Next Generation Brain Hacking, Security, and Interfaces

Prof. Russell Hanson

Locard Cybersecurity Summit Istanbul, Turkey

21 May 2016

LOCARD ISTANBUL CYBER SECURITY SUMMIT

ISTANBUL CYBER SECURITY SUMMIT

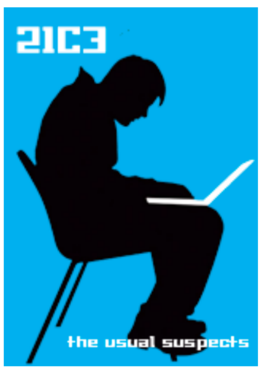
/usr/bin/whoami

http://www.vice.com/read/big-brain-connectome-interview

VICE ▾ United States ▾

HOME VIDEO NEWS MUSIC FASHION PHOTO TRAVEL SPORTS TECH FOOD NSFW MAGAZINE DOS & DON'TS

THIS GUY WANTS TO HELP YOU DOWNLOAD YOUR BRAIN



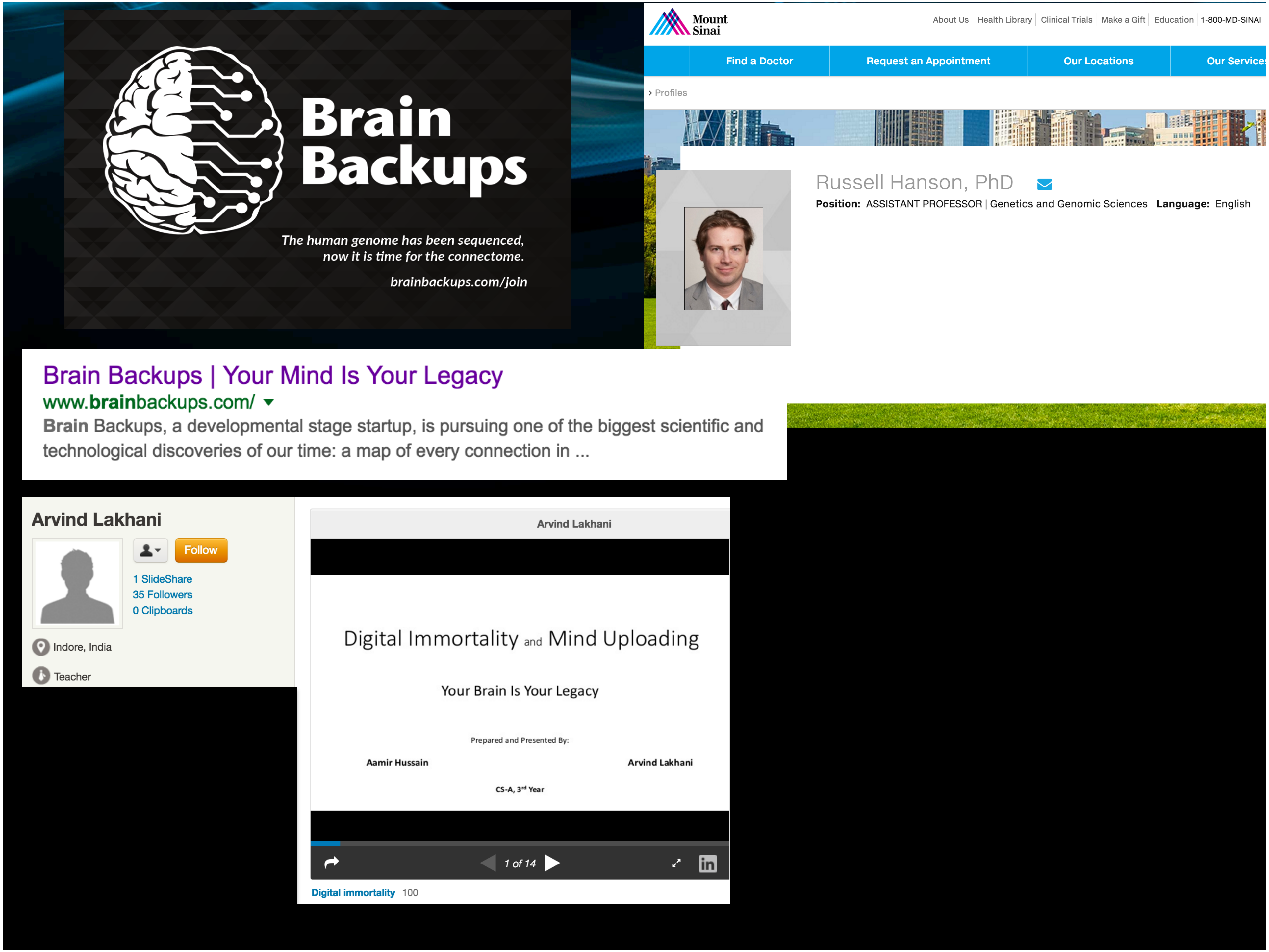
21C3 Schedule Release 1.1.7

21st Chaos Communication Congress
Speakers and moderators

Russell Hanson

EVENTS

Hacking The Genome


Brain Backups
The human genome has been sequenced,
now it is time for the connectome.
brainbackups.com/join
Mount Sinai
About Us | Health Library | Clinical Trials | Make a Gift | Education | 1-800-MD-SINAI
Find a Doctor
Request an Appointment
Our Locations
Our Services
› Profiles
Russell Hanson, PhD
Position: ASSISTANT PROFESSOR | Genetics and Genomic Sciences Language: English
Brain Backups | Your Mind Is Your Legacy
www.brainbackups.com/
Brain Backups, a developmental stage startup, is pursuing one of the biggest scientific and technological discoveries of our time: a map of every connection in ...
Arvind Lakhani
Follow
1 SlideShare
35 Followers
0 Clipboards
Indore, India
Teacher
Arvind Lakhani
Digital Immortality and Mind Uploading
Your Brain Is Your Legacy
Prepared and Presented By:
Aamir Hussain
Arvind Lakhani
CS-A, 3rd Year
1 of 14
Digital immortality 100

Firstly, what is a Brain Backup, and what is it good for?

- Brain Backups® is a trademarked name for the *connectome,* or the network of neural connections in your brain, and some metadata about those neurons.
- We see that the *connectome* has many parallels to the human genome, which has revolutionized science and medicine down to the $1000 genome, and the $150 gene chip (23andMe). Genomic tech is a trillion USD business.
- Why would anyone want such a thing, really?
  - Health: Alzheimer's, Parkinson's, dementia, psychological disorders can be better understood and treated. "Digital immortality"/"Singularity"?
  - Education: Image someone's brain before university and after university, use that info to transfer the knowledge to another brain, or selected pieces of that knowledge.
  - Technology: Use the brain image "Brain Backup" to inform a machine, minion, AI, robot, other person, whatever of a task that needs doing. Copy these minions, do more stuff, spend less time training/teaching/programming.
  - Entertainment? Pretty limitless.
  - Business: Truly limitless. The neural modem described below, if successful will enable telepathic-like interactions and communications. A multi-billion dollar business right there.

I don’t believe you, this sounds like science fiction.

3600 seconds/hour * 40/60 hours =
2400 the factor from real-time human brain emulation, let’s call it 2,000X (ca. 2014).

Time to increase computing power 2,000X?
Introduced by Intel on April 1, 1974, the 8080 had an 8-bit architecture, 6,000 transistors, clock speeds of 2-MHz.

In 1985, Intel 386 80386SX was available in clock speeds of 16MHz, 20MHz, 25MHz, and 33MHz.

On November 20, 2000, Intel released the Willamette-based Pentium 4 clocked at 1.4 and 1.5 GHz.

The Telegraph

Home Video News World Sport Business Money Comment Culture Travel Life W

Apple | iPhone | Technology News | Technology Companies | Technology Reviews | Video Games | Te

HOME » TECHNOLOGY

Supercomputer models one second of human brain activity

The most accurate simulation of the human brain ever has been carried out, but a single second’s worth of activity took one of the world’s largest supercomputers 40 minutes to calculate

10K 5 193 10K Email

The simulation will help scientists create more accurate models in future Photo: Alamy

By Matthew Sparkes
10:04AM GMT 13 Jan 2014

Print this article

Technology

Show me a connectome

- ‘Kay.

https://github.com/openworm/CElegansNeuroML/blob/master/CElegansNeuronTables.xls

Origin	Target	Type	Number of Connections	Neurotransmitter
ADAL	ADAR	GapJunction	1	Generic_GJ
ADAL	ADFL	GapJunction	1	Generic_GJ
ADAL	AIBL	Send	1	Glutamate
ADAL	AIBR	Send	2	Glutamate
ADAL	ASHL	GapJunction	1	Generic_GJ
ADAL	AVAR	Send	2	Glutamate
ADAL	AVBL	Send	4	Glutamate
ADAL	AVBR	Send	7	Glutamate
ADAL	AVDL	Send	1	Glutamate
ADAL	AVDR	GapJunction	2	Generic_GJ
ADAL	AVEL	Send	1	Glutamate
ADAL	AVJR	Send	5	Glutamate
ADAL	FLPR	Send	1	Glutamate
ADAL	PVQL	GapJunction	1	Generic_GJ
ADAL	RICL	Send	1	Glutamate
ADAL	RICR	Send	1	Glutamate
ADAL	RIML	Send	3	Glutamate
ADAL	RIPL	Send	1	Glutamate
ADAL	SMDVR	Send	2	Glutamate
ADAR	ADAL	GapJunction	1	Generic_GJ
ADAR	ADFR	GapJunction	1	Generic_GJ
…	…	…	……	

What do I do with a connectome? Simulate it.

nest::

The Neural Simulation Tool

current release: nest v2.10.0

[>> Download Release v2.10.0 (Dec 31 2015)]

DOI 10.5281/zenodo.44222 | license GPLv2+

NEST 2.10.0 contains 303 repository commits by 25 developers since v2.8.0. The most notable changes over v2.8.0 are:

- Support for simulations of gap junctions (see Jan Hahne et al., 2015)
- Framework for structural plasticity (see Markus Butz et al., 2013 and Markus Butz et al., 2014)
- Full support for the K computer (just in case you found one under your Christmas tree ;-))

C Elegans Neurorobotics

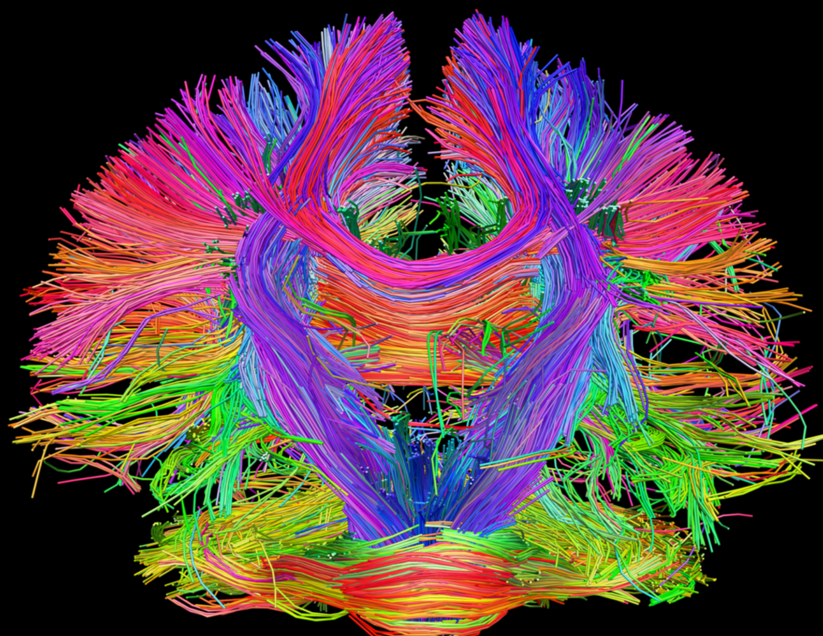
Timothy Busbice
interintelligence@gmail.com
http://www.connectomeengine.com

You are your connectome

Without a brain, no non-plant organism larger than a single cell would be able to respond to its environment in any way other than that dictated by physics and simple, binary responses. The entire sum of who you are resides in the activity of your brain.

