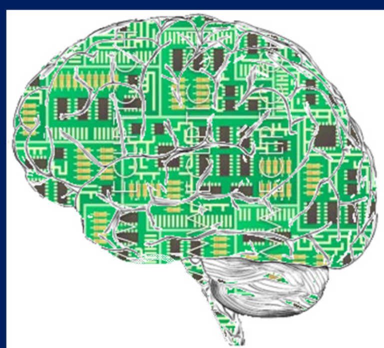
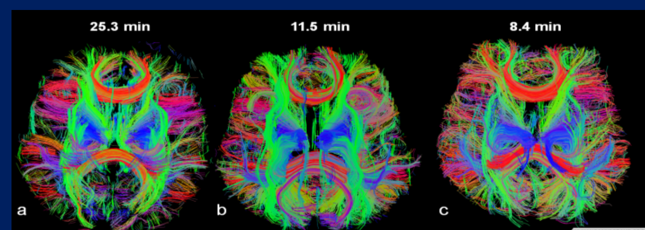
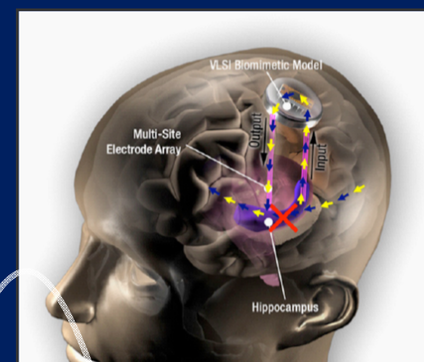
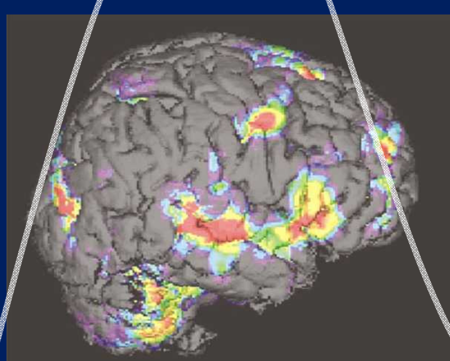
Brain Research through Advancing Innovative Neurotechnologies (BRAIN)
Perspectives from the National Science Foundation

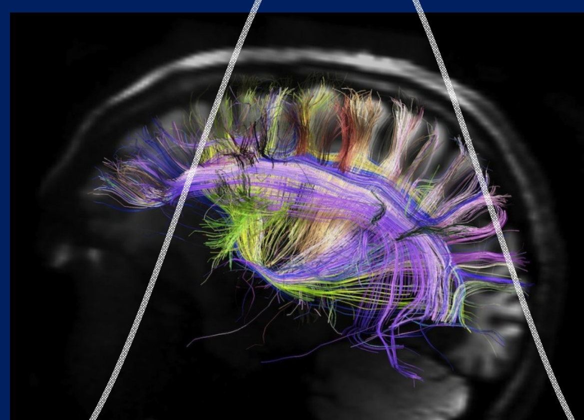
John C. Wingfield
Assistant Director for Biological Sciences

