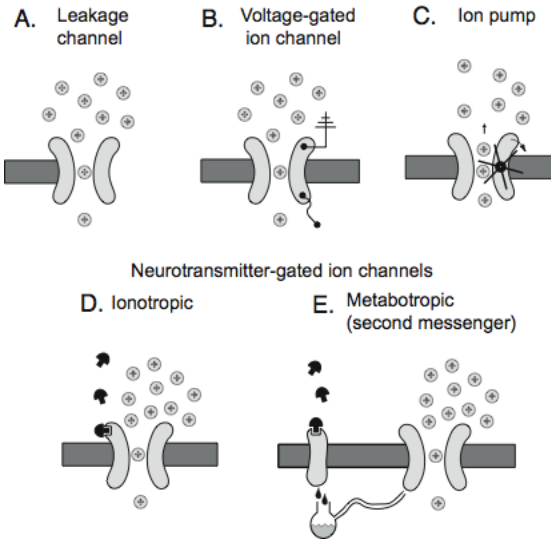


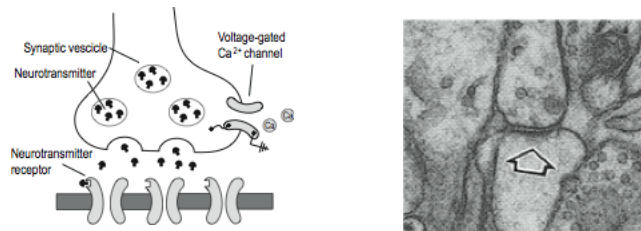
2

## Ion channels



3

## Synapse

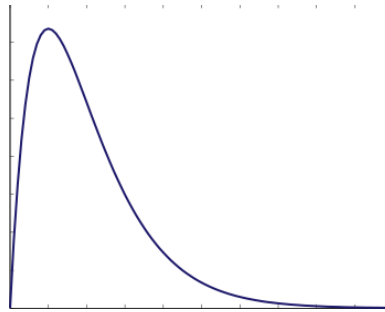


4

## Non-NMDA: AMPA, GABA



$$\Delta V_m^{\text{non-NMDA}} \propto t e^{-t/t^{\text{peak}}}$$



5

## Conductance-based models

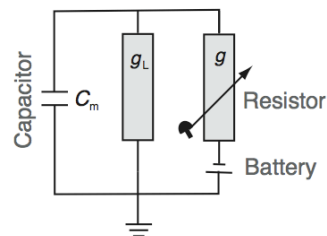


$$C_m \frac{dV(t)}{dt} = -I$$

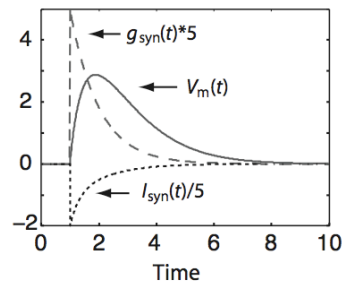
$$I(t) = g_0 V(t) - g(t)(V(t) - E_{\text{syn}})$$

$$\tau_{\text{syn}} \frac{dg(t)}{dt} = -g(t) + \delta(t - t_{\text{pre}} - t_{\text{delay}})$$

