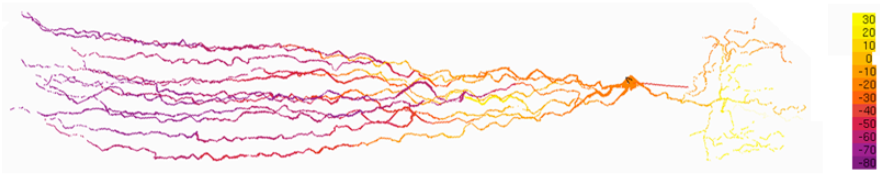
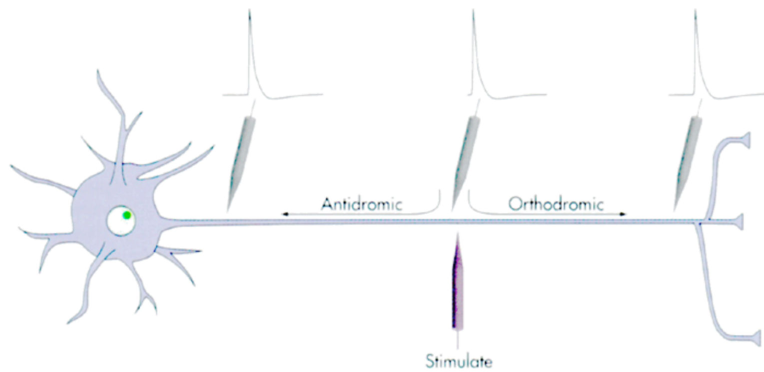
Compartmental models, cable properties, spike propagation





The Human Brain: An Introduction to Its Functional Anatomy (1999) John Nolte

0_axonProp.psd

Hodgkin-Huxley Equation

injected current, sodium current, potassium current, leak current

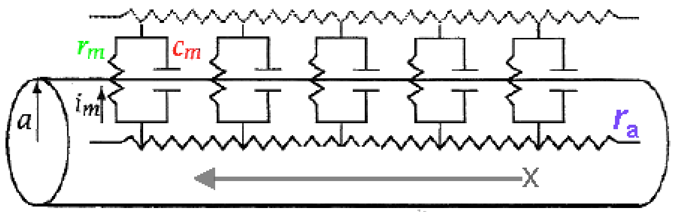
$$\frac{1}{r_a}\frac{\partial^2 V}{\partial x^2} + C\,\frac{dV}{dt} = I - \bar{g}_{Na} m^3 h (V - V_{Na}) - \bar{g}_K n^4 (V - V_K) - g_L (V - V_L)$$

$$\frac{dm}{dt} = \alpha_m(V)(1-m) - \beta_m(V)m \qquad \frac{dh}{dt} = \alpha_h(V)(1-h) - \beta_h(V)h$$

$$\frac{dn}{dt} = \alpha_n(V)(1-n) - \beta_n(V)n$$

00_hh_eq_space.psd

Cable Equation for Membrane Segments



Membrane resistance (Ω cm) **Membrane capacitance** (F cm^{-1}) **Axial resistance** (Ω cm^{-1})

$$r_m = \frac{R_m}{2\pi a} \qquad c_m = C_m 2\pi a \qquad r_a = \frac{R_a}{\pi a^2}$$

1.Ohm's law: $\Delta V = -i_a r_a \Delta x \Rightarrow \dfrac{\partial V}{\partial x} = -i_a r_a$

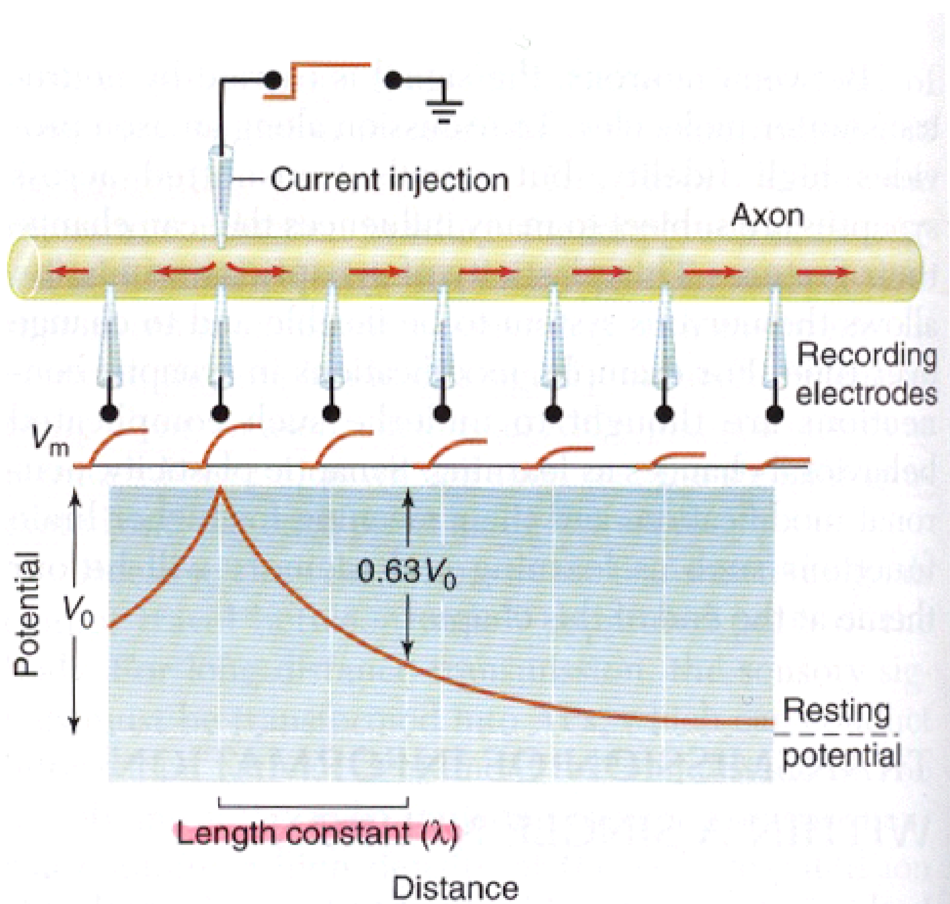
2. Kirchoff's law: $\Delta i_a = -i_m \Delta x \Rightarrow \dfrac{\partial i_a}{\partial x} = -i_m$