Only recently have we had any ability to **understand** the complexity of the brain. The Human Connectome Project Consortium is elucidating neural circuits or pathways in the brain and sub-organ structure, and interconnectivity between brain regions, to understand the design and function of the connectome.

Quantifiably, a connectome is a 3 dimensional mapping of all the "wired" neural connections within a brain. Living connectomes are highly dynamic – an individual's varies continuously throughout their lifetime. Your connectome today is different from when you were a child – and its structure is directly related to your previous connectomic configurations.



Question: How big is a connectome (in bytes)?

The human brain contains about ~100 billion nerve cells, or neurons.
On average, each neuron is connected to other neurons through about 10 000 synapses.
The actual figures vary greatly, depending on the local neuroanatomy.

100 000 000 000 neurons * 10 000 synapses = 1 000 000 000 000 000

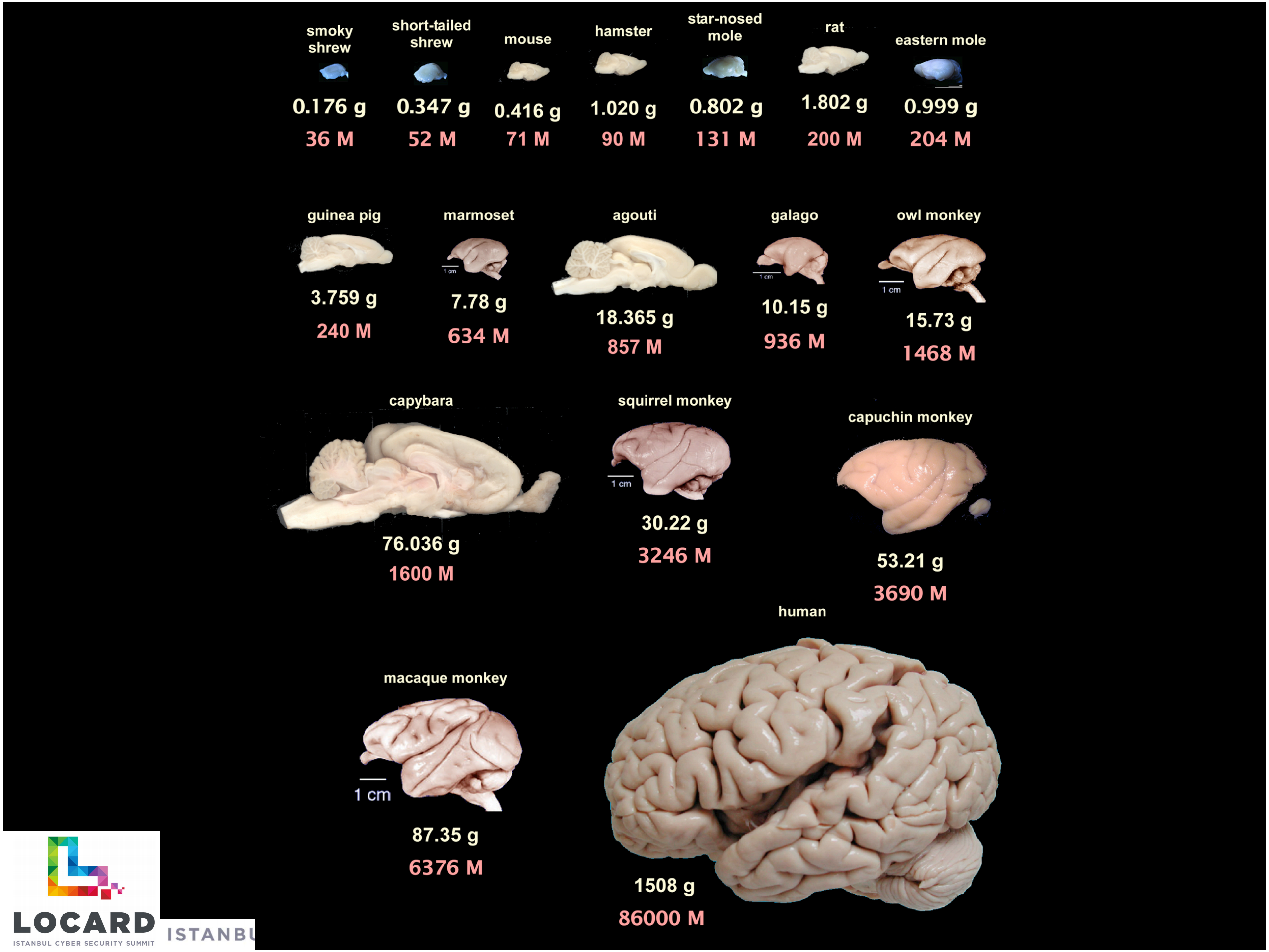
1 terabyte = 1 099 511 627 776 bytes

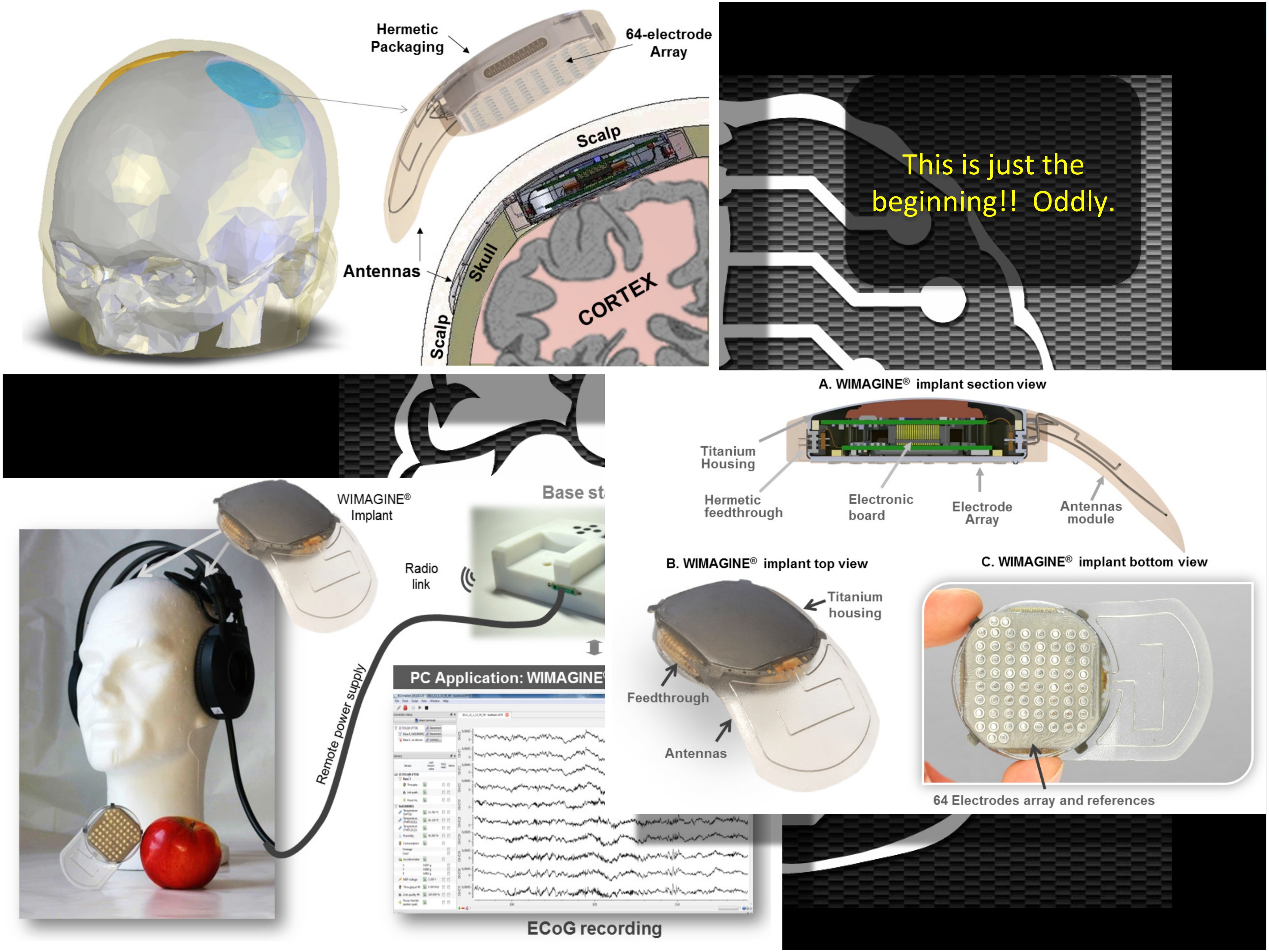
1 000 000 000 000 000/1 099 511 627 776 = 909.49 terabytes

1 terabyte HD storage = ~$28.31 → storage for all human neurons and synapses ~$28.31 * 909.49 = ~$25,747.66

Connectivity: Assuming avg. 500 inputs per neuron, adjacency list is avg. 37•500=18,500 bits≈2kB per neuron. Neuronal type: Assume 10^3 cell types => 10 bits. Configuration: Assume each input synapse has 10^3 states => additional 5,000 bits. Total 3kB•2^37=384TB. Assume ~50% achievable compression ratio. Estimate: 200-300TB.