A. Electric circuit of basic synapse



B. Time course of variables



6

## MATLAB program



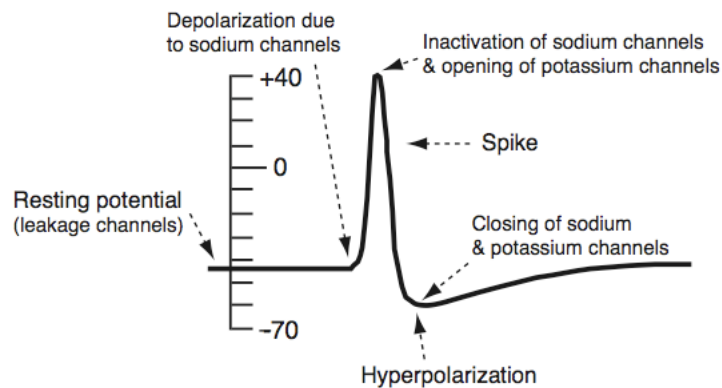
```

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

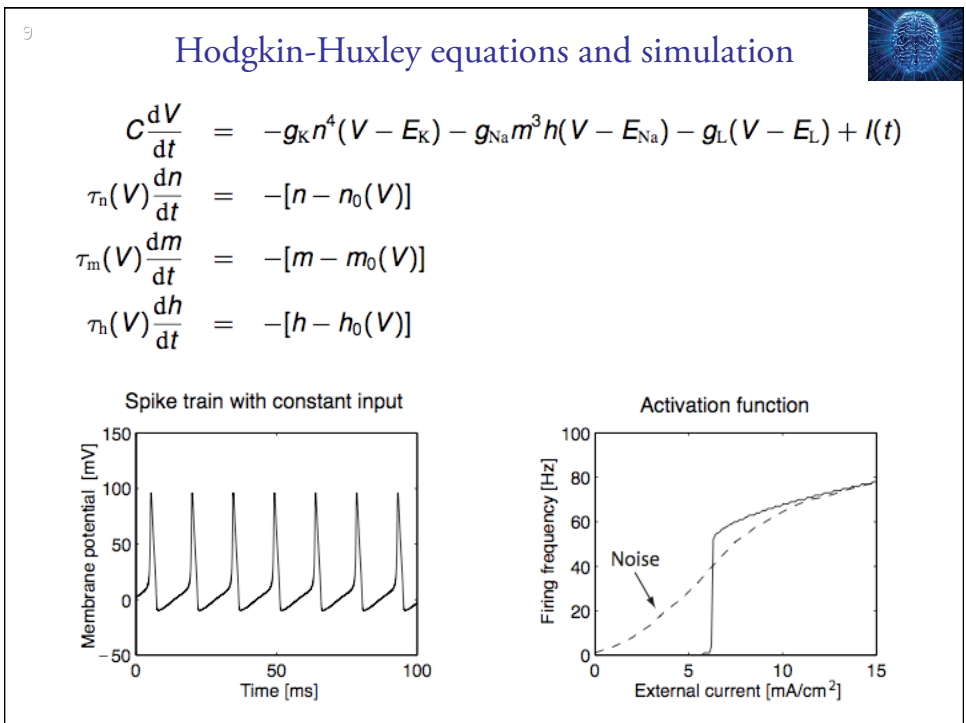
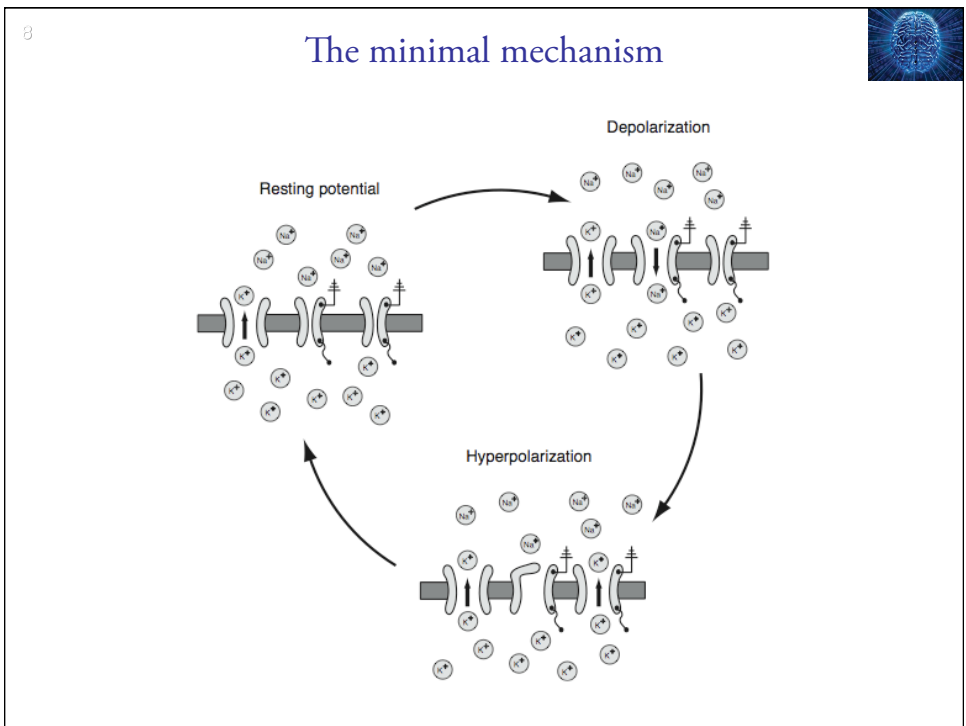
## Hodgkin-Huxley model



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)



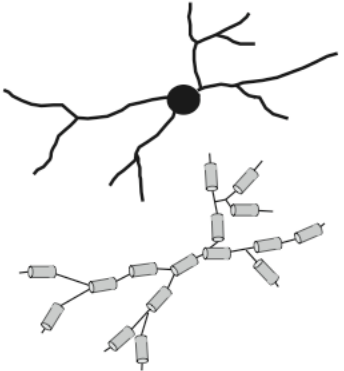
10

## Compartmental models

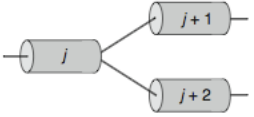
**A. Chain of compartments**



**C. Compartmental reconstruction**

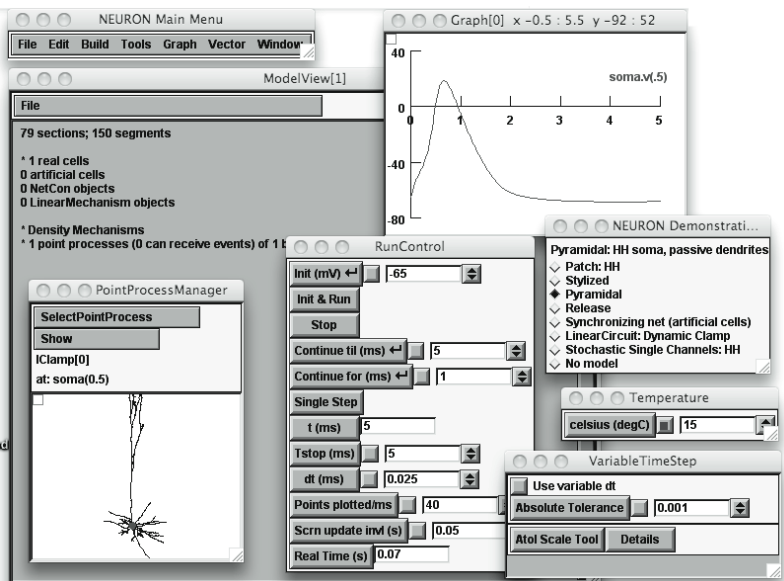


**B. Branching compartments**



11

## Simulators



The screenshot displays the NEURON software interface with several windows open:

- NEURON Main Menu:** Shows standard menu options like File, Edit, Build, Tools, Graph, Vector, and Window.
- ModelView[1]:** Displays a list of model components:
  - 79 sections; 150 segments
  - \* 1 real cells
  - 0 artificial cells
  - 0 NetCon objects
  - 0 LinearMechanism objects
  - \* Density Mechanisms
  - \* 1 point processes (0 can receive events) of 1 k
- PointProcessManager:** Shows a 'SelectPointProcess' dialog with 'IClamp[0]' selected at 'soma(0.5)'. A small diagram of the neuron is visible below.
- RunControl:** Contains simulation parameters:
  - Init (mV): -65
  - Continue till (ms): 5
  - Continue for (ms): 1
  - Single Step: t (ms) 5, Tstop (ms) 5, dt (ms) 0.025
  - Points plotted/ms: 40
  - Scrn update invt (s): 0.05
  - Real Time (s): 0.07
- Graph[0]:** A plot of 'soma.v(.5)' showing a membrane potential spike from -65 mV to approximately 10 mV over time.
- NEURON Demonstrati...:** A list of model mechanisms with checkboxes:
  - Pyramidal: HH soma, passive dendrites
  - Patch: HH
  - Stylized
  - Pyramidal
  - Release
  - Synchronizing net (artificial cells)
  - Linear Circuit: Dynamic Clamp
  - Stochastic Single Channels: HH
  - No model
- Temperature:** Set to 'celsius (degC)' at 15.
- VariableTimeStep:** Includes 'Use variable dt', 'Absolute Tolerance' (0.001), and 'AtoI Scale Tool'.

## 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.