Neuroinformatics 2022

February 23, 2022

Introduction

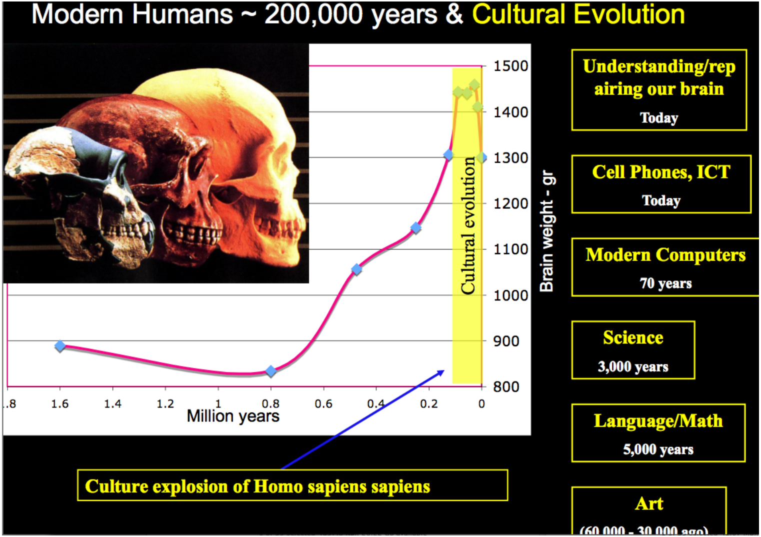
What is Computational Neuroscience?

Computational Neuroscience is the theoretical study of the brain to uncover the principles and mechanisms that guide the development, organization, information processing and mental abilities of the nervous system.

What is Neuroscience?

- How does the brain work?
- What are the biological mechanism involved?
- How is organised?
- How did evolve?
- How does it change during lifetime?
- What are the origins of the degenerative diseases and the possible rehabilitation?

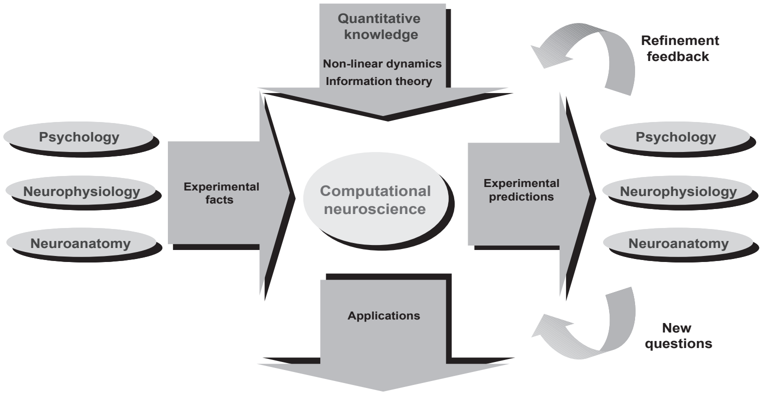
Brain r-evolution



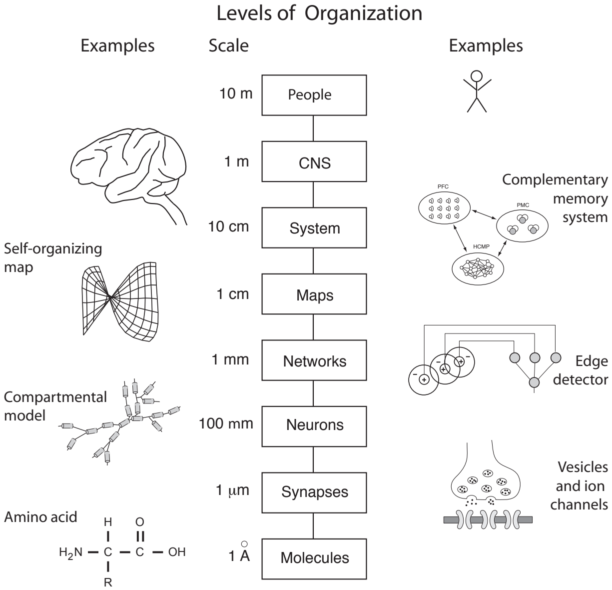
Tools in Neuroscince?

