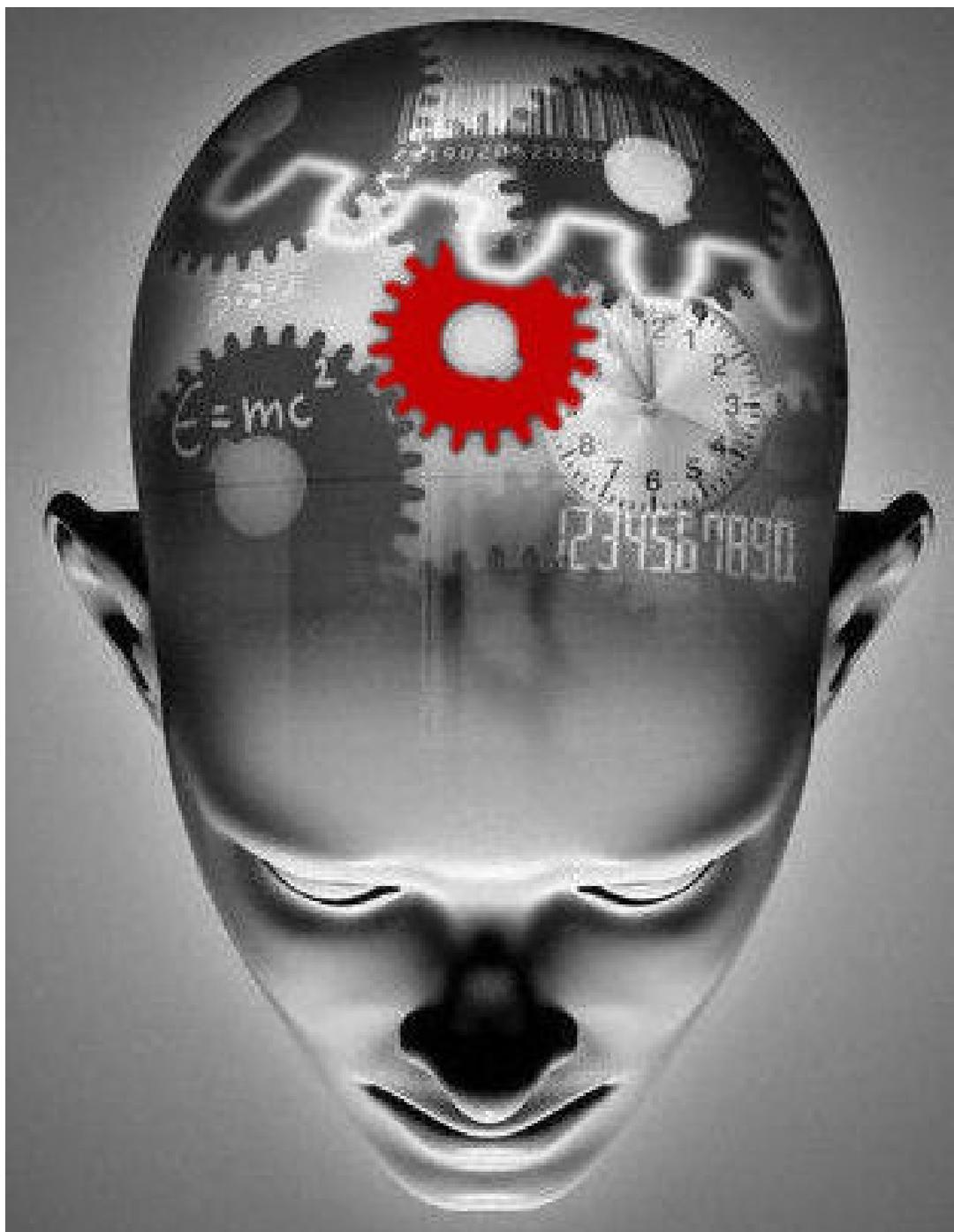


NEUROTECHNOLOGY IN ACTION

9.123/20.203



Courtesy of [digitalbob8](#) on Flickr. License CC BY.

life before neurotechnology...



Image is in public domain.