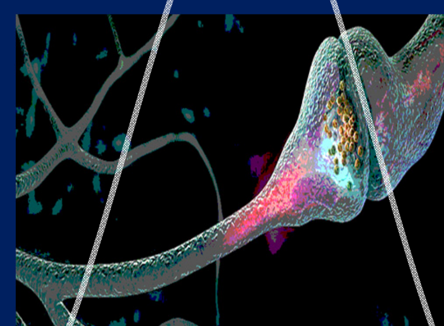












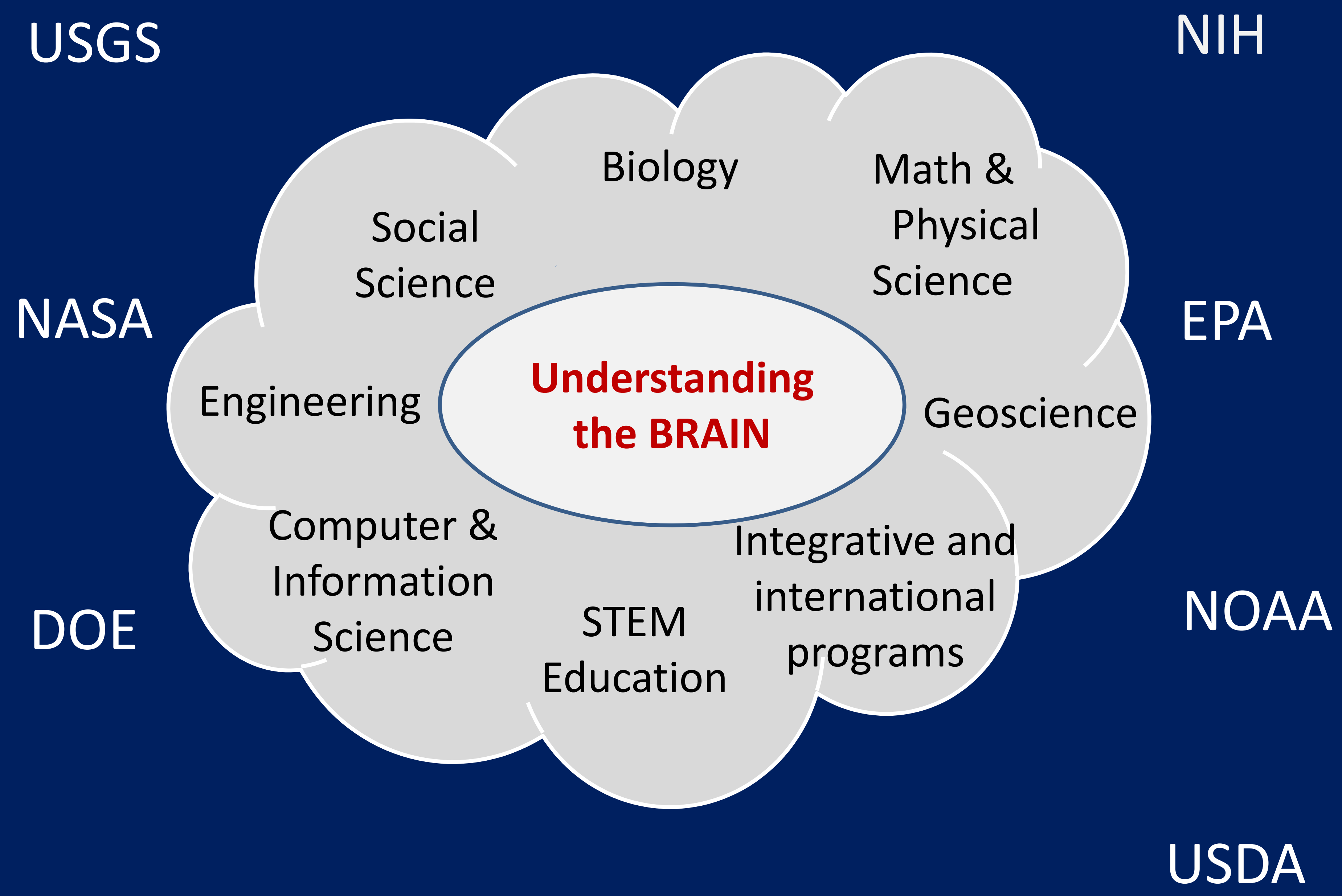
Basic research challenges required to achieve the BRAIN initiative goals

- **Foundational knowledge**
- **Tools for high-resolution measurements**
- **Computational models and theoretical frameworks**
- **Data storage, management and analysis**

The NSF Role

NSF is uniquely positioned to lead a multidisciplinary effort by scientists and engineers to advance the original research and tool development and educate the workforce needed for the BRAIN initiative to succeed.

Collaborations in Neurosciences



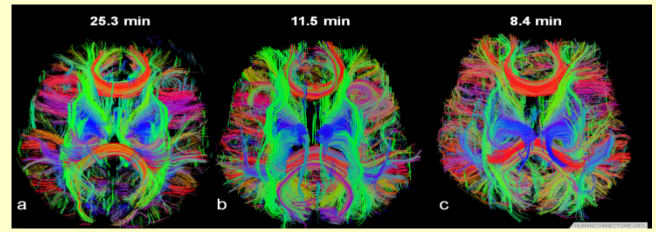
NSF Core, MRI and INSPIRE Programs Support Research to:

1. Develop molecular-scale probes
2. Sense and record neural network activity
3. Develop imaging and related nanotechnologies to determine the genomic architecture, synaptic activity, and neural circuitry that underly the emergent properties of the brain
4. Establish relevant conceptual & theoretical frameworks

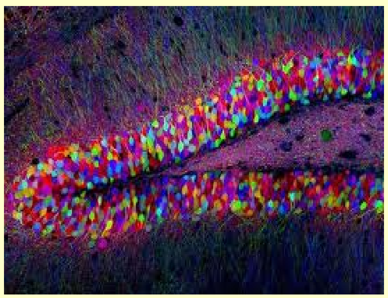
- Link brain activity patterns to cognitive and behavioral functions in ecological, evolutionary, developmental and social contexts.
- Apply social science theory and methods to link patterns of brain activity to individual behaviors relevant to the human experience.