$\Big\}$ --> $i_m = \dfrac{V}{r_m} + c_m \dfrac{\partial V}{\partial t}$

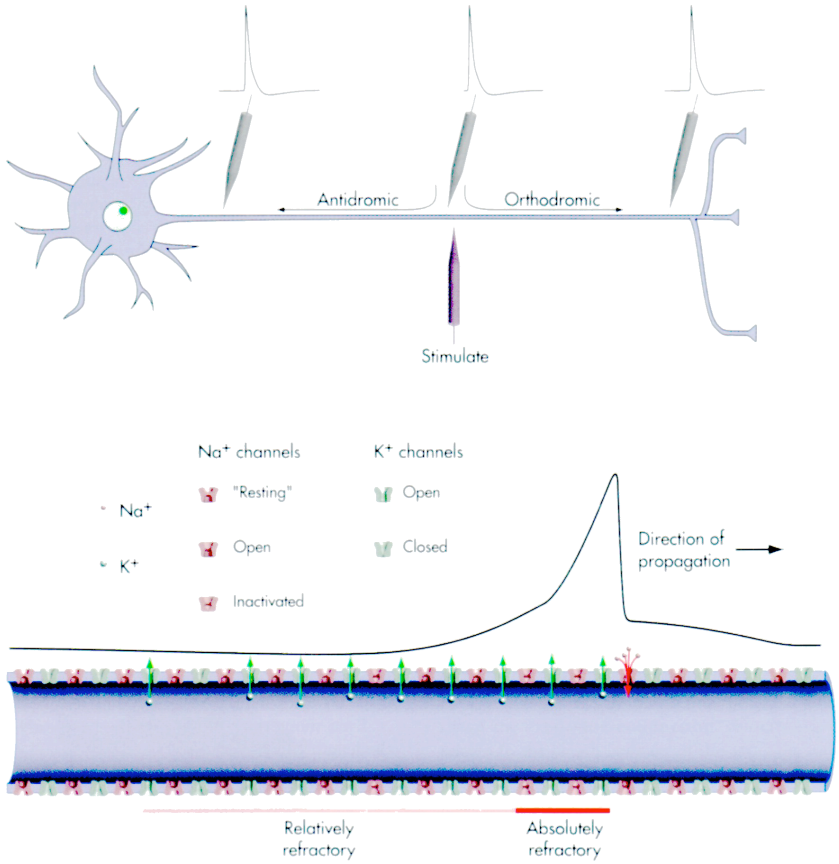
3. Cable Eq:

$$\lambda^2 \frac{\partial^2 V}{\partial x^2} - \tau \frac{\partial V}{\partial t} - V = 0 \qquad \tau = r_m c_m,\ \lambda = \sqrt{\frac{r_m}{r_a}}$$

01_cableEq.psd



02_lengthConst.psd



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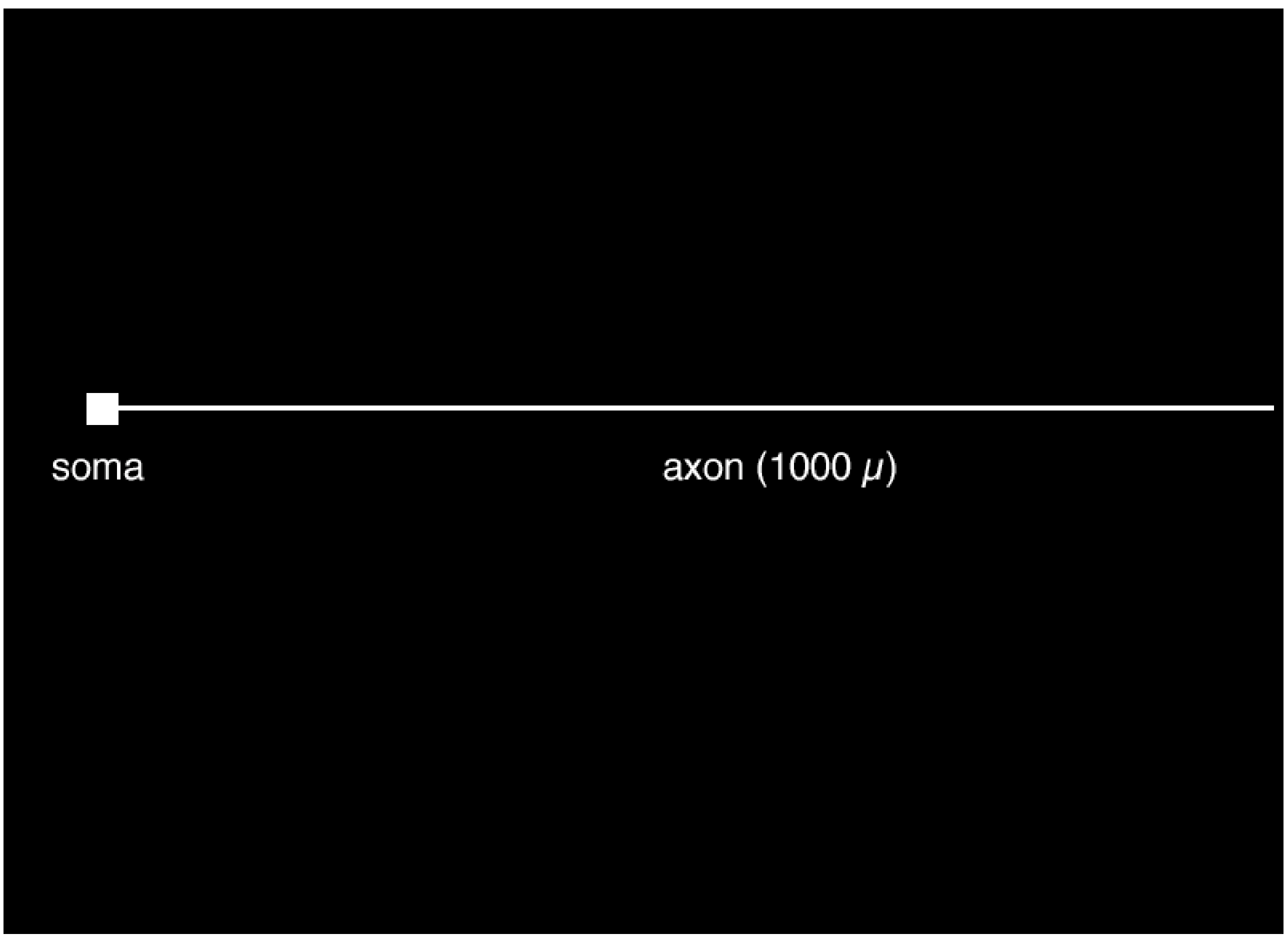
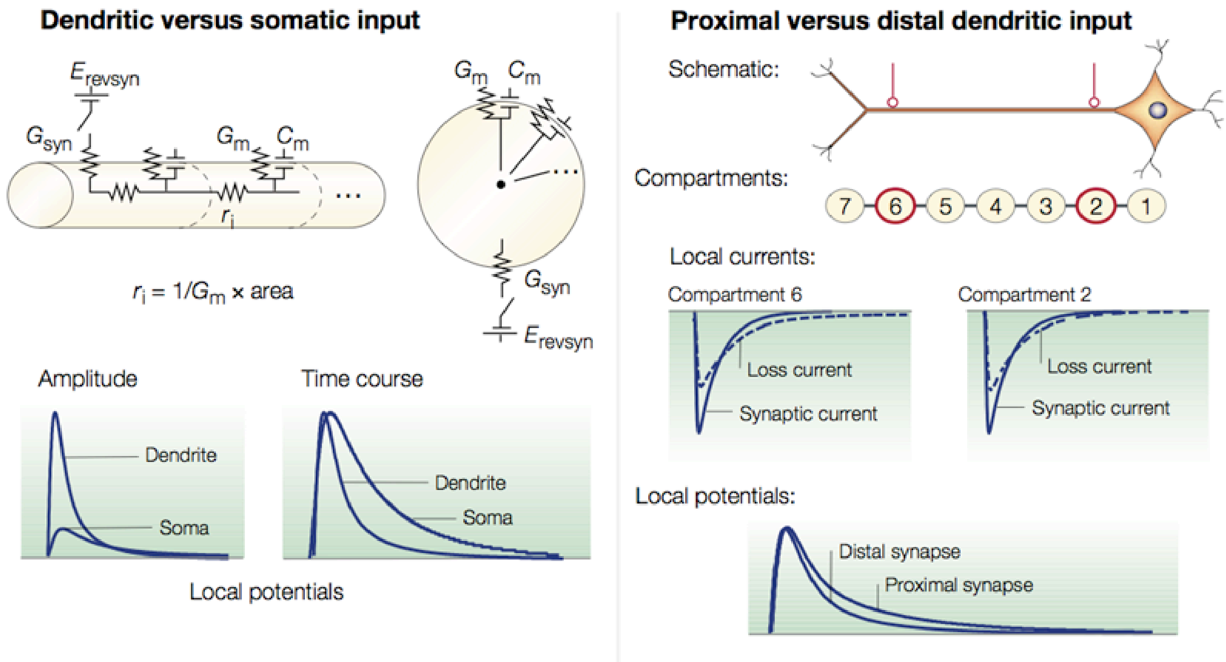
02a_axonProp.psd



