UNIVERSIDAD AUTONOMA DE MADRID

Escuela Politécnica Superior

NEUROINFORMATICS:

Pablo Varona (Coordinator): pablo.varona@uam.es

Eduardo Serrano : eduardo.serrano@uam.es

Francisco de Borja Rodríguez: f.rodriguez@uam.es

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INTRODUCTION TO COMPUTATIONAL NEUROSCIENCE:

- Fundamentals of Neuroscience
- Introduction to neural information processing
- Scales and strategies in neural modeling

Computational Neuroscience

- Computational Neuroscience studies the nervous system from the perspective of information processing.

- Computational Neuroscience is a multidisciplinary field: it uses knowledge from biology, biophysics, biochemistry, computer science, engineering, medicine, psychology….

- **What is it useful for?**

  - To understand the function of the brain
  - To study several types of diseases and to design prosthetic deices and brain machine interfaces.
  - To design novel bio-inspired paradigms in artificial intelligence, robotics and bio-inspired devices.

The brain and the computers

Information Processor	Processing elements	Element size	Power	Processing speed	Type of computation	Fault - tolerant	Able to learn	Intelligent Concious
	10^{14} synapses	10^{-6} m	30 W	100 Hz	Parallel, distributed	Yes	Yes	Often
	10^{8} transistors	10^{-6} m	30W (CPU)	10^{9} Hz	Serial, centralized	NO	A little	No (yet)

Nature and human engineering

- **Nature** uses a different “engineering” strategy than humans.

- **Classic human engineering** is based on control (controlling dynamics, controlling noise, controlling quality, etc.) and is primarily goal-oriented.

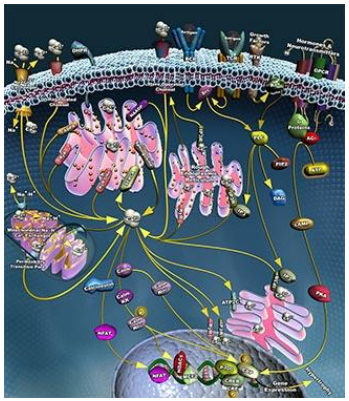
Thus, its capabilities are limited by the imagination of those setting the goals. Things like noise, oscillation, transients and combinatorial richness interfere with this imagination and are thus seen as hazards.

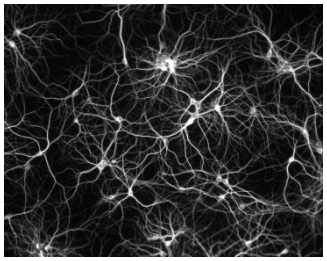
Engineering by Nature

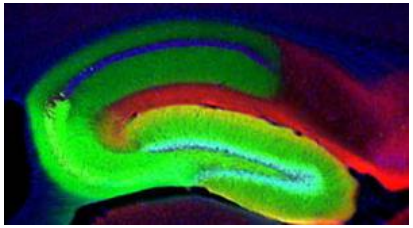
- **Nature´s engineering**, is based on exploitation (of oscillations, noise, diversity and combination, etc). As this natural engineering configures more complex phenomena, the space of possibilities expands, thus making even more complex phenomena possible.

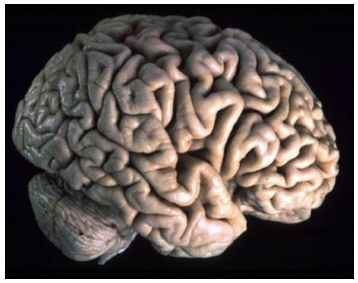
- Nature's engineering is open-ended, and things such as noise, variation, **transients** and combinatorial richness are seen as enablers rather than problems.