Brain Science at Scale

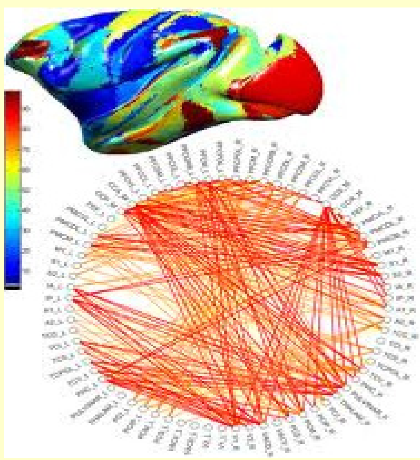
Optogenetics



The Connectome

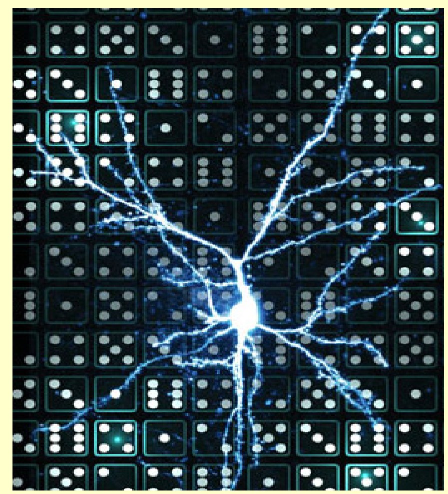


The Brainbow &
High Resolution Imaging



Systems Neuroscience

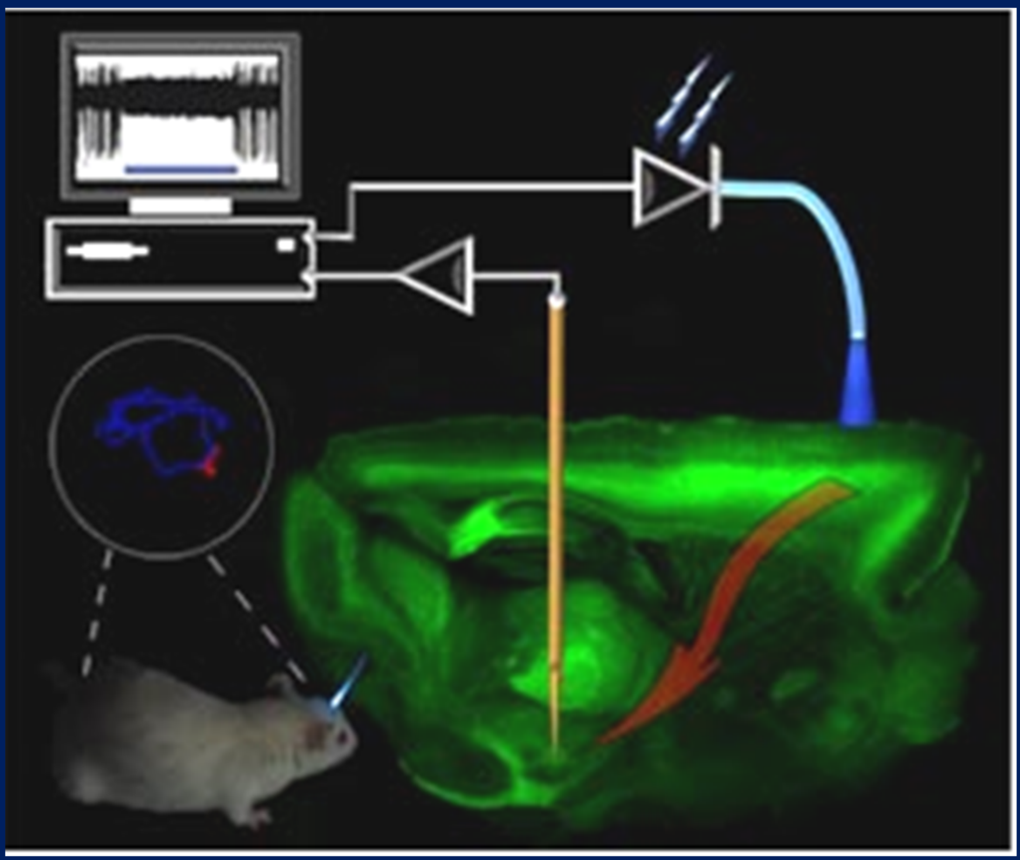
Computational Neuroscience



Nano-properties of neurons

Optogenetics: How Does the Brain Work?

Rhodopsin proteins introduced into neuron membranes can excite or inhibit neuron activity in response to light.

