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Dr. Vijayalakshmi Ravindranath is the Founder Director of the National Brain Research Centre, a Deemed University, which has been recently established by the Government of India as a centre of excellence to co-ordinate and network neuroscience research groups in the country. After completing her Master's degree, she obtained her Ph.D in Biochemistry from Mysore University in India and carried out post-doctoral research at the National Institutes of Health, USA. Prior to taking over the current position at NBRC, she was a Professor of Neurochemistry at National Institute of Mental Health and Neurosciences, Bangalore where her research centered on identifying the factors involved in differential drug responses often seen in patients with mental illnesses. She has also been studying the molecular mechanisms underlying the pathogenesis of neurodegenerative disorders such as Parkinson's disease and motor neuron disease. She has spear-headed the establishing of the NBRC and networked over 45 institutions involved in neuroscience research and helped to develop multi-institutional and multi-disciplinary collaborations while making available the facilities at NBRC to neuroscientists from other centers.

She has won many awards like Shanti Swarup Bhatnagar Award for Medical Sciences, 1996, Omprakash Bhasin Award for Science and Technology, 2001 & K.P. Bhargava Medal of INSA (2001). She is the fellow of The National Academy of Sciences, India, 1998, Indian Academy of Science, 2001, Third World Academy of Sciences, 2002 and Indian National Science Academy, 2004. She is also member of Governing Council of International Brain Research Organisations, Council of Federation of Asian and Oceanian Neuroscience Societies, International Neurotoxicology Association & International Society for Neurochemistry, American Association for Advancement in Science to name a few. She is member of various editorial boards like Progress in Neurobiology, International Journal Neurotoxicity Research, Neuroscience research and Current Science.

The Human Brain:
Biological Networks and Complexity

The human brain is a complex structure endowed with properties ranging from learning and memory, to perception, cognition and consciousness. Understanding how such properties emerge as a result of the molecular and biochemical machinery remains a fundamental conceptual challenge confronting science today. This complexity arises through synergistic interactions across multiple levels of organization, with each level of organization emerging from a lower level. For example, in order to understand a neuron, it is necessary to understand the molecular and biochemical machinery that makes up the cell; the interaction of neurons in turn, through electrical signals generated from the interaction of ion channels, gives rise to local neural networks that are capable of processing simple information; the interaction of these neural networks across different brain areas in turn helps the processing of more complex information. Thus, from the integration of information across different networks, such as those that process sensory and motor information, emerge higher order functions like decision-making and cognition. Complete understanding of brain functions in health and disease is an inter-disciplinary effort spanning molecular and cellular systems and cognitive levels of organization. New insights have been gained into the molecular under-pinning of human cognitive processes and the biological basis of behaviour and cognition has been irrevocably established. Further, discoveries in the last decade have demonstrated the capacity of the brain to change during one's life span and during injury. This plasticity is seen to the utmost during development although it is evident all through life. Although more has been learnt of the human brain in the last decade than in the previous hundred years, we are cognizant of the enormity of what is yet to be understood, which will come about through an interdisciplinary approach involving molecular biology, physiology, psychology and computational science.

The Human Brain: Biological Networks and Complexity

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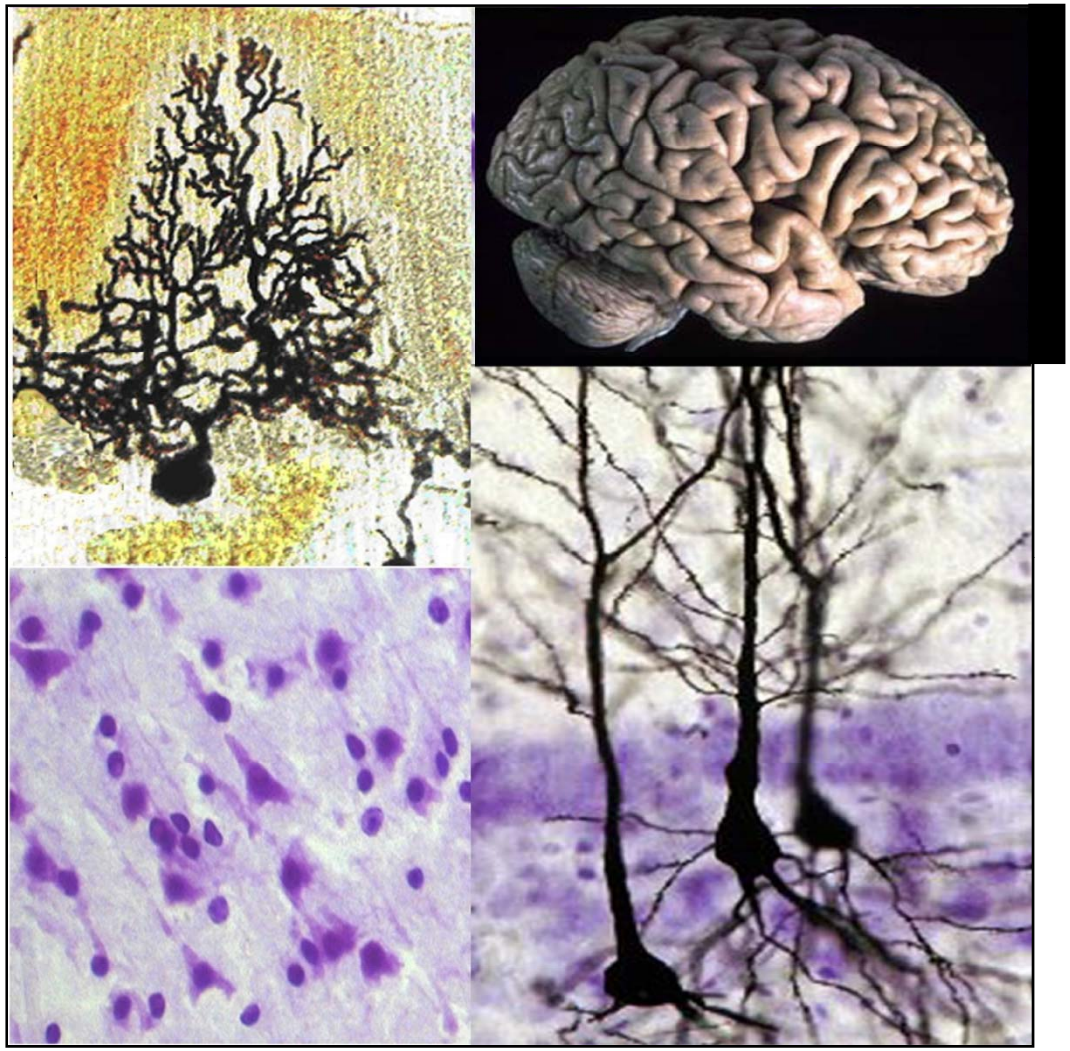


THE HUMAN BRAIN

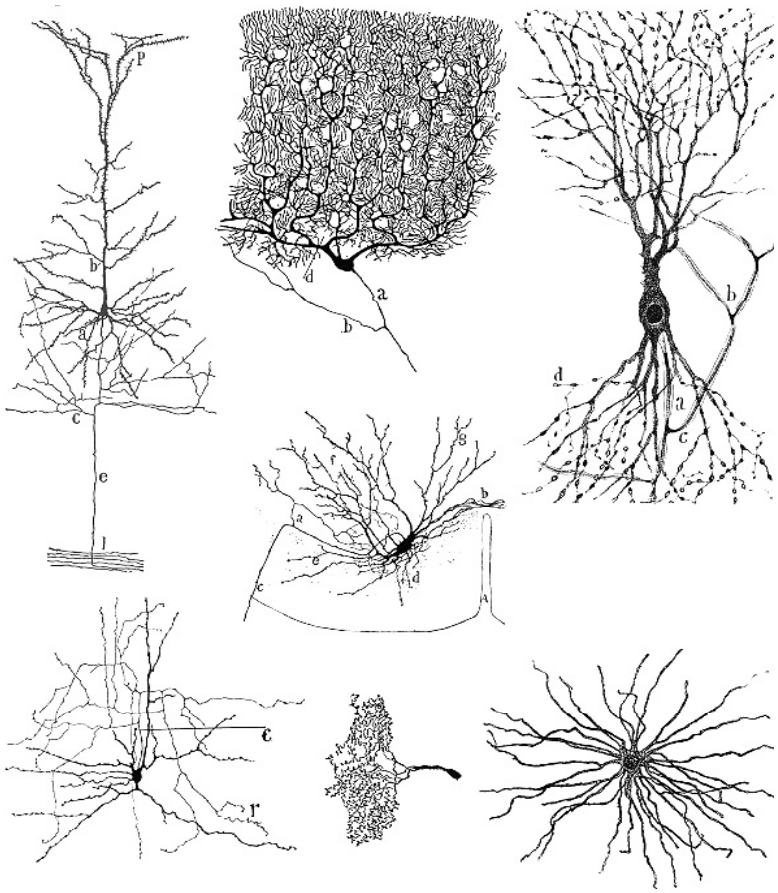
NETWORKS & COMPLEXITY

National Brain Research Centre
NBRC

THE HUMAN BRAIN

Brain does not replicate the outside world, but abstracts and restructures external reality.

