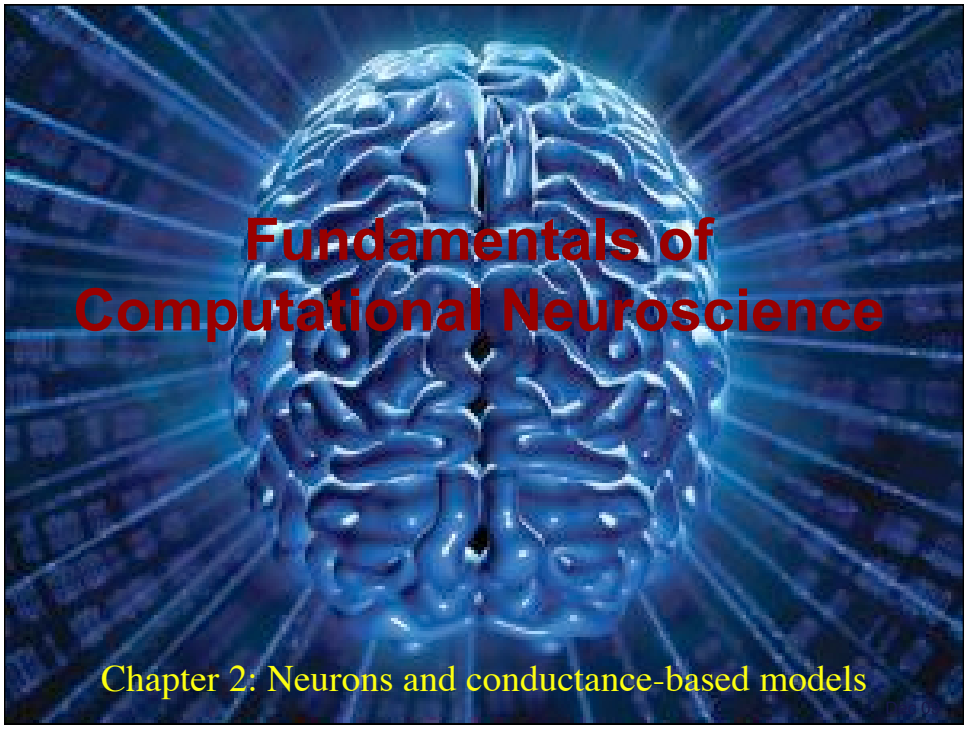
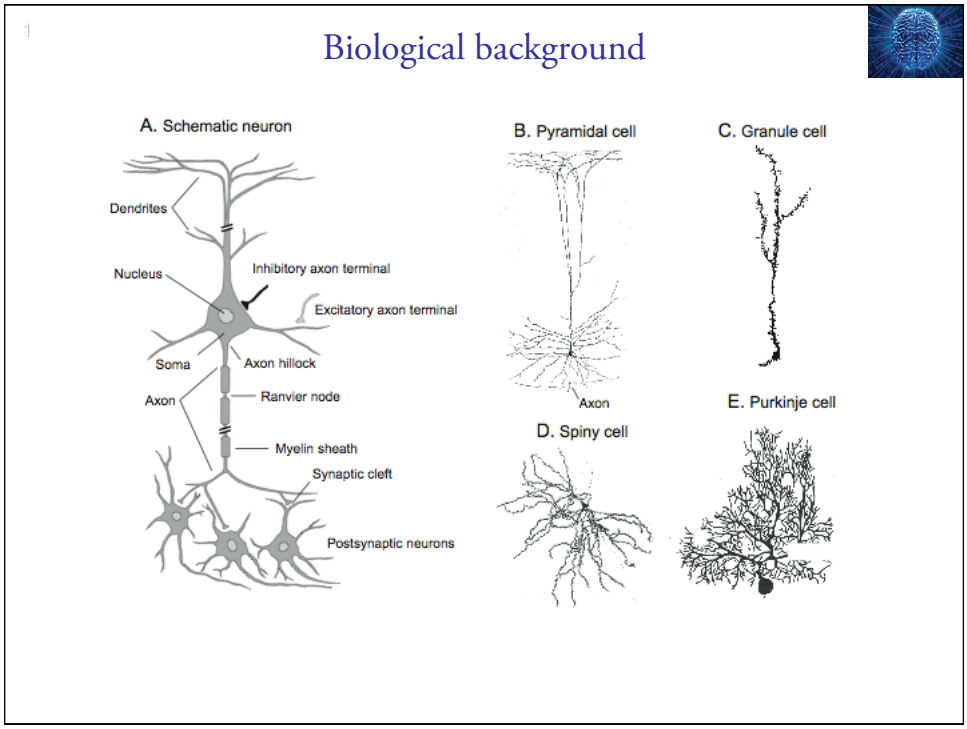
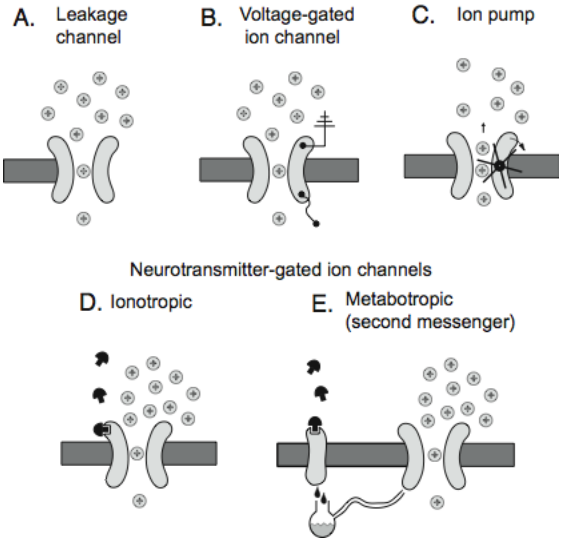

