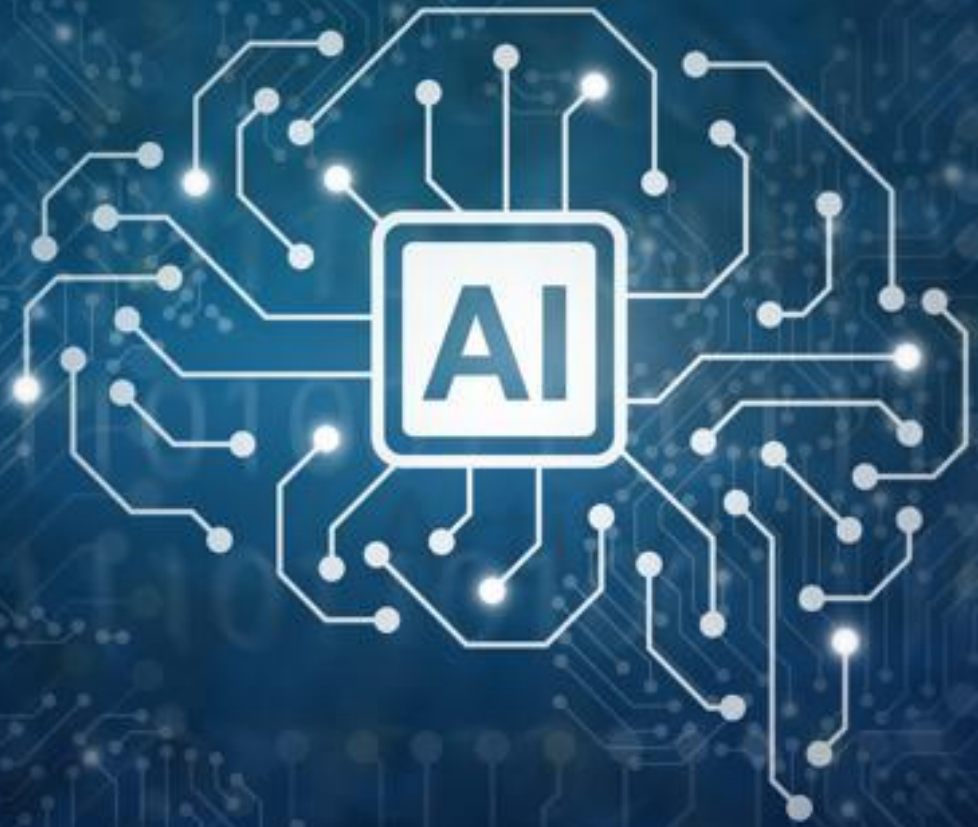
Brain and cognitive information: from biological to artificial intelligence



Konstantin Anokhin
Institute for Advanced Brain Studies, Moscow State University

4th Korea-Russia Science Day, 2-3 December 2020

The main unresolved task of modern neuroscience is to understand the nature of COGNITIVE TRANSITION – the emergence of biological systems with cognitive capabilities

Answer to this question might lead to new clues for the development of ARTIFICIAL COGNITIVE SYSTEMS

Addressing this issues is the goal of a new Russian cross-disciplinary project

Brain and Information: From Natural to Artificial Intelligence

The focus of the project is the notion of cognitive information – encoding by the system's elements of interactions of the whole system with the relevant environment

Participating institutions:

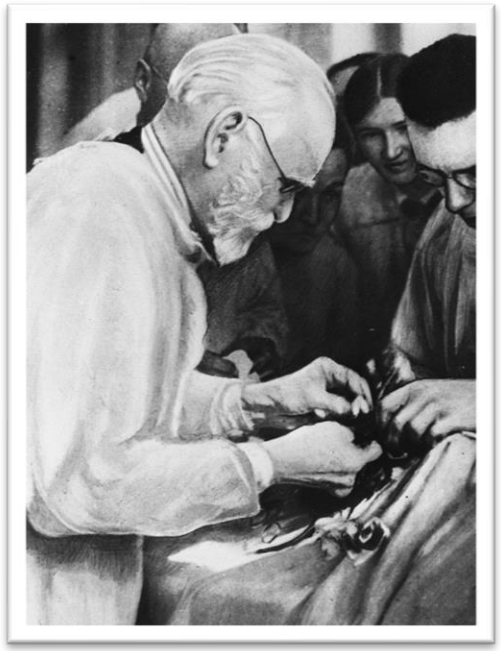
- Lomonosov Moscow State University
- Institute of Higher Nervous Activity and Neurophysiology, Russian Academy of Sciences
- Marchuk Institute of Numerical Mathematics, Russian Academy of Sciences