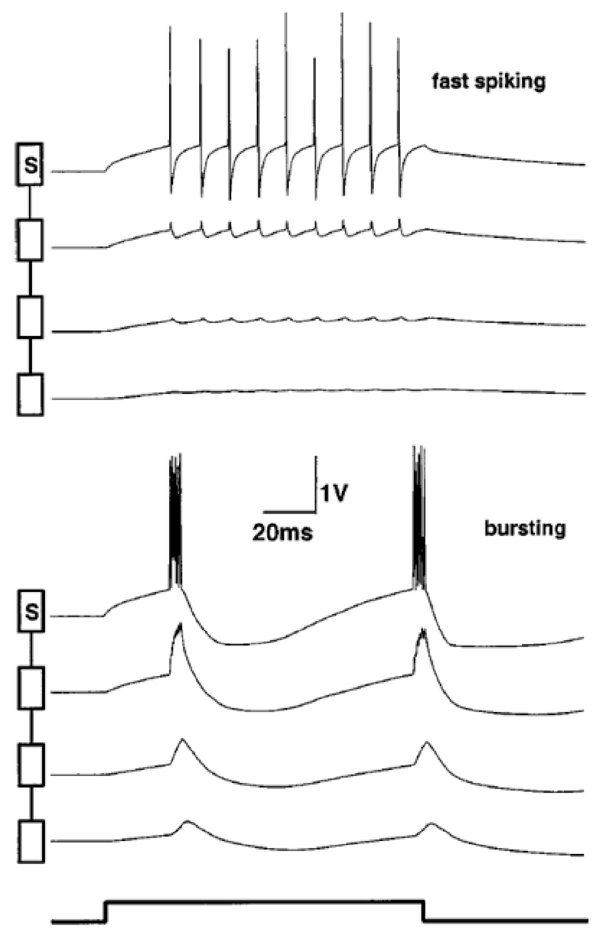
02b_axonSimul.psd

Theoretical dependence of synaptic input on location

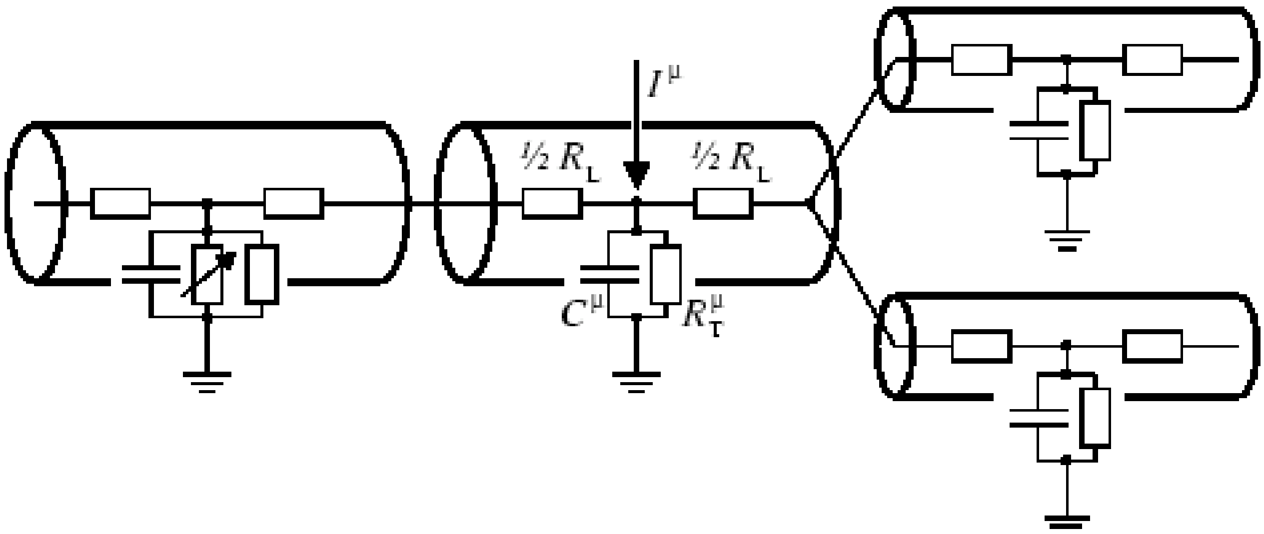


Magee (2000) "Dendritic integration of excitatory synaptic input" Nat Rev Neurosci, 1: 181-190