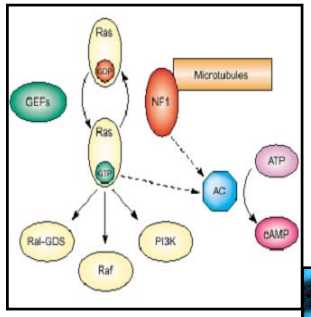
Mental processes are involved in interpreting the sensory inputs and planning and executing its response. This is essential for attributes like attention, memory, feeling, emotions, percepts and concepts etc



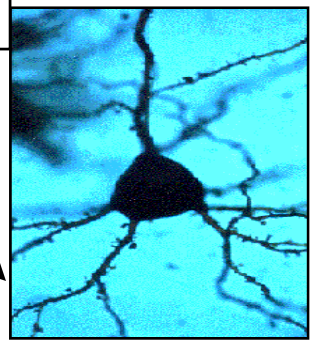
Santiago Ramon y Cajal, 1852-1934

UNDERSTANDING THE BRAIN

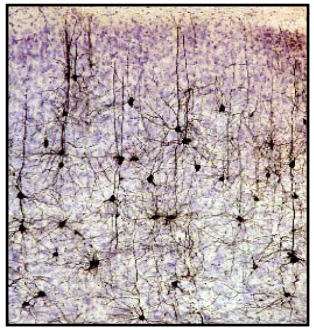
Molecules to Behaviour



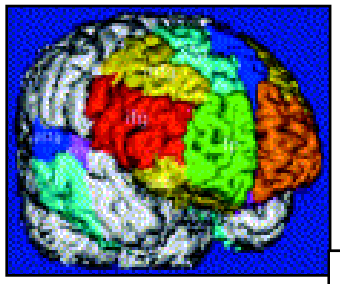
Molecules



Neurons

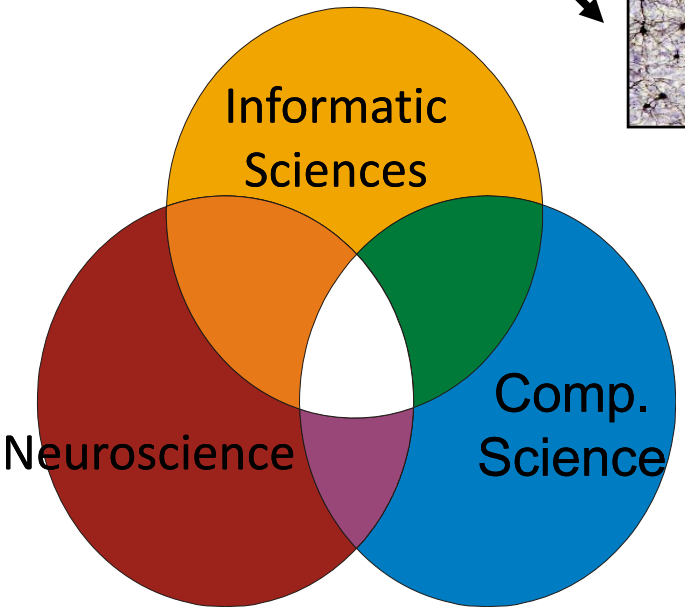


Networks

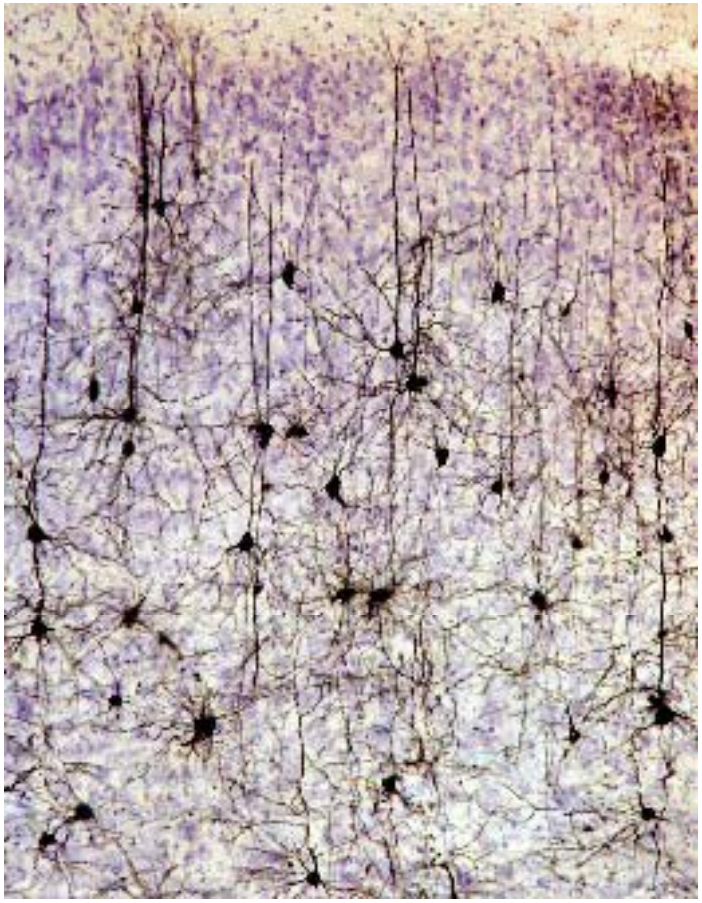


Systems

Behaviour



NEURONS & NETWORKS
Electrical properties and the ability to generate networks



Neurons are connected together by fibres that conduct electrical signals.

Each neuron makes connections via its axon/dendrites with over a thousand target neurons.

The pattern of trillions of connections is essential for perception, memory, movement, emotion, and consciousness.

