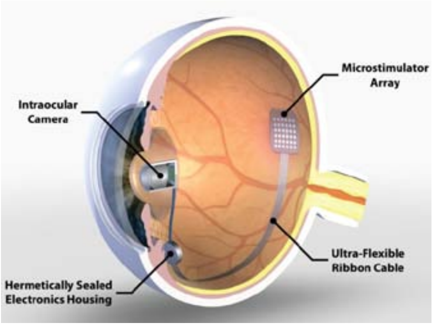


Biomimetic microelectronic systems will form direct high-density interfaces with the human nervous system to restore lost function

Goals of Testbeds

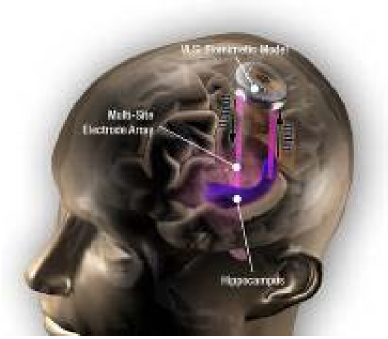
Retinal Testbed:

To research and develop a biomimetic microelectronic system to restore reading and face recognition to the blind



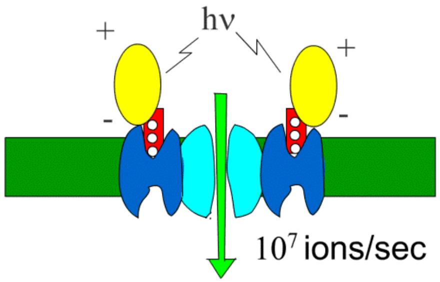
Cortical Testbed:

To research and develop a biomimetic microelectronic system to restore cognitive functions such as formation of new memories



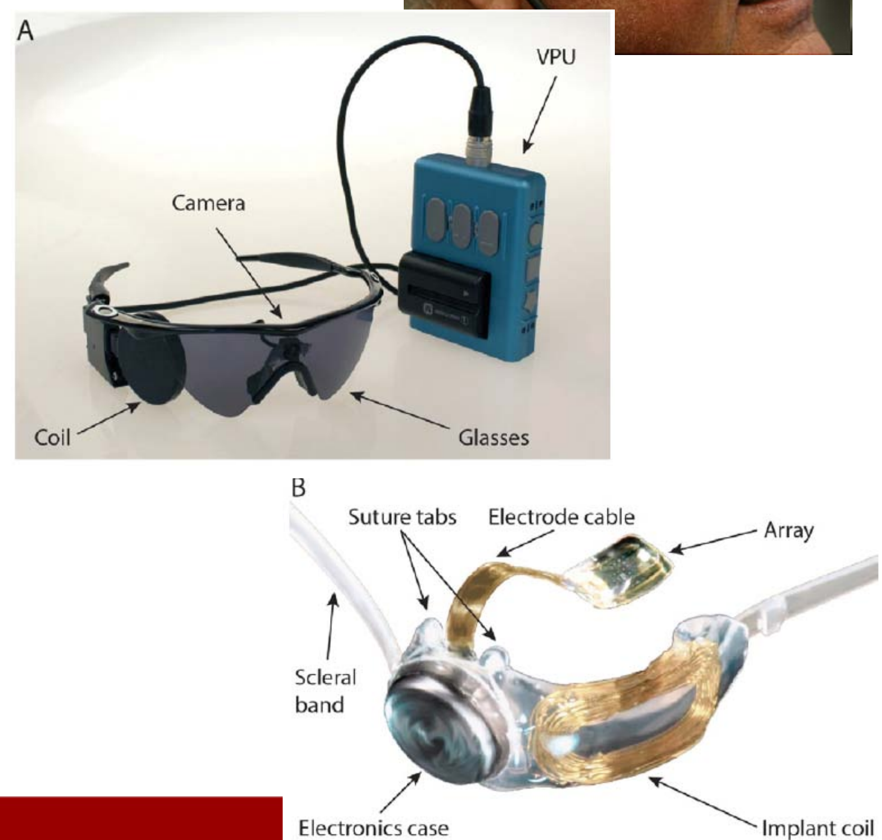
CellularTestbed:

To develop a photoactivated cellular switch to impart light sensitivity to neurons



Argus II Retinal Prosthesis
Second Sight Medical Products, Inc.