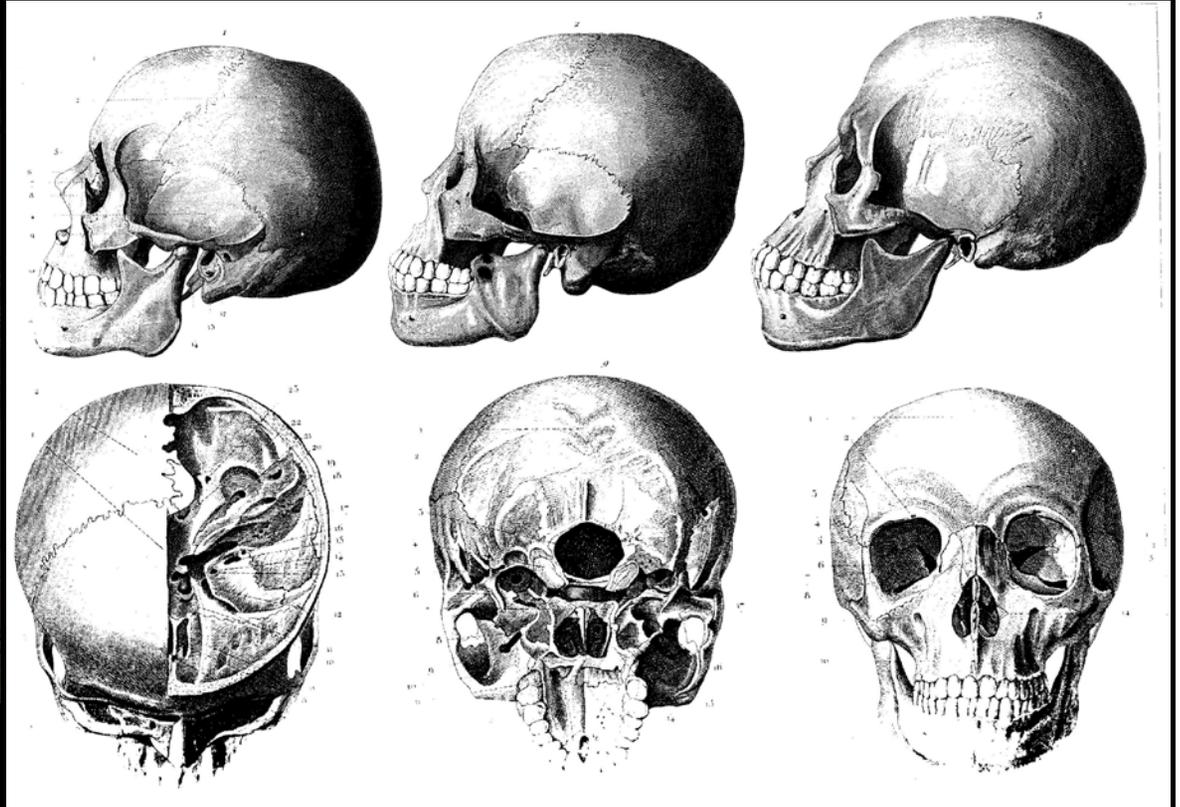
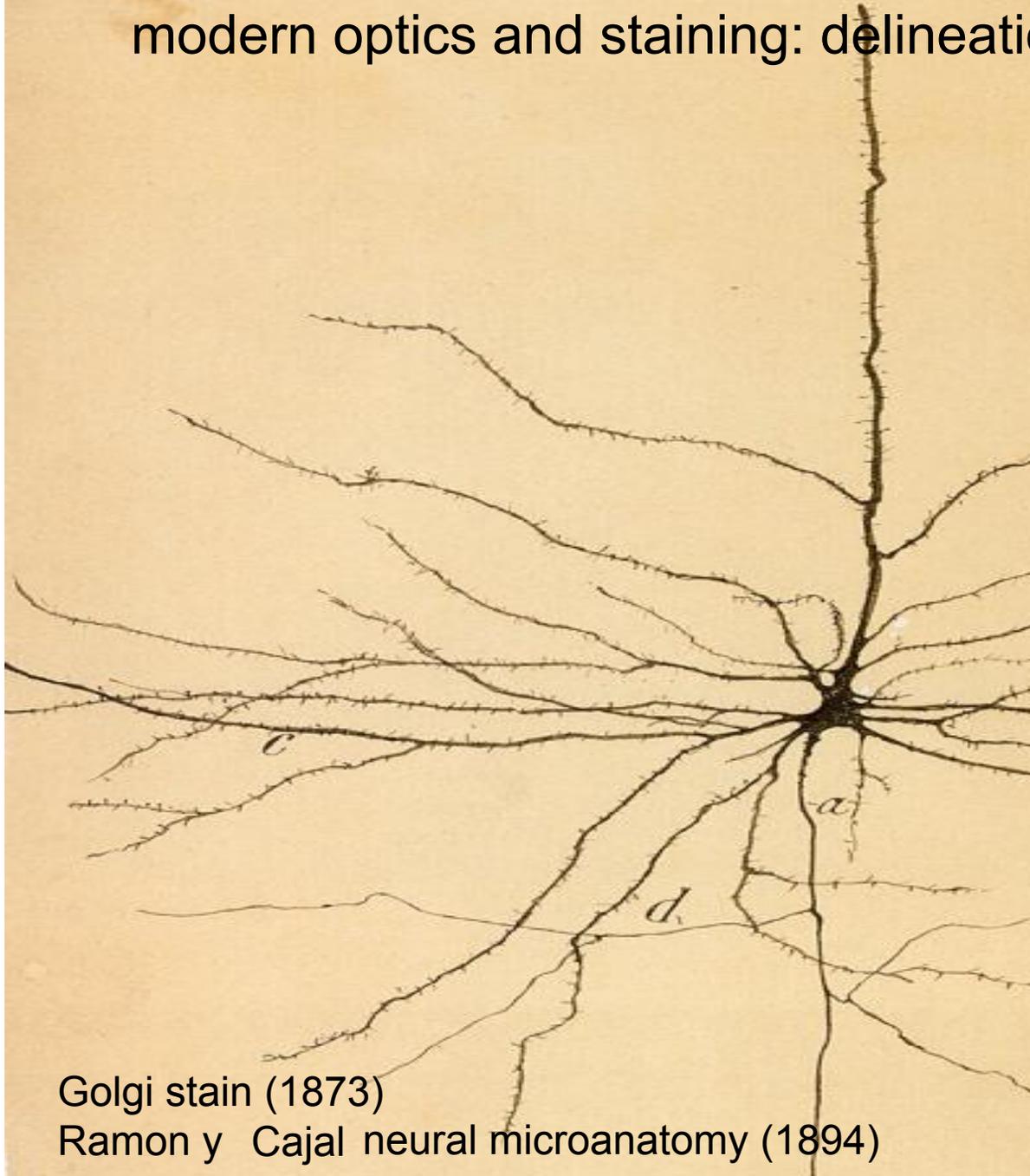


Image is in public domain. The Iconographic Encyclopaedia of Science, Literature and Art, 1851, via Wikimedia Commons.

modern optics and staining: delineation of the neuron



Golgi stain (1873)
Ramon y Cajal neural microanatomy (1894)