- Genetic manipulations
- Brain slices
- Optical imaging
- Functional brain imaging
- Psychophysiological measurement
- Computational simulations (analytic solutions & Numeric simulations !!!)

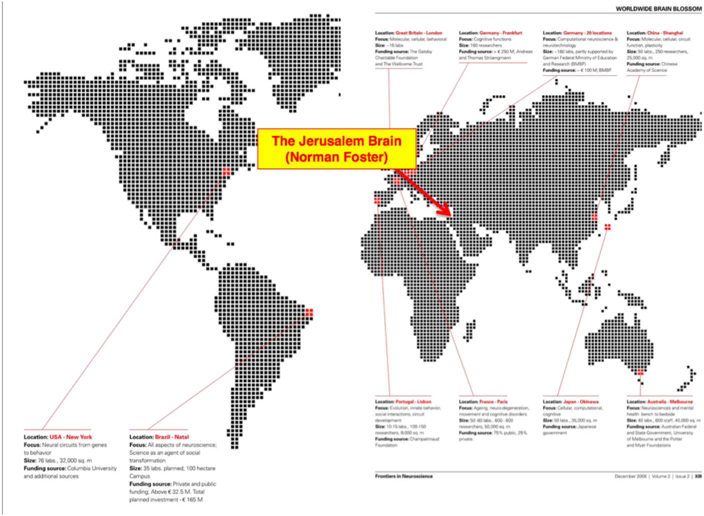
Computational/theoretical tools in context



Levels of organizations in the nervous system



Brain blossom



Jerulasem Brain

Jerulasem Brain - view from inside

Projects

Perspective: Some new dramatic ($ billions) projects for the brain

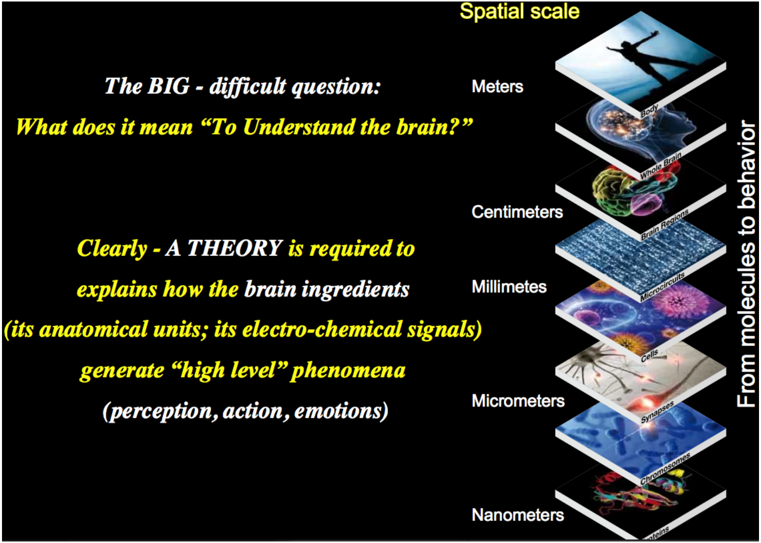
1. Allen Institute – Seatle, USA (Mouse/Human brain atlas – recently new focus on mouse vision)

2. Janelia farm – DC, USA (Industrial scale Inst. for connecting network level anatomy and physiology to s specific behavior)

3. EU Human Brain Project - EPFL, Lausanne Switzerland (ICT-based brain research platform, integrating data and knowledge from different disciplines, and catalyzing world-wide effort to achieve understanding of the brain, propose new treatments for brain diseases and new brain-like computing technologies) - Lesson #7.