Fundamentals of
Computational Neuroscience
Chapter 2: Neurons and conductance-based models


1
Biological background
A. Schematic neuron
Dendrites
Nucleus
Inhibitory axon terminal
Excitatory axon terminal
Soma
Axon hillock
Axon
Ranvier node
Myelin sheath
Synaptic cleft
Postsynaptic neurons
B. Pyramidal cell
Axon
C. Granule cell
D. Spiny cell
E. Purkinje cell

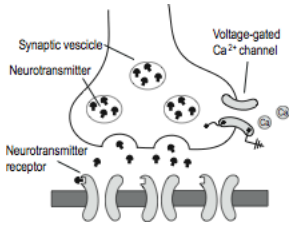
2

Ion channels



3

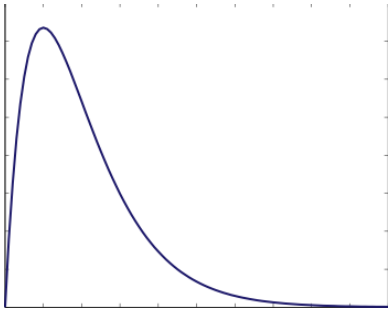
Synapse



4

Non-NMDA: AMPA, GABA

$$\Delta V_{\mathrm{m}}^{\mathrm{non-NMDA}} \propto t\, \mathrm{e}^{-t/t^{\mathrm{peak}}}$$



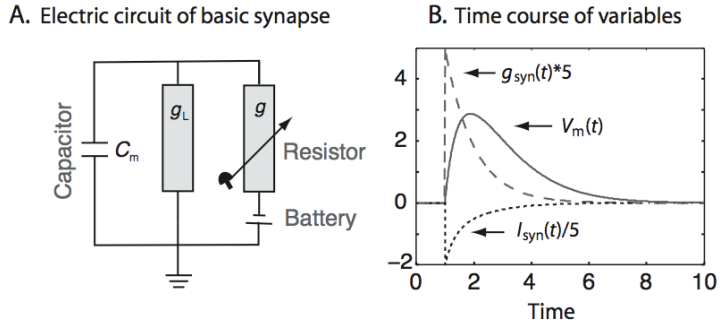
5

Conductance-based models

$$c_m \frac{\mathrm{d}V(t)}{dt} = -I$$

$$I(t) = g_0 V(t) - g(t)(V(t) - E_{\mathrm{syn}})$$

$$\tau_{\mathrm{syn}} \frac{\mathrm{d}g(t)}{\mathrm{d}t} = -g(t) + \delta(t - t_{\mathrm{pre}} - t_{\mathrm{delay}})$$