Project Director

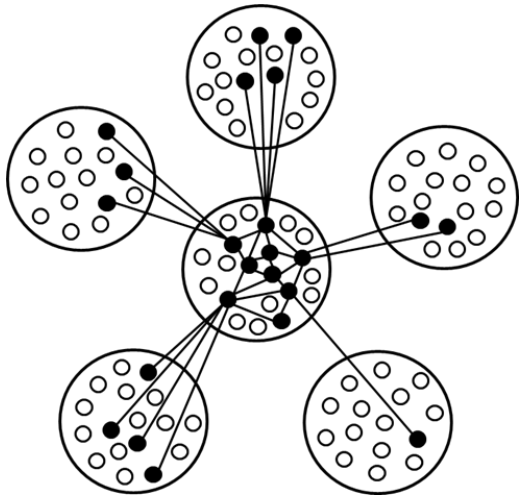
Prof. Viktor Sadovnichiy

Faculty of Mechanics and Mathematics, Moscow State University

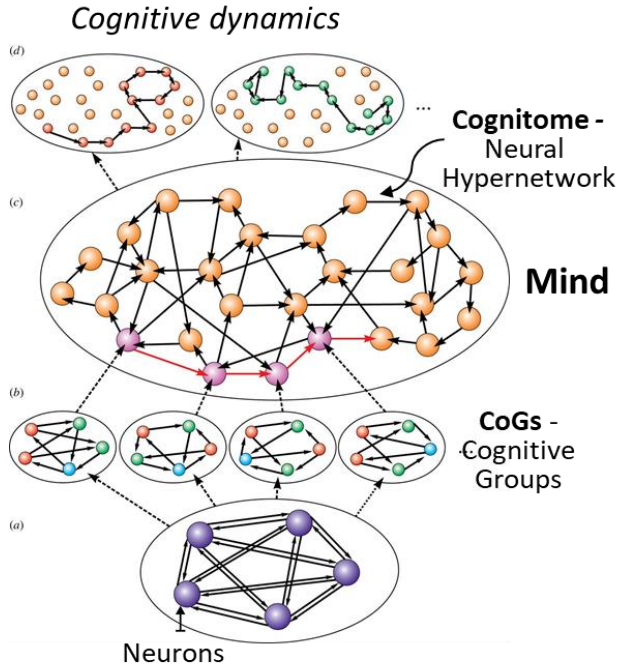
Our background I: Physiology of the higher nervous activity



“How the matter of the brain produces subjective experience?”
(Ivan Pavlov, 1907)