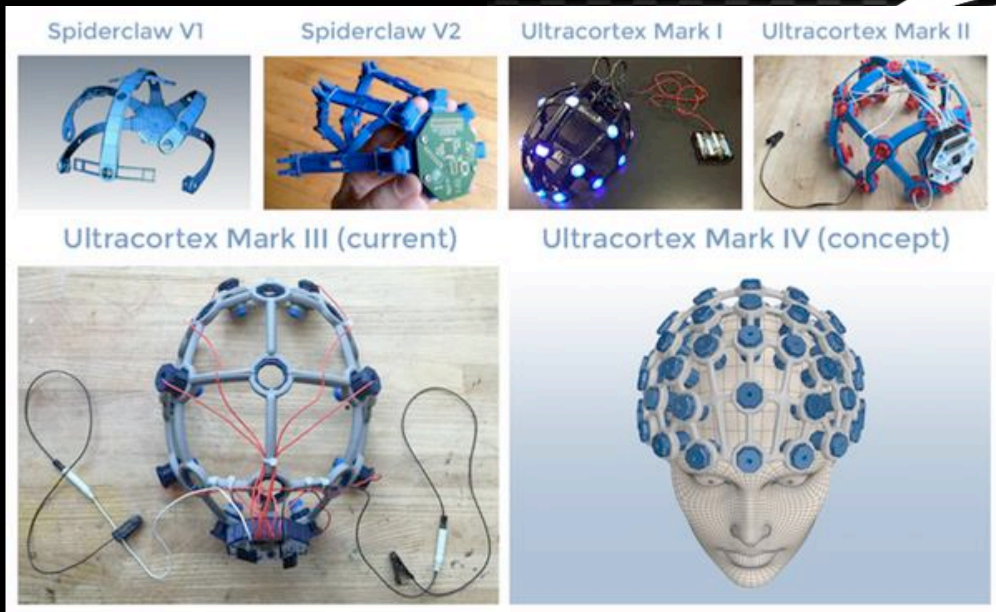
LOCARD
ISTANBUL CYBER SECURITY SUMMIT

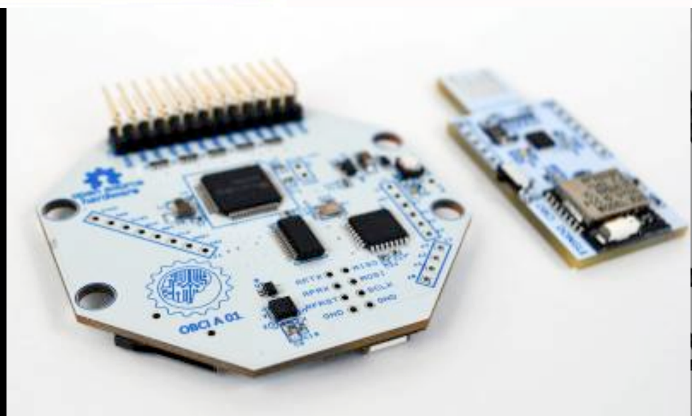

smoky shrew
0.176 g
36 M
short-tailed shrew
0.347 g
52 M
mouse
0.416 g
71 M
hamster
1.020 g
90 M
star-nosed mole
0.802 g
131 M
rat
1.802 g
200 M
eastern mole
0.999 g
204 M
guinea pig
3.759 g
240 M
marmoset
7.78 g
634 M
agouti
18.365 g
857 M
galago
10.15 g
936 M
owl monkey
1 cm
15.73 g
1468 M
capybara
76.036 g
1600 M
squirrel monkey
1 cm
30.22 g
3246 M
capuchin monkey
53.21 g
3690 M
macaque monkey
1 cm
87.35 g
6376 M
human
1508 g
86000 M

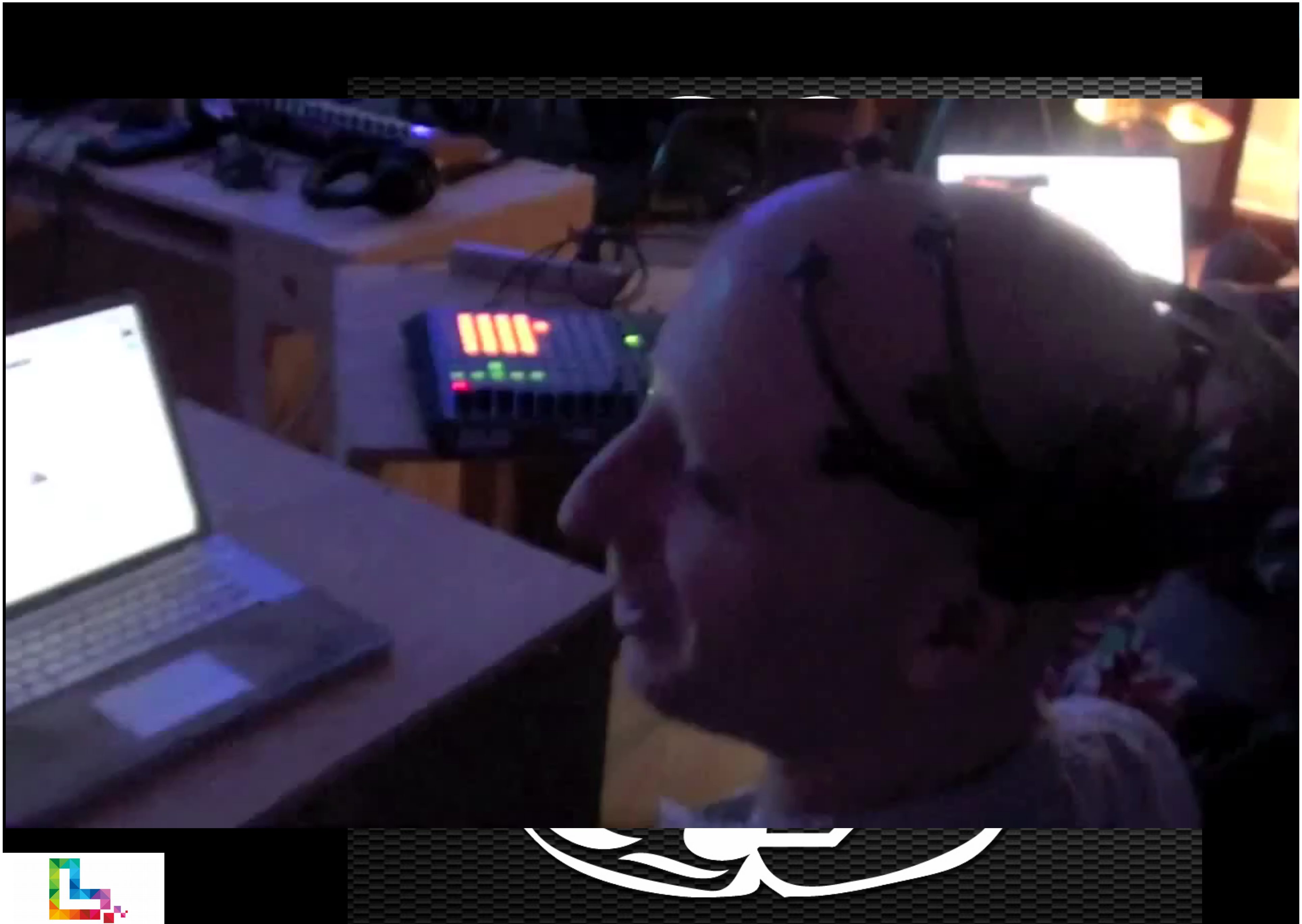


Hermetic Packaging
64-electrode Array
Scalp
Skull
CORTEX
Scalp
Antennas
This is just the beginning!! Oddly.
A. WIMAGINE® implant section view
Titanium Housing
Hermetic feedthrough
Electronic board
Electrode Array
Antennas module
B. WIMAGINE® implant top view
Titanium housing
Feedthrough
Antennas
C. WIMAGINE® implant bottom view
64 Electrodes array and references
WIMAGINE® Implant
Radio link
Base st
Remote power supply
PC Application: WIMAGINE
ECoG recording

EEG headsets: OpenBCI, eMotiv, etc.







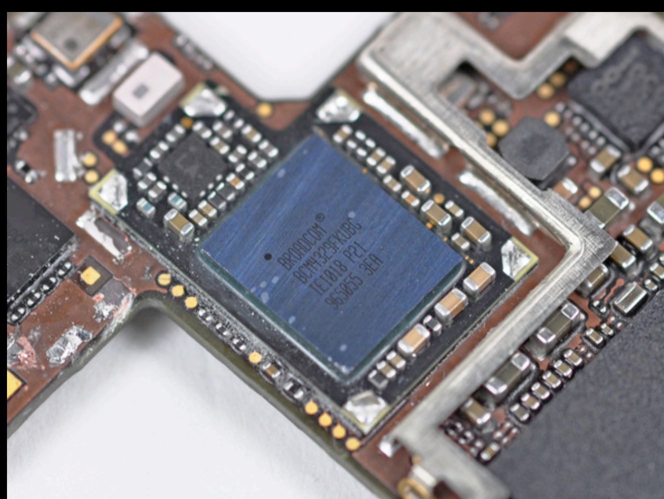
LOCARD
ISTANBUL CYBER SECURITY SUMMIT
ISTANBUL CYBER SECURITY SUMMIT

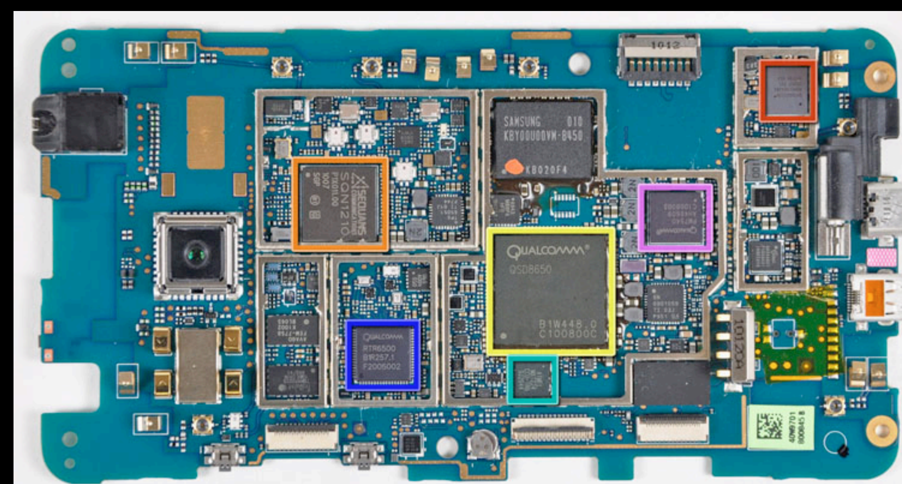
How to make a Wifi connected brain – seems useful, right?

```
[root@brain ~]# ifconfig brain0 up
```

Should one use motor cortex? ECOG? Nanodevices like our nanoparticles?

Broadcom BCM4329 chip
that powers Wi-Fi, bluetooth on iphone 4, HTC EVO





Brain Modem: DARPA NESD $60M – read from 1,000,000 neurons stimulate 100,000 neurons

Neural Engineering System Design

Solicitation Number: DARPA-BAA-16-09
Agency: Other Defense Agencies
Office: Defense Advanced Research Projects Agency
Location: Contracts Management Office