4. President Obama's "Brain Activity Map" initiative (Creating revolutionary tools to measure/stimulate millions or even billions or neurons simultaneously)

Scale


Spatial scale
The BIG - difficult question:
What does it mean "To Understand the brain?"
Clearly - A THEORY is required to
explains how the brain ingredients
(its anatomical units; its electro-chemical signals)
generate "high level" phenomena
(perception, action, emotions)
Meters
Centimeters
Millimetes
Micrometers
Nanometers
Body
Whole Brain
Brain Regions
Microcircuits
Cells
Synapses
Chromosomes
From molecules to behavior

New-breaking methods

Recent Brain-Excitements

1. **Connectomics – Complete 3D road-map for the brain**

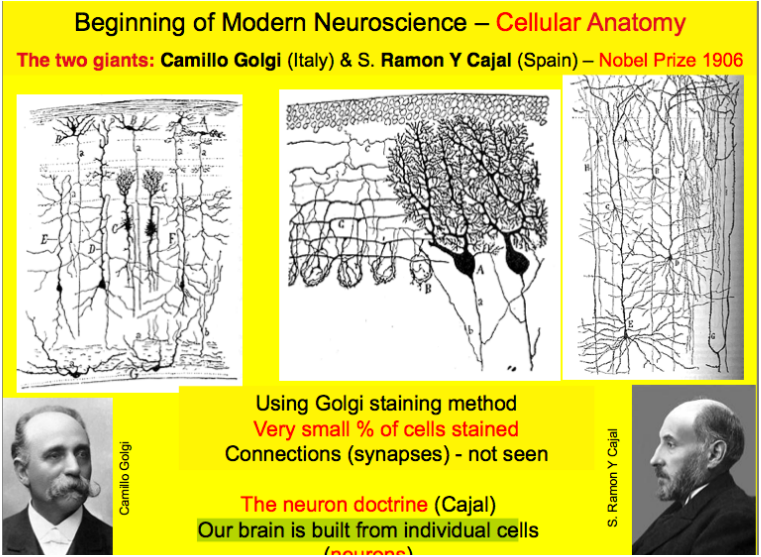
2. Brainbow – Colorful, genetically-designed, brains

3. Brain-machine/computer interface (BMI)

4. Optogenetics – Light-activated brain circuits

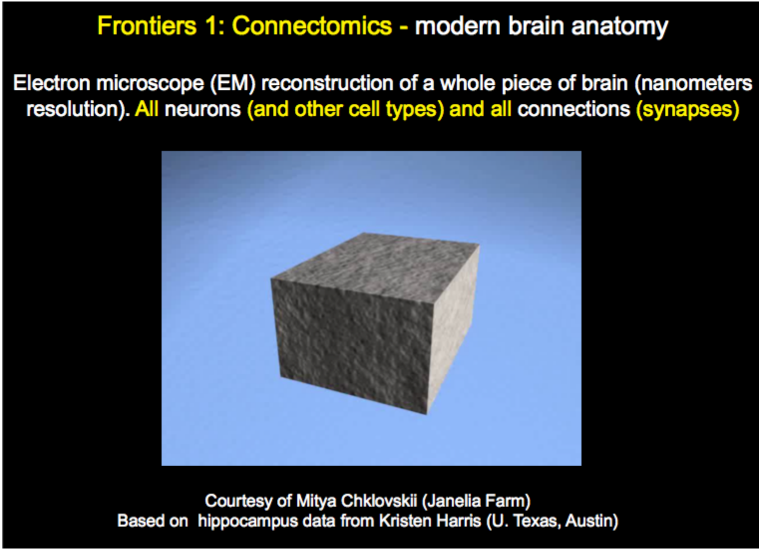
5. Computer simulation of the brain - "Blue Brain Project"

Begining



Beginning of Modern Neuroscience – Cellular Anatomy
The two giants: Camillo Golgi (Italy) & S. Ramon Y Cajal (Spain) – Nobel Prize 1906
Using Golgi staining method
Very small % of cells stained
Connections (synapses) - not seen
Camillo Golgi
S. Ramon Y Cajal
The neuron doctrine (Cajal)
Our brain is built from individual cells