- Commercially available in Europe, FDA advisory panel recommended HDE approval
- 6x10 micro-fabricated electrode array
  - Polymer substrate
  - High surface area platinum
- Improved mobility demonstrated in multi-center clinical trial (n=30)
- Letter reading in majority of subjects
- Implant can be controlled while in MRI



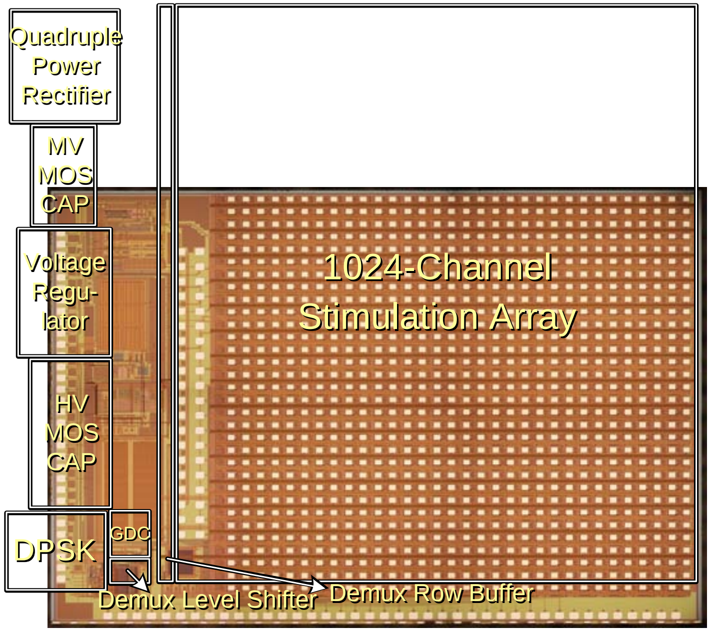
Blind patient recognizing letters with the Argus II retinal implant

Retinal Prosthesis Video (orientation and mobility)

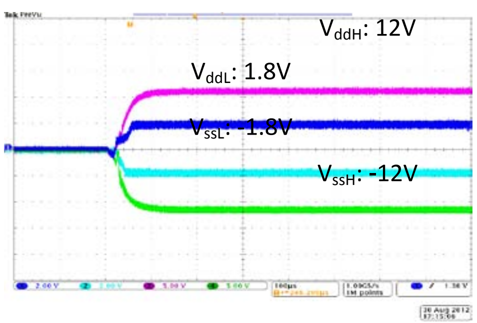
Blind patient using Argus II retinal implant in an ambient/every day environment

Power and Data Thrust – 1024 Channel SoC

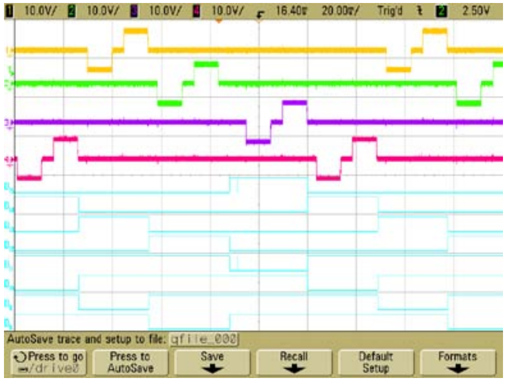
- Design, fabrication, and testing of a fully-integrated 1024-channel SoC
  - Power and data telemetry and stimulator drivers are all integrated in a single SoC.
  - Chip functions as designed in preliminary tests
  - Further tests and characterizations are on-going
- Integrated power telemetry eliminates off-chip diodes and also achieves higher efficiency
- Capable of supporting 4096 individual electrodes under master-slave mode



Chip dimension: 5.7 mm x 6.6 mm

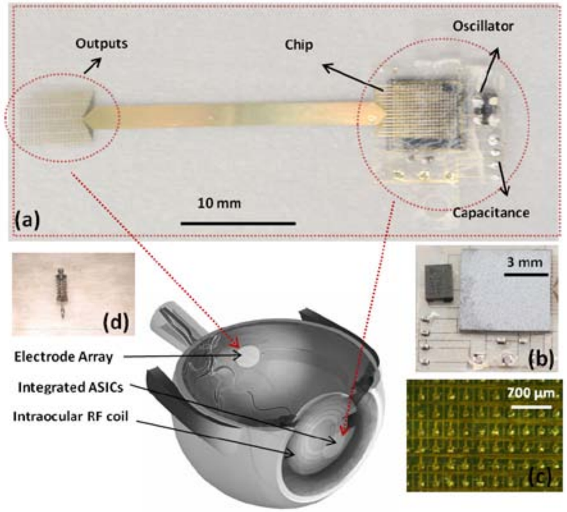


On-chip power converter generates 4 DC voltages after power up.