Notice Details | Packages | Interested Vendors List

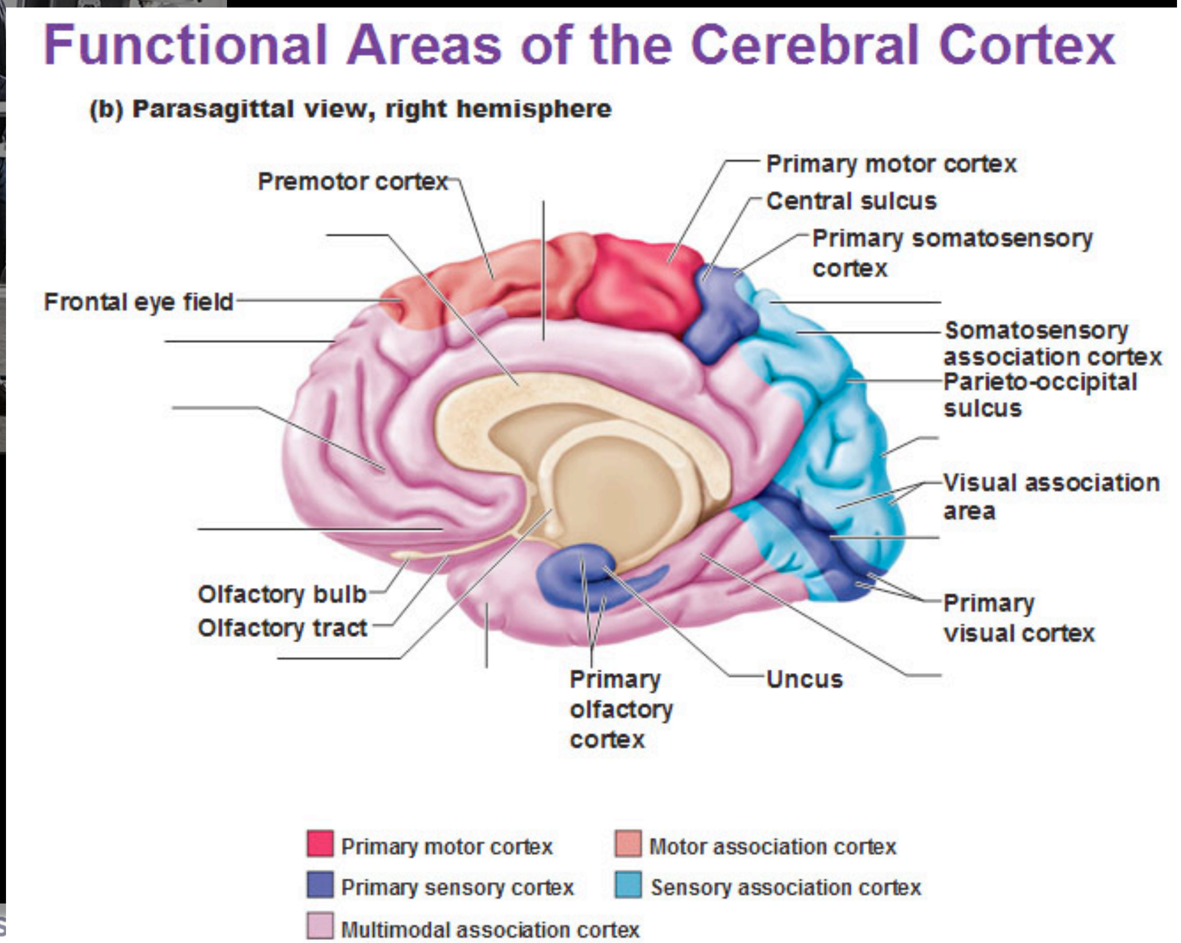
Original Synopsis
Jan 21, 2016
11:58 am

Return To Opportunities List

Solicitation Number:	**Notice Type:**
DARPA-BAA-16-09	Presolicitation

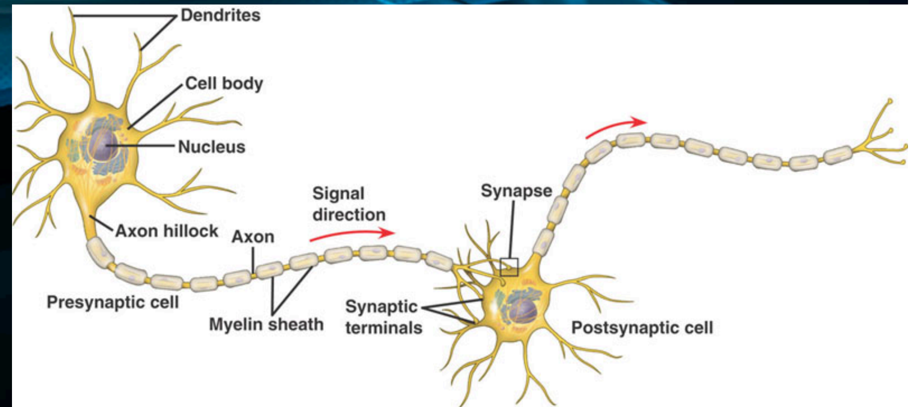
Synopsis:
Added: Jan 21, 2016 11:58 am
DARPA seeks proposals to design, build, demonstrate, and validate a neural interface platform capable of recording from more than 1,000,000 neurons and stimulating more than 100,000 neurons in proposer-defined regions of the human auditory, visual and somatosensory cortex. The complete system must demonstrate high-precision detection, transduction, and encoding of neural activity.

MOTOR CORTEX and sensory cortices



Fundamental components of a neural network system

- Synaptic weight
- Neurotransmitters
- Long term potentiation (LTP)
- Long term depotentiaion (LTD)



To model a network of LT neurons, assume that their activities at time t are given by the N variables, $x_1(t)$, $x_2(t)$ ..., $x_N(t)$ which take on the values 0 or 1, that is, a neuron is either active ("1") or silent ("0"). Then the activities at time $t + 1$ are given by

$$x_i(t+1) = H\left(\sum_{j=1}^{N} W_{ij}x_j(t) - \theta_j\right) \qquad \textbf{(E–1)}$$

where H is the Heaviside step function defined by $H(u) = 1$ for $u \geq 0$ and $H(u) = 0$ otherwise, W_{ij} is the strength or weight of the synapse between neuron i and the presynaptic neuron j, and θ_j is the threshold of neuron i. For a network of N neurons, the synaptic weights W_{ij} form an $N \times N$ matrix, and the thresholds θ_j an N-dimensional vector.

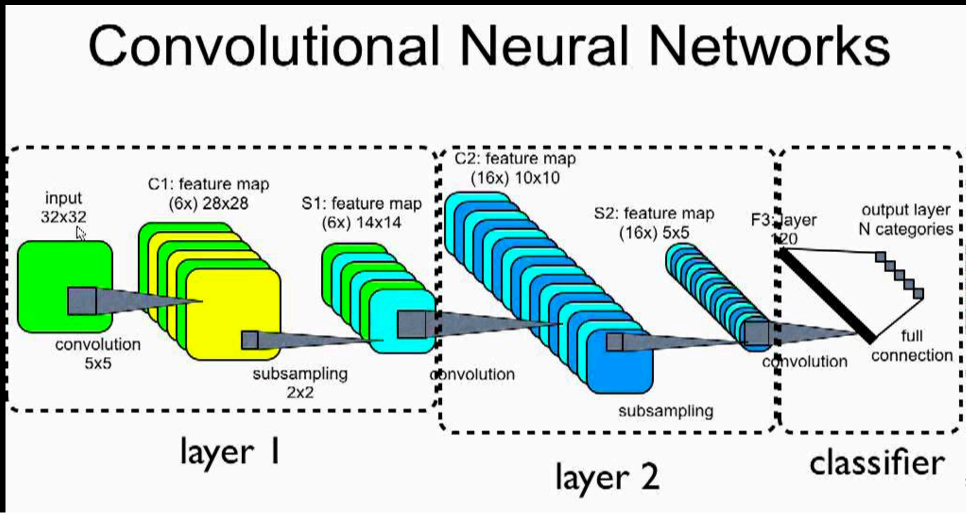
Nanoconnectomic upper bound on the variability of synaptic plasticity

Thomas M Bartol Jr[1*], Cailey Bromer[1], Justin Kinney[1,2†], Michael A Chirillo[3], Jennifer N Bourne[3‡], Kristen M Harris[3*], Terrence J Sejnowski[1,4*]

Abstract Information in a computer is quantified by the number of bits that can be stored and recovered. An important question about the brain is how much information can be stored at a synapse through synaptic plasticity, which depends on the history of probabilistic synaptic activity. The strong correlation between size and efficacy of a synapse allowed us to estimate the variability of synaptic plasticity. In an EM reconstruction of hippocampal neuropil we found single axons making two or more synaptic contacts onto the same dendrites, having shared histories of presynaptic and postsynaptic activity. The spine heads and neck diameters, but not neck lengths, of these pairs were nearly identical in size. We found that there is a minimum of 26 distinguishable synaptic strengths, corresponding to storing 4.7 bits of information at each synapse. Because of stochastic variability of synaptic activation the observed precision requires averaging activity over several minutes.

Key differences between classical ML/AI/deep learning and biological brain

- Specific networks for specific functions, significance of connectivity between these regions
- “Supervisor”/”teacher” to say when done, to move on to next task
- Highly optimized yet optimization procedure unknown
- Only 86 billion neurons, energy consumption 12 watts
- Highly integrated with peripheral nervous system (somatic nervous system and autonomic nervous system)
- Human intelligence while a general intelligence also performs many distinctly human functions



Connectome Mapping Today

The current methodology of mapping the connectome today relies on imaging of the neurons in a brain, in one way or another. All current methods are:

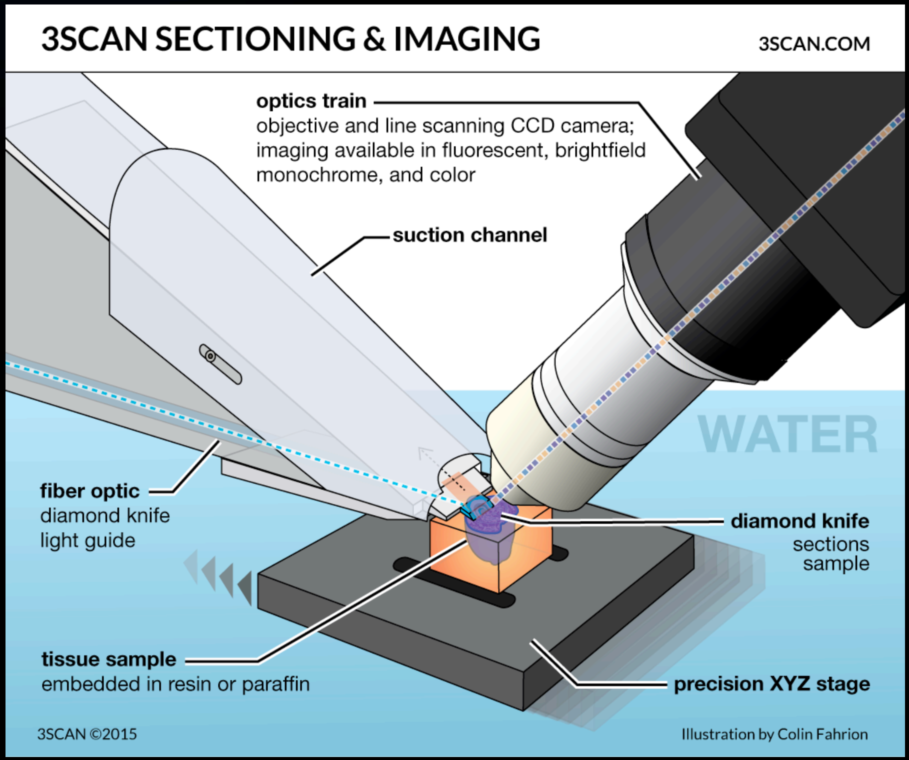
Highly Destructive

Highly Invasive

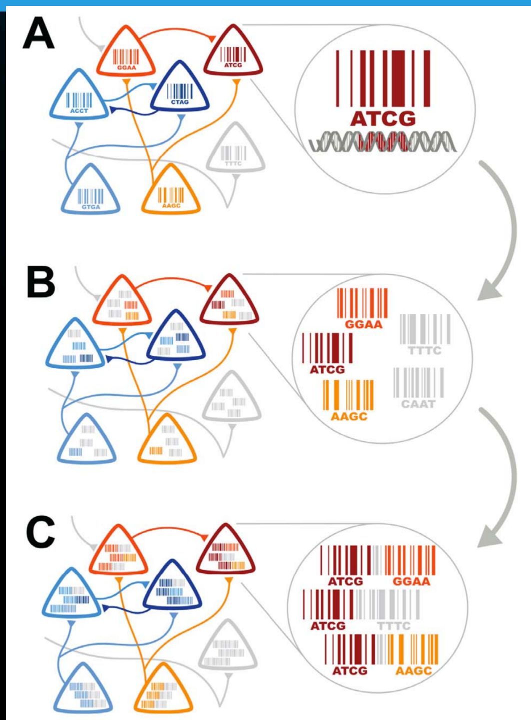
or

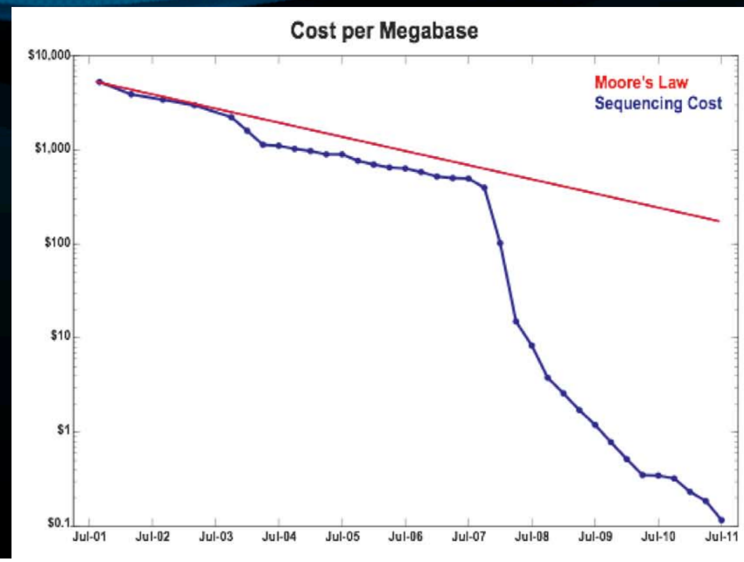
Very Low Resolution

Don't destroy the thing you want to image!!

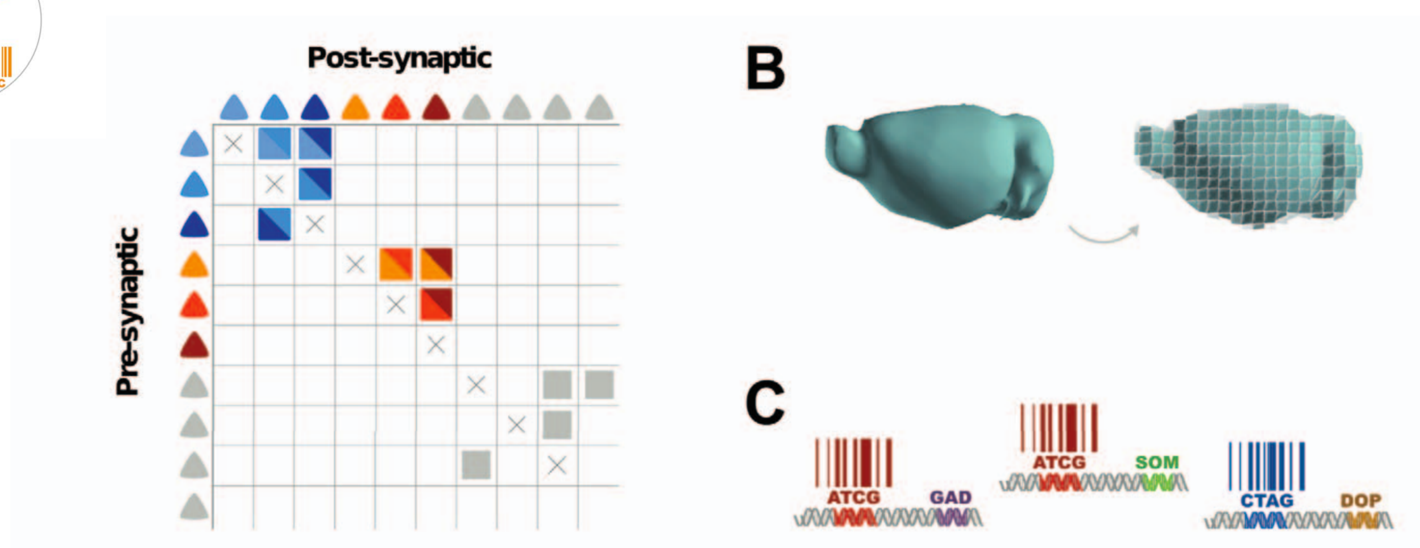


Using genome sequencing for connectome sequencing





It's still destructive!! ☹☹☹☹



Novel, non invasive, *in vivo* Imaging Methodology

Non-destructive non-invasive imaging of neural targets to map tissue structure and visualize dynamic biochemical processes at sub-second timescales from 1mm to 300nm. Nanoparticle imaging-agents may be “barcoded” for MRI and dual mode/spectral CT.

Design:

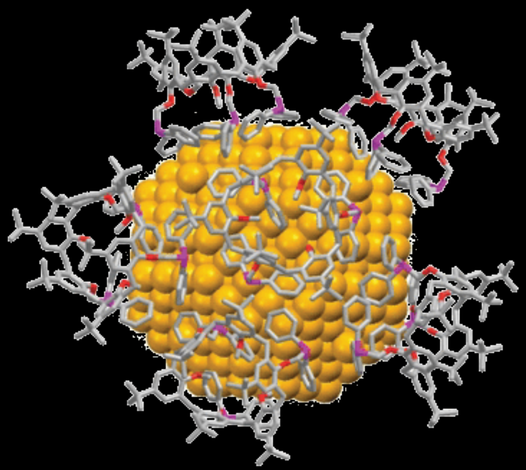
Ligand + Contrast-providing agent =

Specific targeted contrast particle/agent

AptaMark:

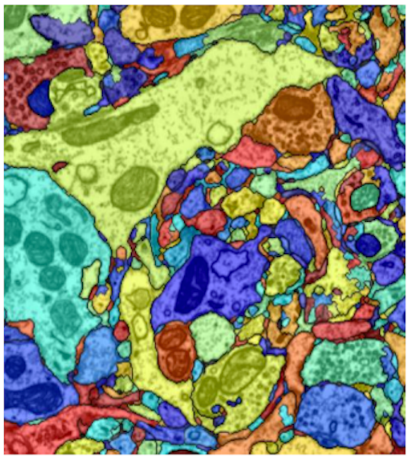
Targeted RNA aptamers + gold nanoparticles =

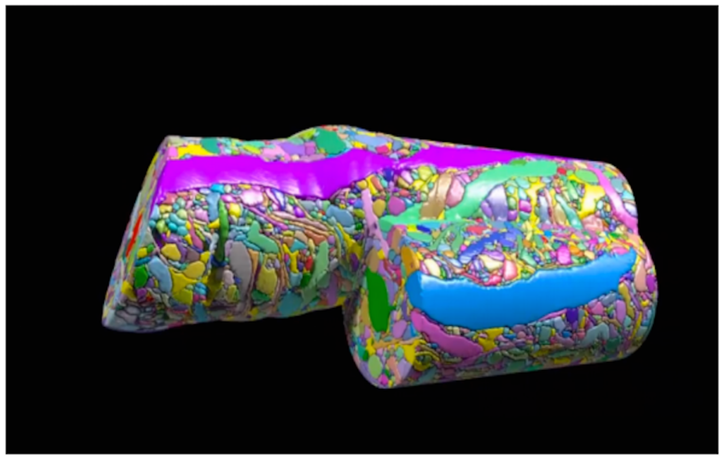
Specific targeted contrast particle/agent



Quoting Randal Koene…

Where are we now - on reconstructing brains?





?

$$C\frac{dV}{dt} = -g_1 m^3 h(V - E_1) - g_2 n^4 (V - E_2) - g_3(V - E_3) + I_{\text{stim}},$$

$$\frac{dm}{dt} = (1 - m)\alpha_m(V - E_0) - m\beta_m(V - E_0),$$

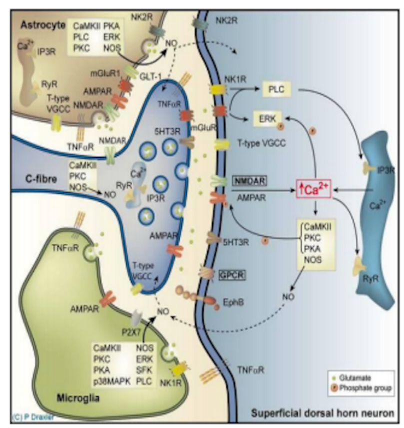
$$\frac{dn}{dt} = (1 - n)\alpha_n(V - E_0) - n\beta_n(V - E_0),$$

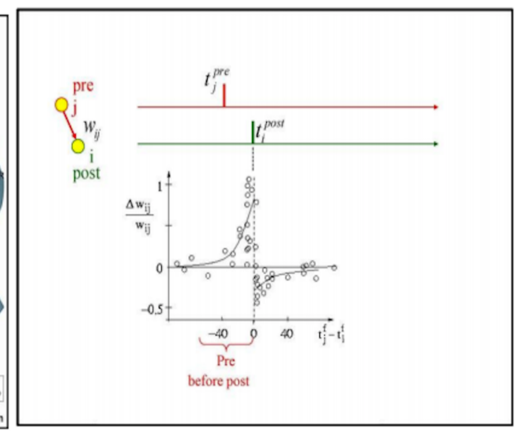
$$\frac{dh}{dt} = (1 - h)\alpha_h(V - E_0) - h\beta_h(V - E_0),$$

We lack information to infer function from structure

We can do direct functional system identification (see hippocampal prosthesis)