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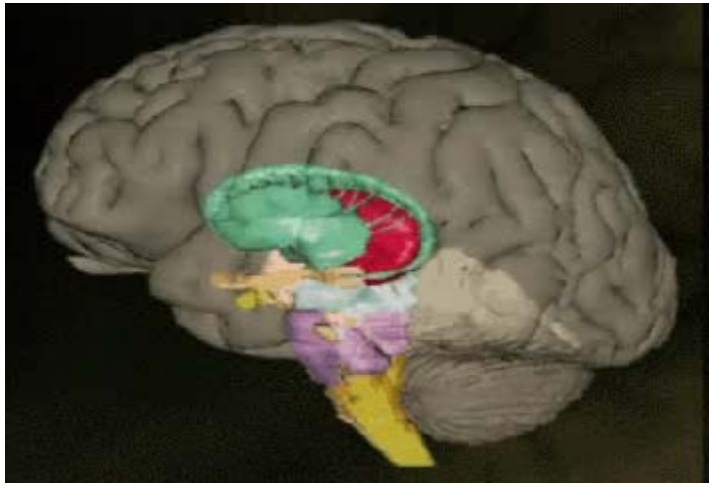
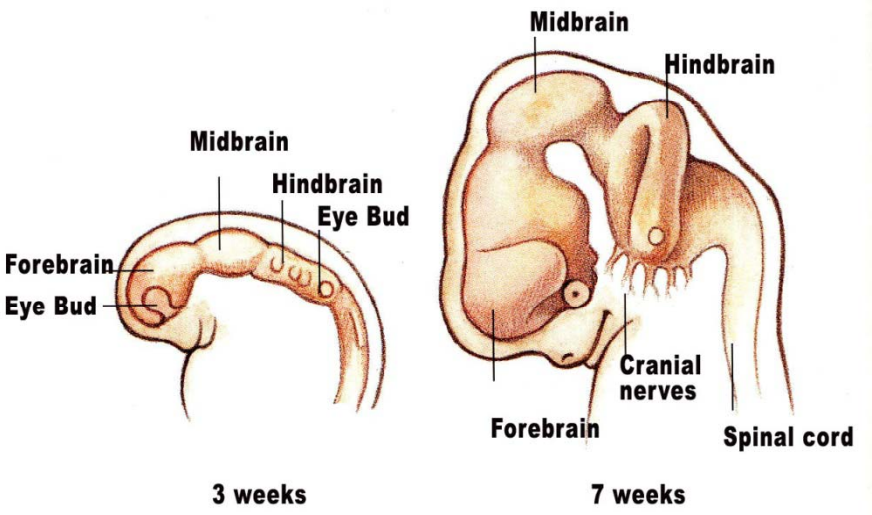
GENOME: US AND THE WORMS

- 100 billion neurons
- Million-billion synapses
- 3.2 million km of wiring
- **30,000 genes**

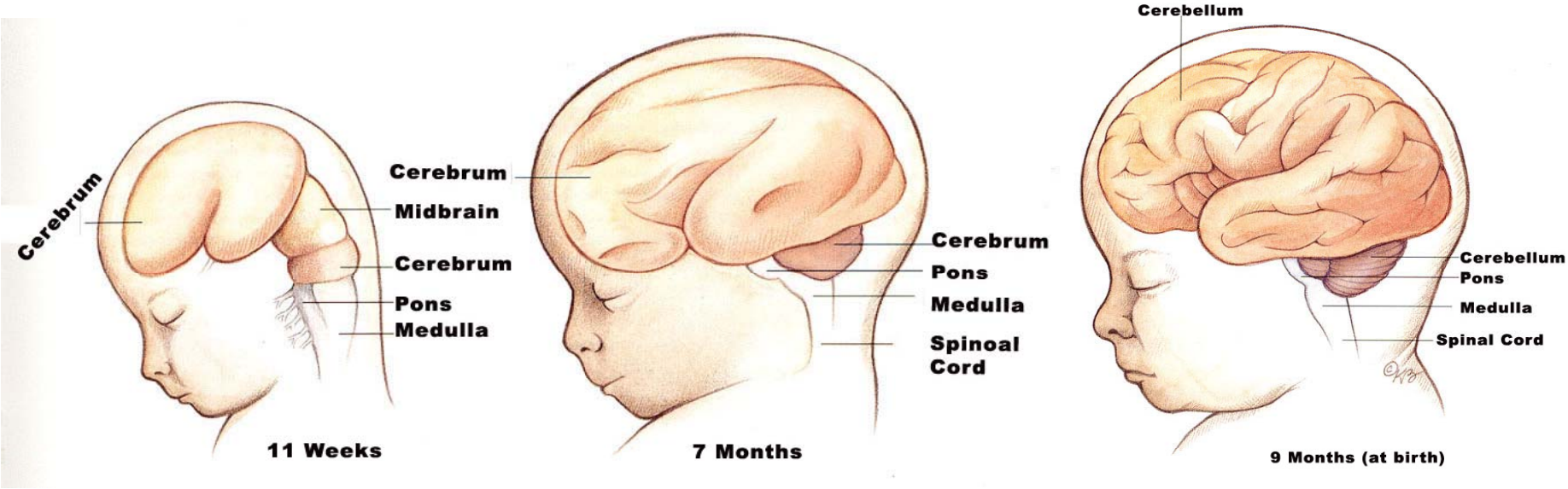
- 302 neurons
- ~5000 synapses
- **20,000 genes**



The level and complexity of the mind is determined by the complexity of neuronal networks of its nervous system circuits.



AT 3 WEEKS NEURONS FORM AT THE RATE 250,000 CELLS/MIN. AT BIRTH THERE ARE MORE THAN 100 BILLION NEURONS EACH MAKING OVER 10,000 CONNECTIONS.



Neural Connections & Plasticity

birth 3 months old 2 years old

Learning and experience change architecture of brain dramatically.

Structure of individual neurons changes during learning to accommodate new connections.