Image is in public domain.

electrophysiology: electrical behavior of neurons

Hodgkin-Huxley model (1952)

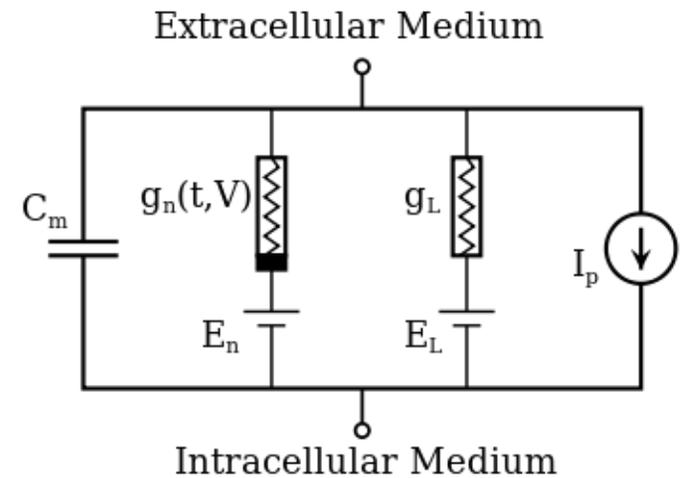


Image is in public domain.



NERVE-CELL ENIGMA SOLVED

The British scientists, A. L. Hodgkin and A. F. Huxley, experimenting with the nerve fibers of squids and lobsters.

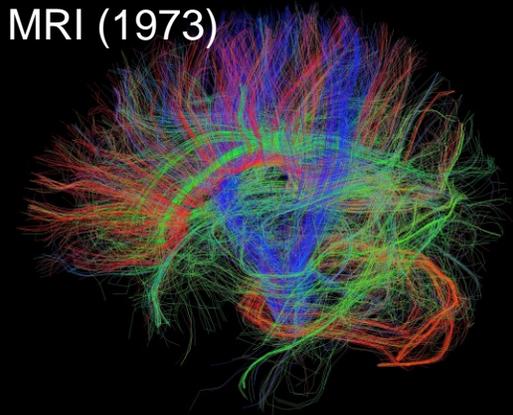
brain imaging: noninvasive studies of structure and function

X-ray CT (1971)



Image is in public domain.

MRI (1973)



Courtesy of the Laboratory of Neuro Imaging and
Martinos Center for Biomedical Imaging, Consortium
of the Human Connectome Project -
www.humanconnectomeproject.org.

PET (1975)

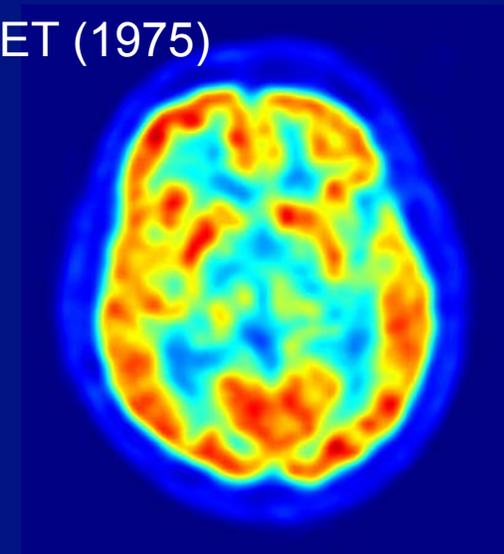


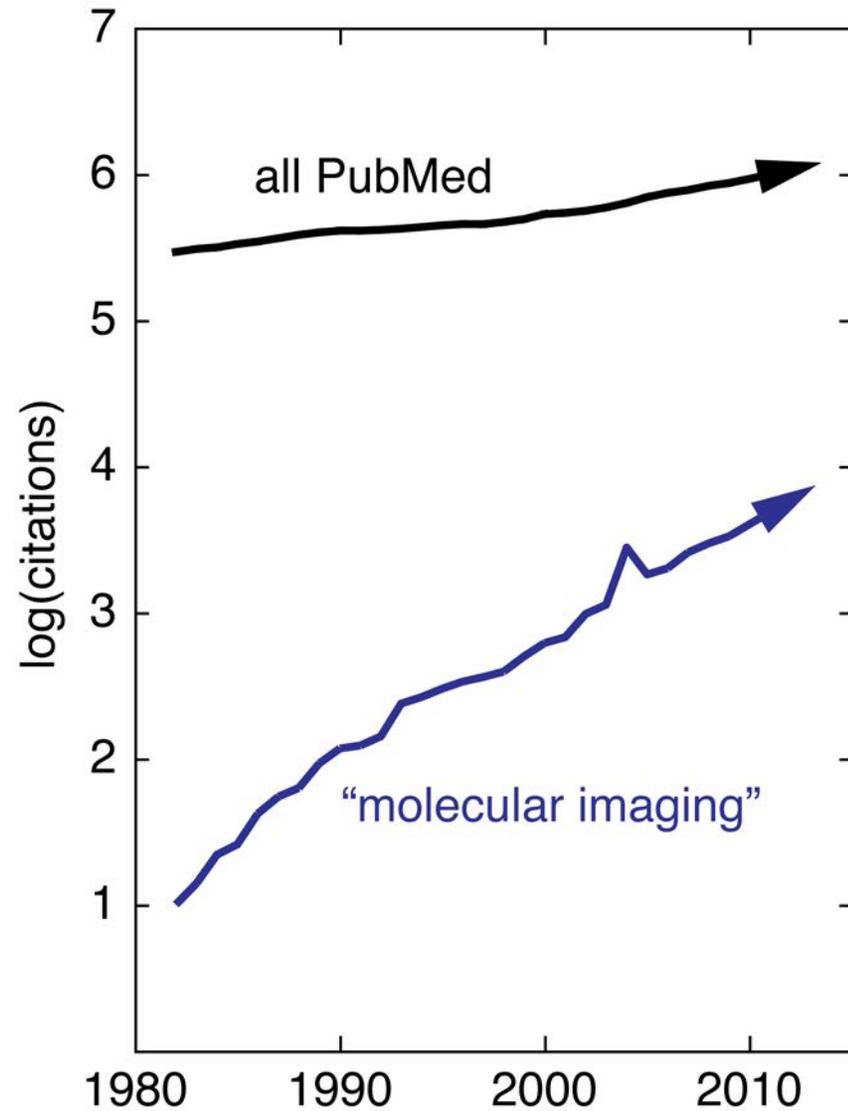
Image is in public domain.