Begining

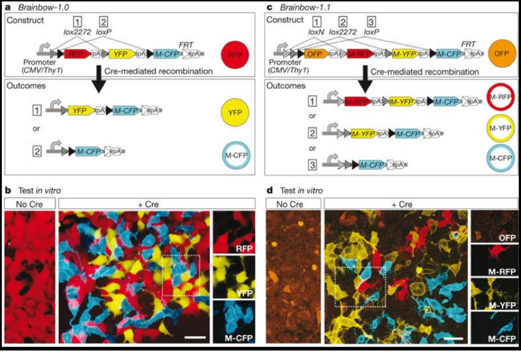

Frontiers 1: Connectomics - modern brain anatomy
Electron microscope (EM) reconstruction of a whole piece of brain (nanometers resolution). All neurons (and other cell types) and all connections (synapses)
Courtesy of Mitya Chklovskii (Janelia Farm)
Based on hippocampus data from Kristen Harris (U. Texas, Austin)

Brainbow

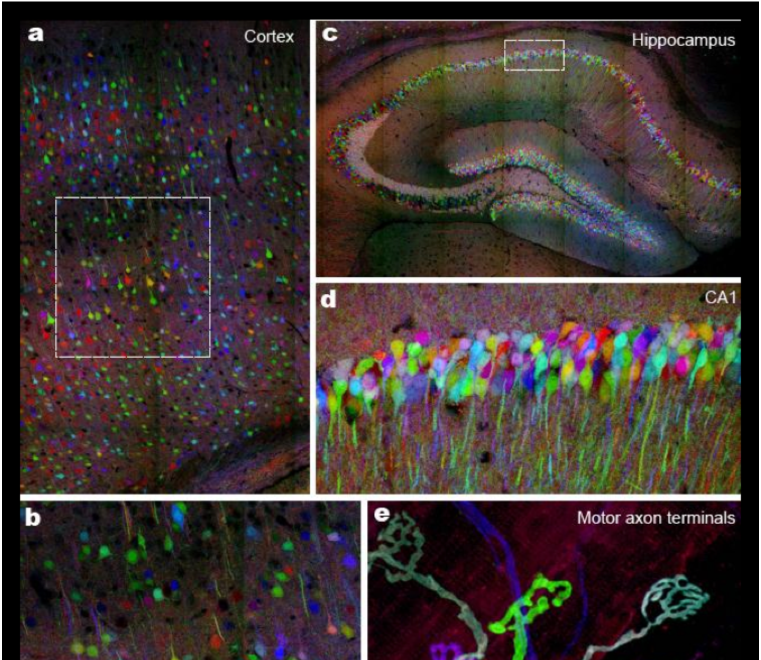
Frontiers 2. “Brainbow” technology

Genetic staining of neurons *in vivo* (light microscope – micrometer resolution)

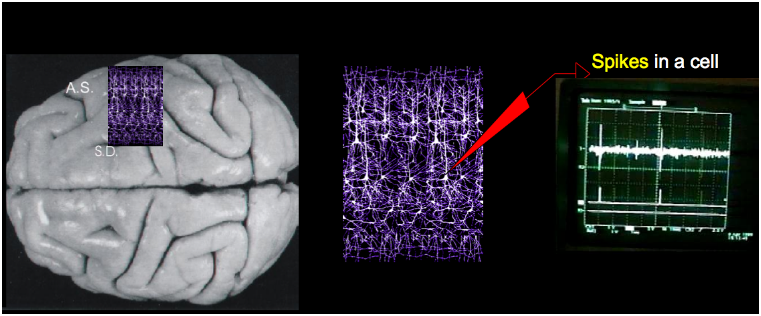
Courtesy of Jeff Lichtman, Jean Livet and Joshua R. Sanes