Demands better recording & stimulation

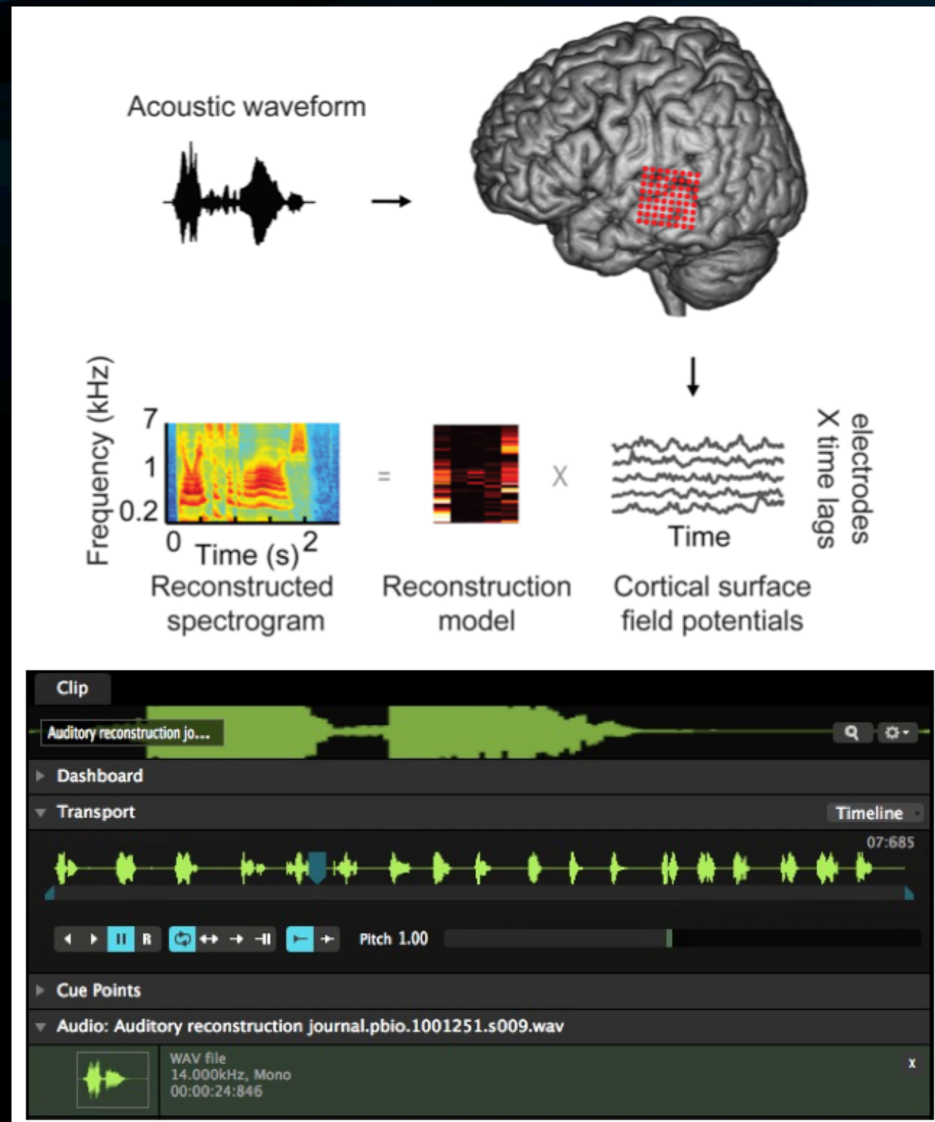




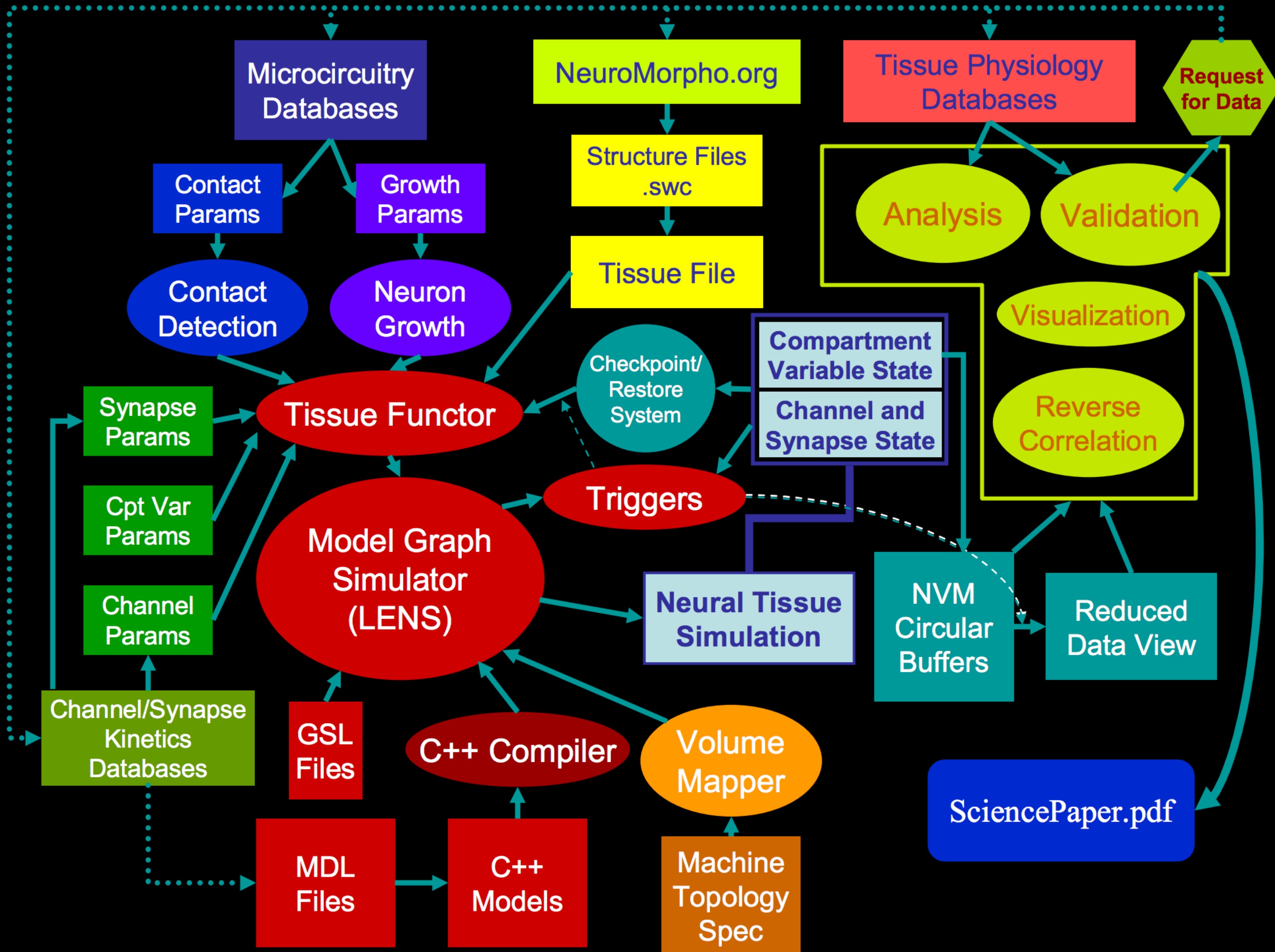
evolutionary patchwork vs the 'language' of the brain