Sensitive Period for acquisition of speech and vocalization in humans

Learning speech

Brain wiring is complete

20 days

35 days

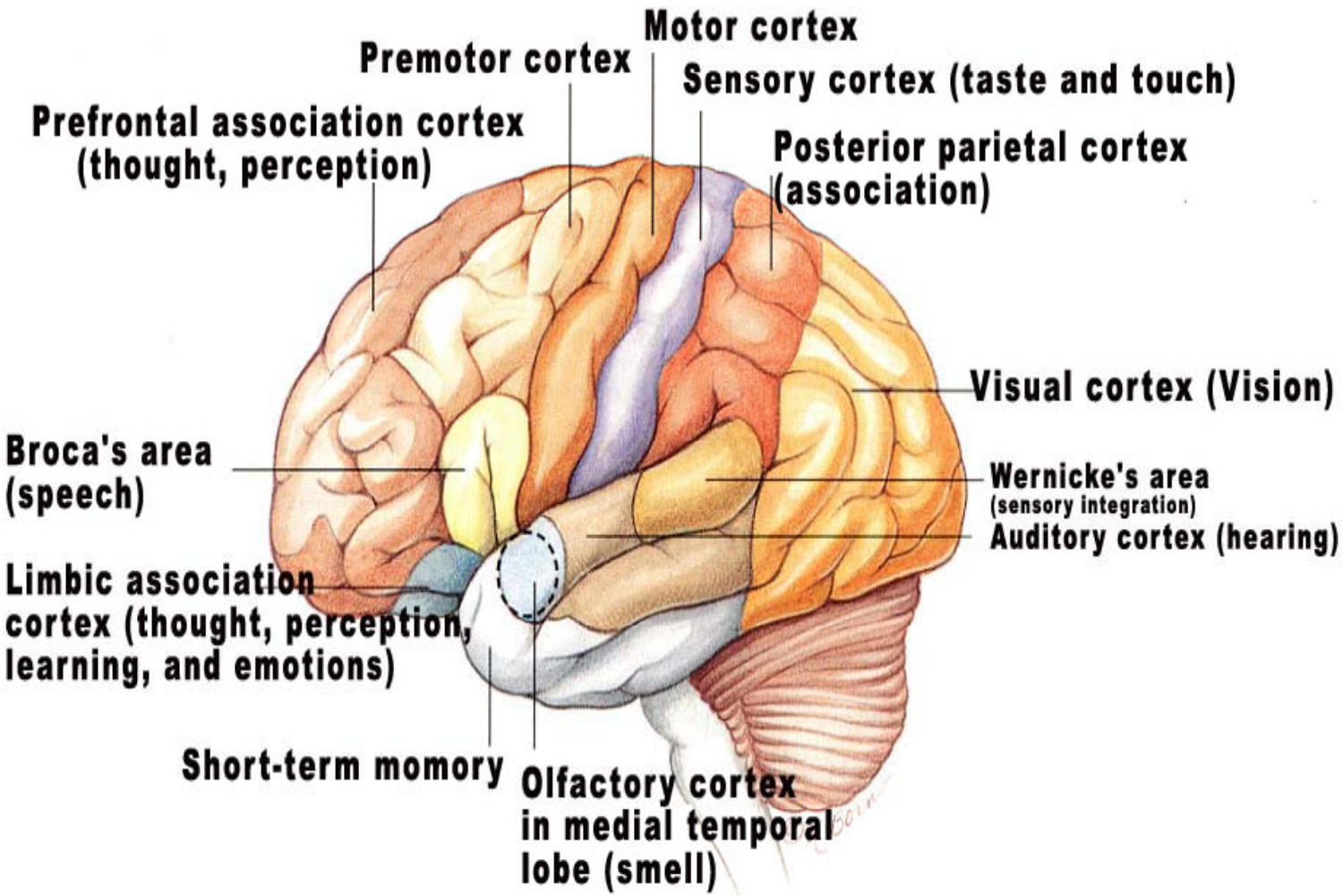
Adult

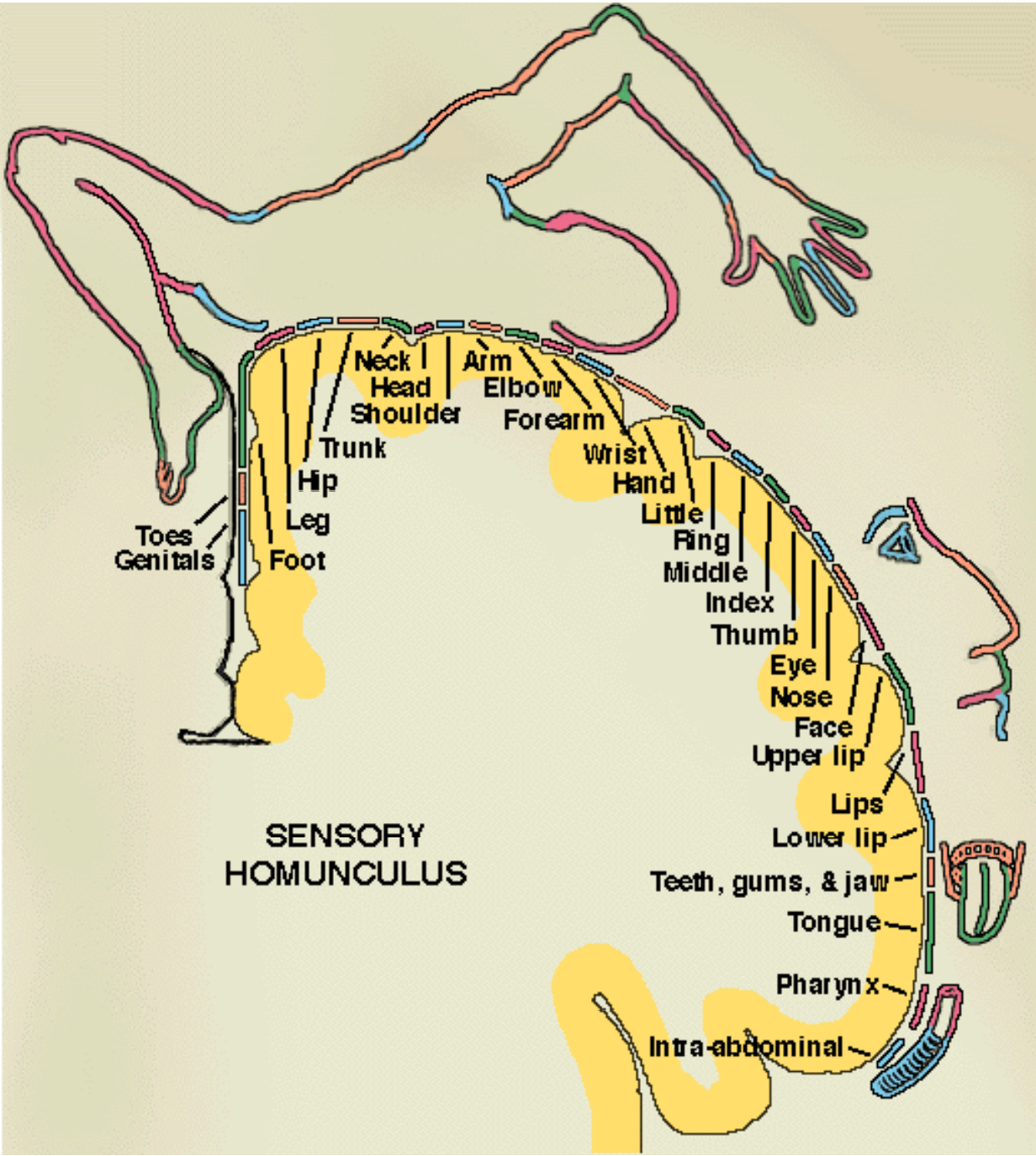
Experience provides the basis for neural connections

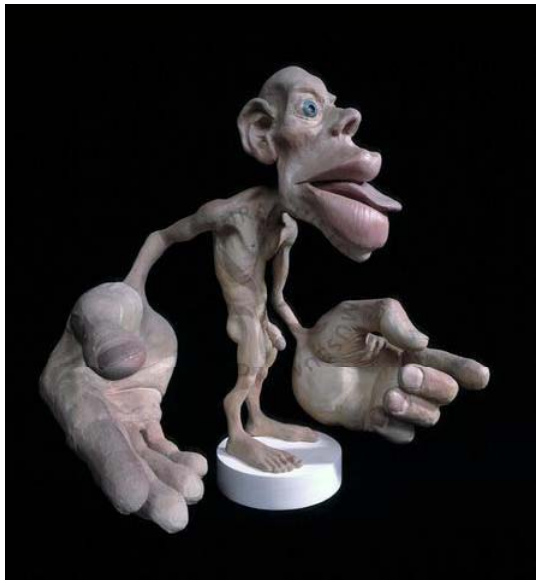
Use it or lose it.

Iyengar et al, 2002

HUMAN BRAIN STRUCTURES



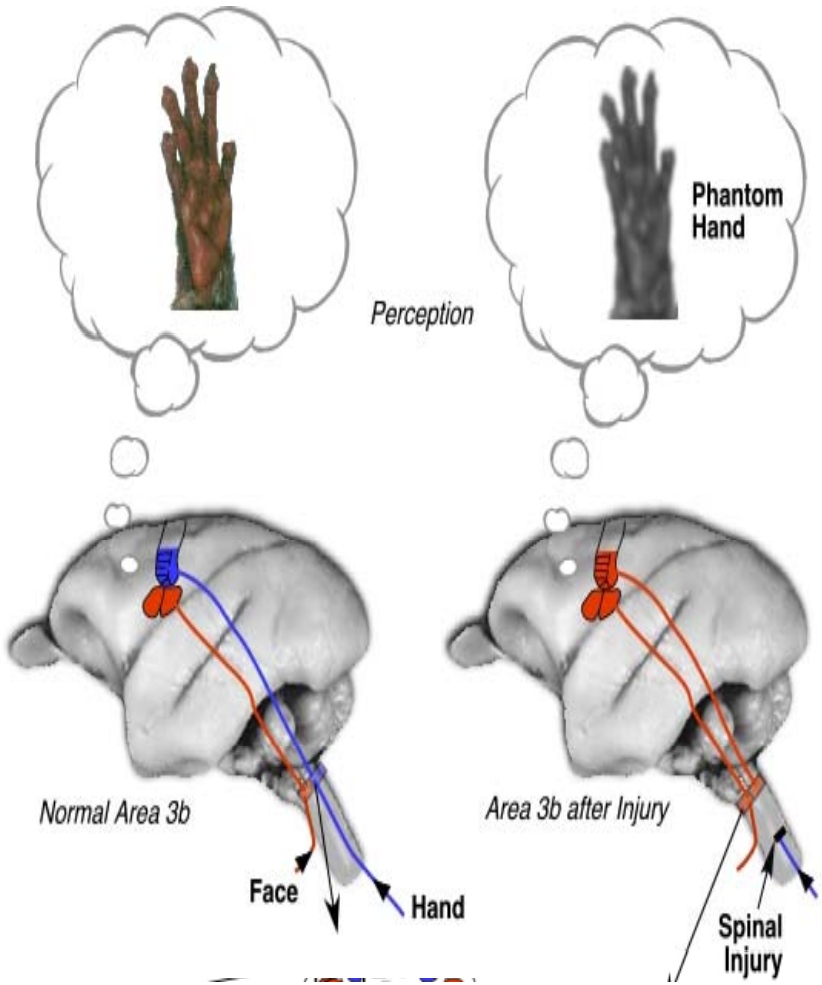

Neck
Head
Shoulder
Arm
Elbow
Forearm
Trunk
Wrist
Hand
Hip
Little
Leg
Ring
Toes
Genitals
Foot
Middle
Index
Thumb
Eye
Nose
Face
Upper lip
Lips
SENSORY
HOMUNCULUS
Lower lip
Teeth, gums, & jaw
Tongue
Pharynx
Intra-abdominal