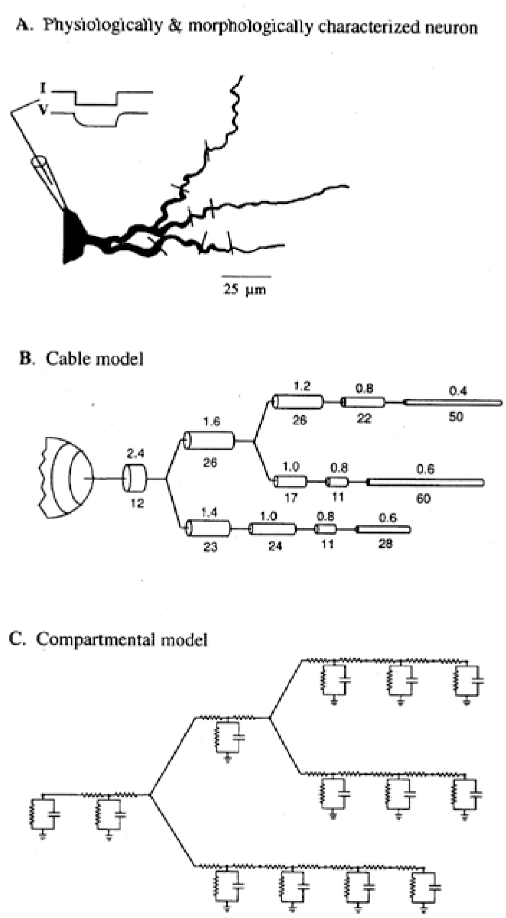
03a_dendriticLoc.psd



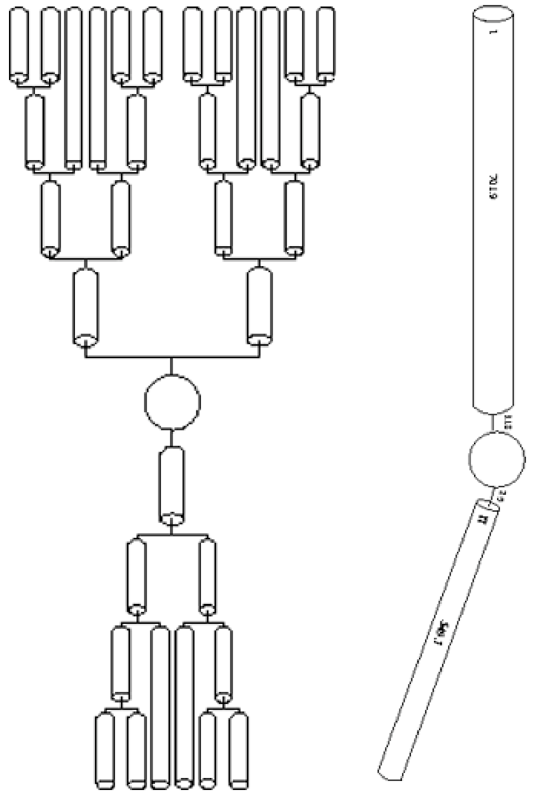
03b_dendritic_decay.psd



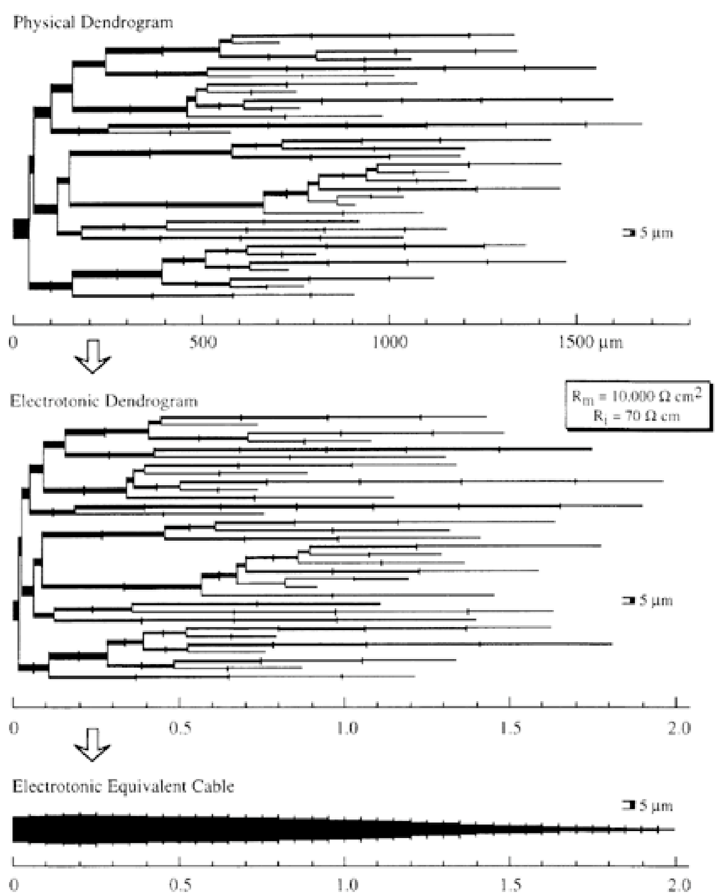
04_compart.gif



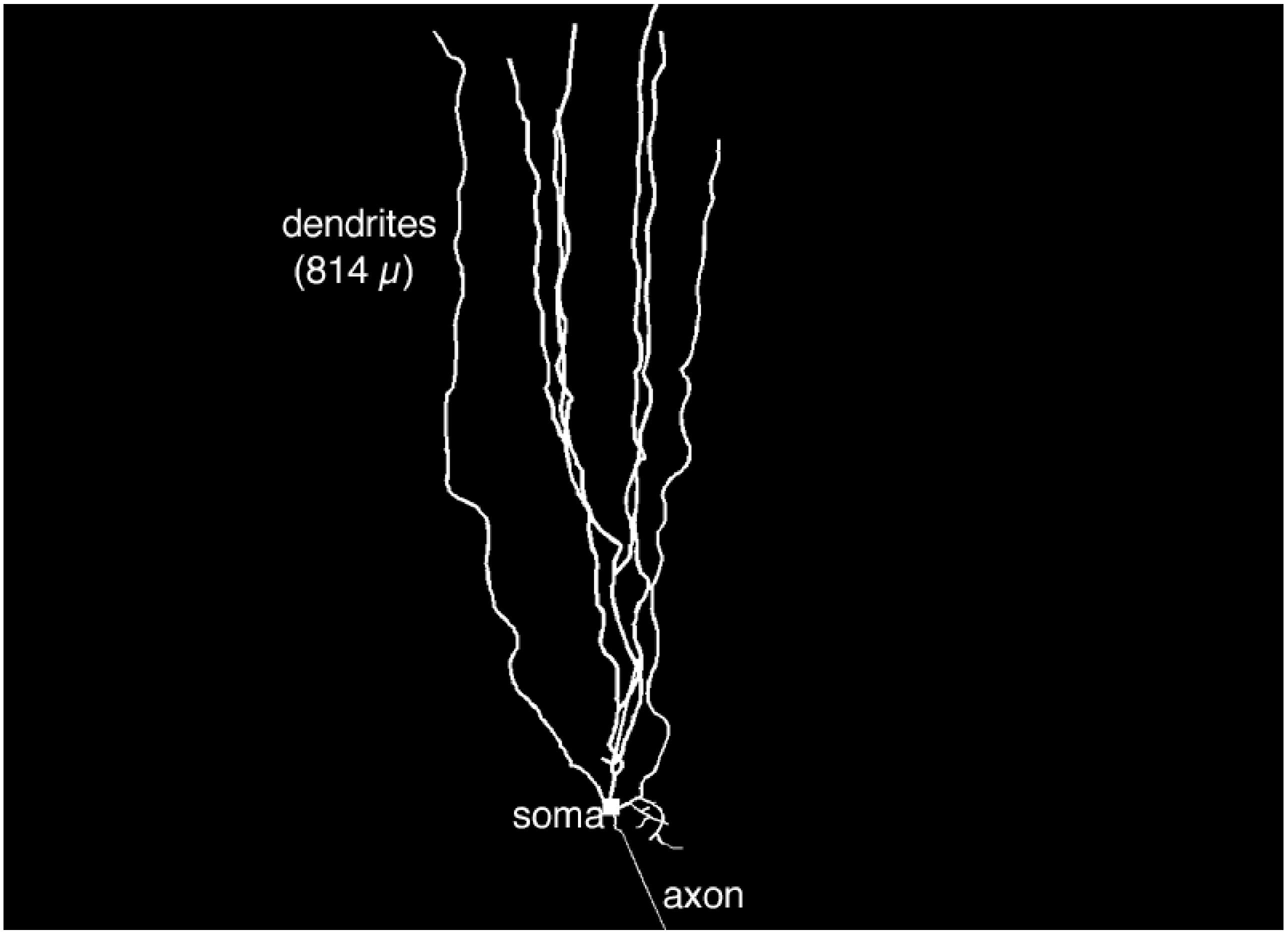