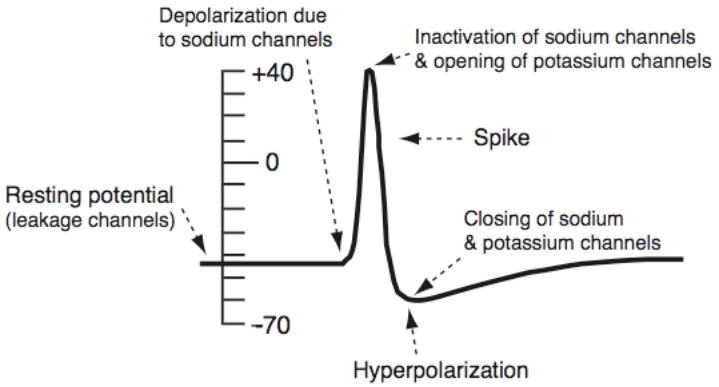
6

MATLAB program

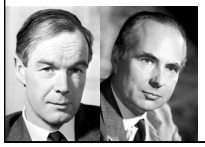
```
1   %% Synaptic conductance model to simulate an EPSP
2    clear; clf; hold on;
3
4   %% Setting some constants and initial values
5    c_m=1; g_L=1; tau_syn=1; E_syn=10; delta_t=0.01;
6    g_syn(1)=0; I_syn(1)=0; v_m(1)=0; t(1)=0;
7
8   %% Numerical integration using Euler scheme
9    for step=2:10/delta_t
10     t(step)=t(step-1)+delta_t;
11     if abs(t(step)-1)<0.001; g_syn(step-1)=1; end
12     g_syn(step)= (1-delta_t/tau_syn) * g_syn(step-1);
13     I_syn(step)= g_syn(step) * (v_m(step-1)-E_syn);
14     v_m(step) = (1-delta_t/c_m*g_L) * v_m(step-1) ...
15                     - delta_t/c_m * I_syn(step);
16   end
17
18  %% Plotting results
19   plot(t,v_m); plot(t,g_syn*5,'r--'); plot(t,I_syn/5,'k:')
```

7

Hodgkin-Huxley model



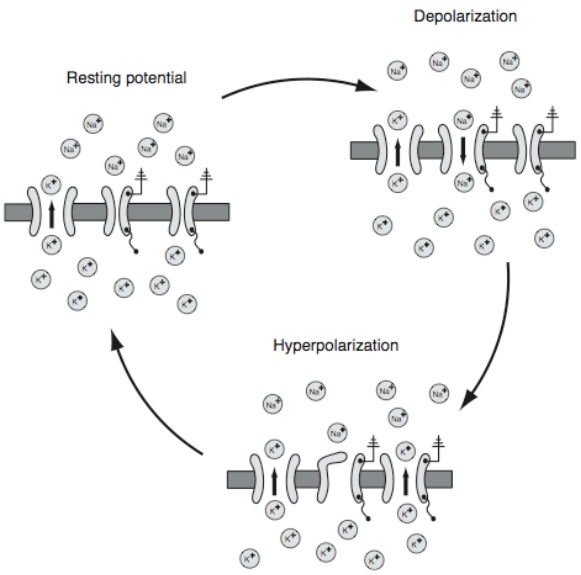
Typical form of an action potential; redrawn from an oscilloscope picture from Hodgkin and Huxley (1939).