continuing innovation



(diversity wanted)

rapid growth





Reverse-engineer the brain

The intersection of engineering and neuroscience promises great advances in health care, manufacturing, and communication.

National Academy of Engineering. Accessed October 14, 2010. <http://www.nationalacademies.org>.

WHITEHOUSE.GOV ▾



Tuesday, April 2nd, 2013

BRAIN Initiative

Today at the White House, President Obama unveiled the "BRAIN" Initiative—revolutionize our understanding of the human mind and uncover new ways to like Alzheimer's, schizophrenia, autism, epilepsy, and traumatic brain injury.

 SHARE ON FACEBOOK  SHARE ON TWITTER

★ ★ ★ ★ ————— the WHITE HOUSE —————

PRESIDENT OBAMA IS CALLING ON THE SCIENCE COMMUNITY
TO JOIN HIM IN PURSUING A GRAND CHALLENGE FOR ENGINEERING

BRAIN BRAIN RESEARCH THROUGH ENGINEERING



Human Brain Project




PROJECT PROGRAMME HBP COMMUNITY PARTICIPATE HBP SUMMIT 2013

COLLABORATION

THE HUMAN BRAIN PROJECT



Project

The WHITEHOUSE. "Brain Initiative." Accessed April 2, 2013. <https://www.whitehouse.gov/BRAIN>.

Human Brain Project. <https://www.humanbrainproject.eu/>.

the scale of the brain...



numerous brain regions
macroscale to nanoscale
 10^{11} neurons
 10^{14} synapses

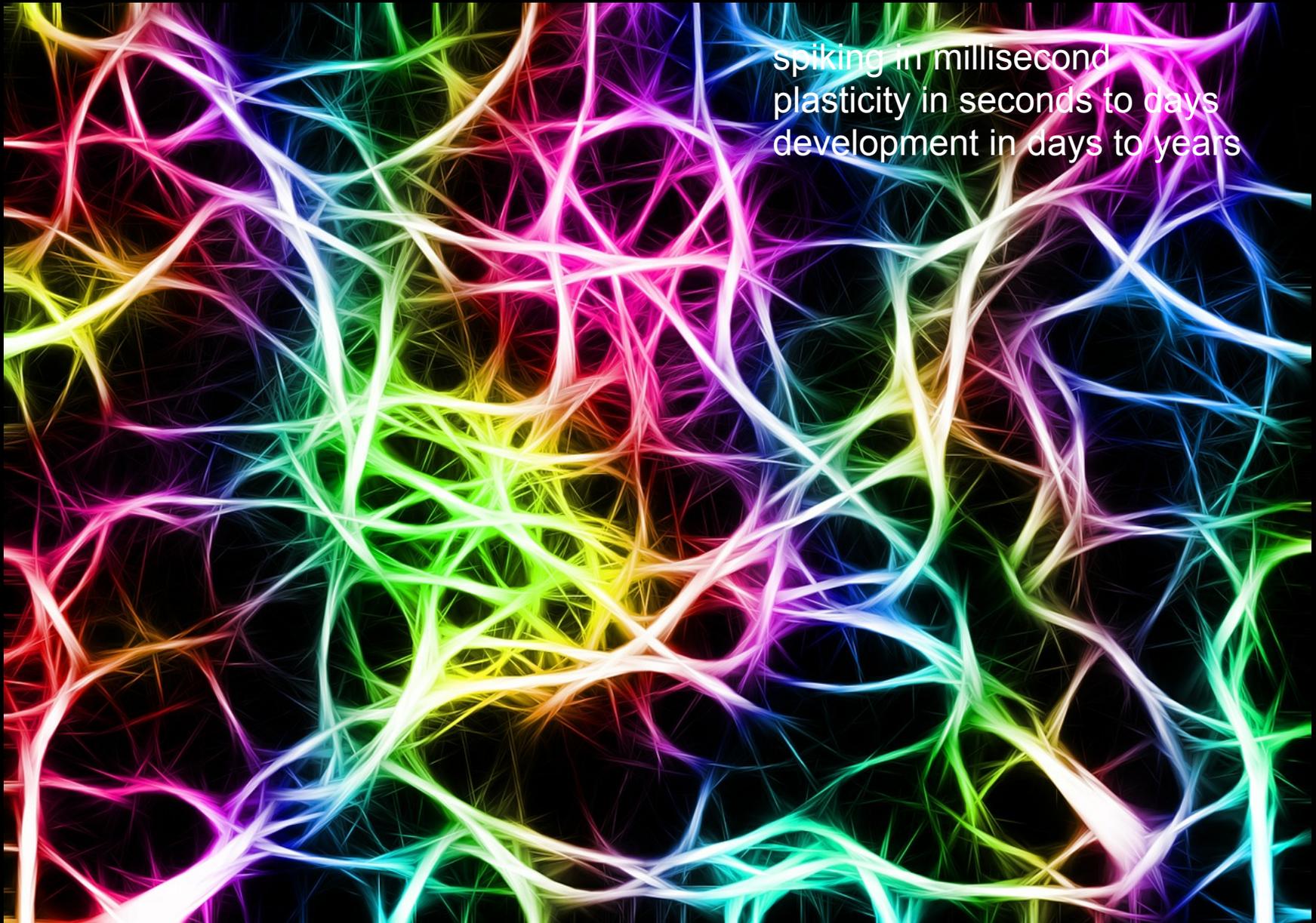
the complexity of the brain...