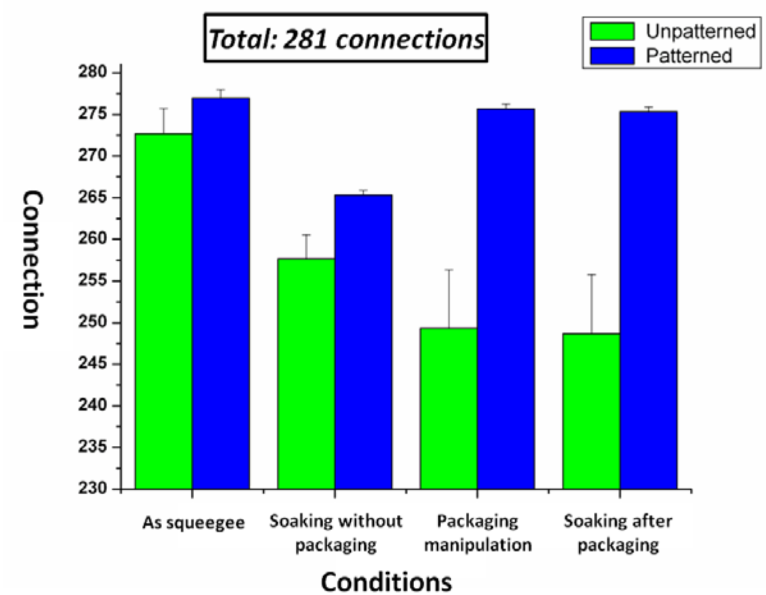


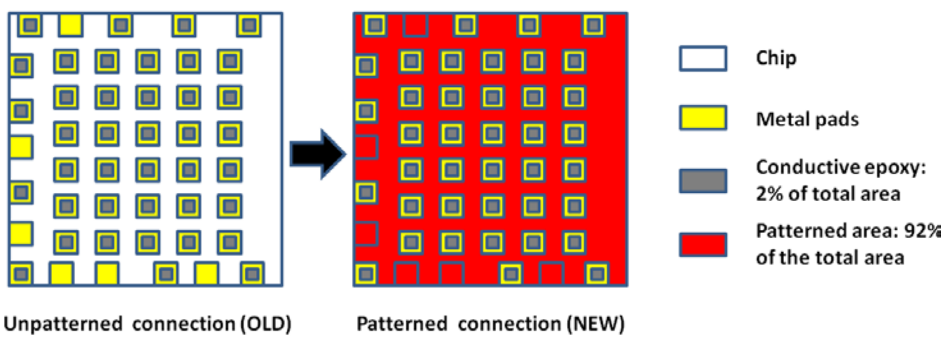
Each pixel has a 1:4 demux to support four electrodes.

Parylene Packaging Technology Improvements



Surgical Device Demonstrated





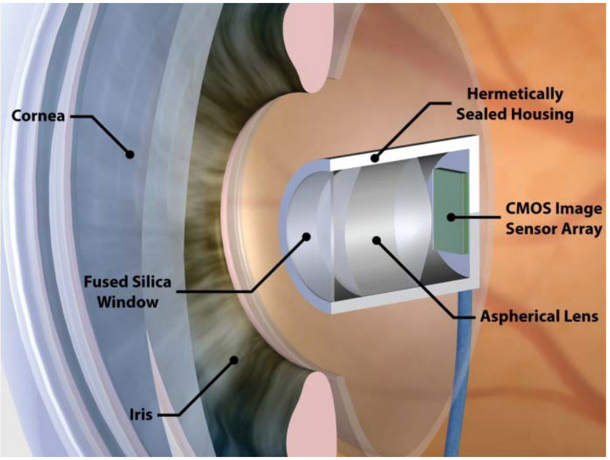
Yield Improved with non-conductive epoxy

50 um pad and spacing possible

Addition of non-conductive epoxy improves adhesion

Advanced Imaging Technologies for Retinal Prostheses

- **Integration of intraocular camera with haptic elements and new flex cable system (in progress)**
- **Demonstration of novel implantable sensor technology for early detection of breaches in hermeticity**