Levels of information processing in the brain





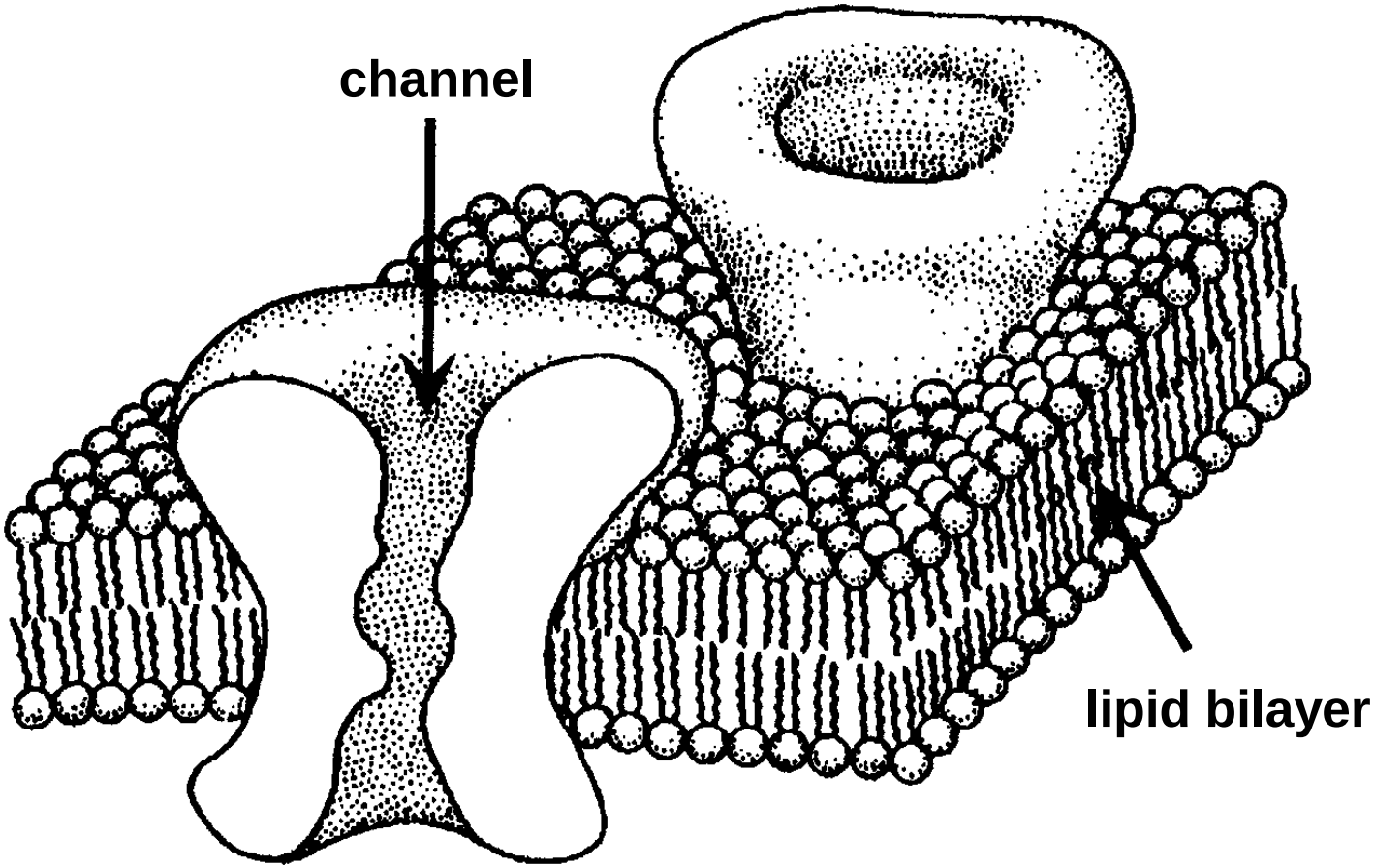




- Subcellular
- Cellular
- Network
- System
- Brain

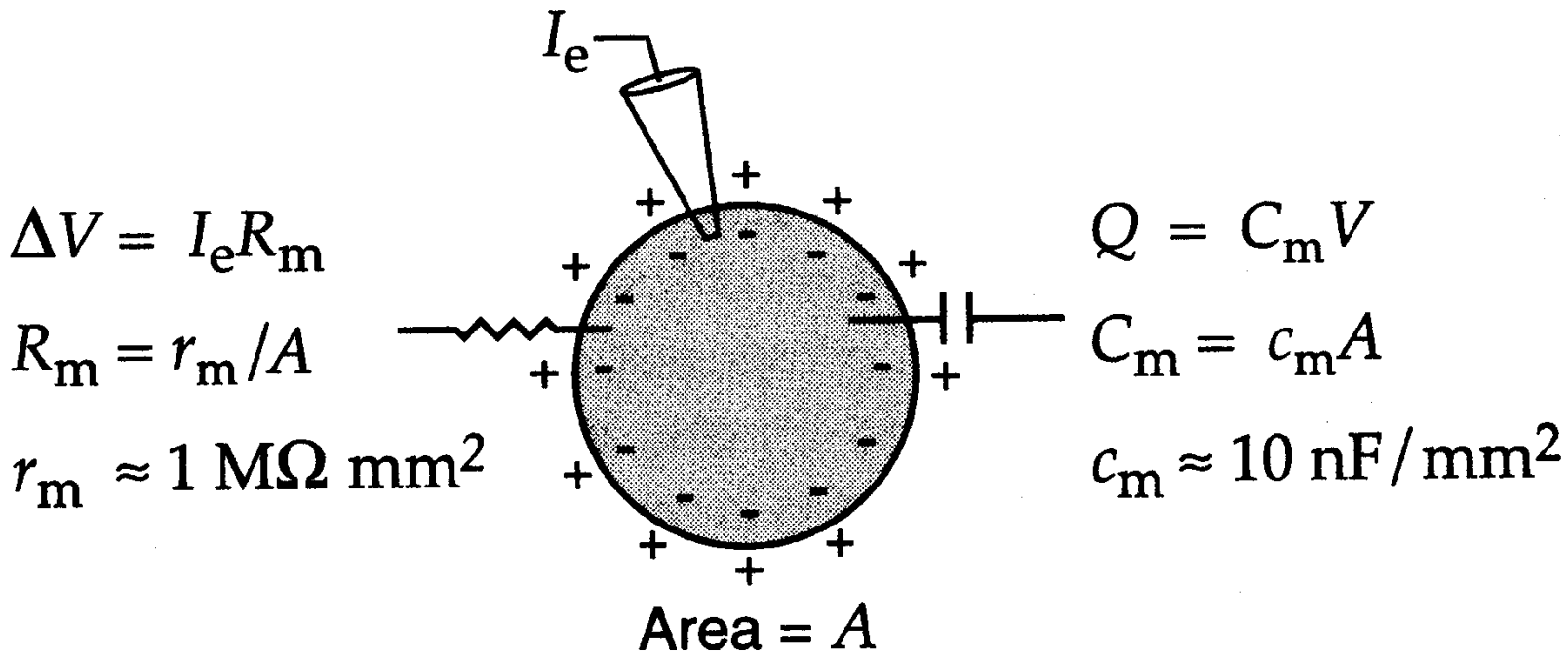
Informational complexity