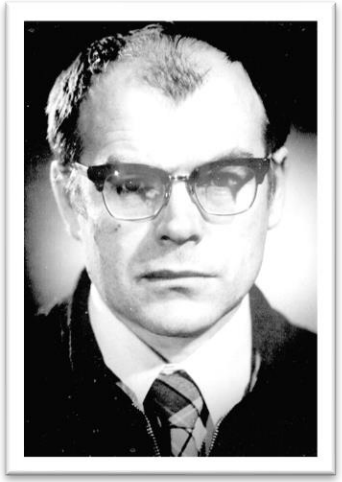
Functional Systems Theory



Neural Hypernetwork Theory

Our background I: Physiology of the higher nervous activity

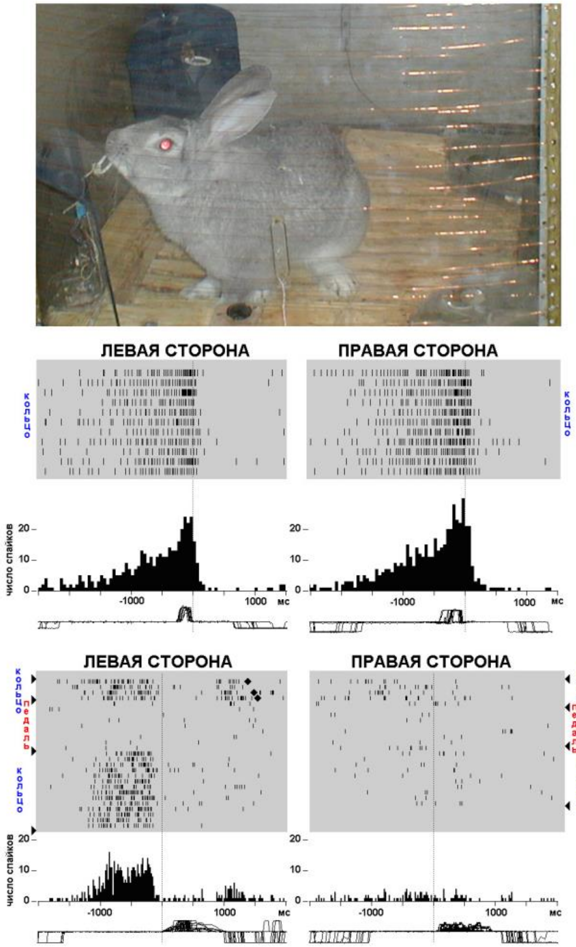
The cellular bases and neuronal mechanisms of functional systems
Were extensively studied in the Russian neuroscience