Alan Hodgkin and Andrew Huxley
The Nobel Prize in Physiology or Medicine 1963 (with John Eccles)

8

The minimal mechanism



9

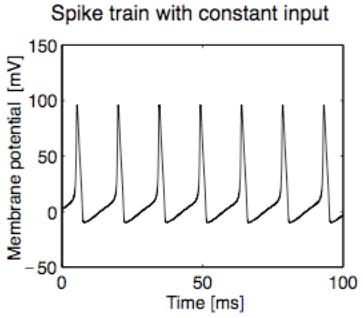
Hodgkin-Huxley equations and simulation

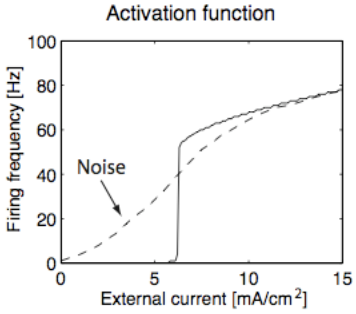
$$C\frac{dV}{dt} = -g_K n^4 (V - E_K) - g_{Na} m^3 h (V - E_{Na}) - g_L (V - E_L) + I(t)$$

$$\tau_n(V)\frac{dn}{dt} = -[n - n_0(V)]$$

$$\tau_m(V)\frac{dm}{dt} = -[m - m_0(V)]$$

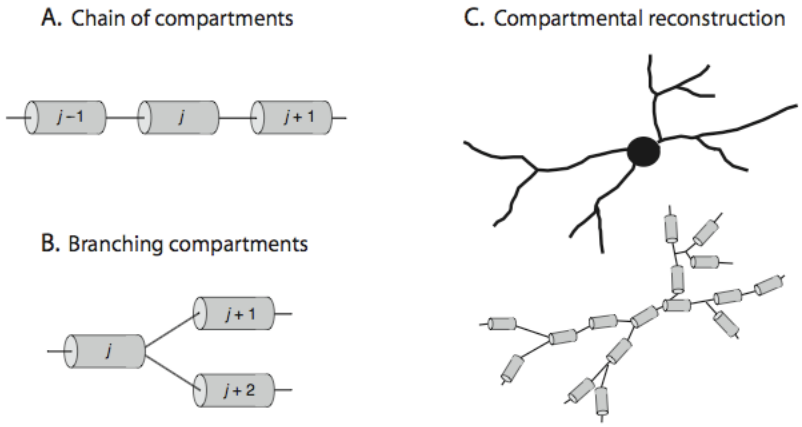
$$\tau_h(V)\frac{dh}{dt} = -[h - h_0(V)]$$





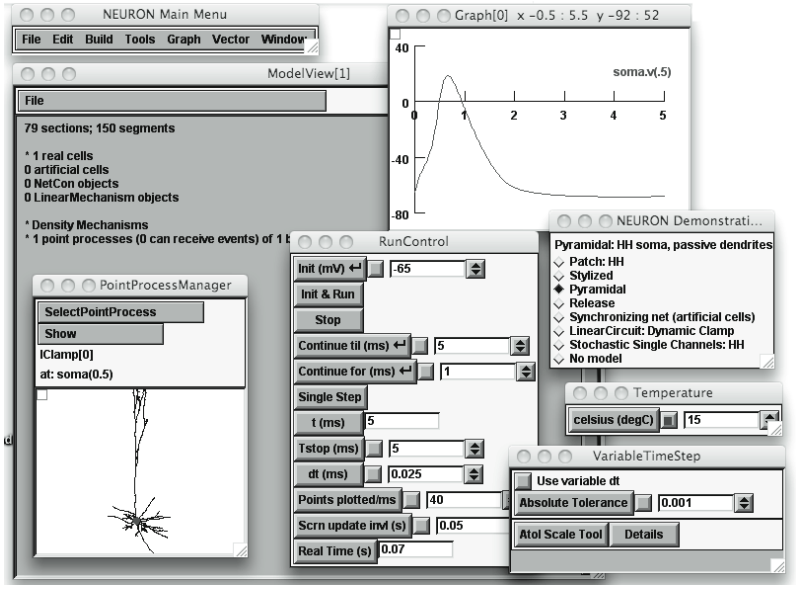
10

Compartmental models



11

Simulators



12

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

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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.