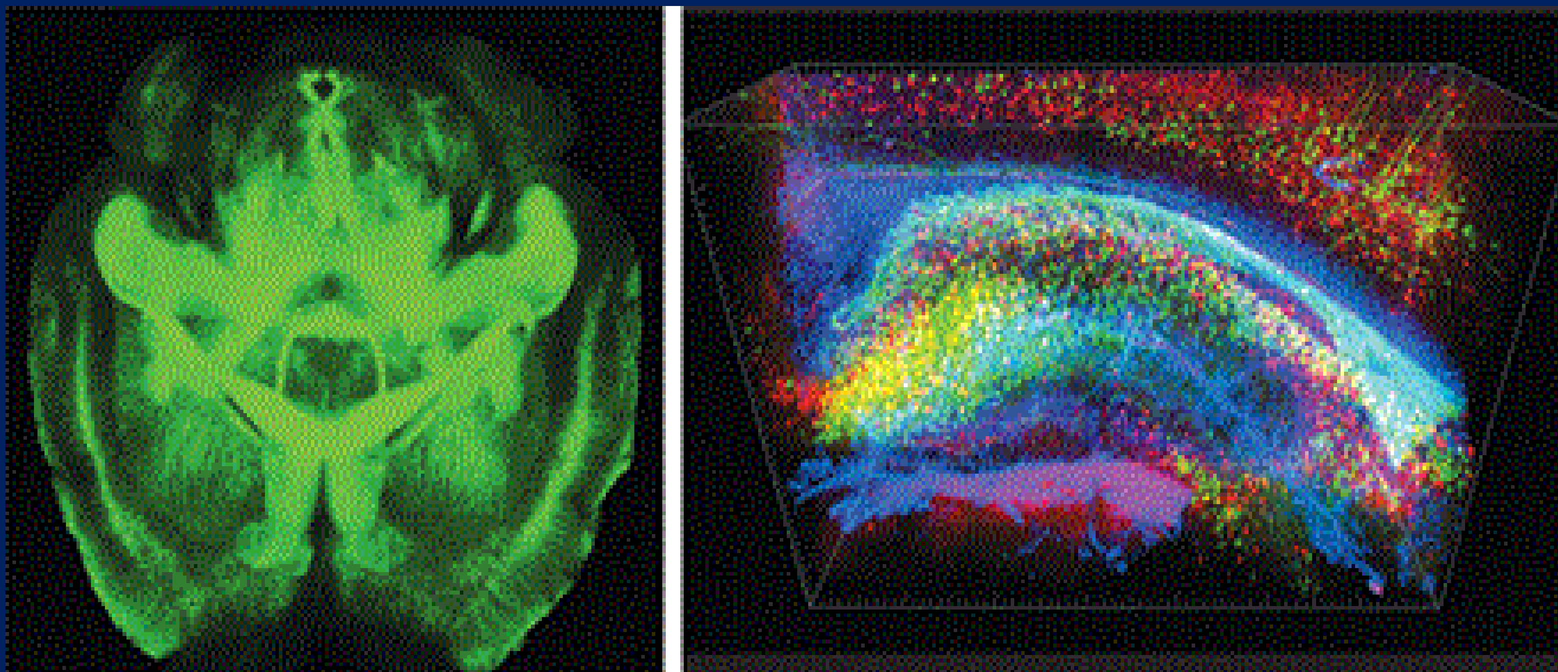


K. Deisseroth
Nature Methods 8: 26-29 (2011)

Membrane rhodopsins enable:

1. **Non-invasive imaging of living tissue in real time**
2. **Precise control of neurons and simultaneous measurement of effects**

CLARITY: Brain Imaging

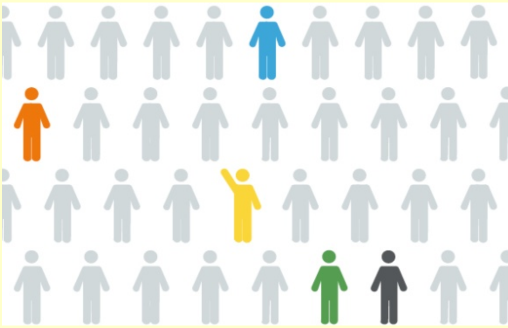


CLARITY allows researchers to image specific neurons and molecules within an intact mouse brain (left) and hippocampus (right) without making a single cut.