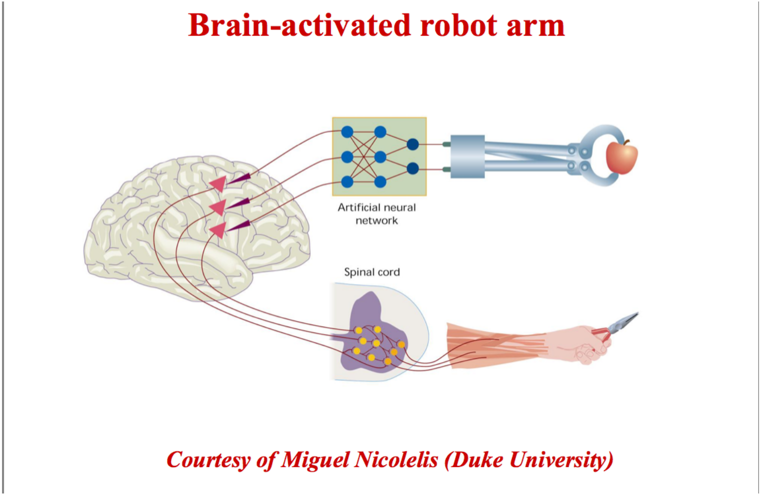
Brainbow



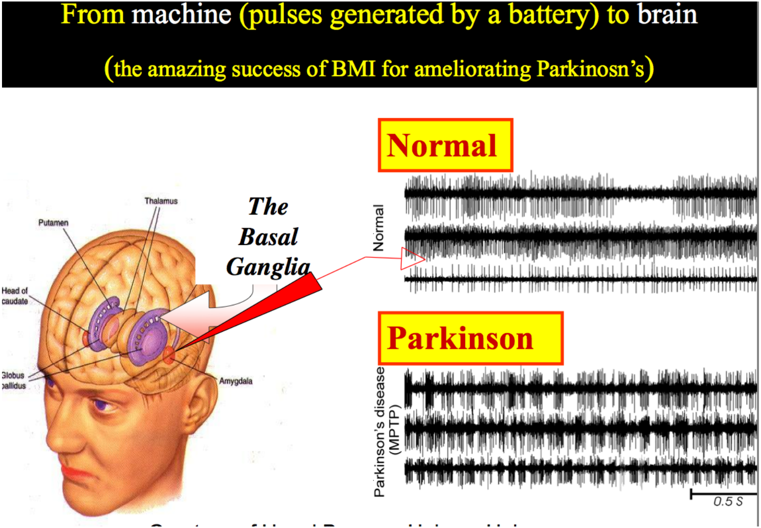
Brain Computer interface



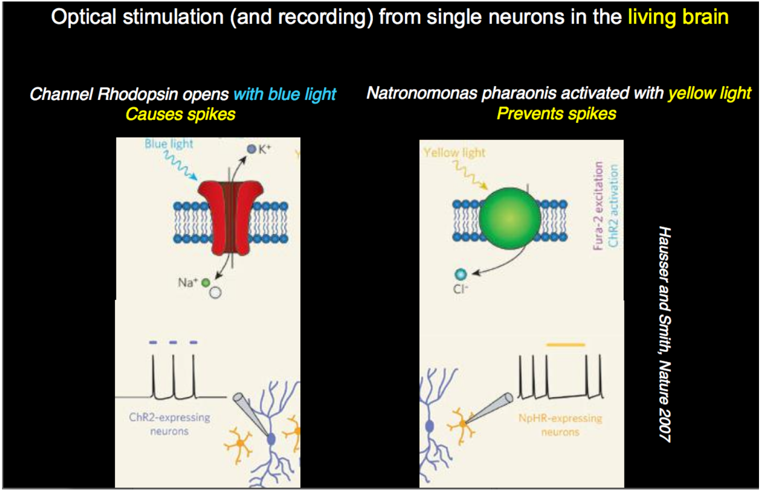
World Footbal Championship



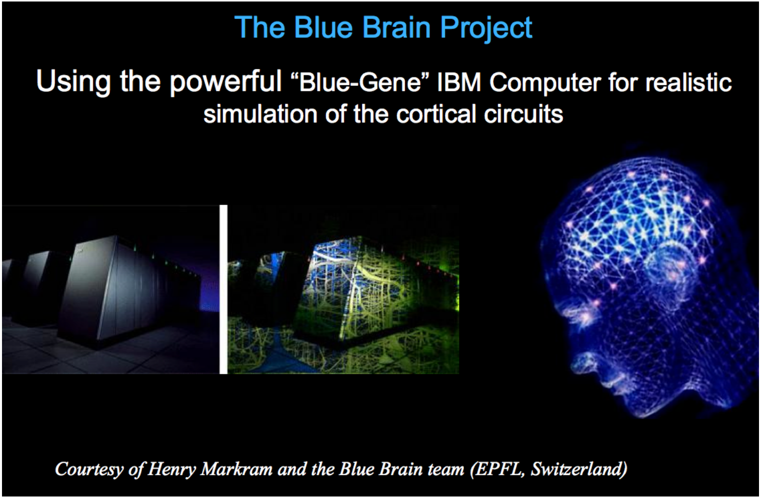
DBS


From machine (pulses generated by a battery) to brain
(the amazing success of BMI for ameliorating Parkinosn's)
The Basal Ganglia
Thalamus
Putamen
Head of caudate
Globus pallidus
Amygdala
Normal
Normal
Parkinson
Parkinson's disease (MPTP)
0.5 S

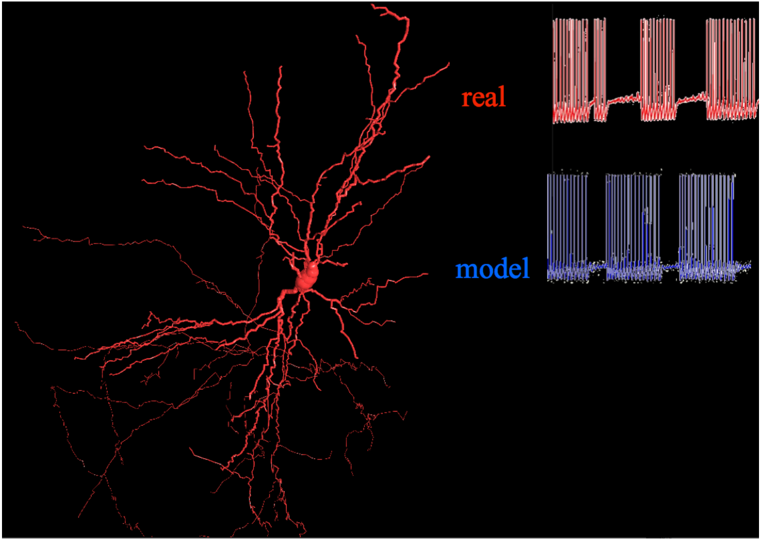
Optogenetics



Blue Brain Project



Modelling