05_morphReduction.psd



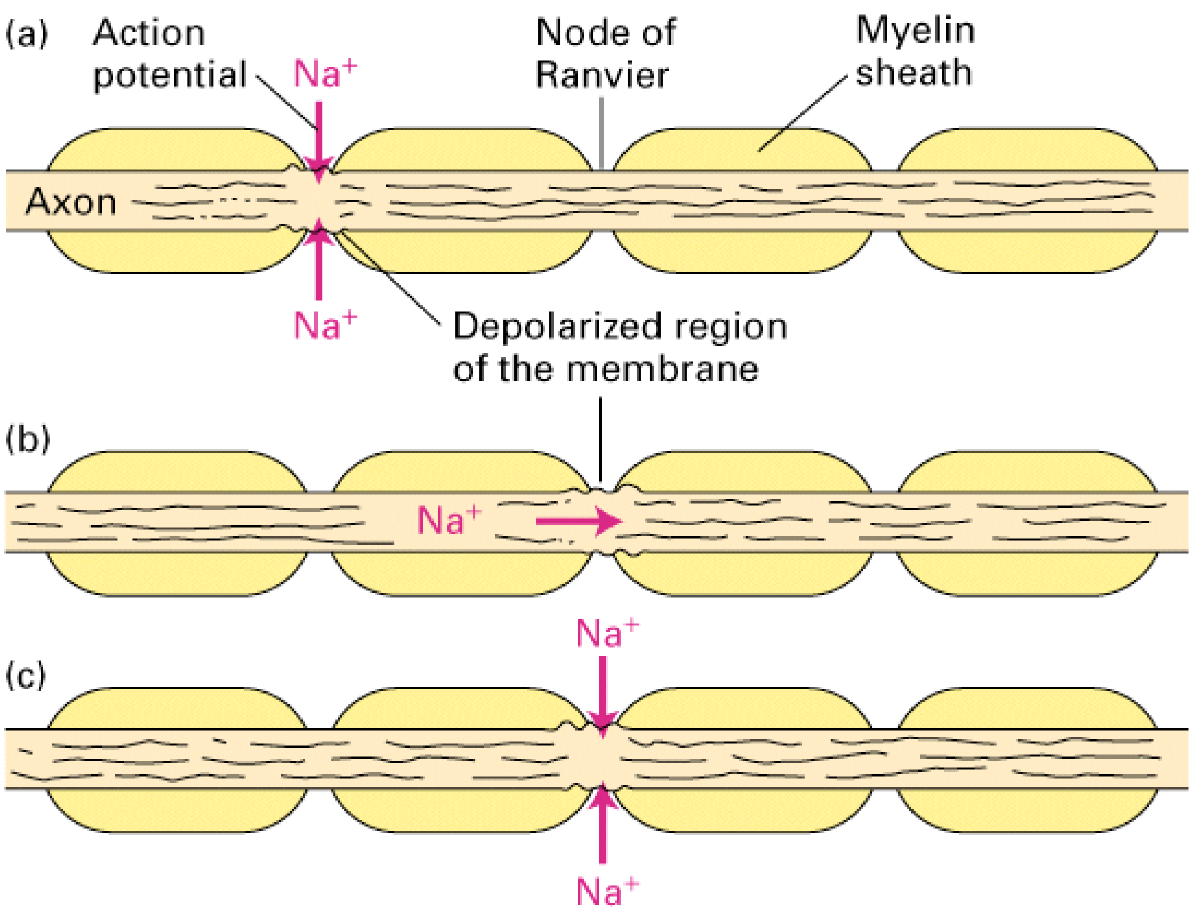
06_electro_reduction.psd



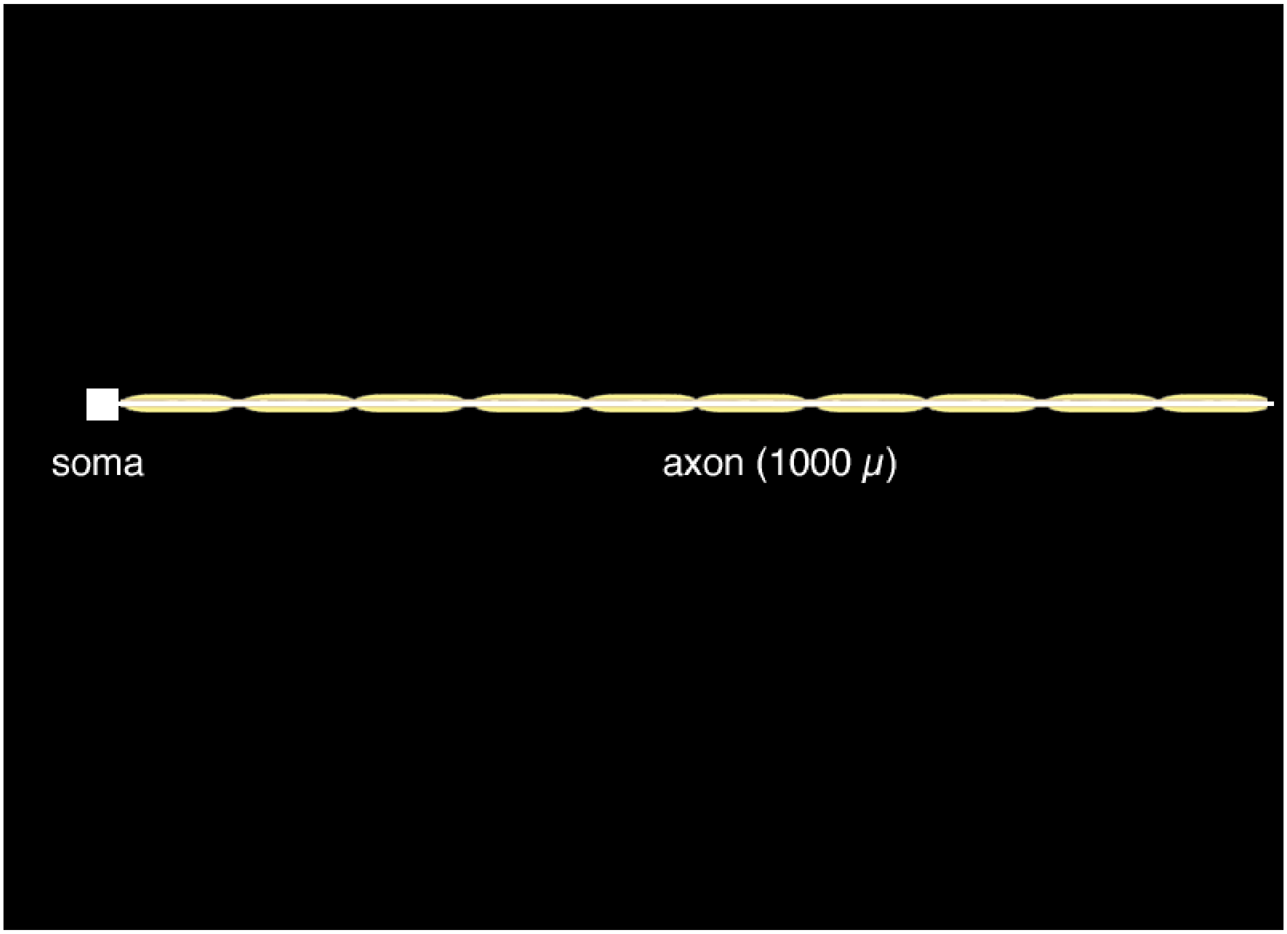
07_physElectEquiv.psd



08_MGCellSimul.psd

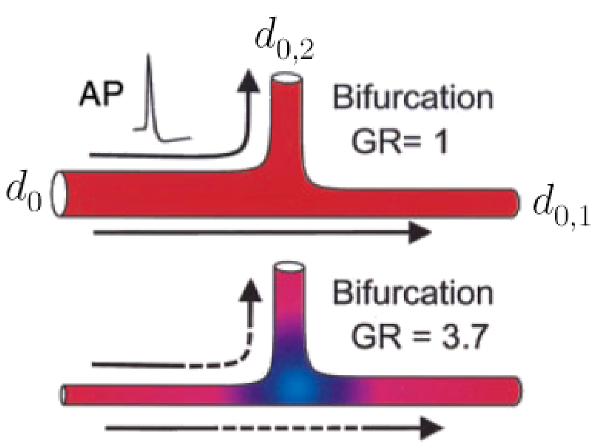