Mechanisms to generate information at the cellular level

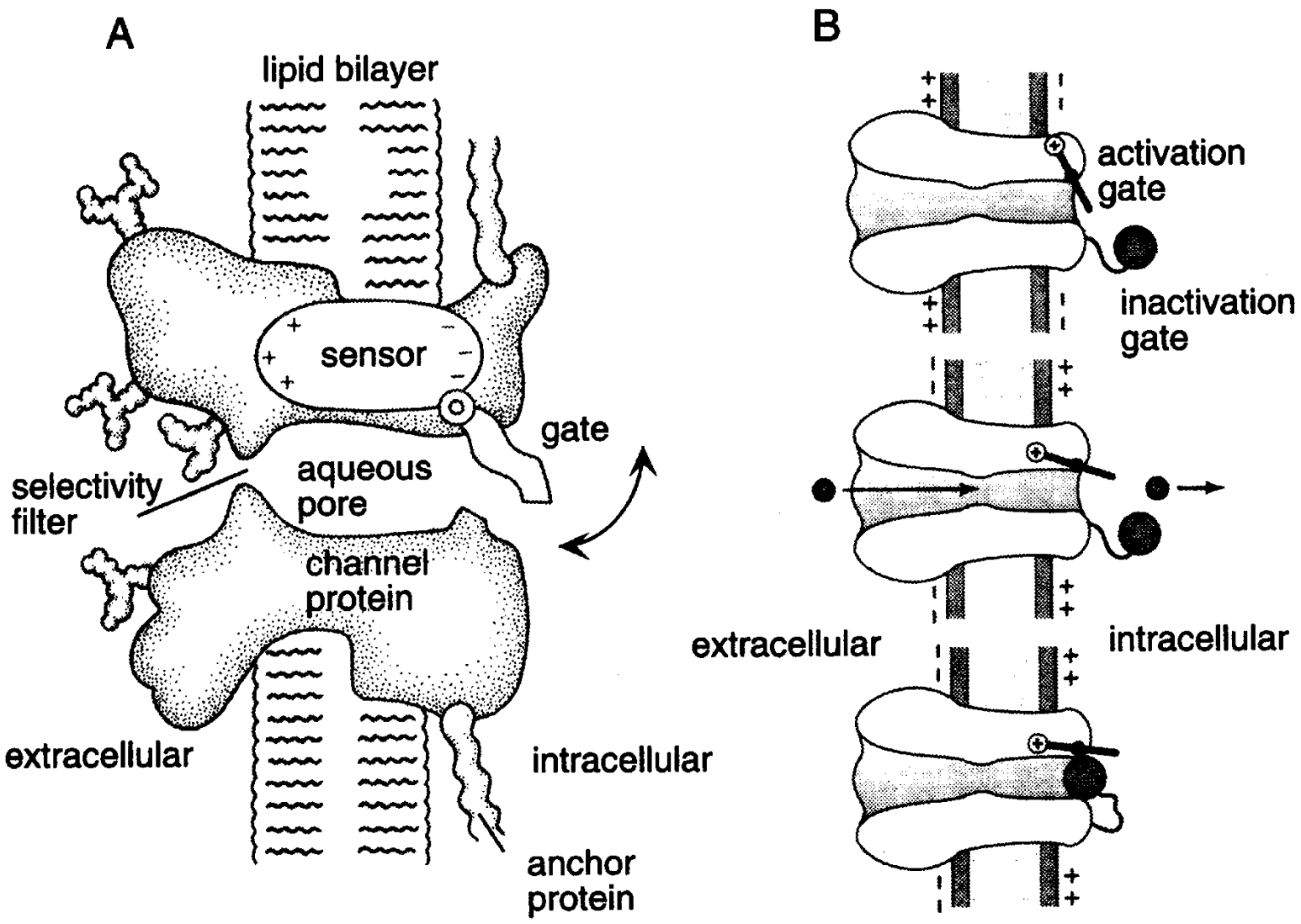


The neuron excitability arises from the electrical properties of its membrane.

Membranes keep different ionic concentrations