Intraocular camera with refractive lens and fused silica window

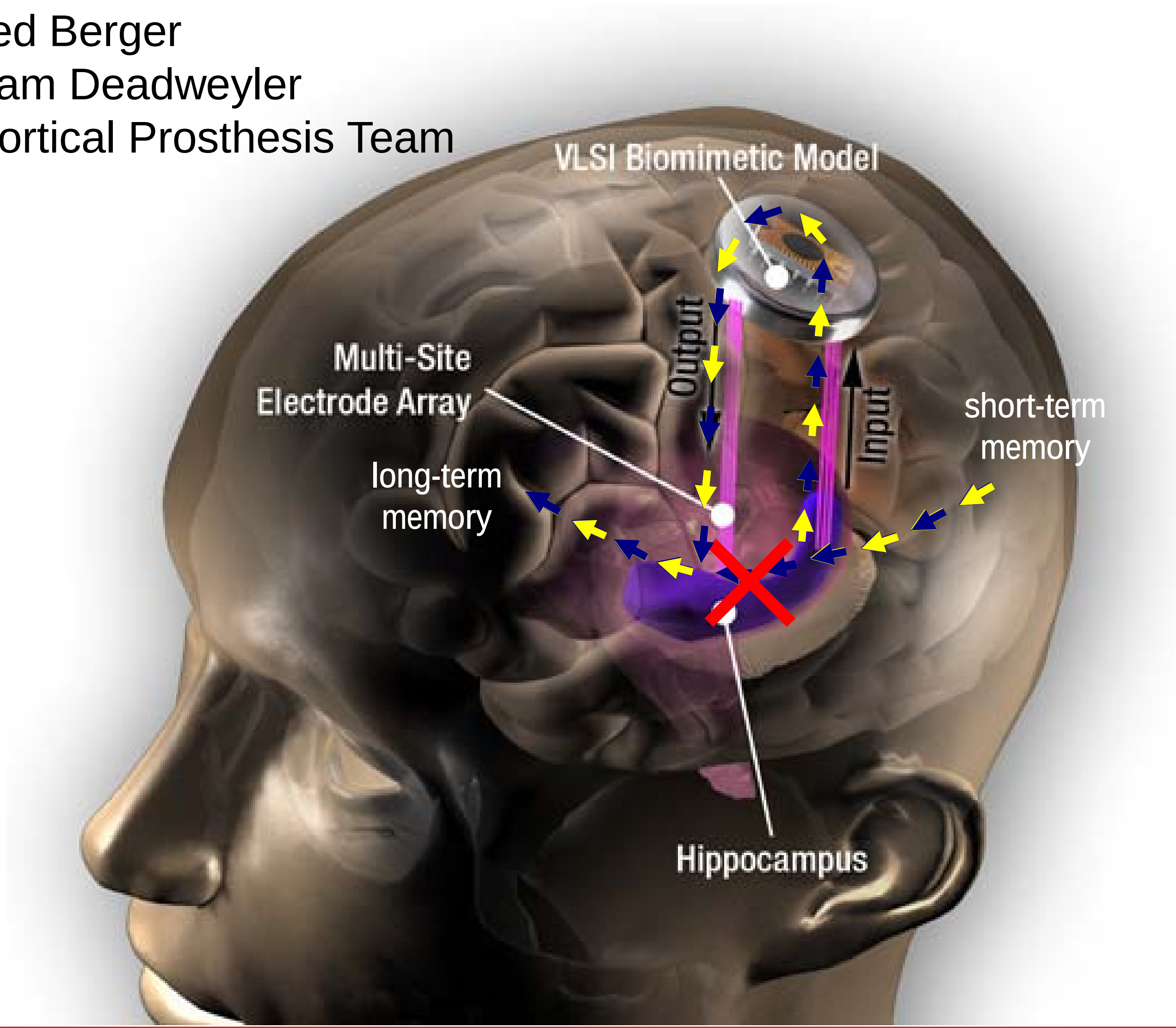
IOC with lens and image sensor awaiting haptic elements

Cortical Prosthesis System

Strategy:

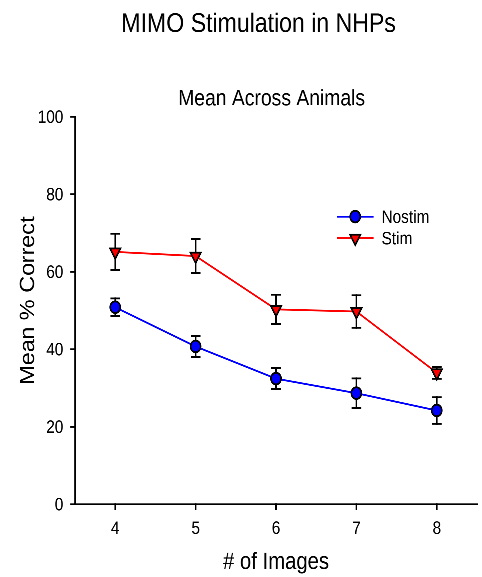
1. Biomimetic model/device that mimics signal processing function of hippocampal neurons/ circuits
2. Implement model in VLSI for parallelism, rapid computational speed, and miniaturization
3. Multi-site electrode recording/stimulation arrays to interface biomimetic device with brain
4. Goal: to "by-pass" damaged brain region with biomimetic cognitive function