“forest” of cell types
complex interconnectivity
cellular and subcellular features

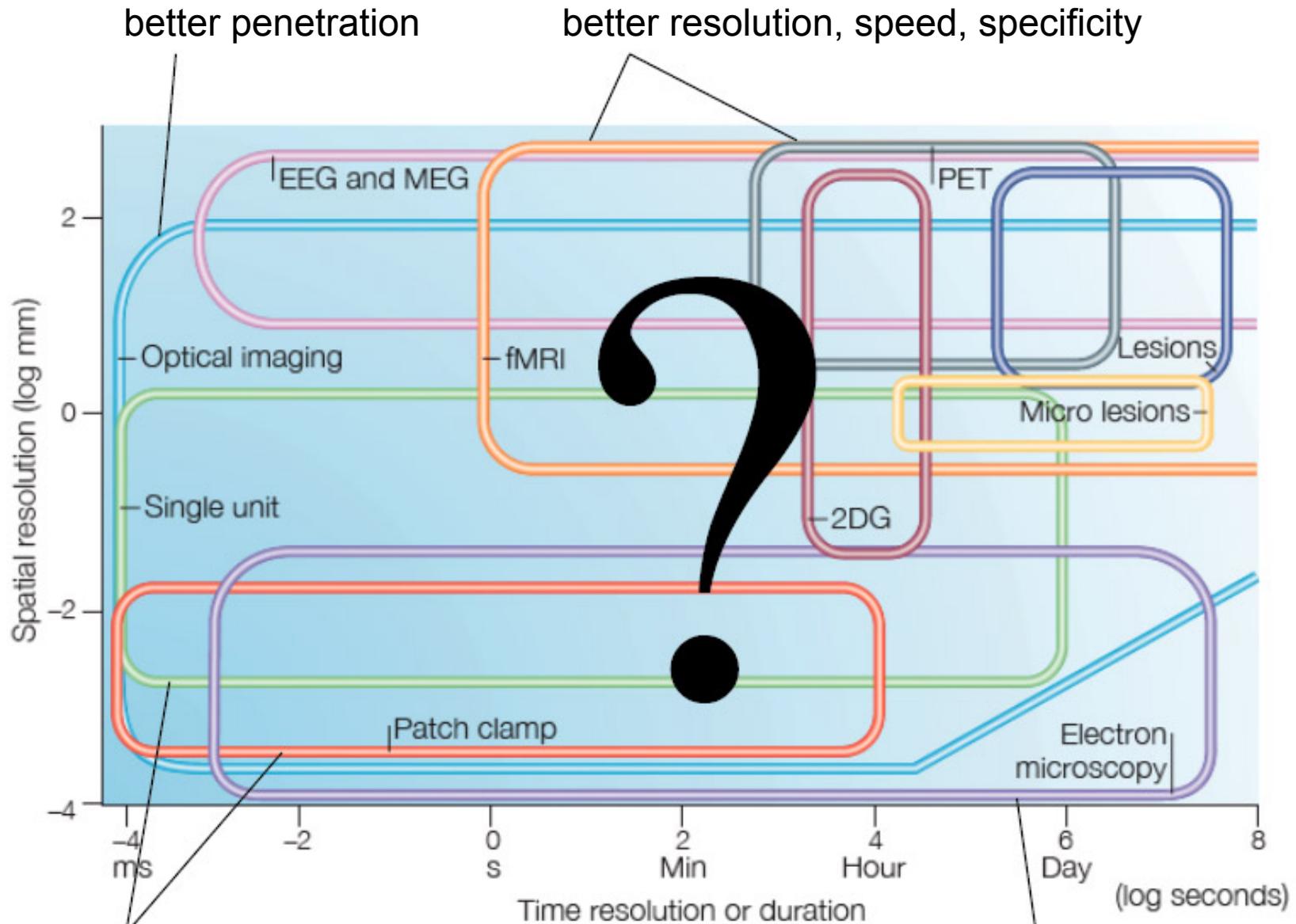


Image of [neural signaling](#) is in public domain.

the speed of the brain...



spiking in millisecond
plasticity in seconds to days
development in days to years



better penetration

better resolution, speed, specificity

greater density, less invasive
(also cf. optogenetics)

higher throughput

Grinvald & Hildesheim (2004) *Nat. Rev. Neurosci.*

Reprinted by permission from Macmillan Publishers Ltd: *Nature Reviews Neuroscience* © 2004.
 Source: Grinvald, Amiram, and Rina Hildesheim. "VSDI: A New Era in Functional Imaging of Cortical Dynamics."
Nature Reviews Neuroscience 5, no. 11 (2004): 874-85.

New technology will be essential for advances in all aspects of neuroscience.

- improvements in existing methods
- completely new paradigms

How can you prepare to contribute to innovation and application of cutting-edge neurotechnology?

Read papers?