Further Readings

Patricia S. Churchland and Terrence J. Sejnowski, 1992, **The computational Brain**, MIT Press

Peter Dayan and Laurence F. Abbott 2001, **Theoretical Neuroscience**, MIT Press

Jeff Hawkins with Sandra Blakeslee 2004, **On Intelligence**, Henry Holt and Company

Norman Doidge 2007, **The Brain That Changes Itself: Stories of Personal Triumph from the Frontiers of Brain Science**, James H. Silberman Books

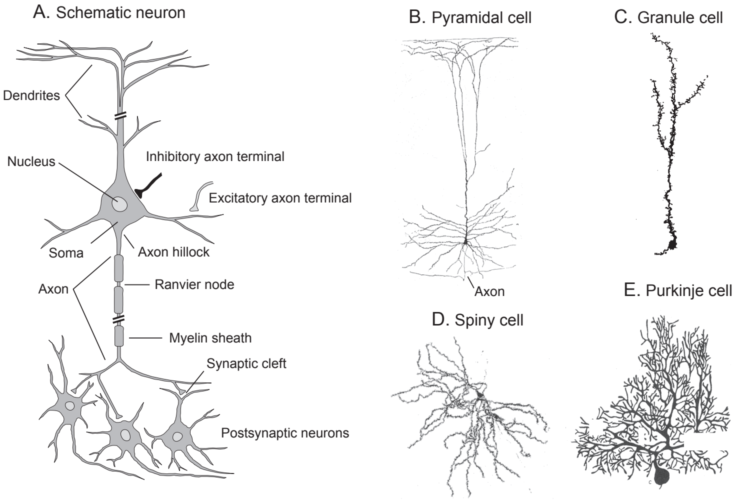
Paul W. Glimcher 2003, **Decisions, Uncertainty, and the Brain: The Science of Neuroeconomics**, Bradford Books