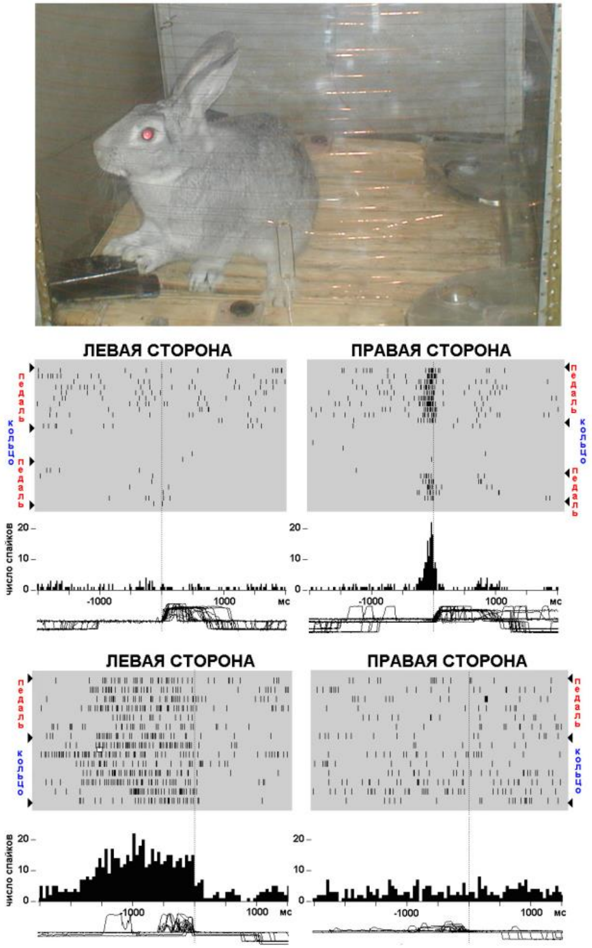


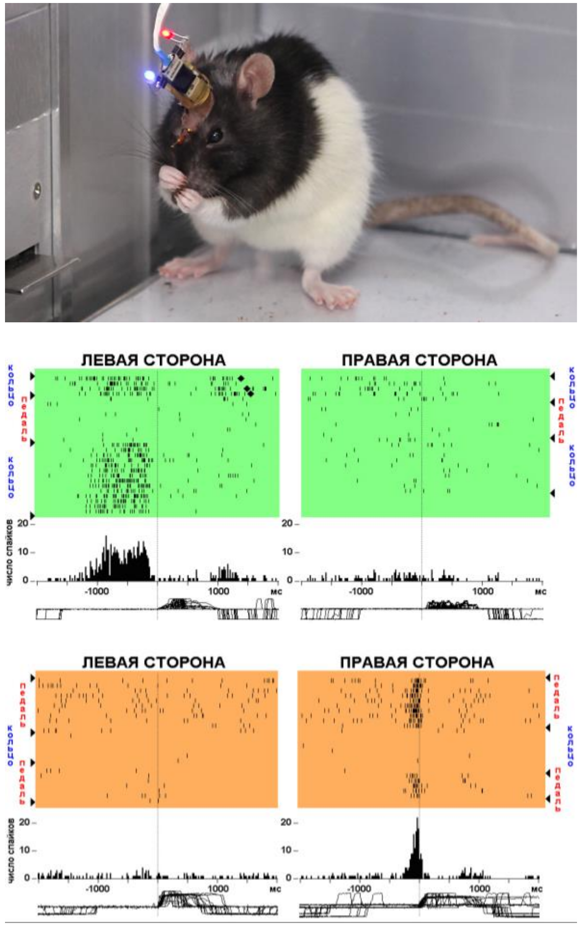
V.B. Shvyrkov
(1940-1994)