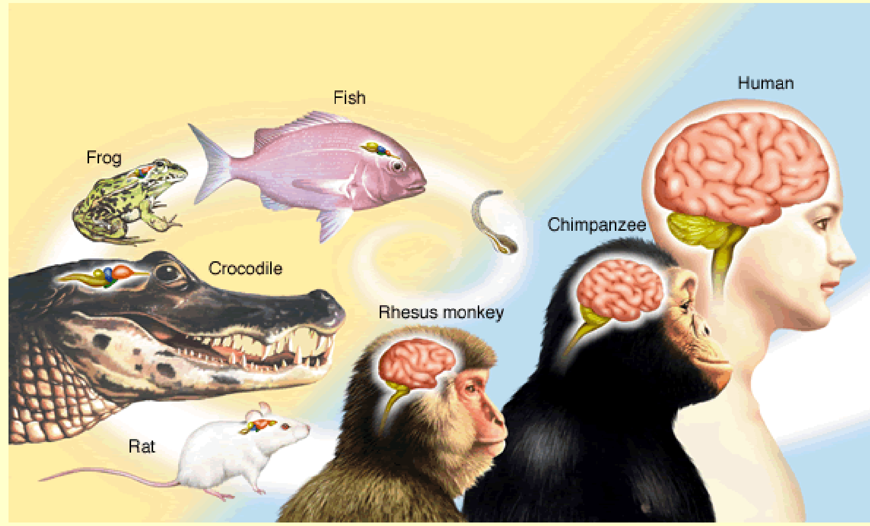
"CREDIT: KWANGHUN CHUNG AND KARL DEISSEROTH, HOWARD HUGHES MEDICAL INSTITUTE/STANFORD UNIVERSITY"

Science 12 April 2013: Vol. 340 no. 6129 pp. 131-132

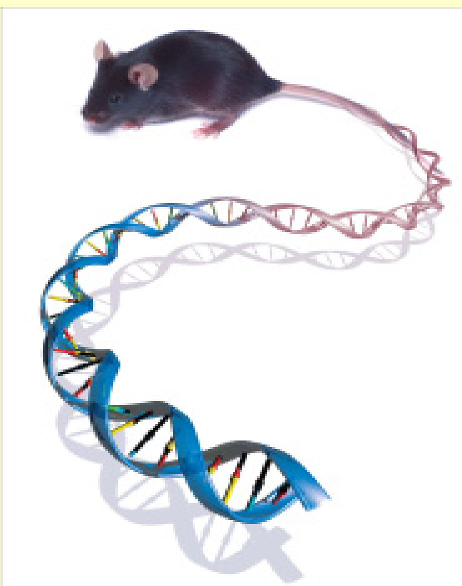
Individuality & Diversity



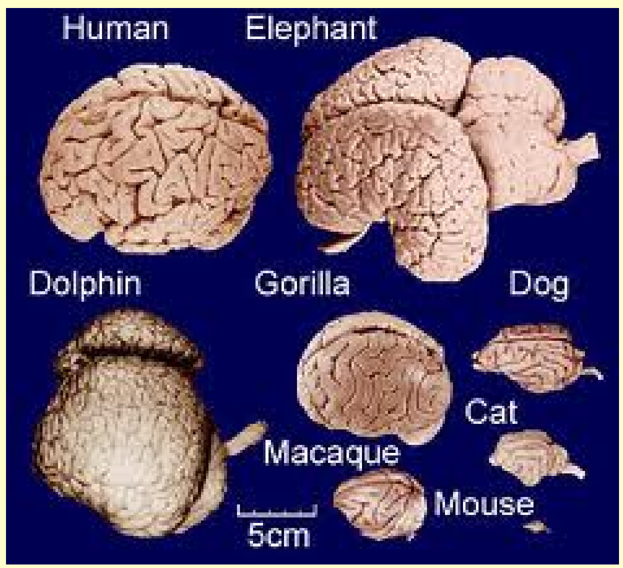
Individual / gender differences



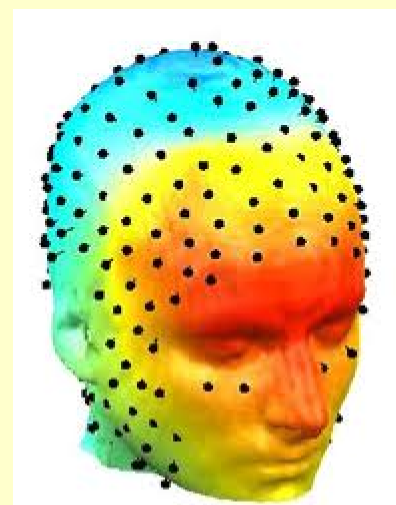
Brain Evolution



Epigenetics

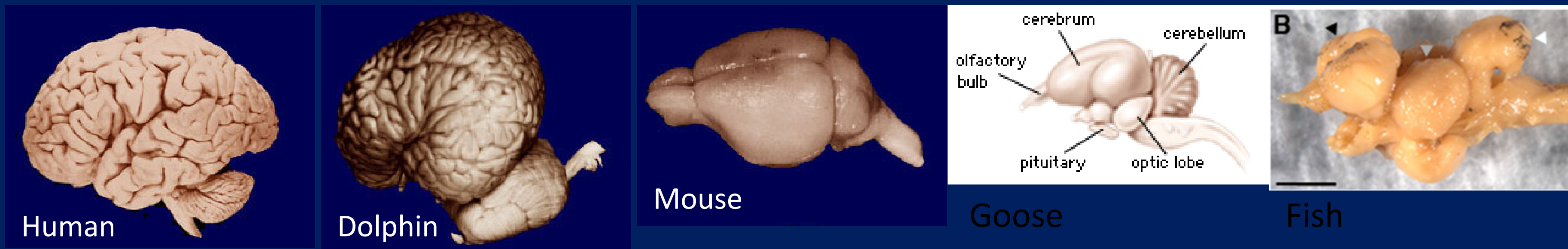


Species Comparisons



Cognitive Neuroscience

What is the Genetic Basis of Brain Diversity?