between the inside and the outside of the cell

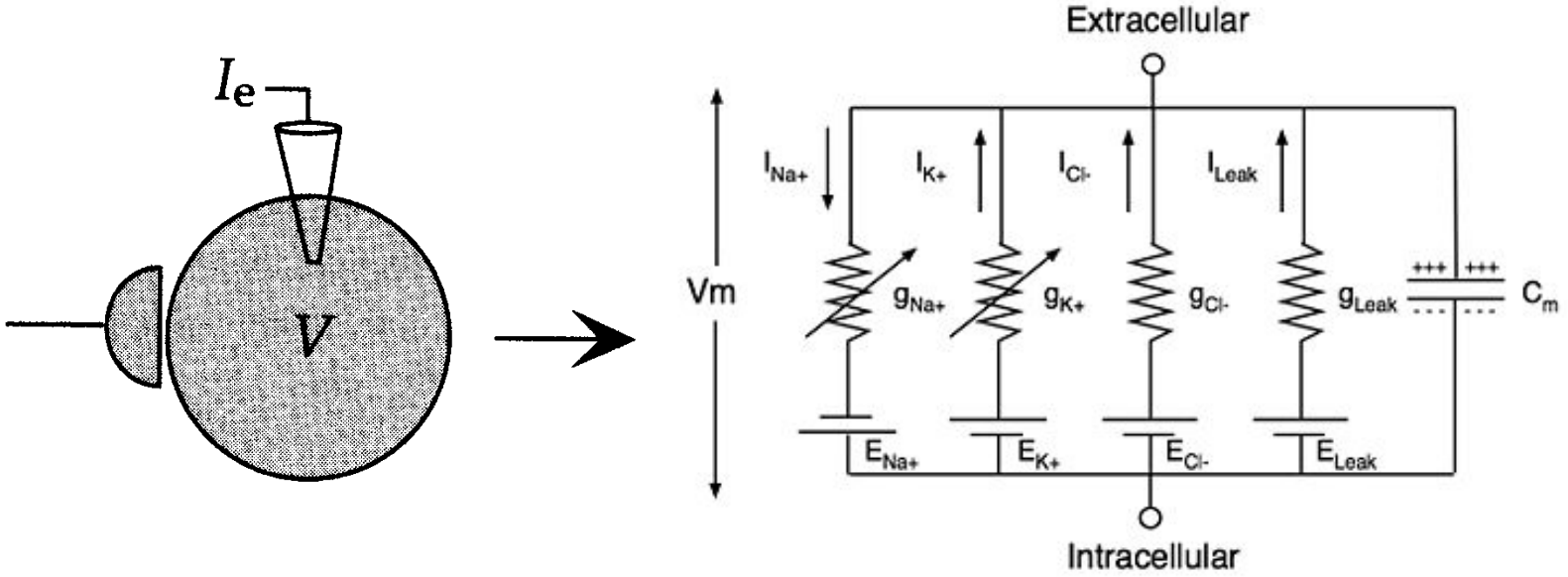


This creates a <u>voltage</u> difference between the inside and the outside, and a concentration of changes at the surface.