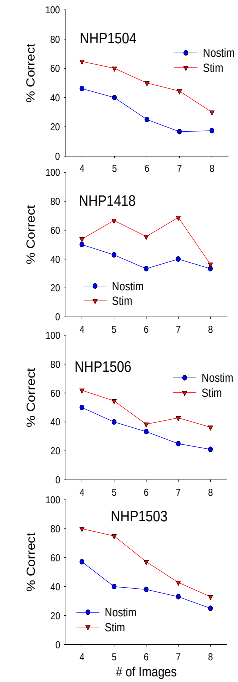
Ted Berger
Sam Deadweyler
Cortical Prosthesis Team

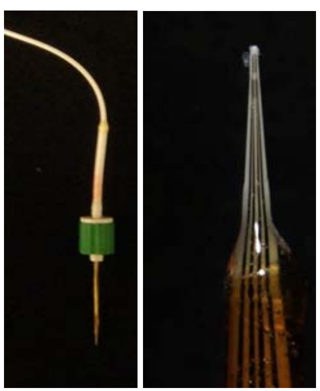


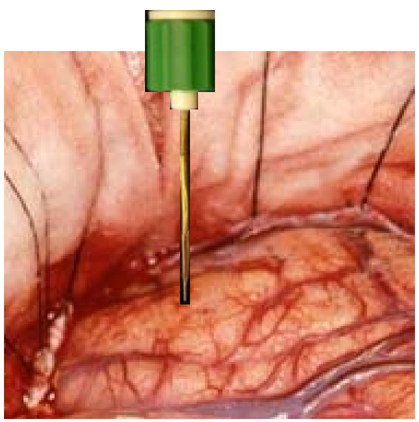
Non-Human Primate (NHP) MIMO Model for PFC Neurons

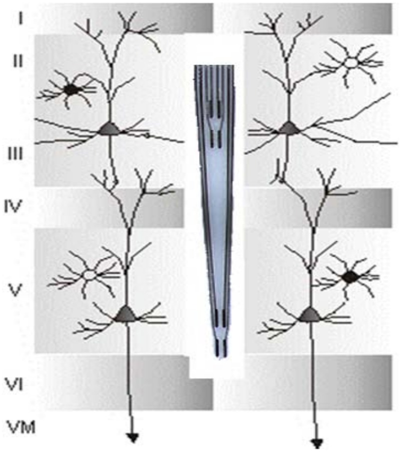
- Delayed-match-to-sample task for NHPs
- Increased performance on stimulated trials (red) vs. nonstimulated trials (blue)
- Ceramic multisite electrodes used in study



