Computational Neuroscience

2019

Final discussion

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From the NIH web site:
Committee report: Brain 2025: A Scientific Vision (from 2014)

#1. Discovering diversity: Identify and provide experimental access to the different brain cell types to determine their roles in health and disease. It is within reach to characterize all cell types in the nervous system, and to develop tools to record, mark, and manipulate these precisely defined neurons in the living brain. We envision an integrated, systematic census of neuronal and glial cell types, and new genetic and non-genetic tools to deliver genes, proteins, and chemicals to cells of interest in non-human animals and in humans.

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#2. Maps at multiple scales: Generate circuit diagrams that vary in resolution from synapses to the whole brain. It is increasingly possible to map connected neurons in local circuits and distributed brain systems, enabling an understanding of the relationship between neuronal structure and function. We envision improved technologies—faster, less expensive, scalable— for anatomic reconstruction of neural circuits at all scales, from non-invasive whole human brain imaging to dense reconstruction of synaptic inputs and outputs at the subcellular level.

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#3. The brain in action: Produce a dynamic picture of the functioning brain by developing and applying improved methods for large-scale monitoring of neural activity. We should seize the challenge of recording dynamic neuronal activity from complete neural networks, over long periods, in all areas of the brain. There are promising opportunities both for improving existing technologies and for developing entirely new technologies for neuronal recording, including methods based on electrodes, optics, molecular genetics, and nanoscience, and encompassing different facets of brain activity.

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#4. Demonstrating causality: Link brain activity to behavior with precise interventional tools that change neural circuit dynamics. By directly activating and inhibiting populations of neurons, neuroscience is progressing from observation to causation, and much more is possible. To enable the immense potential of circuit manipulation, a new generation of tools for optogenetics, chemogenetics, and biochemical and electromagnetic modulation should be developed for use in animals and eventually in human patients.

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#5. Identifying fundamental principles: Produce conceptual foundations for understanding the biological basis of mental processes through development of new theoretical and data analysis tools. Rigorous theory, modeling, and statistics are advancing our understanding of complex, nonlinear brain functions where human intuition fails. New kinds of data are accruing at increasing rates, mandating new methods of data analysis and interpretation. To enable progress in theory and data analysis, we must foster collaborations between experimentalists and scientists from statistics, physics, mathematics, engineering, and computer science.

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#6. Advancing human neuroscience: Develop innovative technologies to understand the human brain and treat its disorders; create and support integrated human brain research networks. Consenting humans who are undergoing diagnostic brain monitoring, or receiving neurotechnology for clinical applications, provide an extraordinary opportunity for scientific research. This setting enables research on human brain function, the mechanisms of human brain disorders, the effect of therapy, and the value of diagnostics. Meeting this opportunity requires closely integrated research teams performing according to the highest ethical standards of clinical care and research. New mechanisms are needed to maximize the collection of this priceless information and ensure that it benefits people with brain disorders.

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#7. From BRAIN Initiative to the brain: Integrate new technological and conceptual approaches produced in Goals #1-6 to discover how dynamic patterns of neural activity are transformed into cognition, emotion, perception, and action in health and disease. The most important outcome of the BRAIN Initiative will be a comprehensive, mechanistic understanding of mental function that emerges from synergistic application of the new technologies and conceptual structures developed under the BRAIN Initiative.

The overarching vision of the BRAIN Initiative is best captured by Goal #7—combining these approaches into a single, integrated science of cells, circuits, brain, and behavior.

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Cross boundaries in interdisciplinary collaborations. No single researcher or discovery will solve the brain's mysteries. The most exciting approaches will bridge fields, linking experiment to theory, biology to engineering, tool development to experimental application, human neuroscience to non-human models, and more, in innovative ways.