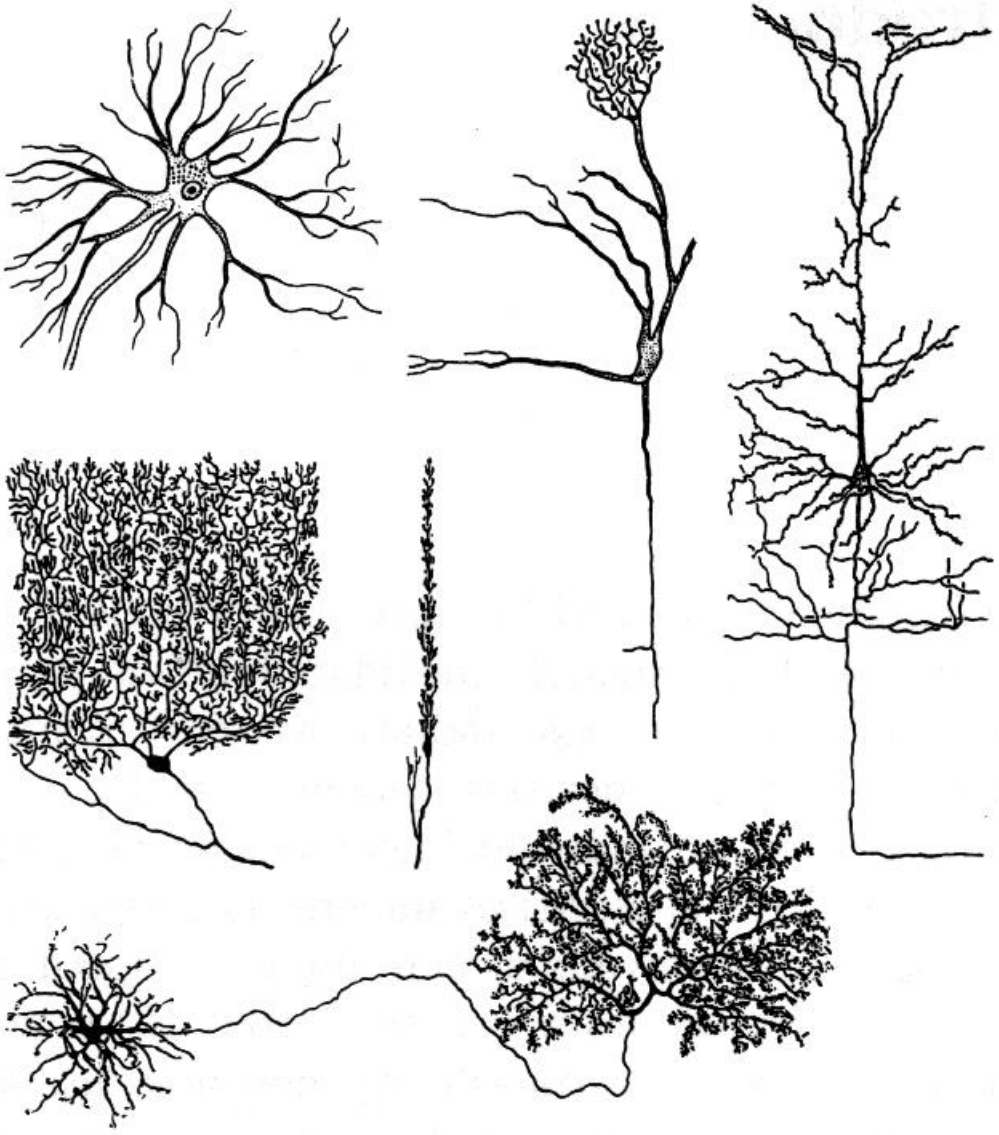
Membranes have passive and active electrical properties.

In addition to electrotonic components (voltage-independent) we have voltage- or concentration-dependent