Plasticity of the Brain

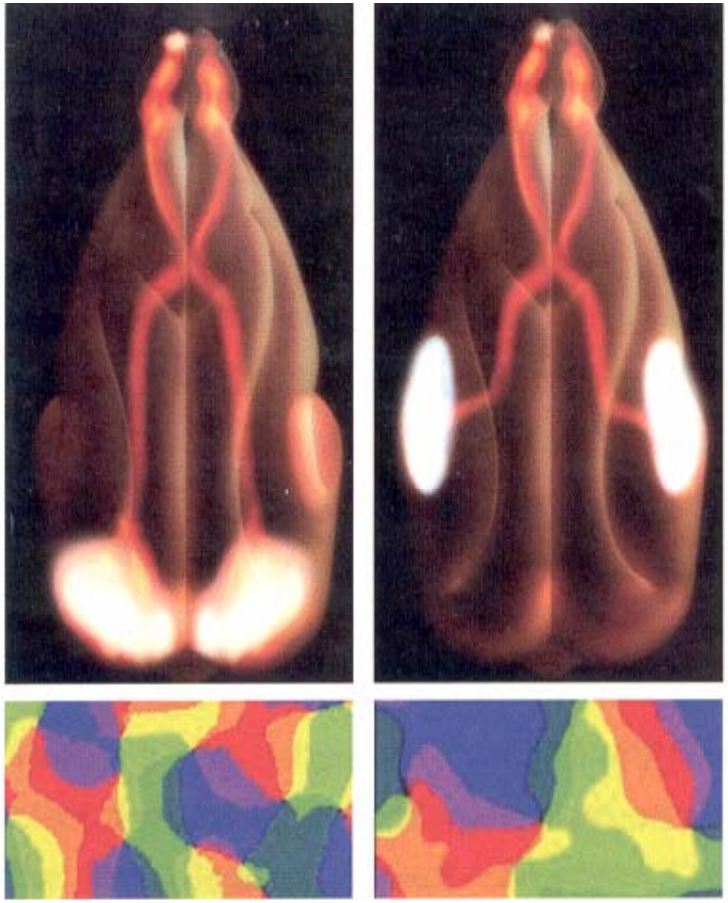
Following injuries to the spinal cord regions of the brain that were connected to the hand now get information from the face.

This can lead to phantom sensations in a part of the body that otherwise has no sensation.



Neeraj Jain & Jon Kaas

REWIRING THE BRAIN: CAN ENVIRONMENTAL CLUES CHANGE FUNCTIONAL RESPONSE?



- Connecting LGN to auditory cortex instead of visual cortex in young ferrets enables neurons in auditory cortex to respond to visual cues.
- Nurture vs nature?

Sharma & Sur , 2001

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DO GENES INFLUENCE OUR BEHAVIOUR?

Episodic hippocampal dependent memory

	n	No. of Words Recalled		
		Immediately	After 5 Minutes	After 24 Hours
rs17070145				
CC	164	23.6 ± 0.3	7.6 ± 0.2*	6.7 ± 0.2H
CT/TT	169	24.1 ± 0.3	9.4 ± 0.2*	8.0 ± 0.2H
rs6439886				
TT	265	23.9 ± 0.2	8.4 ± 0.2I	7.3 ± 0.2'
TC/CC	76	24.2 ± 0.4	9.8 ± 0.4I	8.4 ± 0.4'

* $P = 0.000004$ H $P = 0.0008$ I $P = 0.002$ ' $P = 0.022$

Population stratified into 4 groups based on retrieval success after learning a list of 30 unrelated nouns.

Each group genotyped at 502,627 SNPs.

SNP in intron 9 of KIBRA

KIBRA 'T' allele carriers showed 24% better performance

Papassotiropoulos et al, Science 2006

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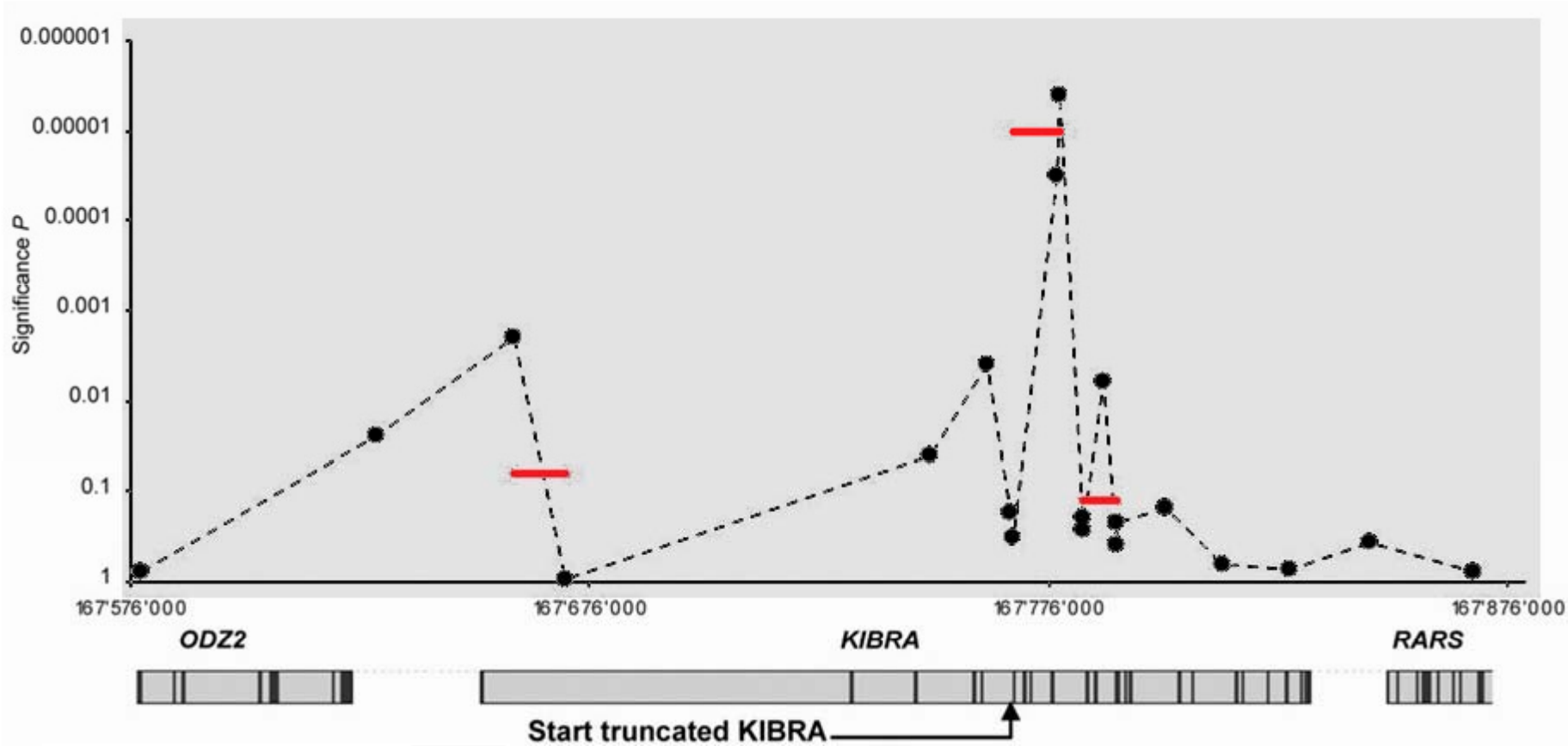
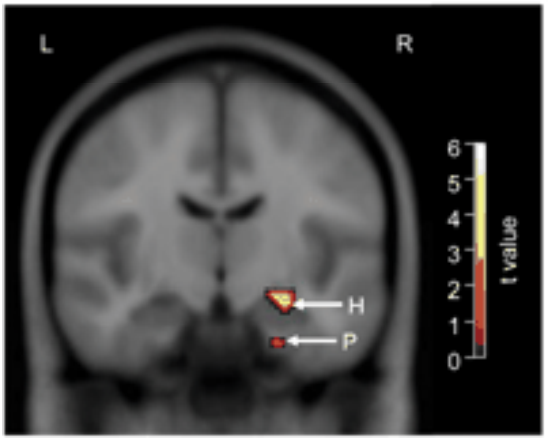