Courtesy of [Sébastien Barré](#) on Flickr. CC license BY-NC-SA.

good way to see results
can assimilate basic concepts
difficult to get a practical feel
strengths/weaknesses opaque
no chance for interaction

*Better to see the
techniques in action!*



MIT CENTER FOR NEUROBIOLOGICAL ENGINEERING

survey of labs: “speed rotations”

ABOUT FACULTY SHARING PARTNERS NEWS CONTACT



POLINA ANIKEEVA

optoelectronic neuroprosthetics, flexible neural probes, minimally invasive neural stimulation



EMERY BROWN

design of algorithms for neural signal processing and studies of mechanisms of general anesthesia



JIM DICARLO

mechanisms of object recognition, tools for measuring and interacting with brain activity



POLINA GOLLAND

medical image analysis, functional brain imaging, functional organization of the brain



ED BOYDEN (co-director)

tools for mapping, controlling and building brain circuits



KWANGHUN CHUNG

brain imaging and molecular/genomic profiling, connectomics, drug screening platforms



MICHALE FEE

novel technologies for recording and manipulating neural circuits in behaving animals

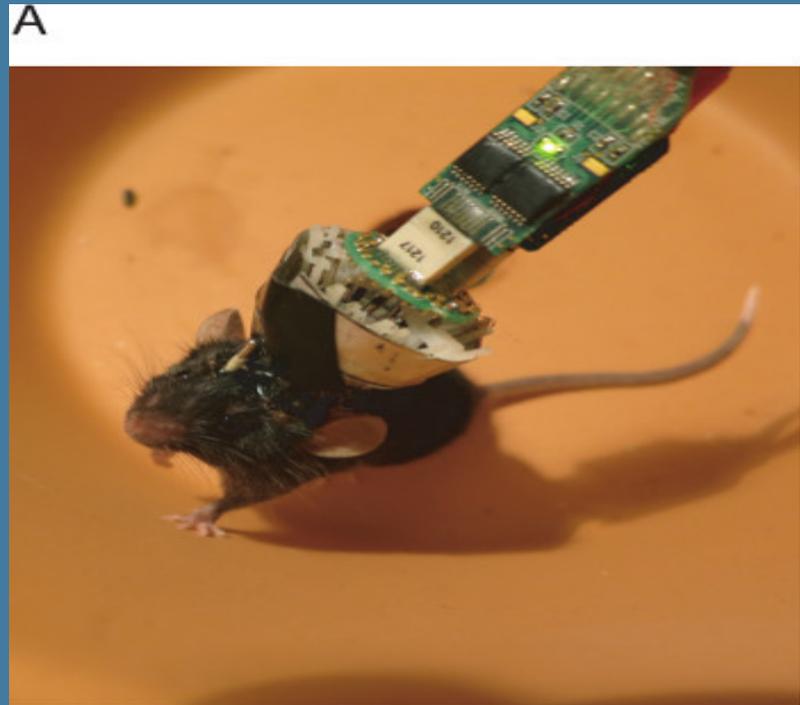


ANN GRAYBIEL

behavioral, electrophysiological, optogenetic and molecular biological studies of cortico-basal ganglia circuits

electrophysiology

high density electrode arrays
chronic recordings



Courtesy of JOVE. CC license BY-NC.

Source: Brunetti, Philip M., Ralf D. Wimmer, et al. "Design and Fabrication of Ultralight Weight, Adjustable Multi-electrode Probes for Electrophysiological Recordings in Mice." *Journal of Visualized Experiments* 91 (2014): e51675.