Systems determination of neuronal activity during behavior

Adv.Physiol.Sci., **14** (1983) 1-27

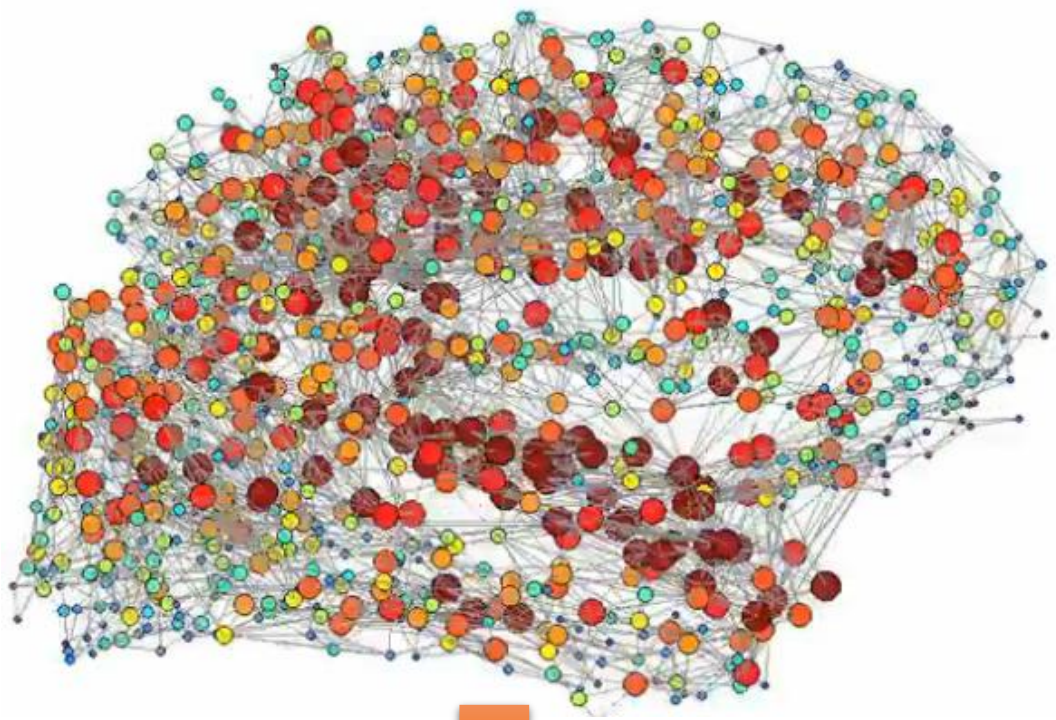






Our background II: Mapping functional systems in the brain

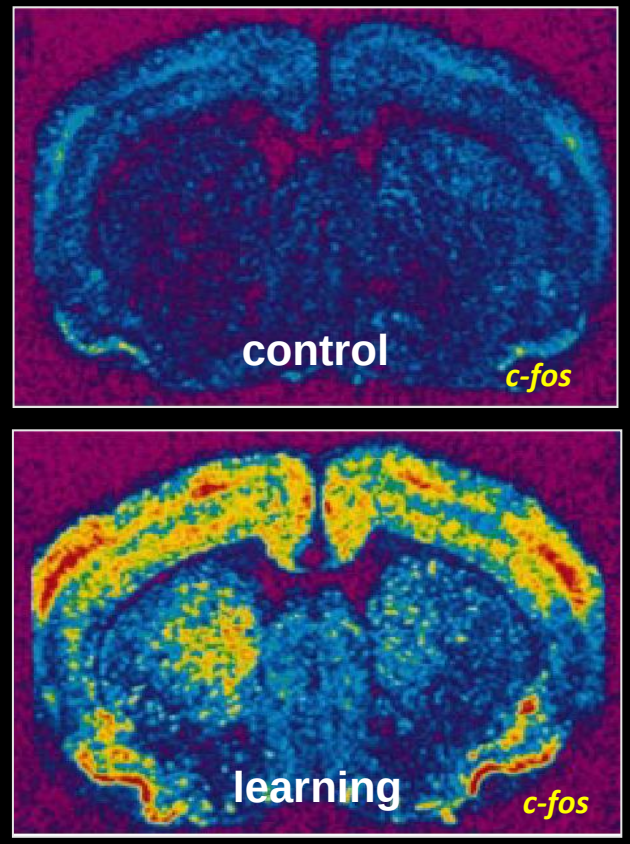
However the difficulty to study functional systems experimentally
was that each such system consists of millions of active neuron distributed over the brain



We have developed a set of new tools to image cellular functional systems in the brain,
to interrogate their formation and to control their operations

Our background II: Mapping functional systems in the brain

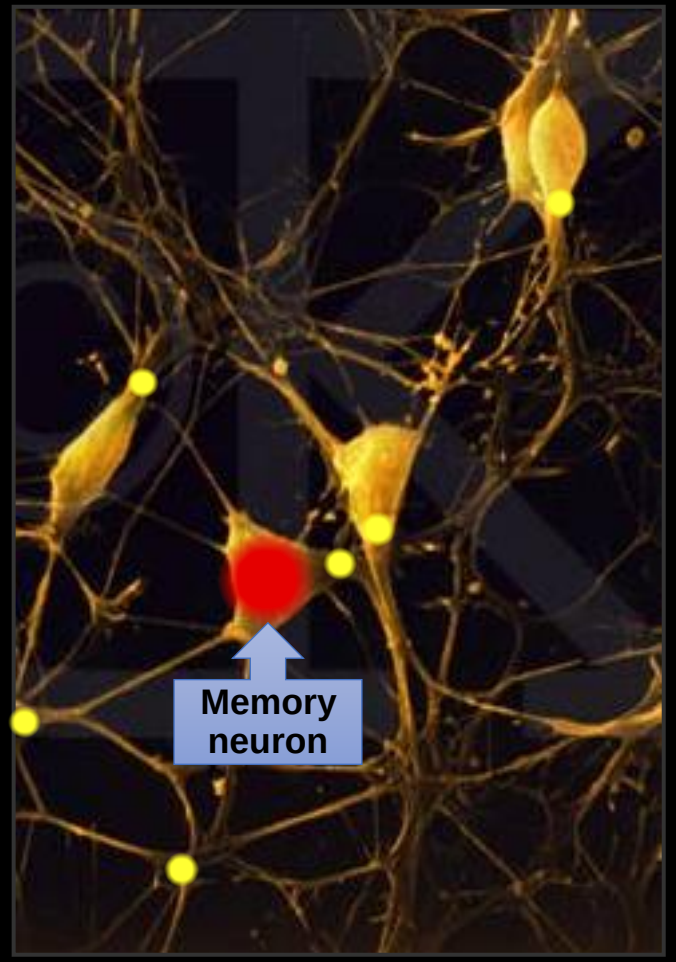
Induction of Immediate Early Genes (IEGs) in nerve cells upon learning