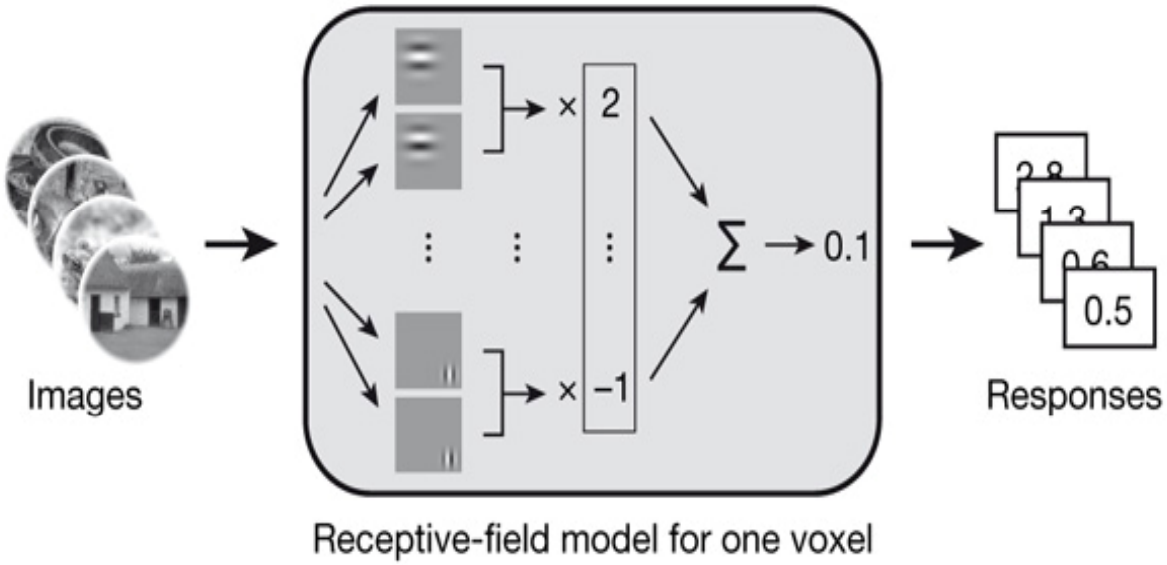
Activations are significantly increased in hippocampus in non-carriers of the T allele compared to T allele carriers (*n* = 15).

In populations of European ancestry, the ‘T’ allele frequence is low (~25% frequency).

In Asian populations the ‘T’ allele is most frequent (75%)