light microscopy

visualization of neuroanatomy & plasticity

high throughput imaging

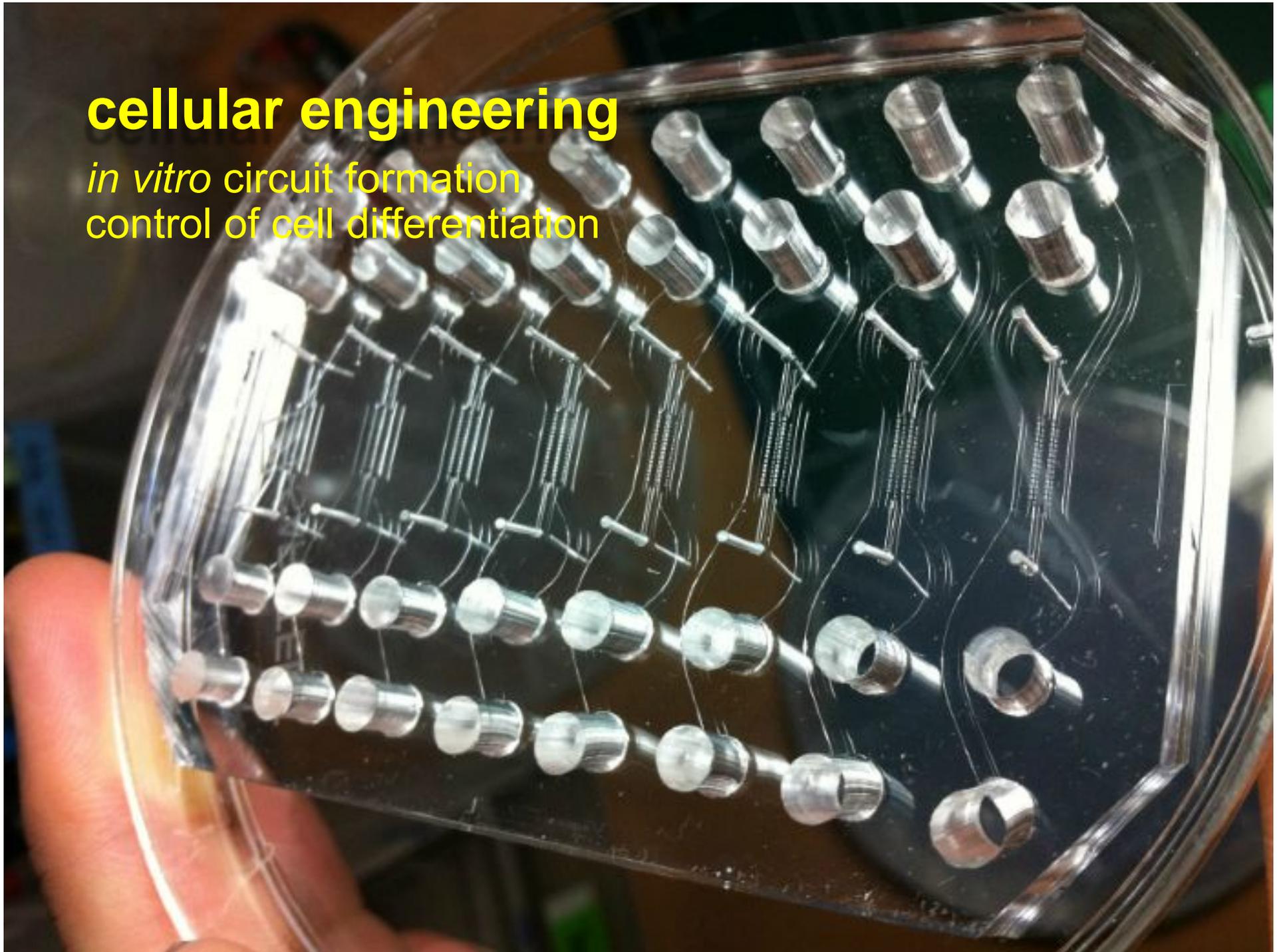
brain clearing techniques

Livet *et al.* (2007) *Nature*

Reprinted by permission from Macmillan Publishers Ltd: *Nature* © 2007.
Source: Livet, Jean, Tamily A. Weissman, et al. "Transgenic Strategies for Combinatorial Expression of Fluorescent Proteins in the Nervous System." *Nature* 450, no. 7166 (2007): 56–62.

cellular engineering

in vitro circuit formation
control of cell differentiation



Courtesy of Roger Kamm. Used with permission.

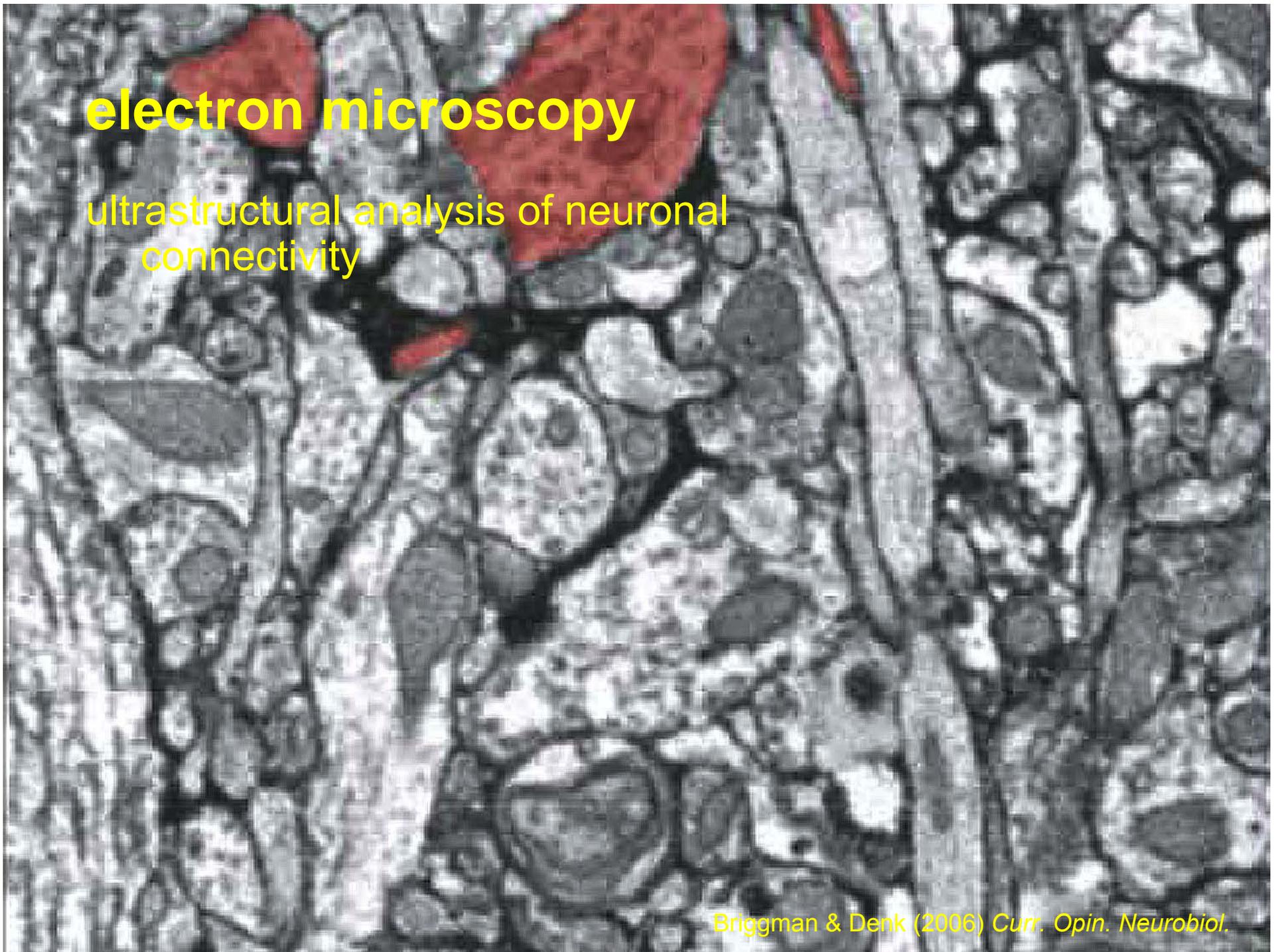
optogenetics

cell-specific neural stimulation



electron microscopy

ultrastructural analysis of neuronal connectivity



Briggman & Denk (2006) *Curr. Opin. Neurobiol.*

Courtesy of Elsevier, Inc., <http://www.sciencedirect.com>. Used with permission.