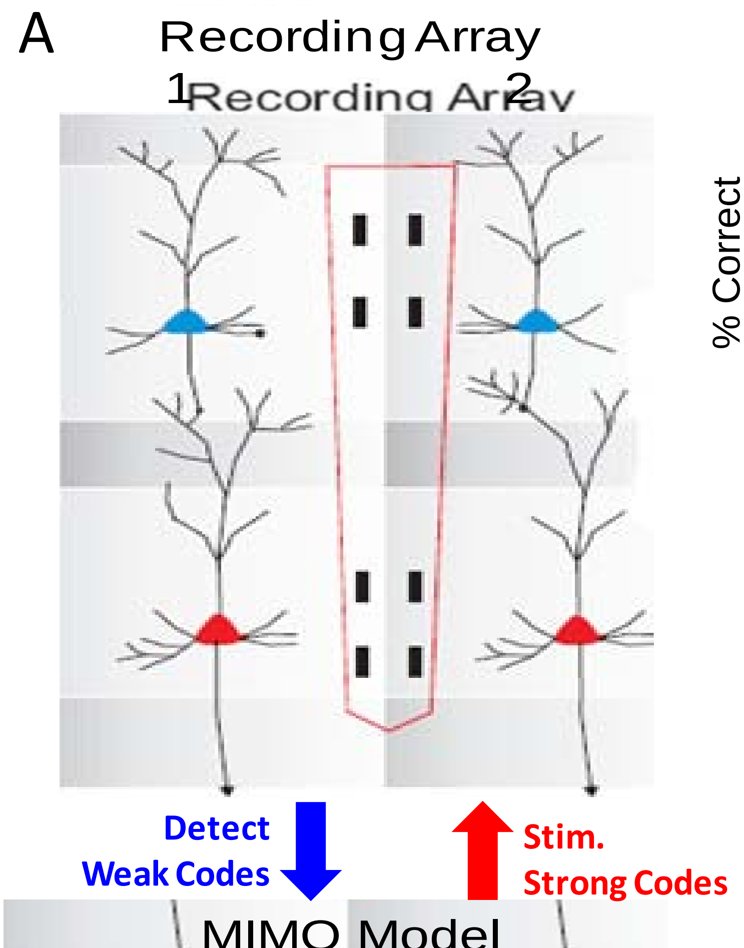




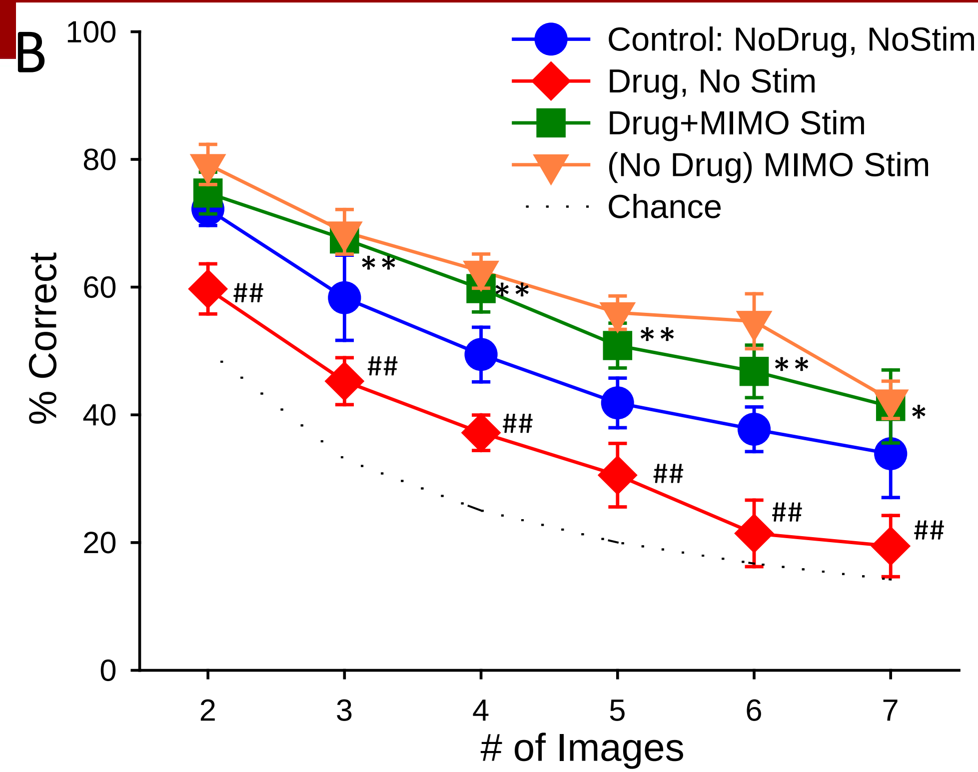


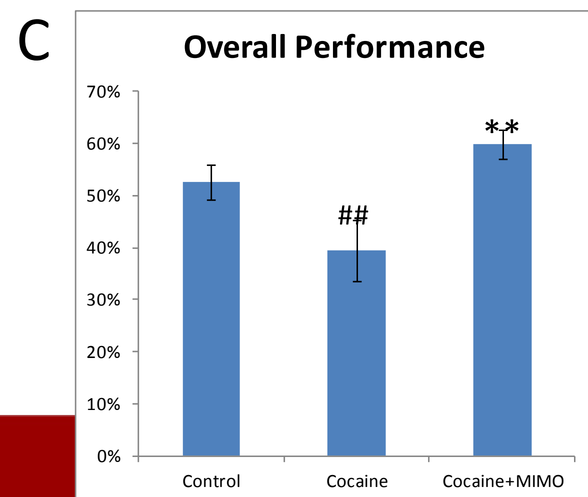


Non- human Primate Tests

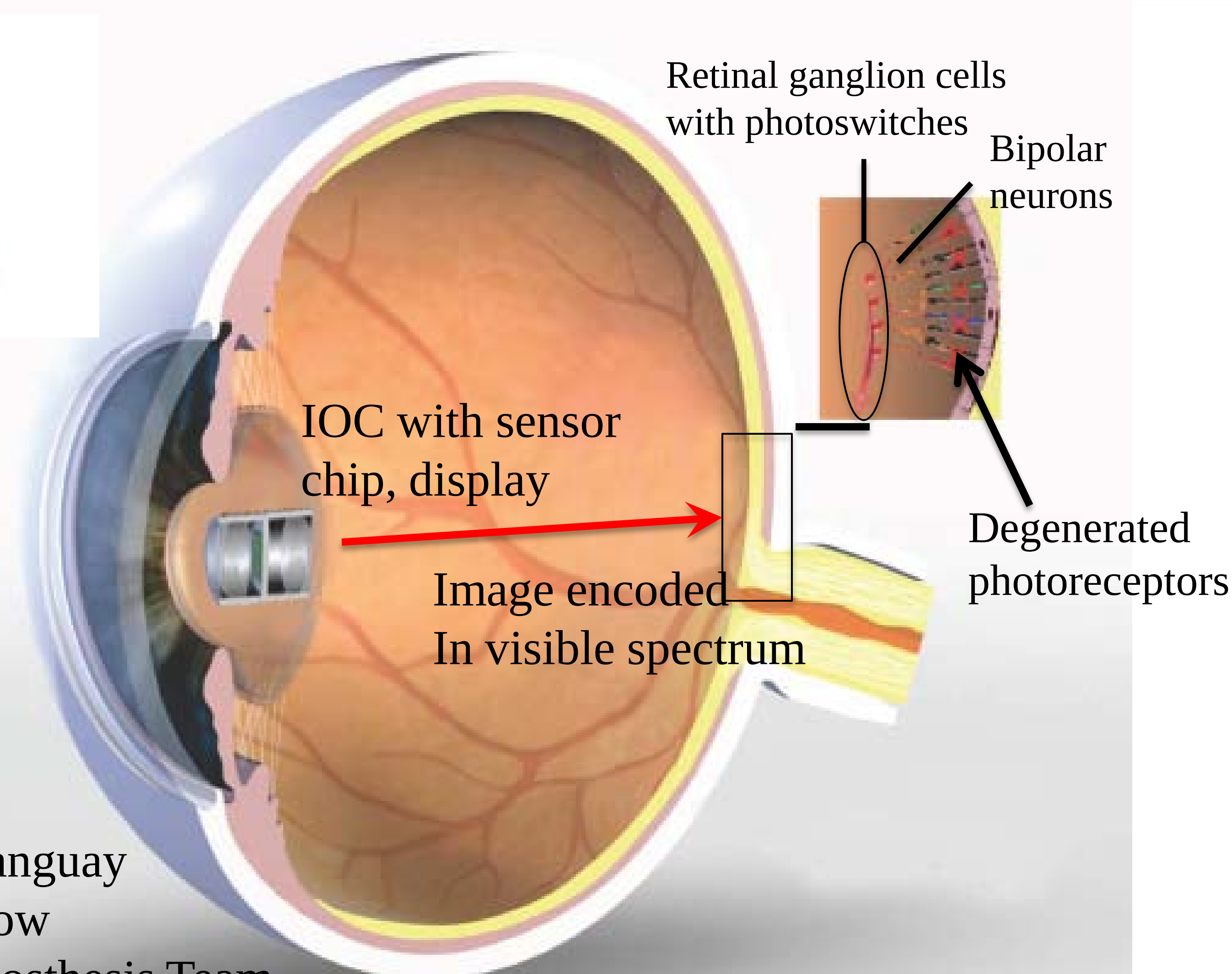


$$u(t)=k_0+\sum_{n=1}^{N}\sum_{\tau=0}^{M_n}k_1^{(n)}(\tau)x_n(t-\tau)+\sum_{n=1}^{N}\sum_{\tau_1=0}^{M_n}\sum_{\tau_2=0}^{M_n}k_{2s}^{(n)}(\tau_1,\tau_2)x_n(t-\tau_1)x_n(t-\tau_2)$$
$$+\sum_{n_1=1}^{N}\sum_{n_2=1}^{n_1-1}\sum_{\tau_1=0}^{M_{n_1}}\sum_{\tau_2=0}^{M_{n_2}}k_{2x}^{(n_1,n_2)}(\tau_1,\tau_2)x_{n_1}(t-\tau_1)x_{n_2}(t-\tau_2)$$
$$+\sum_{n=1}^{N}\sum_{\tau_1=0}^{M_n}\sum_{\tau_2=0}^{M_n}\sum_{\tau_3=0}^{M_n}k_{3s}^{(n)}(\tau_1,\tau_2,\tau_3)x_n(t-\tau_1)x_n(t-\tau_2)x_n(t-\tau_3)+\ldots$$