Cichlid Brains are Diverse, but their Genomes are Comparable

Lake Malawi
(from space)

Rock-dwelling cichlid

Sand-dwelling cichlid

J.B. Sylvester el.al.; NATURE Communications
23 April 2013

Competing Signals Drive Telencephalon Diversity

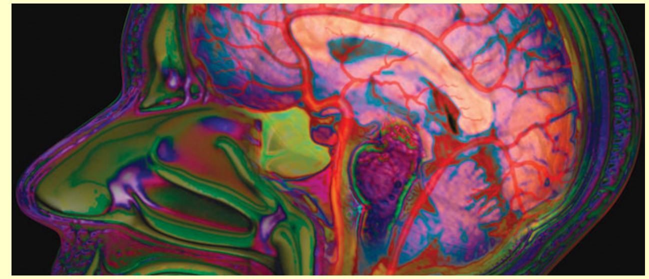
- **Fish from Lake Malawi show differences in strength and timing of opposing Hedgehog (*Hh*) and Wingless (*Wn*) signals that establishes evolutionary divergence in dorsal-ventral telencephalon patterning.**

- **In rock dwellers: extensive early *Hh* activity in ventral forebrain and *foxg1* expression before dorsal Wn signals => *larger subpallium*.**

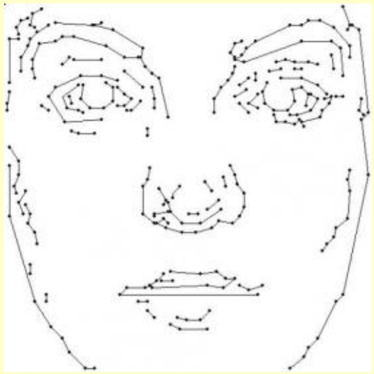
- **In sand dwellers: rapid deployment of *Wn* and later *foxg1* expression => *larger pallium*.**

- **Manipulation of *Hh* and *Wn* pathways in cichlid and zebra fish embryos mimic natural brain differences.**