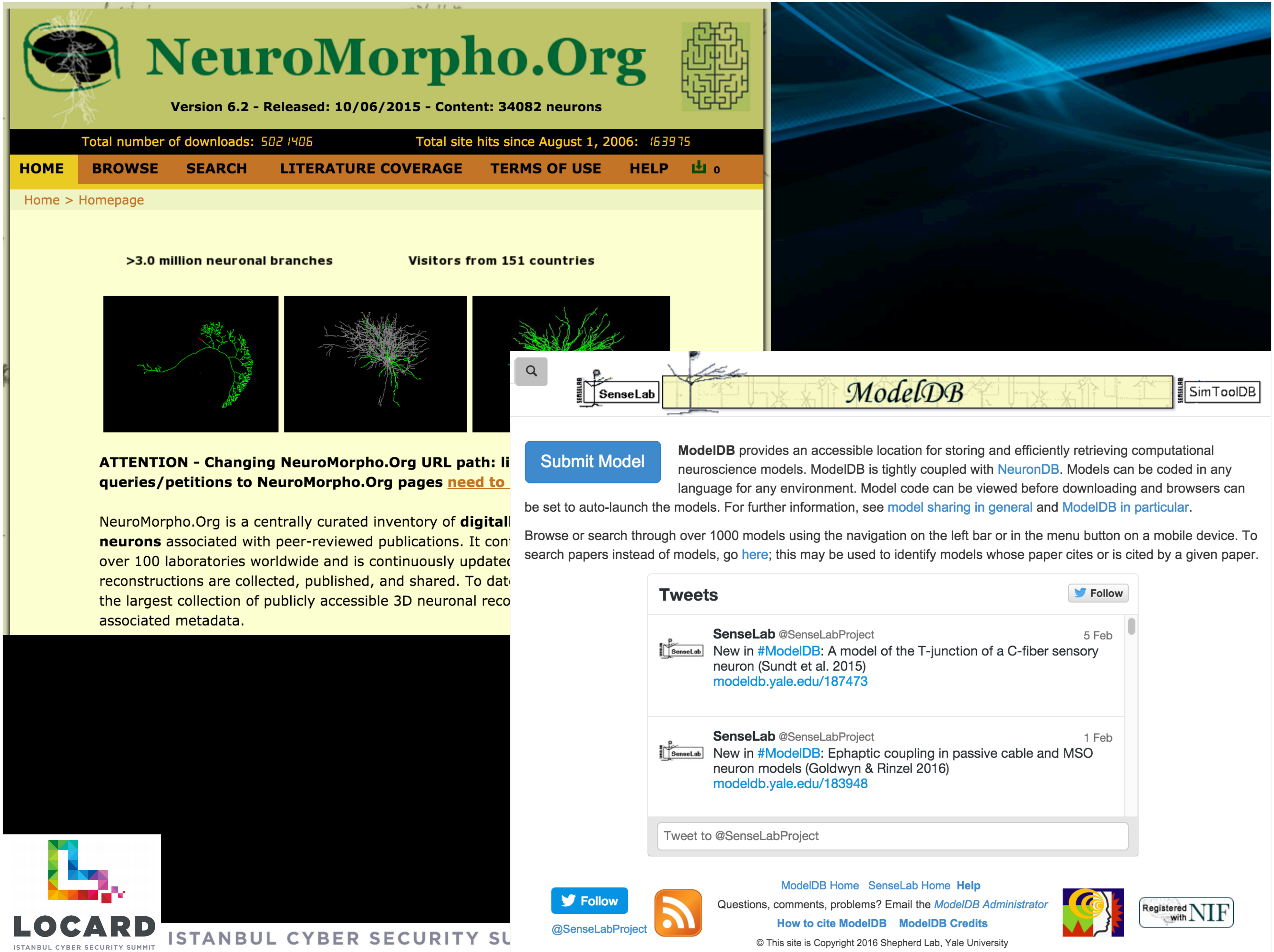
Decoding the visual cortex

Decoding the auditory cortex



Neural Tissue Simulator Workflow

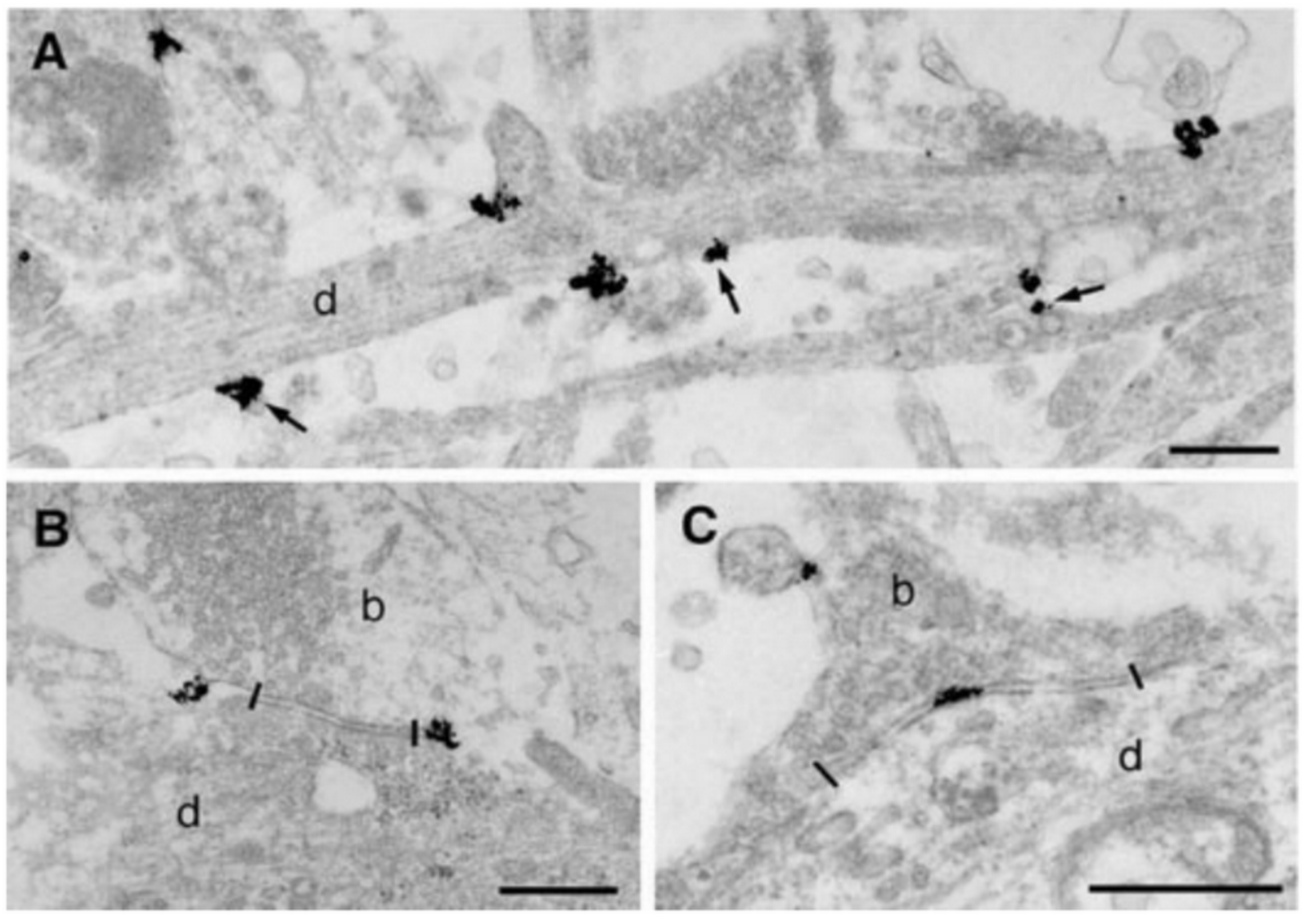



NeuroMorpho.Org
Version 6.2 - Released: 10/06/2015 - Content: 34082 neurons
Total number of downloads: 502 1406
Total site hits since August 1, 2006: 163975
HOME BROWSE SEARCH LITERATURE COVERAGE TERMS OF USE HELP 0
Home > Homepage
>3.0 million neuronal branches
Visitors from 151 countries
ATTENTION - Changing NeuroMorpho.Org URL path: li
queries/petitions to NeuroMorpho.Org pages need to
NeuroMorpho.Org is a centrally curated inventory of digital
neurons associated with peer-reviewed publications. It con
over 100 laboratories worldwide and is continuously updated
reconstructions are collected, published, and shared. To dat
the largest collection of publicly accessible 3D neuronal reco
associated metadata.
SenseLab
ModelDB
SimToolDB
Submit Model
ModelDB provides an accessible location for storing and efficiently retrieving computational neuroscience models. ModelDB is tightly coupled with NeuronDB. Models can be coded in any language for any environment. Model code can be viewed before downloading and browsers can be set to auto-launch the models. For further information, see model sharing in general and ModelDB in particular.
Browse or search through over 1000 models using the navigation on the left bar or in the menu button on a mobile device. To search papers instead of models, go here; this may be used to identify models whose paper cites or is cited by a given paper.
Tweets
Follow
SenseLab @SenseLabProject 5 Feb
New in #ModelDB: A model of the T-junction of a C-fiber sensory neuron (Sundt et al. 2015)
modeldb.yale.edu/187473
SenseLab @SenseLabProject 1 Feb
New in #ModelDB: Ephaptic coupling in passive cable and MSO neuron models (Goldwyn & Rinzel 2016)
modeldb.yale.edu/183948
Tweet to @SenseLabProject
Follow
@SenseLabProject
ModelDB Home SenseLab Home Help
Questions, comments, problems? Email the ModelDB Administrator
How to cite ModelDB ModelDB Credits
© This site is Copyright 2016 Shepherd Lab, Yale University
Registered with NIF
LOCARD
ISTANBUL CYBER SECURITY SUMMIT
ISTANBUL CYBER SECURITY SU

GlyR-a1 subunits imaged using primary antibody (mAb2b), biotinylated anti-mouse Fab fragments, and streptavidin-coated quantum dots.

EM resolution vs. nanoCT

Fig. 4. Transmission EM detection of QD-GlyRs. QD-GlyRs detected on the dendritic surface and associated with extrasynaptic membranes (arrows) (**A**), at the periphery of synapses (**B**), and within the synaptic cleft (**C**). d, dendrites; b, synaptic boutons. The edges of the synaptic clefts are outlined in (B) and (C). Scale bars, 500 nm.



Neurological Imaging Targets

For memory encoding:

AMPA-R

Exclusive glutamate, excitatory, Na+ influx ONLY, hetero OR homo-tetramer, FAST

NMDA-R

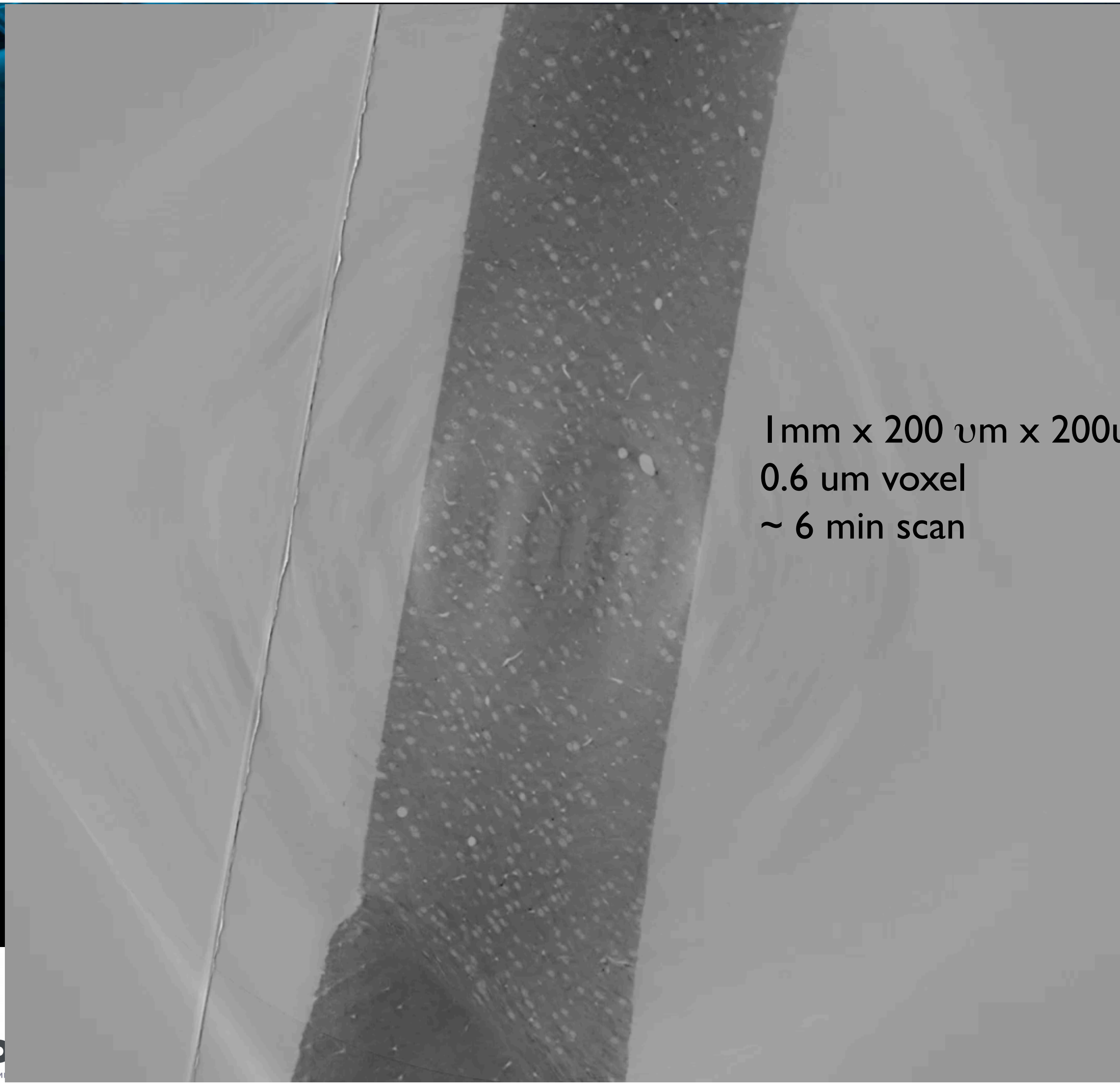
Glutamate and glycine receptor, inhibitory, Ca2+ and Na+ influx, GluN1 GluN2 heterotetramer -- always 2 GluN1 + either GluN2 or GluN3. Has Mg+ in core. SLOW

Type	Subtype	Gene	Uniprot accession number
Adrenergic			
α1A, α1b, α1c, α1d	α1A	ADRA1A	P35348
	α1b	ADRA1B	P35368
	α1c	ADRA1C	Q7KYZ9/Q6LD06
	α1d	ADRA1D	P25100
α2a, α2b, α2c, α2d	α2a	ADRA2A	P08913
	α2b	ADRA2B	P18089
	α2c	ADRA2C	P18825
	α2d	adra2da/adra2db	Q8JG70/Q8JG69
β1, β2, β3	β1	ADRB1	P08588
	β2	ADRB2	P07550
	β3	ADRB3	P13945
Dopaminergic			
D1, D2, D3, D4, D5	D1	DRD1	P21728
	D2	DRD2	P14416
	D3	DRD3	P35462
	D4	DRD4	P21917
	D5	DRD5	P21918
GABAergic			
GABAA, GABAB1a, GABAB1δ, GABAB2, GABAC	GABAA		
	GABAB1a	GABRA1	P14867
...	...	...	...