N. Maleeva et al. (1988) *Genetics*

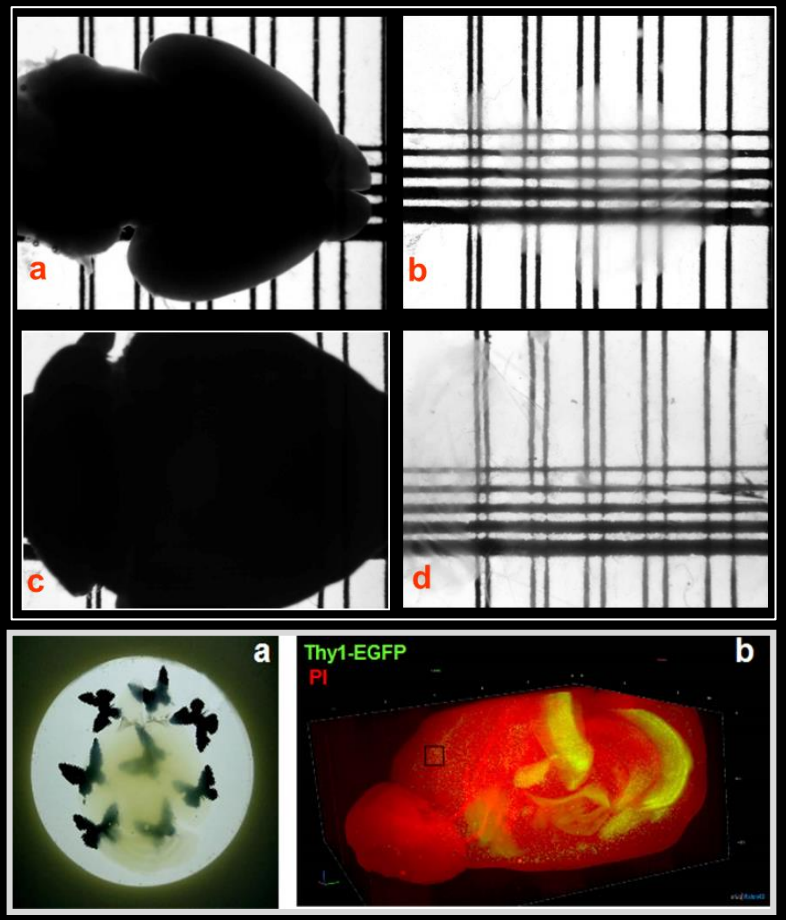
Expression of IEGs can be used to image neuronal traces of learning and memory assemblies in the whole brain

Immediate early gene expression:
Occurs in neurons
Is rapid (mRNA in minutes)
Has low background level
Is induced during learning
Is distributed over various brain areas
Depends on NMDA-R activity
Is involved in long-term changes of neuronal properties
Is required for consolidation of long-term memory



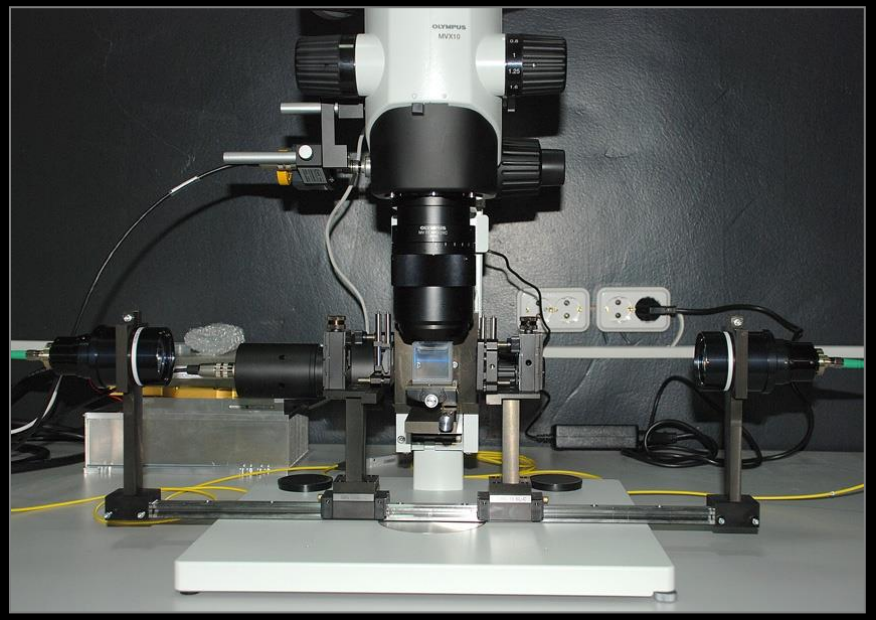
Our background II: Mapping functional systems in the brain