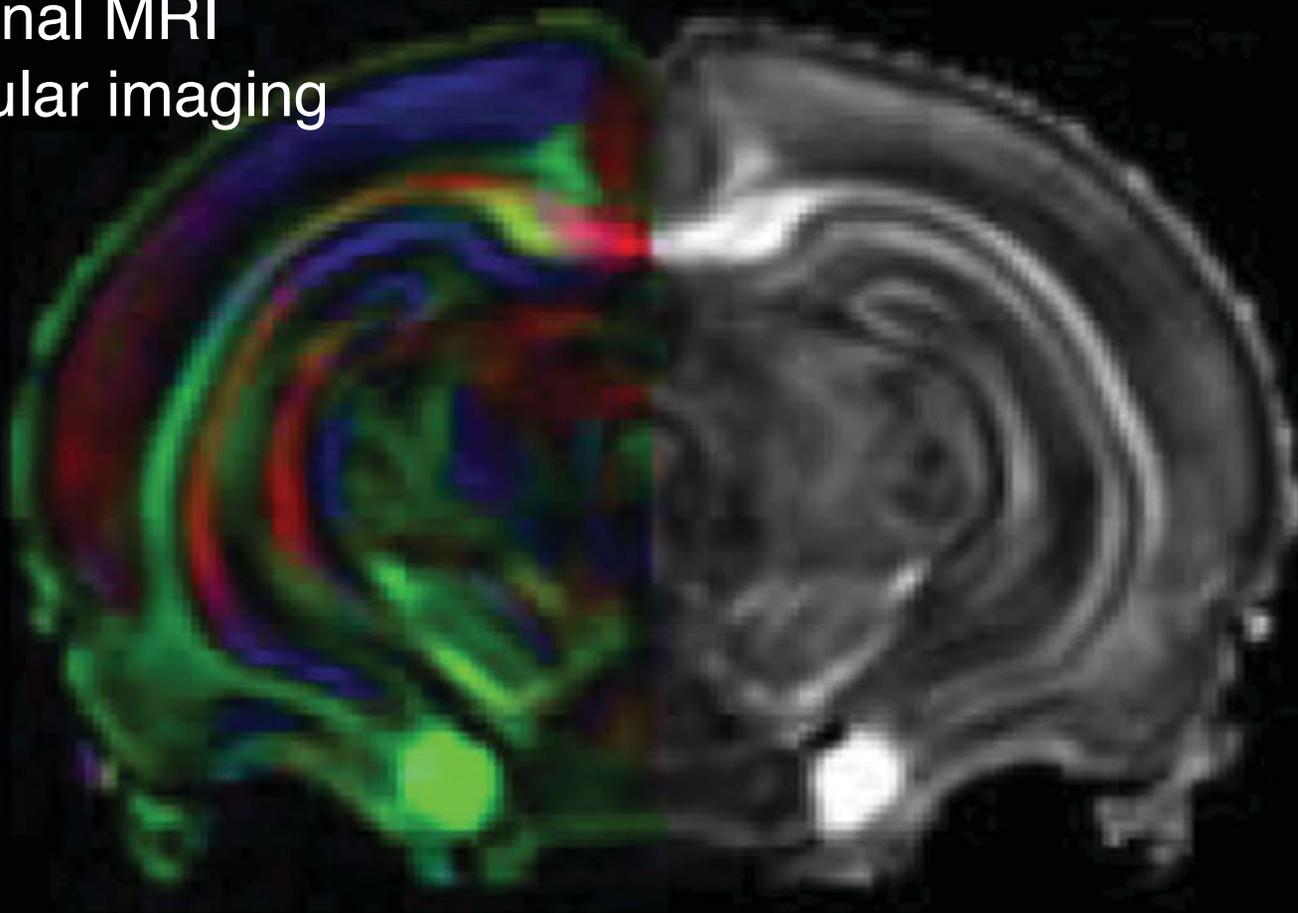
Source: Briggman, Kevin L., and Winfried Denk. "Towards Neural Circuit Reconstruction with Volume Electron Microscopy Techniques." *Current Opinion in Neurobiology* 16, no. 5 (2006): 562-70.

MRI/fMRI

anatomy and connectivity

functional MRI

molecular imaging



Huang *et al.* (2008) *J. Neurosci.*

Courtesy of the Society for Neuroscience.

Source: Huang, Hao, Akria Yamamoto, et al. "Quantitative Cortical Mapping of Fractional Anisotropy in Developing Rat Brains." *The Journal of Neuroscience* 28, no. 6 (2008): 1427–33. Used with permission; available under a CC-BY-NC-SA license.

MEG/EEG

noninvasive
electrophysiology



Image is in public domain.



labs
firsthand demo
in situ lab tours

coursework
in-class quizzes (30%)
homework (30%)
final project (30%)
participation (10%)

lectures
background & context
theoretical description

MIT OpenCourseWare
<http://ocw.mit.edu>

9.123 / 20.203 Neurotechnology in Action
Fall 2014

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