Imaging method (size/time)	Contrast agent	Ligand	Delivery	Indication/ application	Shortcoming
X-ray CT (200-400nm/ 10 mins)	15 nm Au NP	GluR1 aptamer	Insulin, aptamer	Synaptic weights, GluR1 densities, brain mapping	Radiation, expense of machine
"	KI	None	None	Tissue stain	Non-specific
NIR (400nm/ ms)	Upconverting NP	Aptamer/ antibody	Aptamer	Surface receptor densities	Toxicity of NPs (?), slower response time
"	Au nanorod	Aptamer/ antibody	Aptamer	Voltage sensitive	Orientation
MR	Paramagnetic NP	Aptamer/ antibody	Aptamer	Region activity, blood flow, tau, synuclein	1-5mm voxel
Fluorescence microscopy (400nm/ms)	15 nm Au NP	GluR1 aptamer	None, surface accessible	Targeting quality control	Serial sectioning, shallow depth, destructive
Electron microscopy (EM)(10 -40nm/∞)	Osmium tetroxide	None	Histological stain	High-res imaging	No biological metabolites, no protein density info

Technical Specifications & Configurations

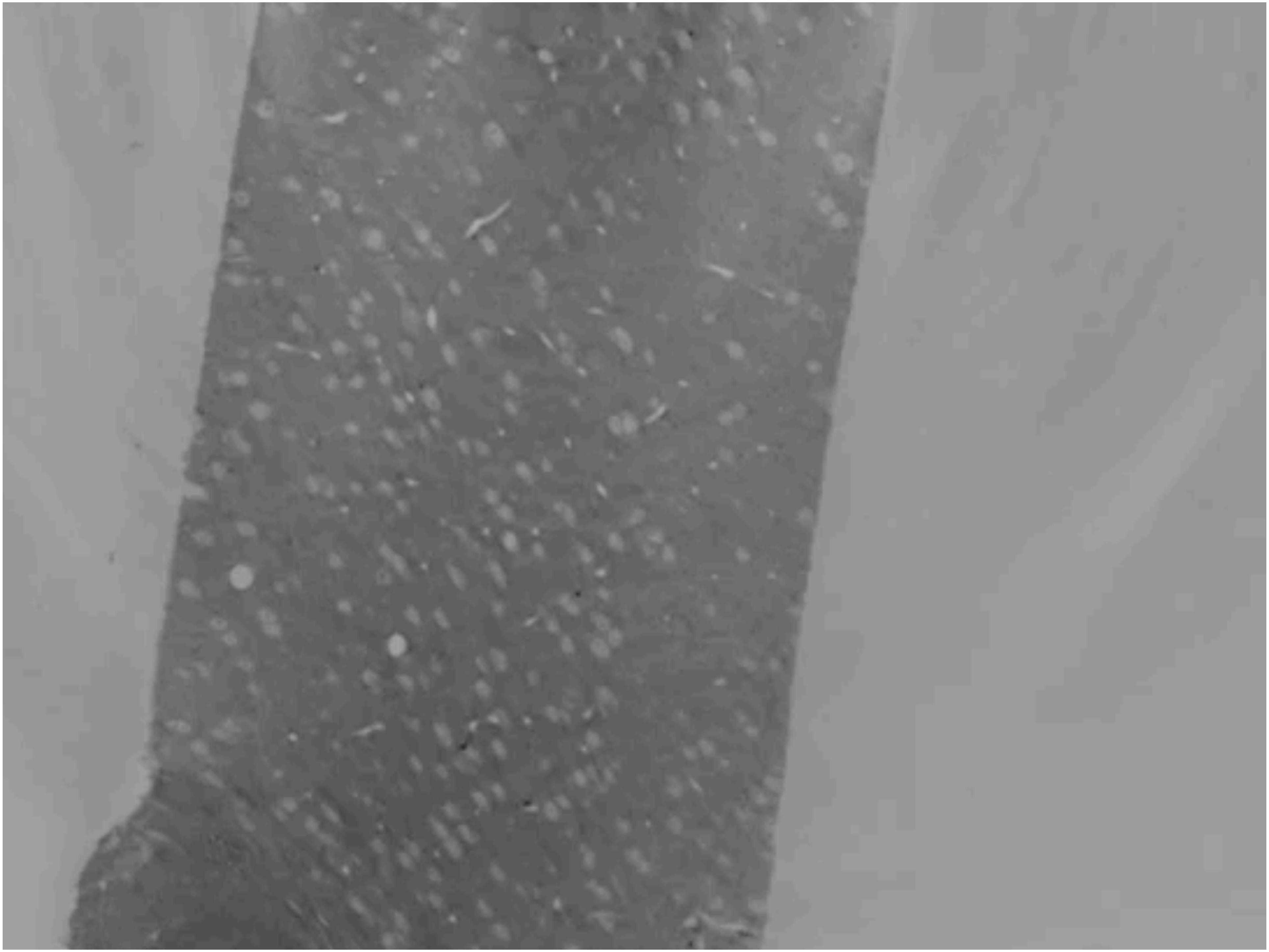
	phoenix nanotom s	phoenix nanotom m
X-ray tube type	Proprietary open high-power nanofocus X-ray tube, optimized for long-term stability	
	Optional X-ray tube cooling	Internal X-ray tube cooling
Max. voltage / power	180 kV / 15 W	
Target	Tungsten on beryllium (optional tungsten on CVD diamond)	Tungsten on CVD diamond for up to 2 times faster data acquisition at the same high image quality level
	Transmission target type, rotatable for multiple use (other target materials, e.g. molybdenum on request)	
Filament	Tungsten hairpin, pre-adjusted plug-in cartridges for fast and easy exchange	
Geom. magnification (3D)	1.7 x - 250 x	1.5 x - 300 x
Detail detectability	Down to 200 nm (0.2 microns)	Down to 200 nm (0.2 microns)
Min. voxel size	Down to 500 nm (0.5 microns)	Down to 300 nm (0.3 microns)
Detector type	High-Contrast|Detector HCD 120-50, 12 bit / 16 bit, 3 x virtual detector enlargement (max. 6,900 pixel detector width)	Temperature-stabilized high dynamic GE DXR, 14 bit / 16 bit, 1.5 x detector enlargement (max. 4,600 pixel detector width)
Pixels	2,300 x 2,300	3,072 x 2,400
Pixel size	50 µm	100 µm
Manipulation	Granite based 5-axes manipulator with vibration insulation, precision rotation table on air bearings	
Variable focus detector distance	from 200 mm to 500 mm	from 220 mm to 600 mm
Max. sample diameter	< 1 mm to 120 mm	< 1 mm to 240 mm
Max. sample height / weight	150 mm / 2 kg (4.4 lbs.)	250 mm / 3 kg (6.6 lbs.)
Sample travel length Y / Z	150 mm / 300 mm	250 mm / 400 mm
Rotation	0° - 360° x n	



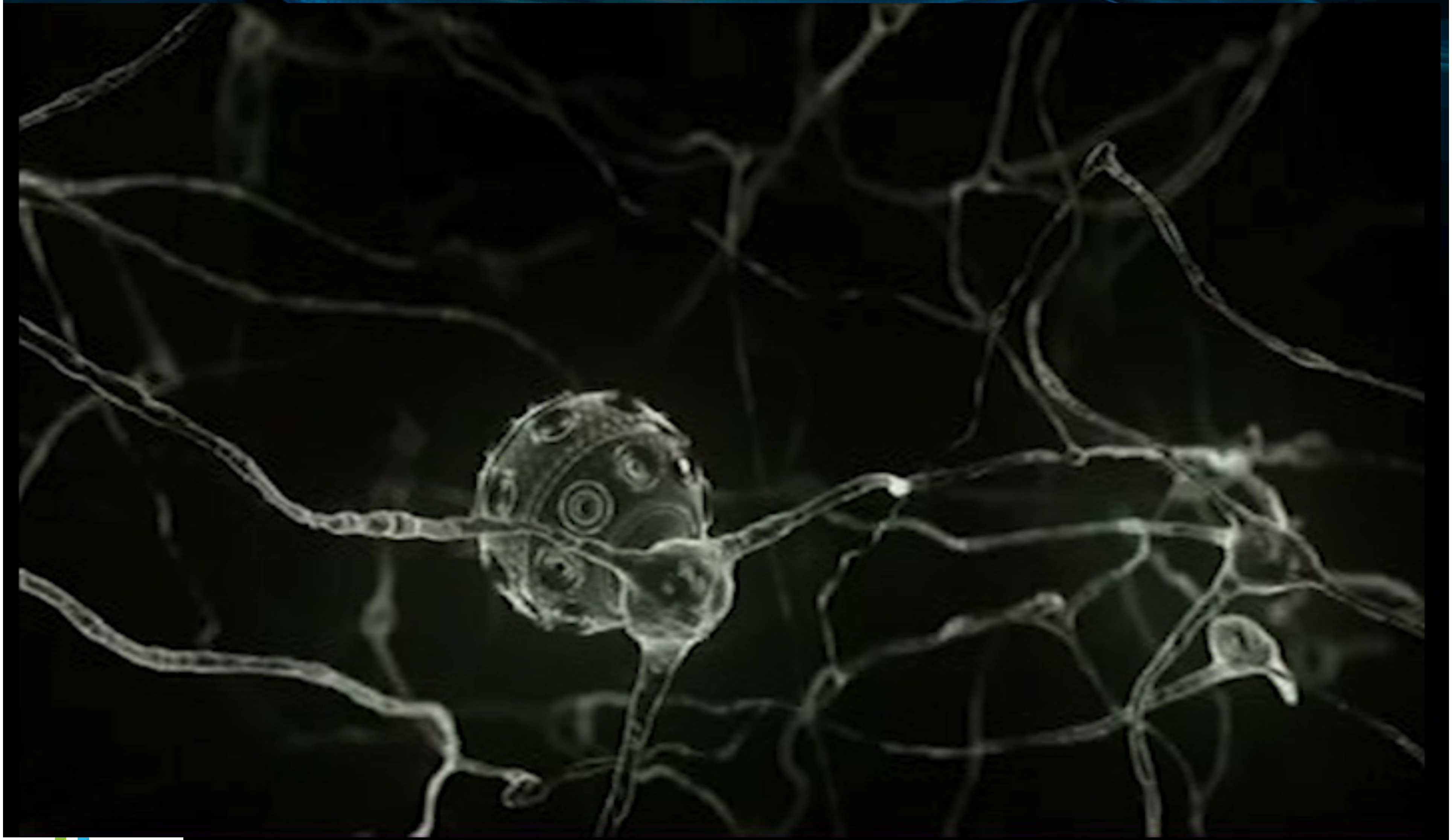
1mm x 200 υm x 200u

0.6 um voxel

~ 6 min scan



Nanorobots



Ex vivo EM imaging: synapses

Dvorsky's Complaint #1: Brain functions are not computable

"Is" and "are" are complicated words, semantically…. Computability, in the sense it's used in Dvorsky's complaint, is a mathematical tool used for modeling certain systems. So his claim would be "brain functions cannot be effectively modeled using computable models."

This is an interesting hypothesis, but there is certainly no scientific evidence for it. Furthermore, within the confines of current science, there is no possible way to gather solid scientific evidence for it. The problem is that all scientific data ever gathered, constitutes one large but finite set of bits (i.e a finite set of finite-precision numbers). Any finite set of bits can be modeled computationally. Of course, someone can claim a non-computable model is "better" than any computational model, for a given finite set of bits. But this then becomes a subjective claim, based on aesthetics, or intuition.

Perhaps some future discipline, going beyond the bounds of science as we know it today, will formulate some new sense in which brains fundamentally cannot be computationally modeled. But this vague possibility seems a rather threadbare excuse for rejecting mind uploading.

Ethical implications of brain imaging?

“My personal view about the ‘ethical implications’ is that it is unethical to NOT permit tetraplegic patients or other injured parties to receive next-generation neural interfaces. And regarding connectome imaging -- again my personal view is that it is unethical to NOT permit patients or other interested parties to image their connectome, just like withholding genetic/genomic data from an oncologist/cancer patient is presently unconscionable. If one is afraid of knowledge, one's head is truly in the sand.”

Outstanding problems, areas for outstanding contributions!

- Implanted CPU with database of neural codes
- Deep learning to improve interfaces using ephys spikes to sensorimotor cortex
- AI/ML to trace neurons/axons in image stack data
- Neural Modem: In the next 3-4 years DARPA wants a device that reads from 1,000,000 neurons stimulates 100,000 neurons. Cochlear implant uses only 4 electrodes.

THE END

Thanks to the Locard team!
And the kind people of Turkey! B)

russellhanson@brainbackups.com
russell.hanson@mssm.edu
http://www.linkedin.com/in/russellhanson
http://twitter.com/russell_hanson
http://www.russellhanson.com/