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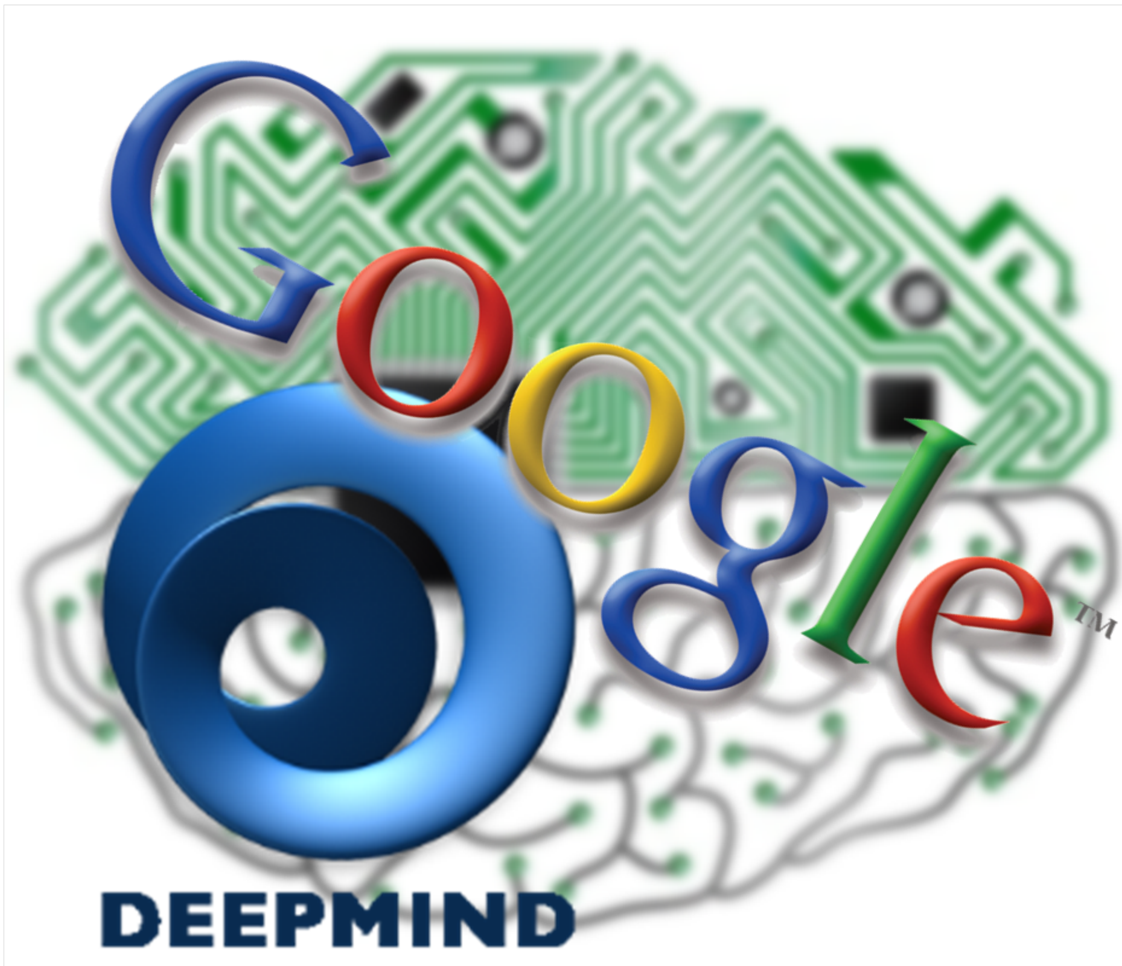
Theory, Modeling, and Statistics Will Be Essential to Understanding the Brain

Ideally, theorists and statisticians should be involved in experimental design and data acquisition, not just recruited at the step of data interpretation.

Lots of recent interest from industry



Google Brain

"We are a machine intelligence team focused on deep learning. We advance the state of the art in order to have a positive impact on the world. We achieve this goal by focusing on highly flexible models that learn their own features, end-to-end, and make efficient use of data and computation. This approach fits into the broader Deep Learning subfield of ML and ensures our work will ultimately make a difference for problems of practical importance."

Computational neuroscience

Deep Mind: solve intelligence.
Use it to make the world a better place

"We joined forces with Google in order to turbo-charge our mission. The algorithms we build are capable of learning for themselves directly from raw experience or data, and are general in that they can perform well across a wide variety of tasks straight out of the box. Our world-class team consists of many renowned experts in their respective fields, including but not limited to deep neural networks, reinforcement learning and systems neuroscience-inspired models."

Computational neuroscience

IBM Research: Cognitive computing:

"The Cognitive Era: By any measure, 2015 has been a landmark year for the discussion around artificial intelligence and its potential impact on business and society. Be part of the conversation as we explore a fascinating and diverse set of issues related to the powerful cognitive technologies that are emerging to augment human capacity and understanding."

Computational neuroscience

Conceptual and technical advances define a key moment for theoretical neuroscience

Anne K Churchland & L F Abbott

Theoretical approaches have long shaped neuroscience, but current needs for theory are elevated and prospects for advancement are bright. Advances in measuring and manipulating neurons demand new models and analyses to guide interpretation. Advances in theoretical neuroscience offer new insights into how signals evolve across areas and new approaches for connecting population activity with behavior. These advances point to a global understanding of brain function based on a hybrid of diverse approaches.

Churchland, A.K. and Abbott, L.F. (2016)

Computational neuroscience

"In the coming years, we will obtain enormous quantities of behavioral, recording (both electrical and optical), connectomic, gene expression and other forms of data. Obtaining deep understanding from this onslaught will require, in addition to the skillful and creative application of experimental technologies, substantial advances in data analysis methods and intense application of theoretic concepts and models."

Fields evolving include …

- Computational Cognitive Neuroscience (new conference combining AI, Cognitive Science, Neuroscience)
- Decision making and reinforcement learning. "Perceptual Decision-Making: A Field in the Midst of a Transformation" (Najafi, Churchland 2018)
- Computational Psychiatry
- Vision and learning …
- New approaches and analyses for making sense of large scale data

Related research areas At UM

- Computational Neuroscience
- Neural Engineering and Brain machine Interfaces
- Machine learning
- Data science
- Large-scale fMRI
- Technology such as optogenetics
- Neuroscience / Biology
- Robotics