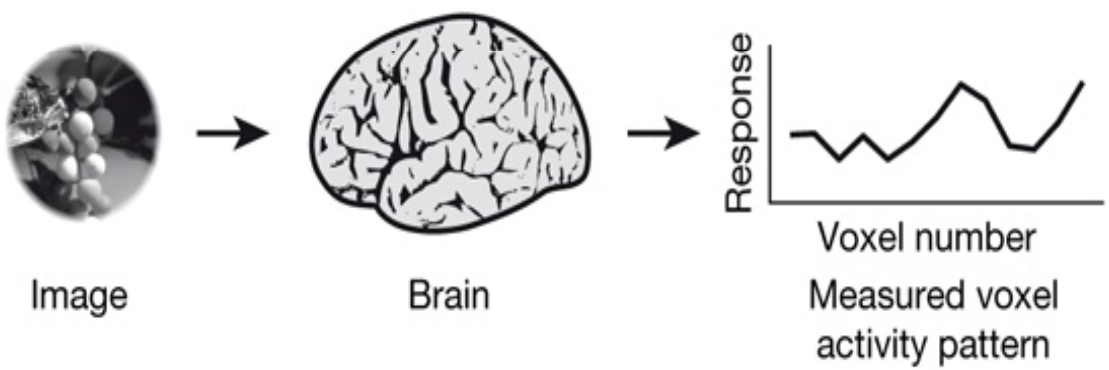
Stage 1: model estimation

Estimate a receptive-field model for each voxel



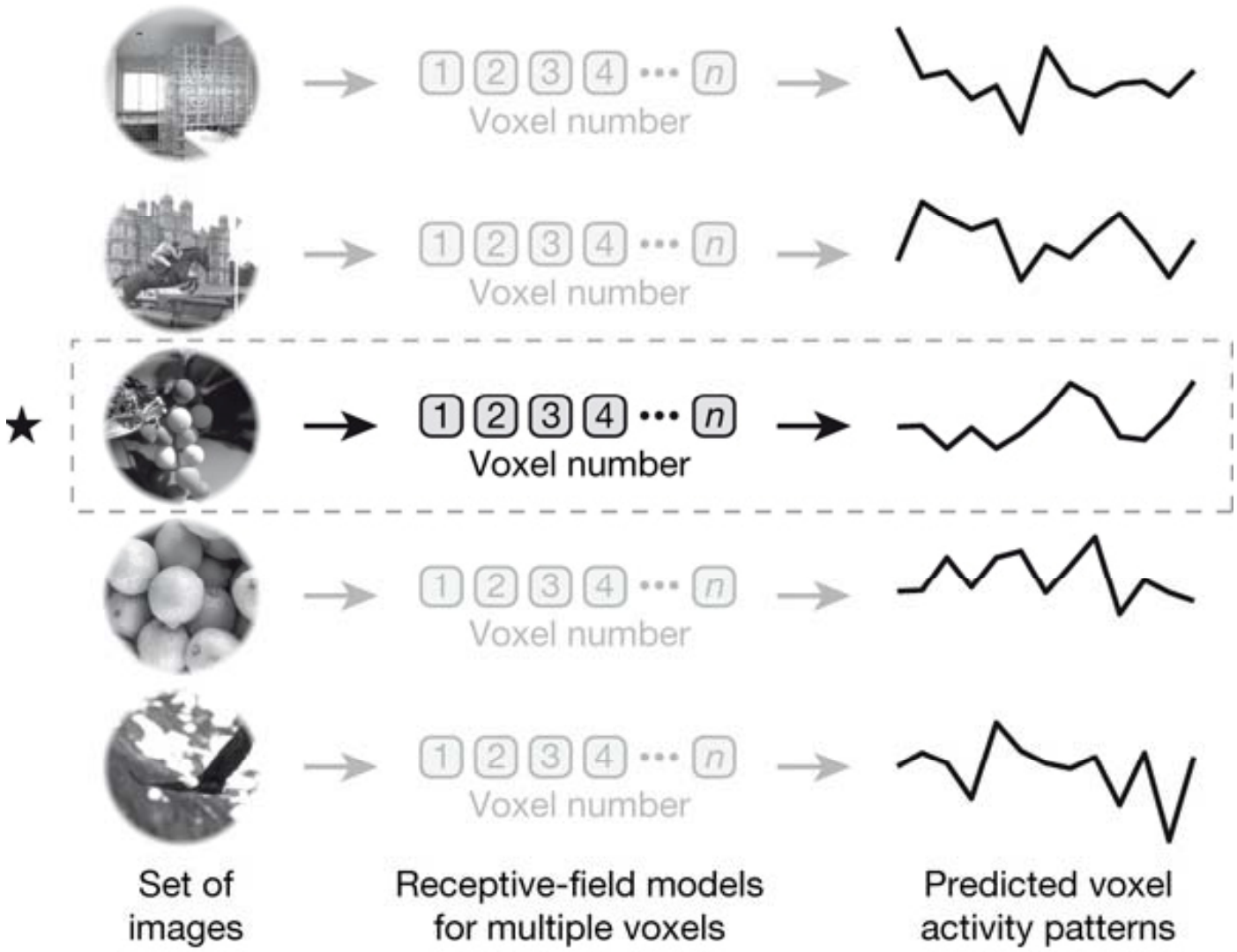
Stage 2: image identification

(1) Measure brain activity for an image

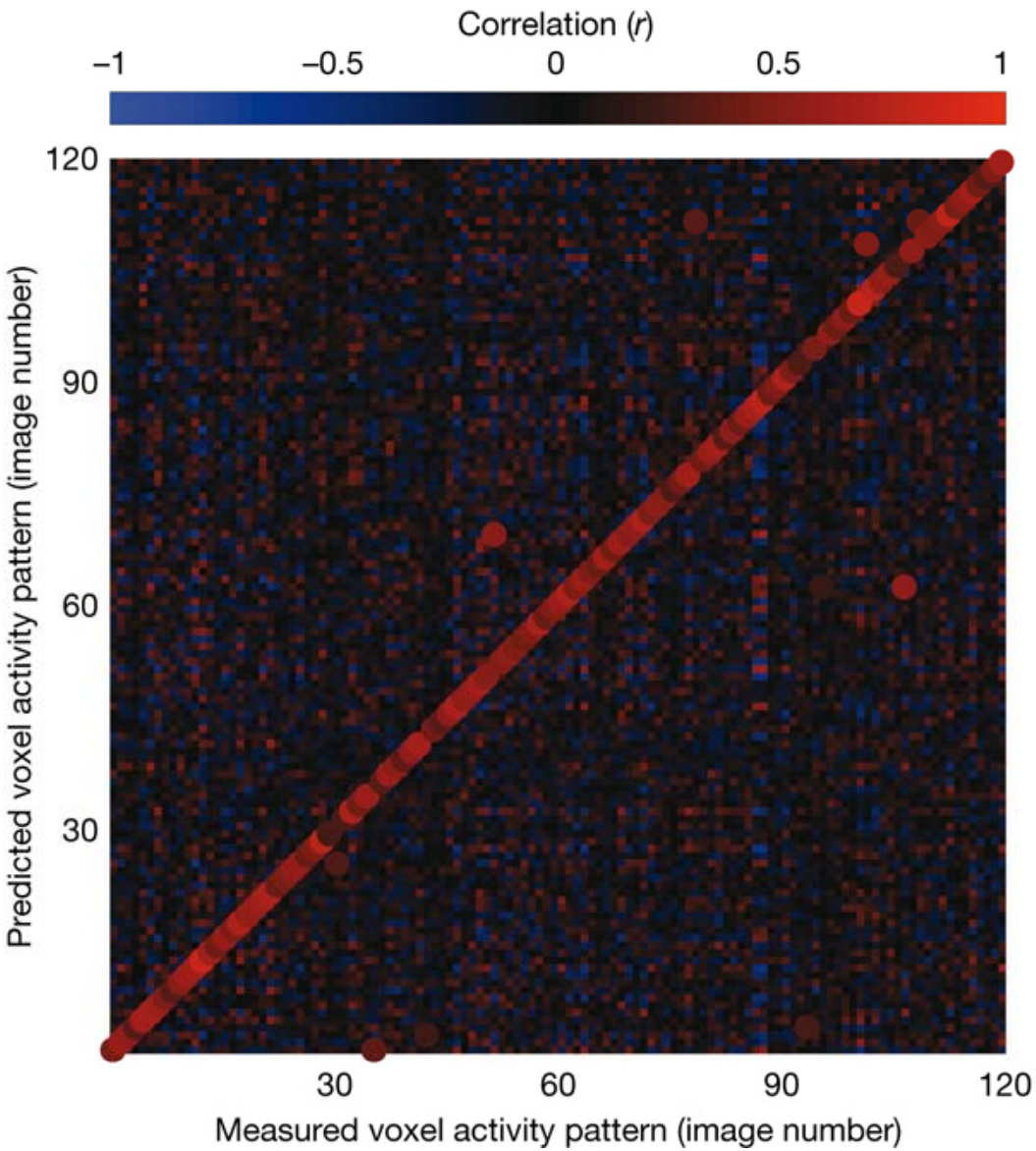


A quantitative receptive-field model for each voxel based on a Gabor wavelet pyramid & described tuning along dimensions of space, orientation & spatial frequency.

(2) Predict brain activity for a set of images using receptive-field models



(3) Select the image (★) whose predicted brain activity is most similar to the measured brain activity



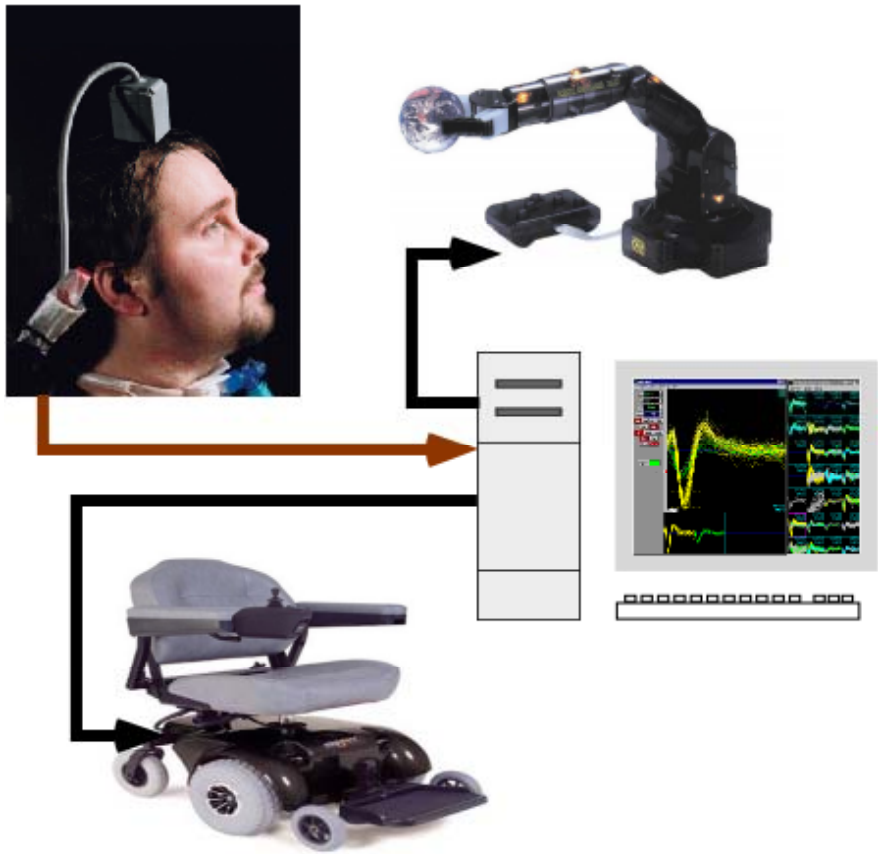
fMRI data were recorded while each subject viewed 120 novel natural images
For this subject 92% (110/120) of the images were identified correctly.
It was 72% for another subject