Thinking in Time



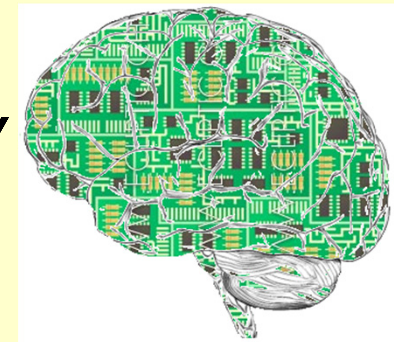
Dynamic Brain Imaging

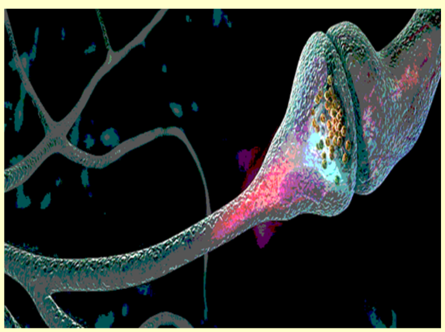


Modeling Object Recognition

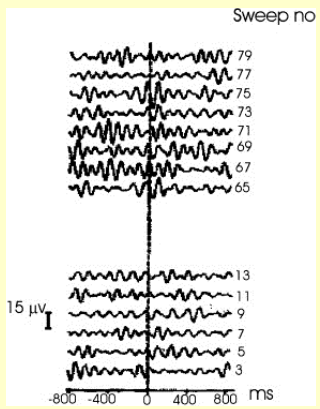
Neural –inspired Robotics

Control Theory & Network Analyses

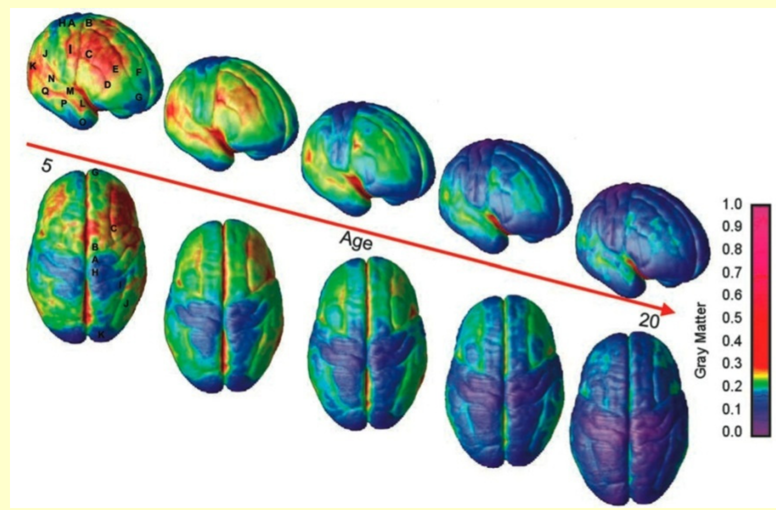




Neuroplasticity



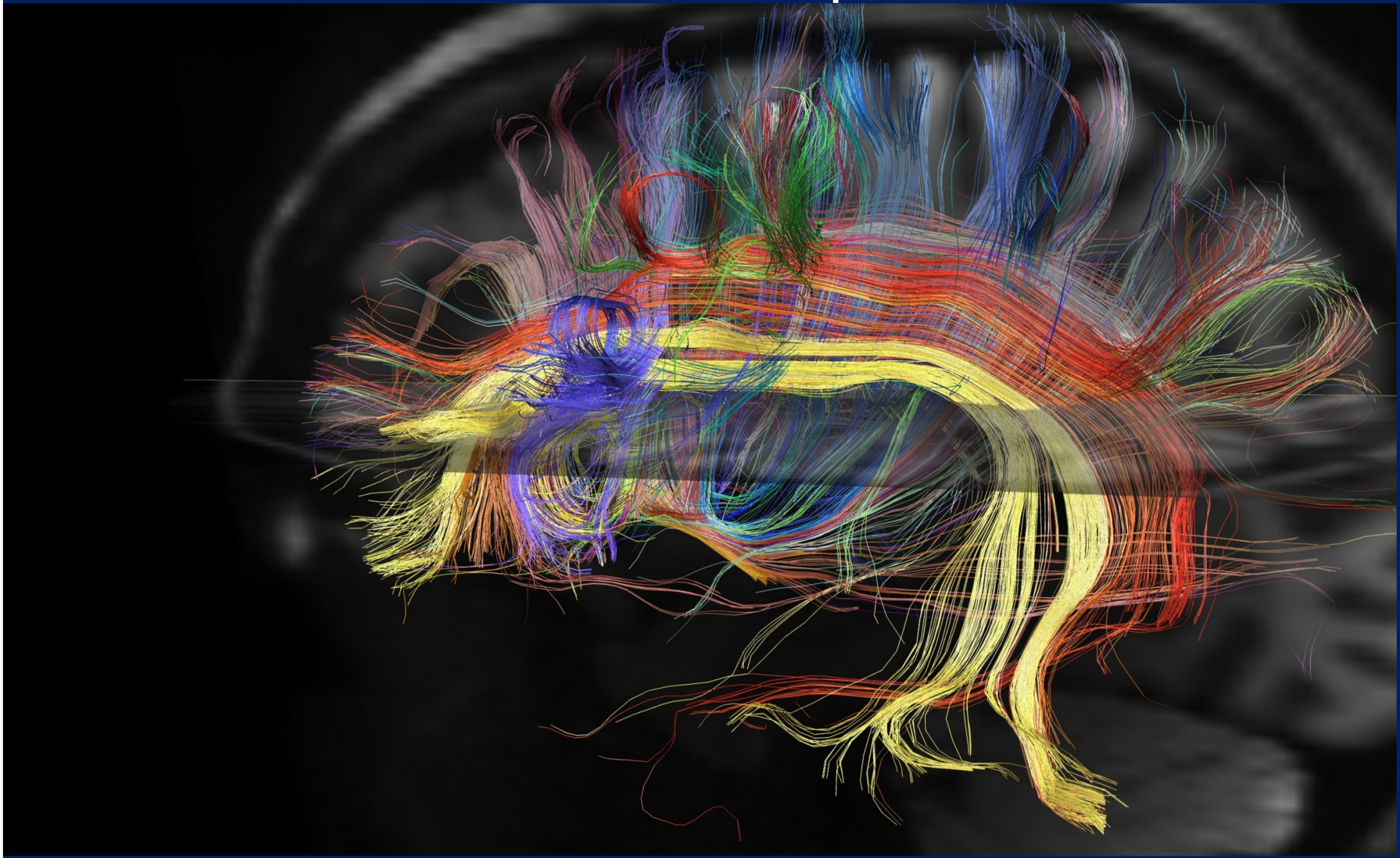
Brain Oscillations & Memory



Brain Development

Adaptive interaction between human nervous systems and sensorimotor devices

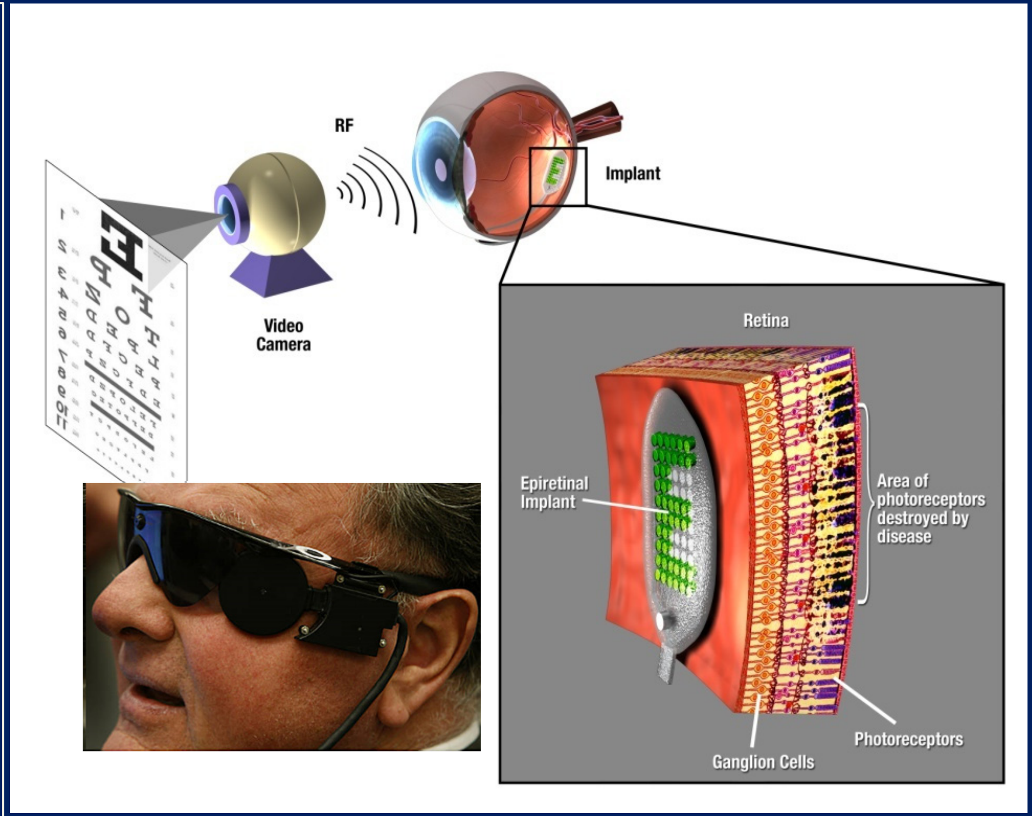
Human Brain Grid structure; the arcuate bundle, yellow, is a central pathway of language. Normal arcuate lateralization left > right is reduced in schizophrenia



Van Wedeen Harvard MGH HCP

Biomimetic Micro Electronic Systems (BMES) Engineering Research Center

- **First FDA-Approved Retinal prosthesis (2013) used to treat adult patients with advanced *retinitis pigmentosa*.**
- **Images from external video camera are transformed into electronic data that is wirelessly transmitted to the retinal prosthesis.**
- **Letter recognition, word reading, improved mobility, object localization, motion detection.**



Second Sight Medical Products Argus II

Video images captured by a miniature camera, housed in the patient's glasses are converted into a series of small electrical pulses that are transmitted wirelessly to an array of electrodes on the surface of the retina (epi-retinal).

John L. Wyatt Jr., MIT
Co-Director, Boston Retinal Implant Project

Wireless tracking of tongue movements for wheelchair control and computer access

Maysam Ghovanloo - Georgia Tech CBET 0828882 (GARDE Program)

1. A wireless and wearable technology that can convert a user's tongue motions to specific commands, such as moving a mouse cursor or a powered wheelchair.

2. The average speed of information transfer between participants and the computer was twice the bandwidth of the fastest brain-computer interfaces that have been tested on human subjects.

3. The subjects had immediate and full control over the powered wheelchair; they were able to perform complex wheelchair navigation tasks, such as driving through an obstacle course.

Physical and Mathematical Principles of Brain Structure and Function

- MPS/BIO sponsored workshop: May 5-7, 2013; Arlington, VA
- Participants include over 100 neuroscientists and technologists
- Identify a set of goals in basic neuroscience and tool development to facilitate mapping activity in large arrays of neurons during behavior.