12_myelin.gif



13_myelinSimul.psd

Impedance Matching



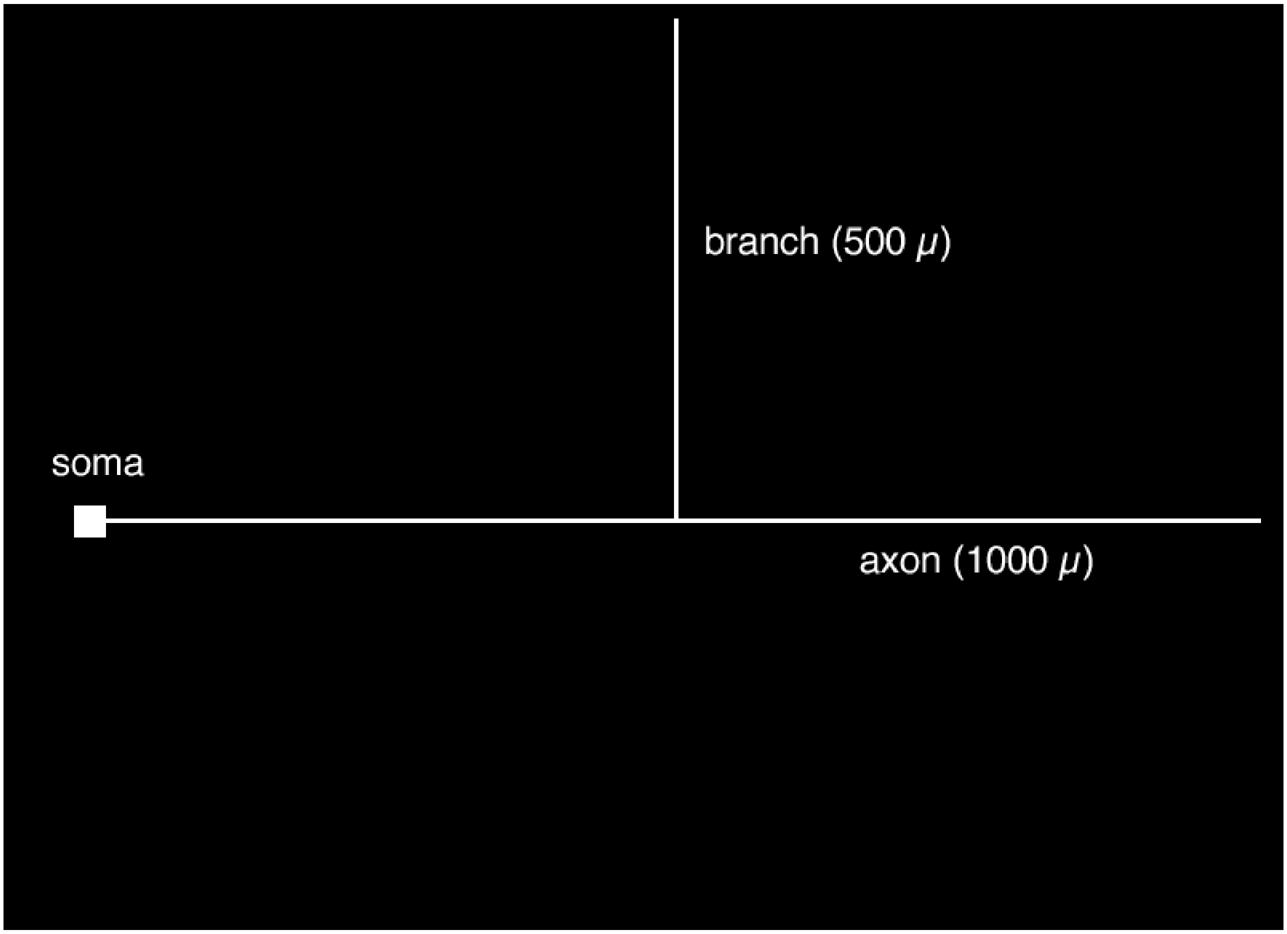
Goldstein–Rall (GR) ratio

$$GR = \frac{d_{0,1}^{3/2} + d_{0,2}^{3/2}}{d_0^{3/2}}$$

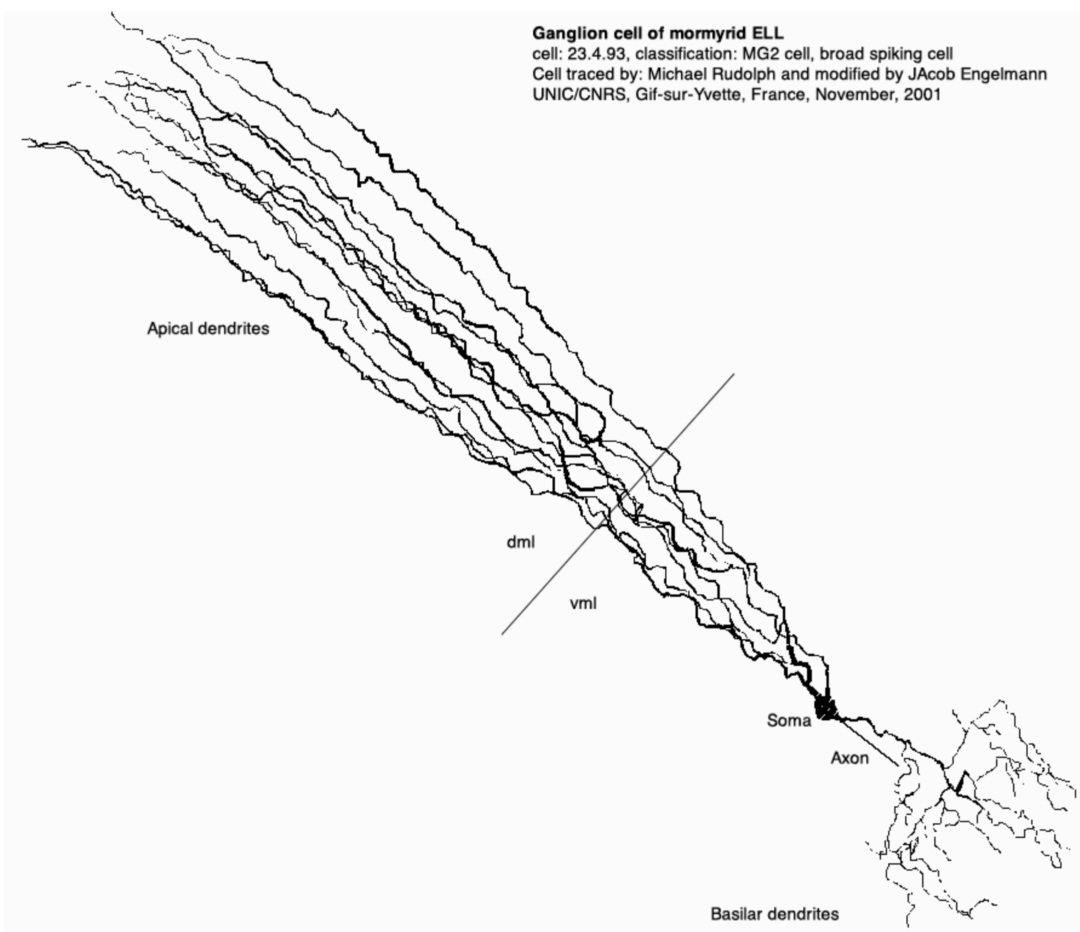
If GR=1 => Impedances match perfectly and spikes propagate without perturbation.
If GR<1 => Action potential acts as if the axon tapers and increases speed.
If GR>1 => Action potential propagation may fail.