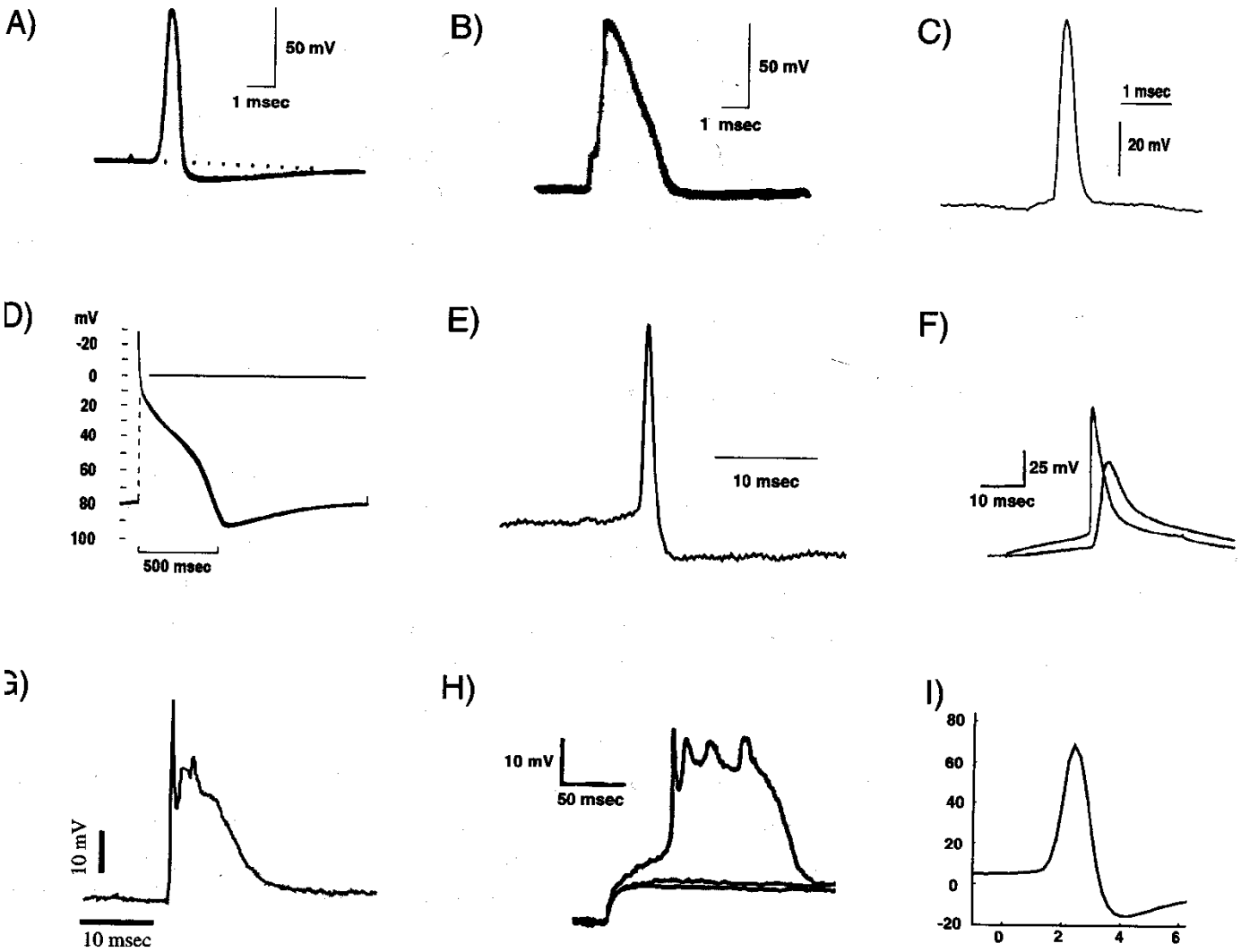
There is a combination of fast and slow dynamics