Cellular Prosthesis System

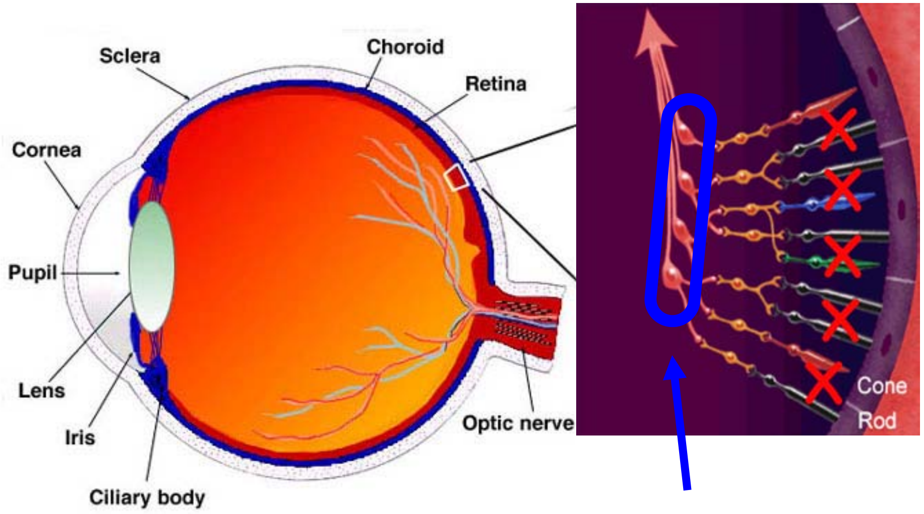


Armand Tanguay
Robert Chow
Cellular Prosthesis Team

Cellular Prosthesis System

– **Enable RGCs to convert light to voltage**
– **Potentially improve retinal prosthetic resolution**

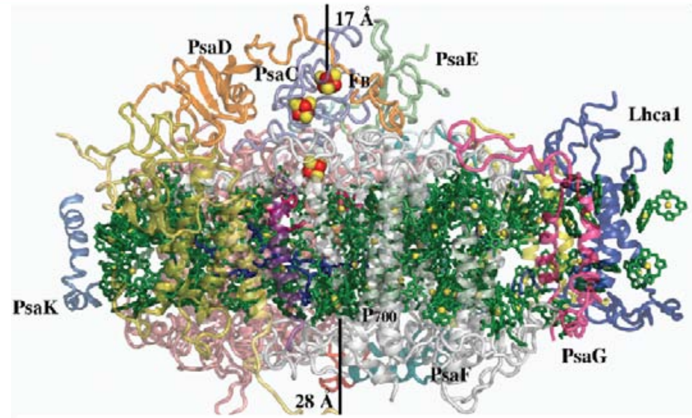
AMD/ RP - Loss of photoreceptors

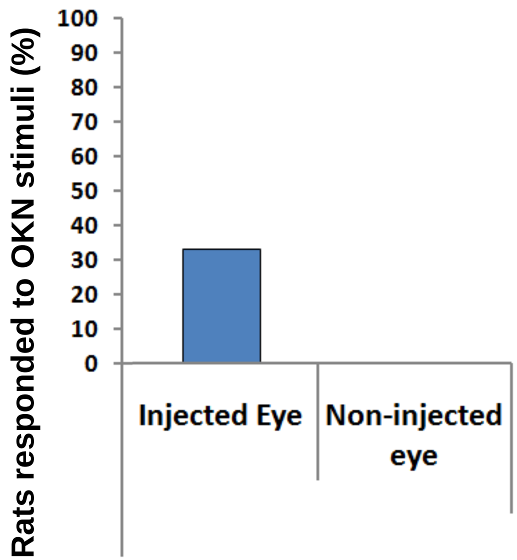


Functional Replacement

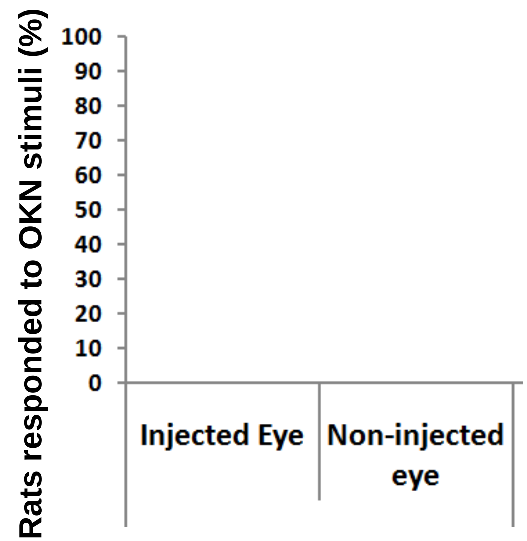
Cellular Prosthesis Update: PS-1 Results in Blind Rats

1. Rats are placed in an OKN chamber
   (4 computer monitors placed as a square)
2. Black & White vertical stripes that are displayed on the computer monitors are moved in clockwise or anticlockwise direction





OKN head-tracking response was observed only in the PS-1 injected eyes (2 out of 6 animals)



None of the rats injected with inactivated PS-1 displayed OKN response*

Conclusions

- Biomimetic high density bioelectronic interfaces with neural systems are challenging but have unique advantages in restoring neural function to possibly millions of patients

- The development of long-term, reliable bioelectronics allow studies in-vivo and hence could further our understanding of fundamental neuronal processes