Neuroinformatics 2022

February 23, 2022

Basic physiology and conductance-based model

Biological background



Gliall cells

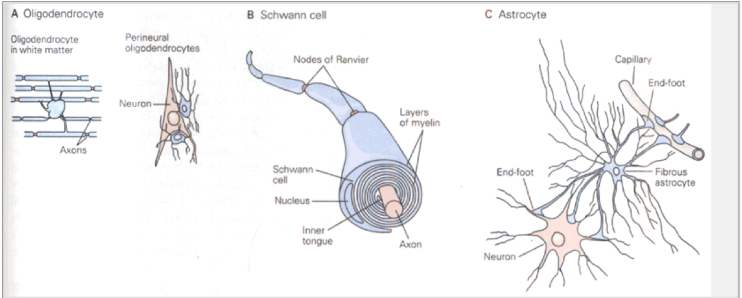
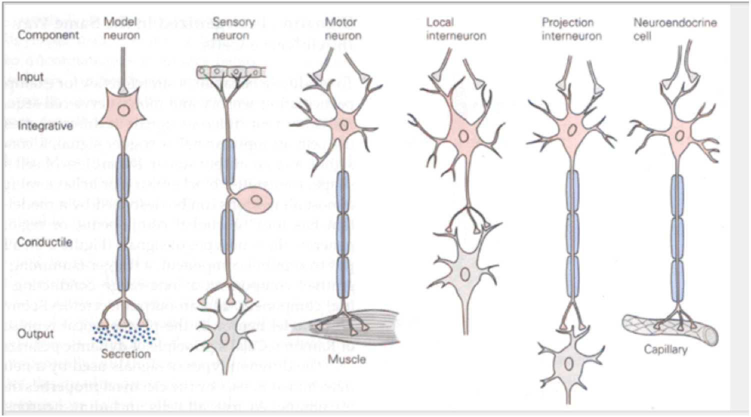
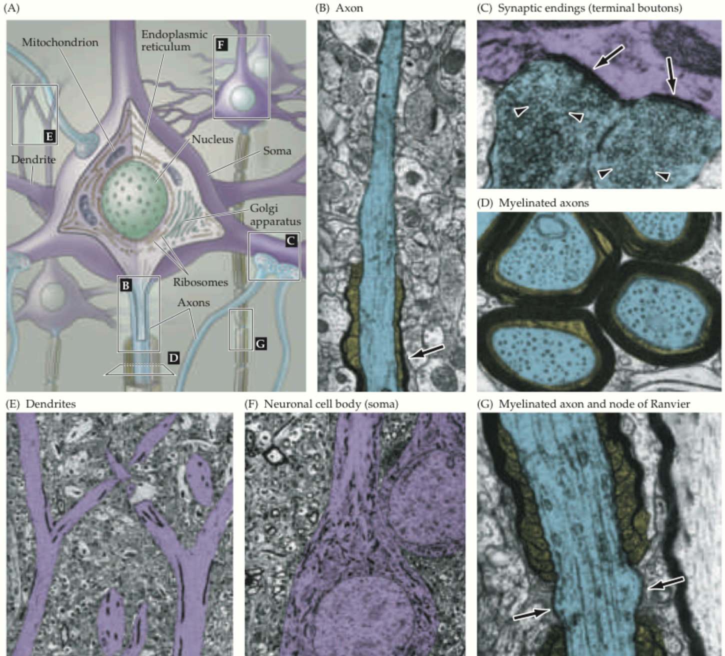


Figure 2-1 The principal types of glial cells in the central nervous system are astrocytes and oligodendrocytes and in the peripheral nervous system, Schwann cells.