neural diversity

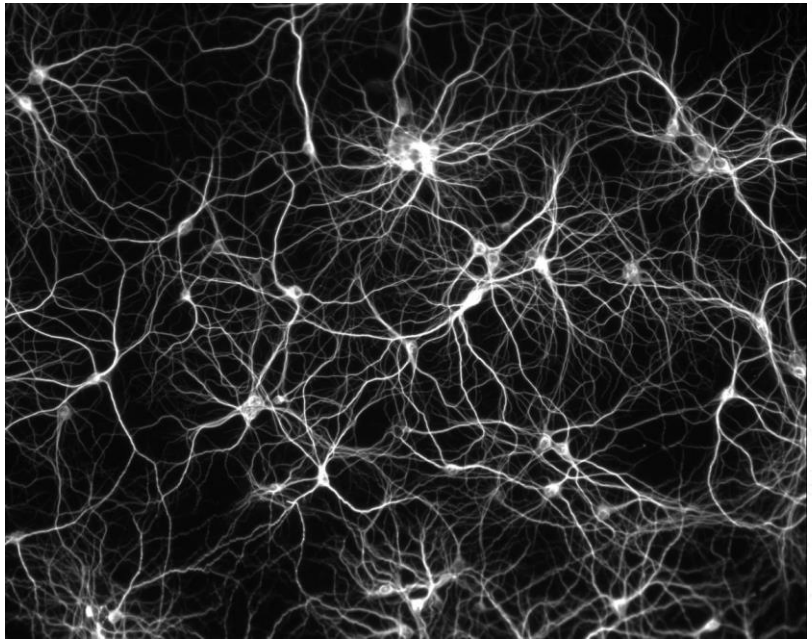


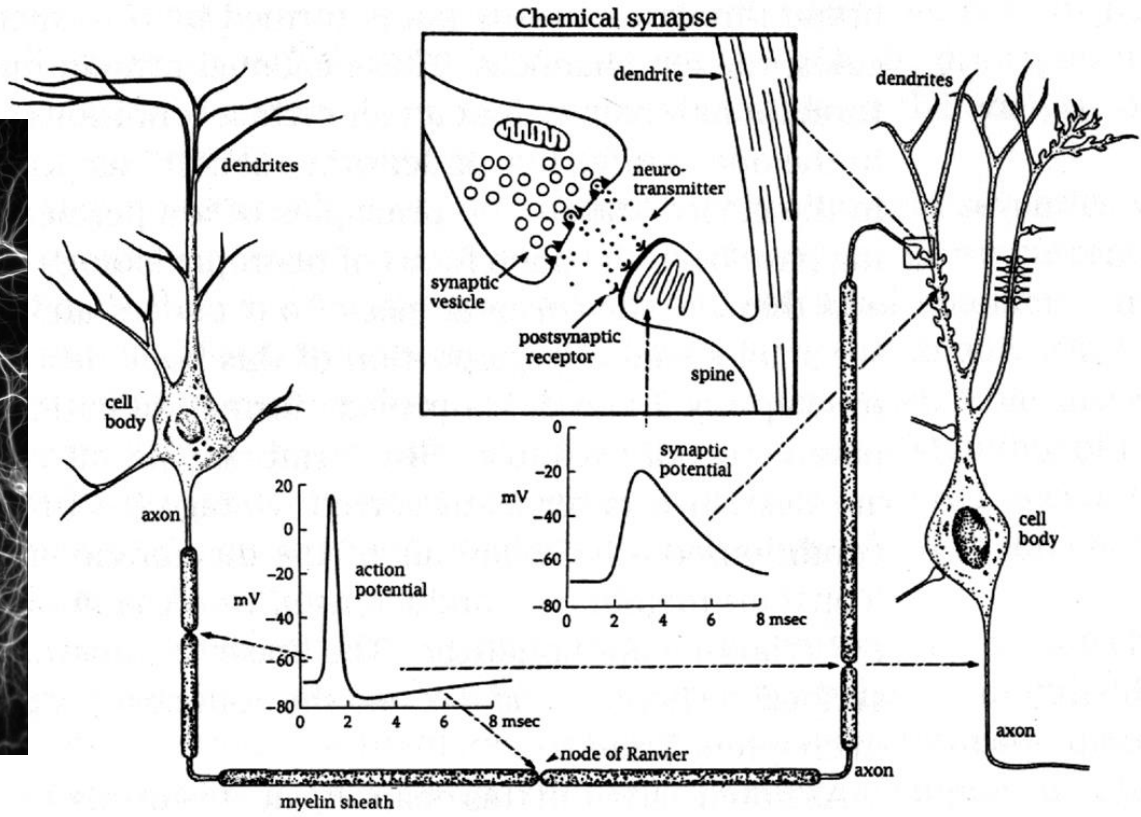
Neurons are the cells that have the largest morphological diversity

Firing diversity



Action potentials also display a large variety of waveforms.

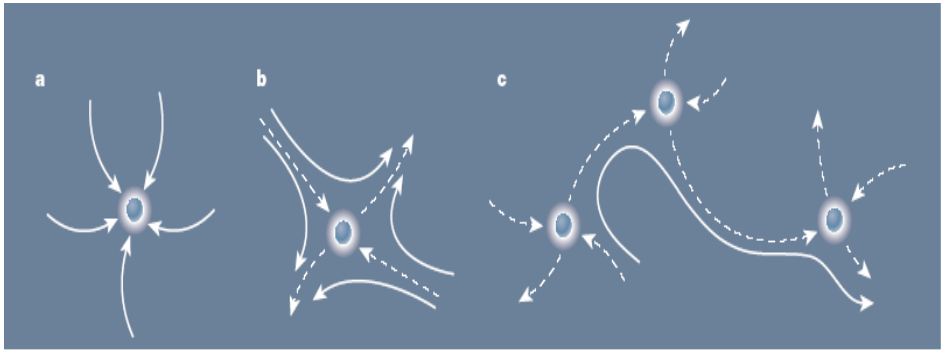



Chemical synapse
dendrite
neuro-
transmitter
synaptic
vesicle
postsynaptic
receptor
spine
dendrites
cell
body
axon
20
0
-20
-40
-60
-80
mV
action
potential
0 2 4 6 8 msec
0
-20
-40
-60
-80
mV
synaptic
potential
0 2 4 6 8 msec
node of Ranvier
myelin sheath
dendrites
cell
body
axon
axon