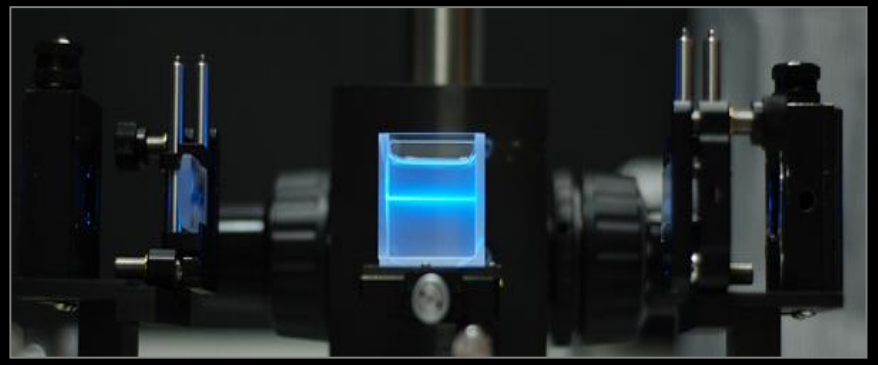
“Transparent Brain” Project (2003-2009)



Whole brain and body optical clearing with LUMOS (LUminocity Maintaining Opti-clearing Solution)

Whole body light-sheet microscopy of optically cleared 20 day-old mouse embryo

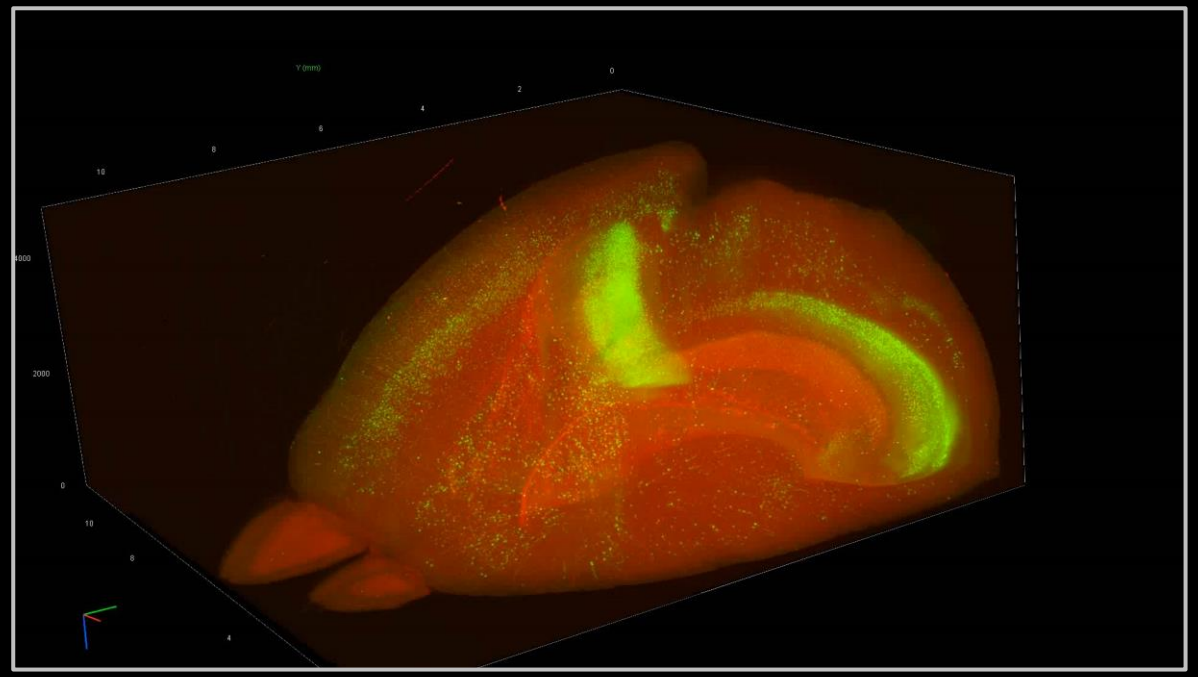


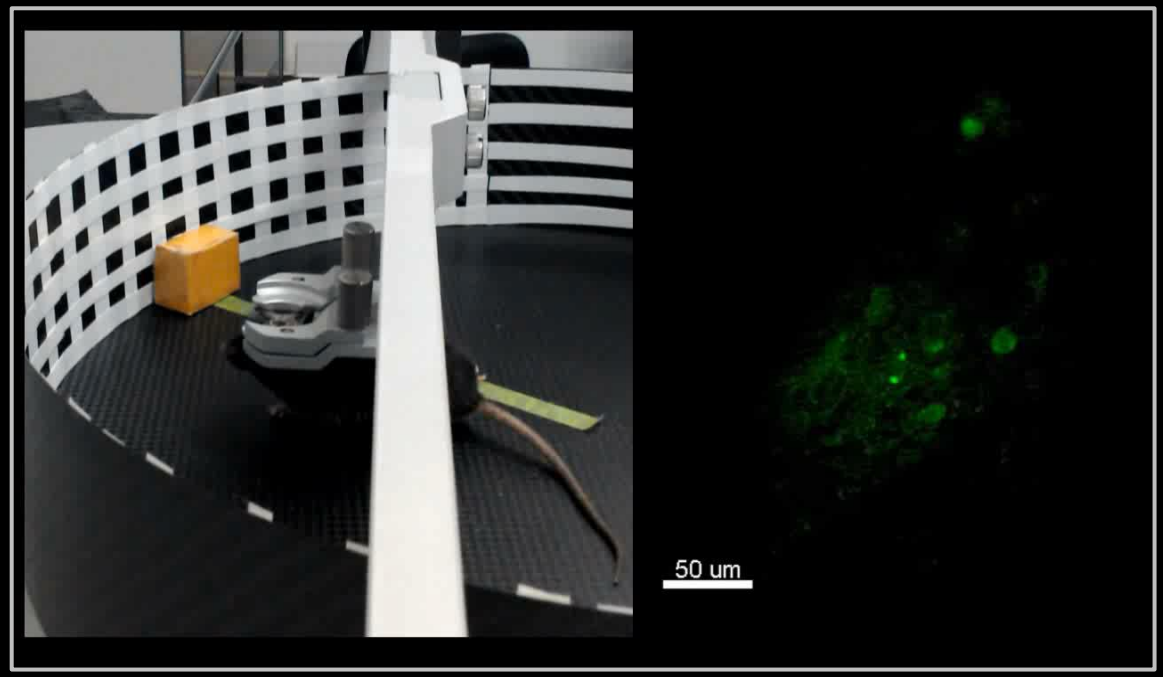


A.Lazutkin et al., 2008

Current project tools: Neural photonics

From Transparent Brain Project to Transparent Neural Intelligence Project





Ex vivo brain cognitive activity cellular imaging

In vivo natural intelligence dynamic imaging

Using these tools we ask the following questions:

- What is the nature of cognitive information in biological neural networks?
- What one bit of cognitive information in the neuronal network?
- How is it acquired and allocated into particular neurons?
- How is it stored in individual neurons and retrieved from memory?
- How cognitive information can be measured quantitively in the brain?
- How can it be it be implemented in artificial neuromorphic systems?

Thank you for attention