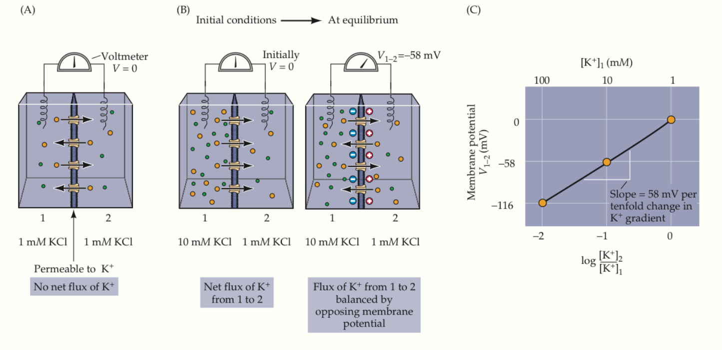
Four components of neurons



Microscopical features of neurons

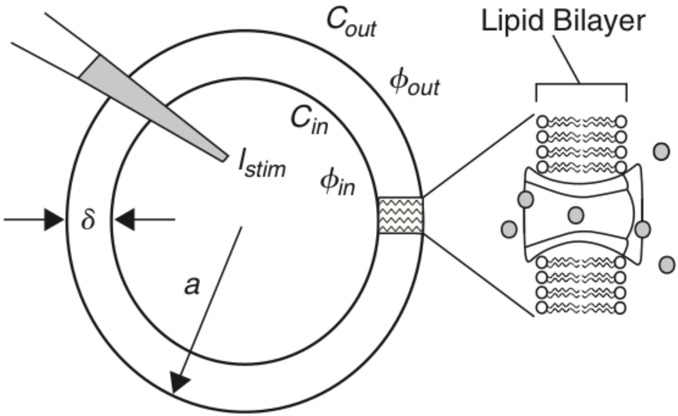


Nerst potential



Calculation of Nerst potential

- Nerst calculation for Cl ion!, $V = \frac{kT}{ze} \log \frac{c_{out}}{c_{in}}$



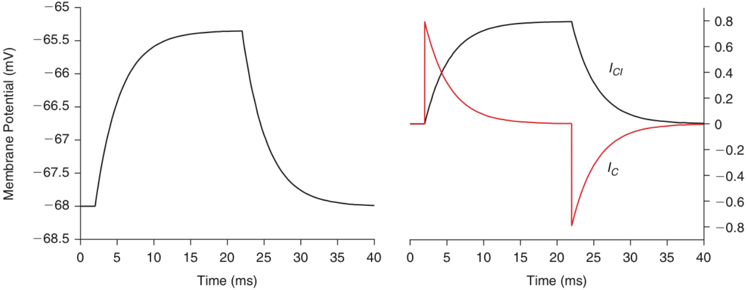
Membrane simulation

- Simulation of membrane

$$I_C(t) = C_m \frac{dV}{dt}(t)$$

$$\tau \frac{dV}{dt} = V_{Cl} - V(t) + \frac{I_{stim}(t)}{A g_{Cl}}$$

$$\tau = \frac{C_m}{g_{Cl}}$$



Further Readings

Mark F. Bear, Barry W. Connors, and Michael A. Paradiso (2006), **Neuroscience: exploring the brain**, Lippincott Williams & Wilkins , 3rd edition.

Eric R. Kandel, James H. Schwartz, and Thomas M. Jessell (2000), **Principles of neural science**, McGraw-Hill, 4th edition

Gordon M. Shepherd (1994), **Neurobiology**, Oxford University Press, 3rd edition.

Christof Koch (1999), **Biophysics of computation; information processing in single neurons**, Oxford University Press

Christof Koch and Idan Segev (eds.) (1998), **Methods in neural modelling**, MIT Press, 2nd edition.

C. T. Tuckwell (1988), **Introduction to theoretical neurobiology**, Cambridge University Press.

Hugh R. Wilson (1999) **Spikes, decisions and actions: dynamical foundations of neuroscience**, Oxford University Press. See also his paper in J. Theor. Biol. 200: 375–88, 1999.