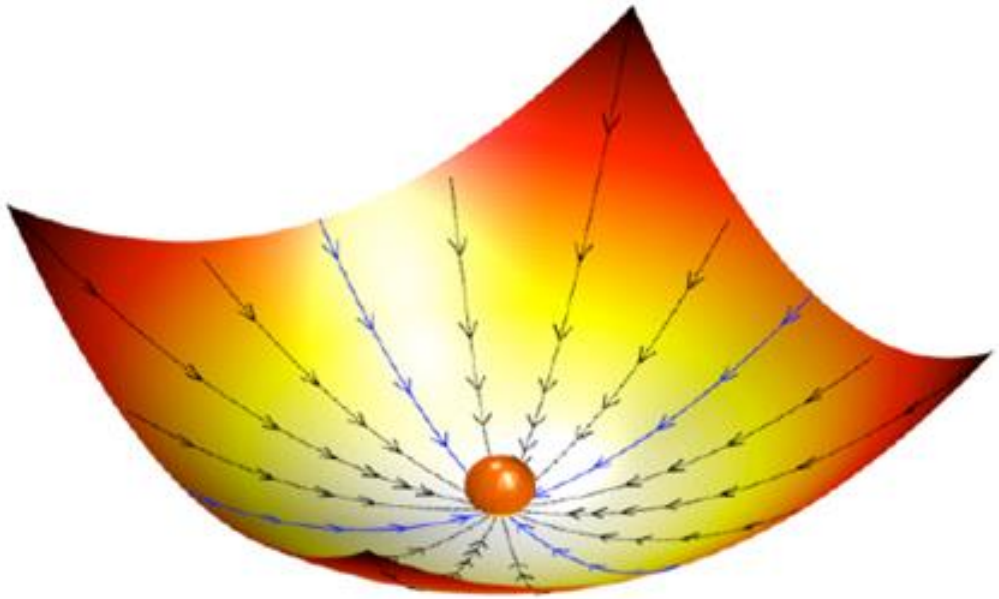
Computational neuroscience uses models of neurons and networks

To study the mechanisms of:

- Information coding
- Information transduction
- Information processing and memory
- Information coordination and creation
- Information execution



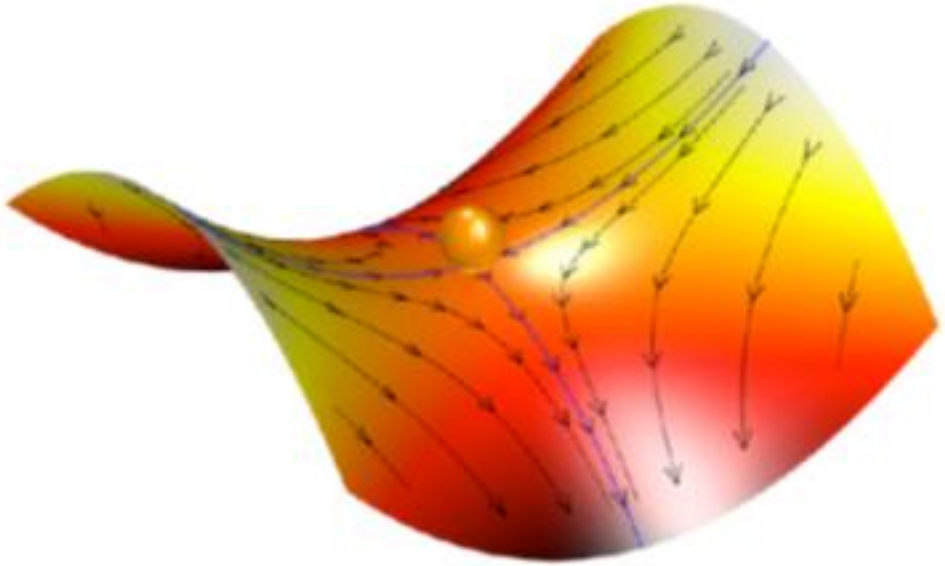
Computing with attractors



Stable node: simple attractor in the phase space of a strongly dissipative dynamical system

Computing with separatrices:

saddle with two stable and two unstable separatrices



A separatrix is a manifold (surface or curve) that refers to the boundary separating two modes of behavior in the phase space of a dynamical system