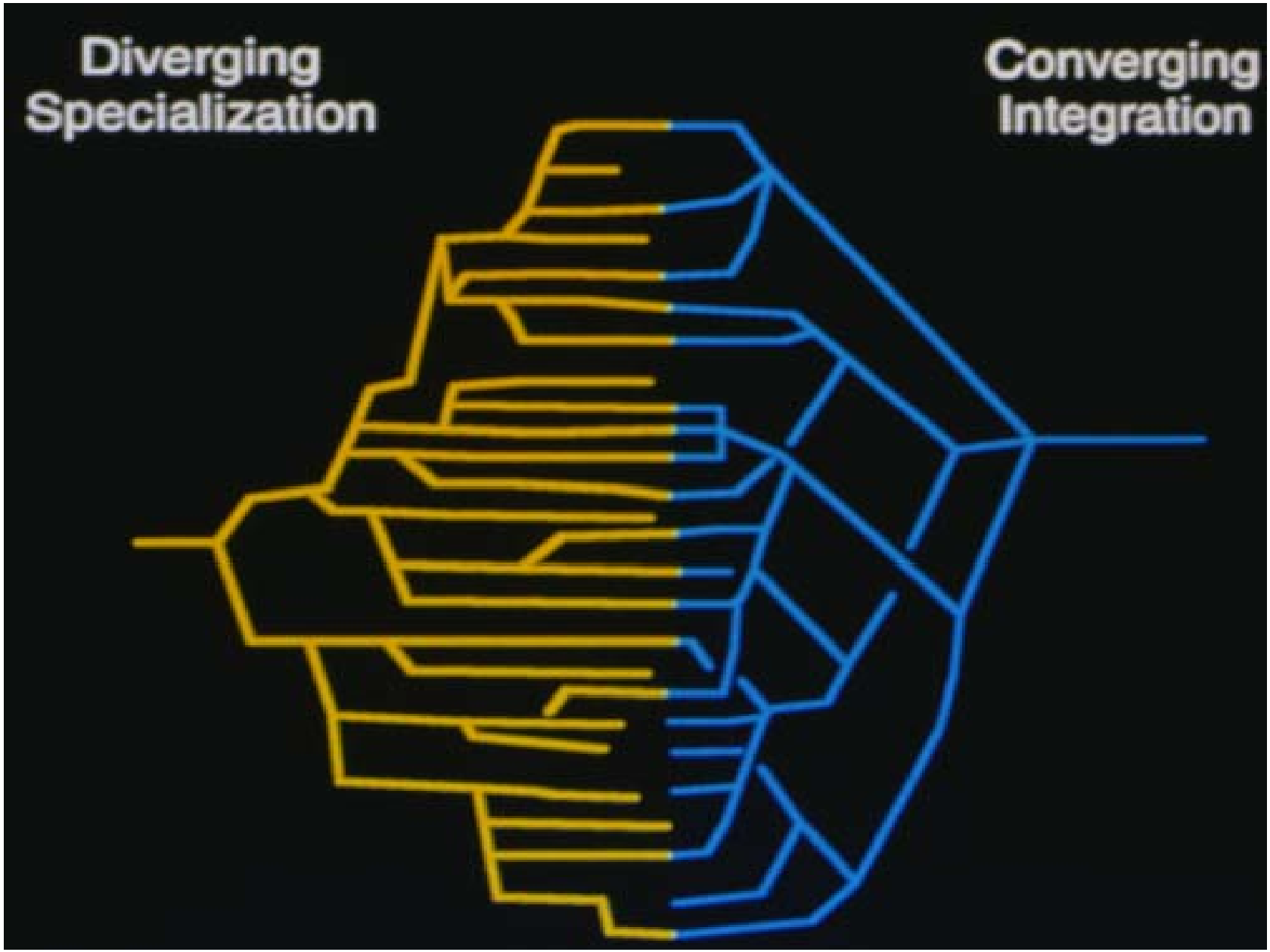
This work can be broadened to developing more general models of how the brain responds to stimuli beyond vision.

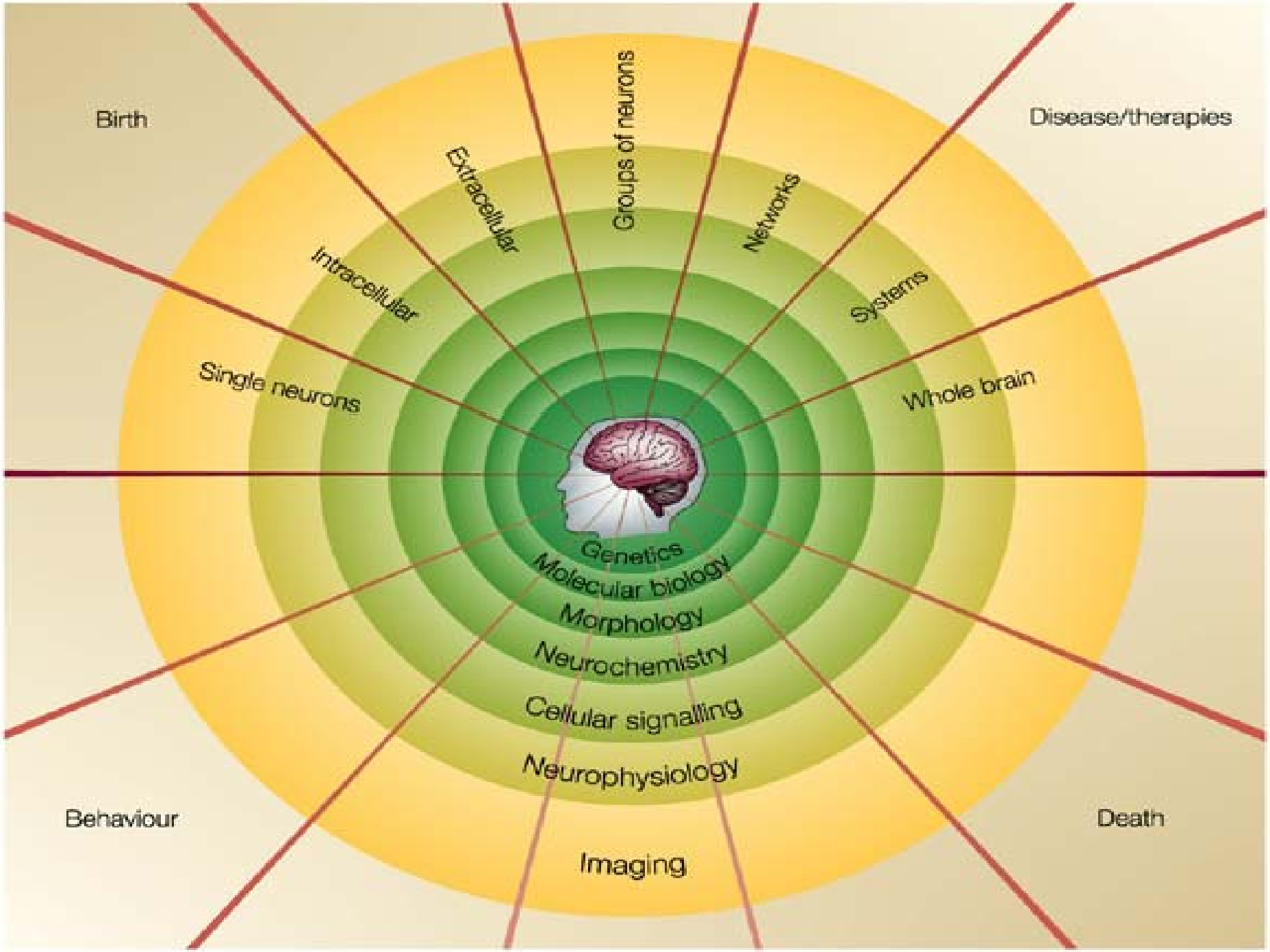
Such brain scans could help understand complex functions, diagnose disease or monitor the effects of therapy.

Brain-Machine Interface
Converting thoughts into action

- Recording electrical activity of neuronal ensembles from the brain.
- Interpreting patterns of activity and relating it to intended actions.
- Use the patterns of activity to drive a machine (e.g. computer, robotic device) to enable the same actions in a reliable fashion.




Diverging
Specialization
Converging
Integration


Birth
Disease/therapies
Behaviour
Death
Groups of neurons
Extracellular
Networks
Intracellular
Systems
Single neurons
Whole brain
Genetics
Molecular biology
Morphology
Neurochemistry
Cellular signalling
Neurophysiology
Imaging

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