Goldstein, S. S. & Rall, W. (1974) Biophys. J. 14, 731–757

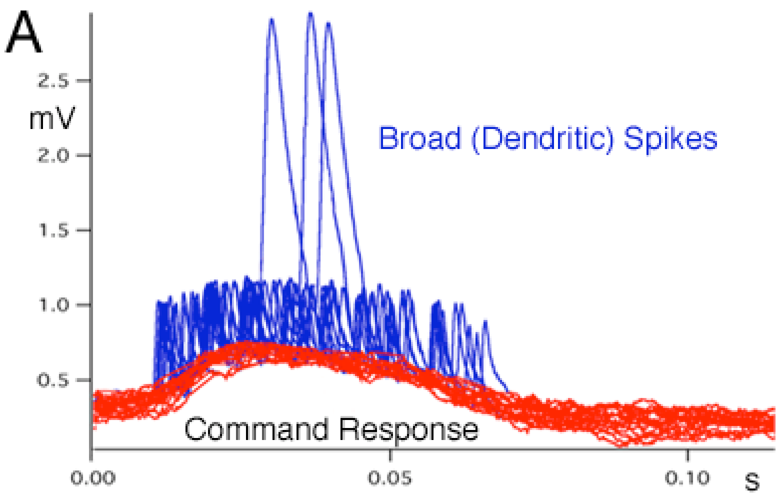
10spkFailure.psd



11_branchSimul.psd

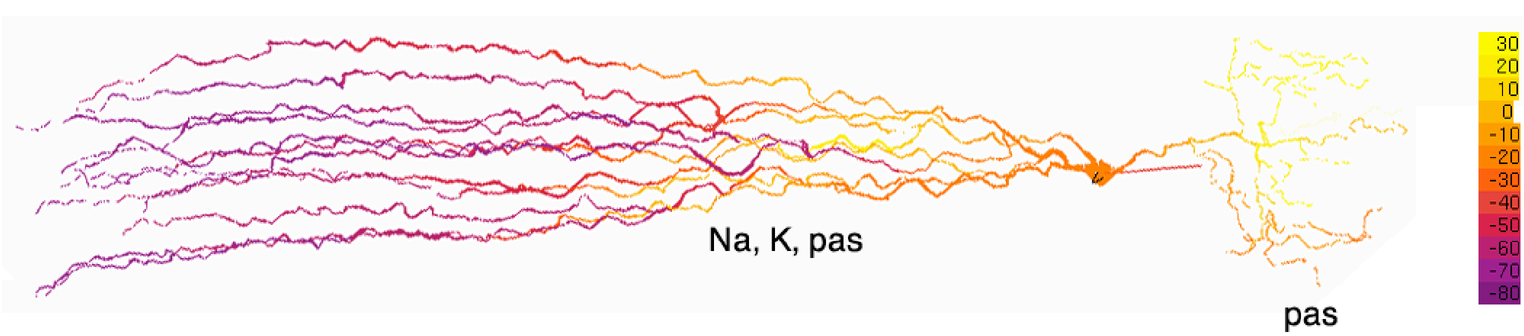


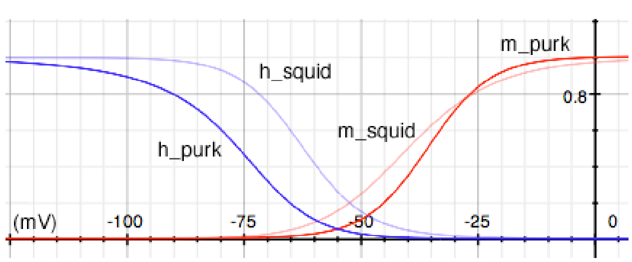
22mg_morphology.psd



23fig_mg.psd

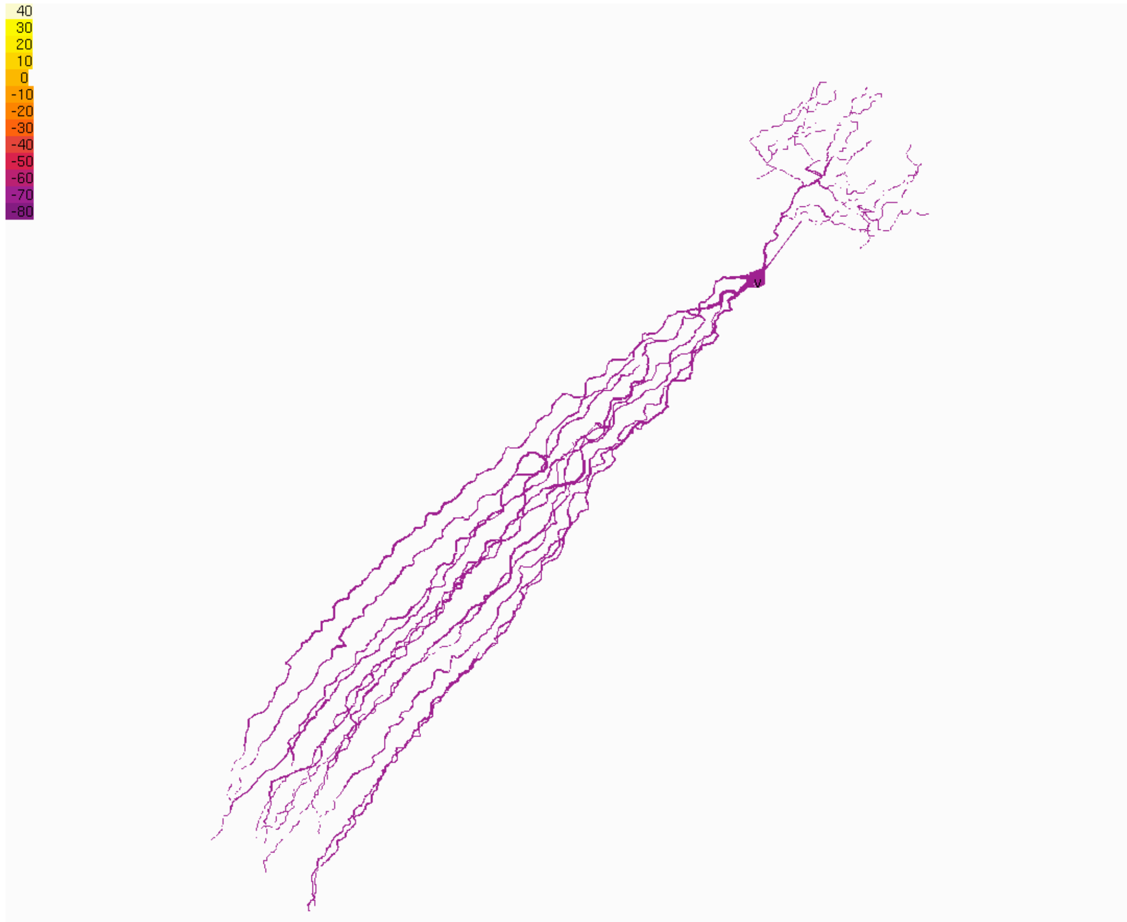
Active currents based on Purkinje cell kinetics [DeSchutter94]



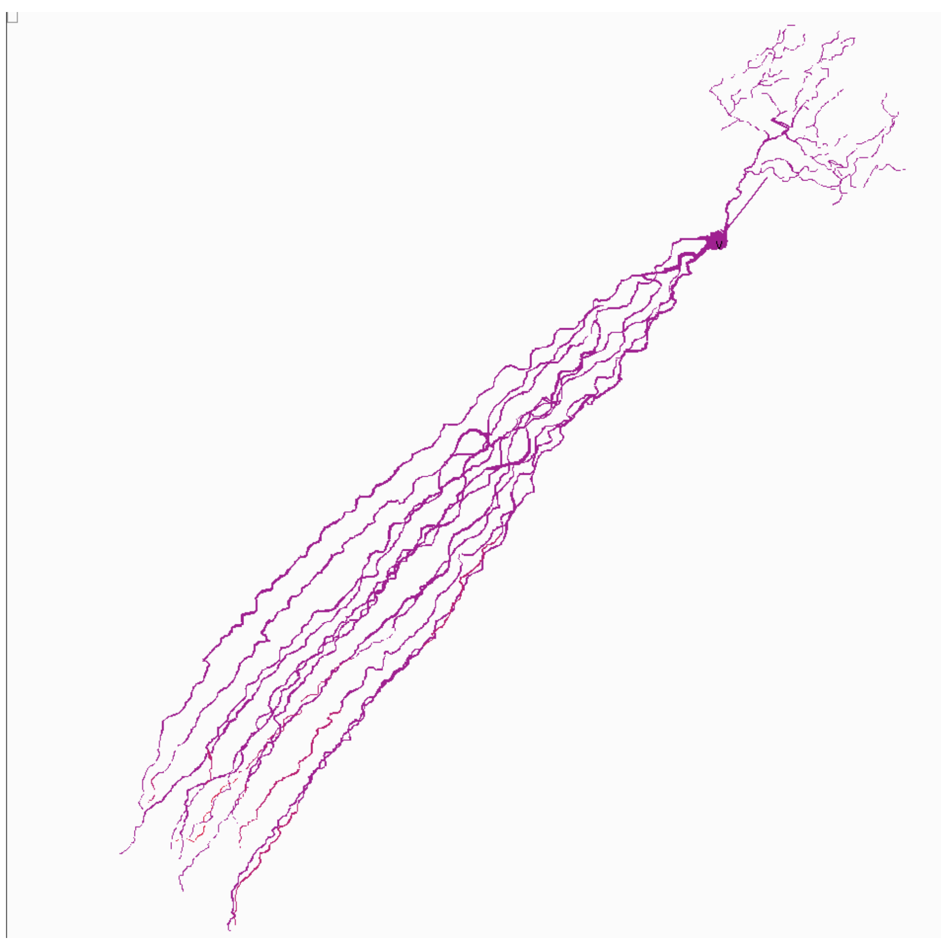


Soma, hillock, basilar dendrites: passive only
Axon: g_Na = 4-0.1, g_K = 0.2-0.03 (mho/cm2)
dml: g_Na = 0.5, g_K = 0.2
vml: g_Na = 0.2, g_K = 0.05

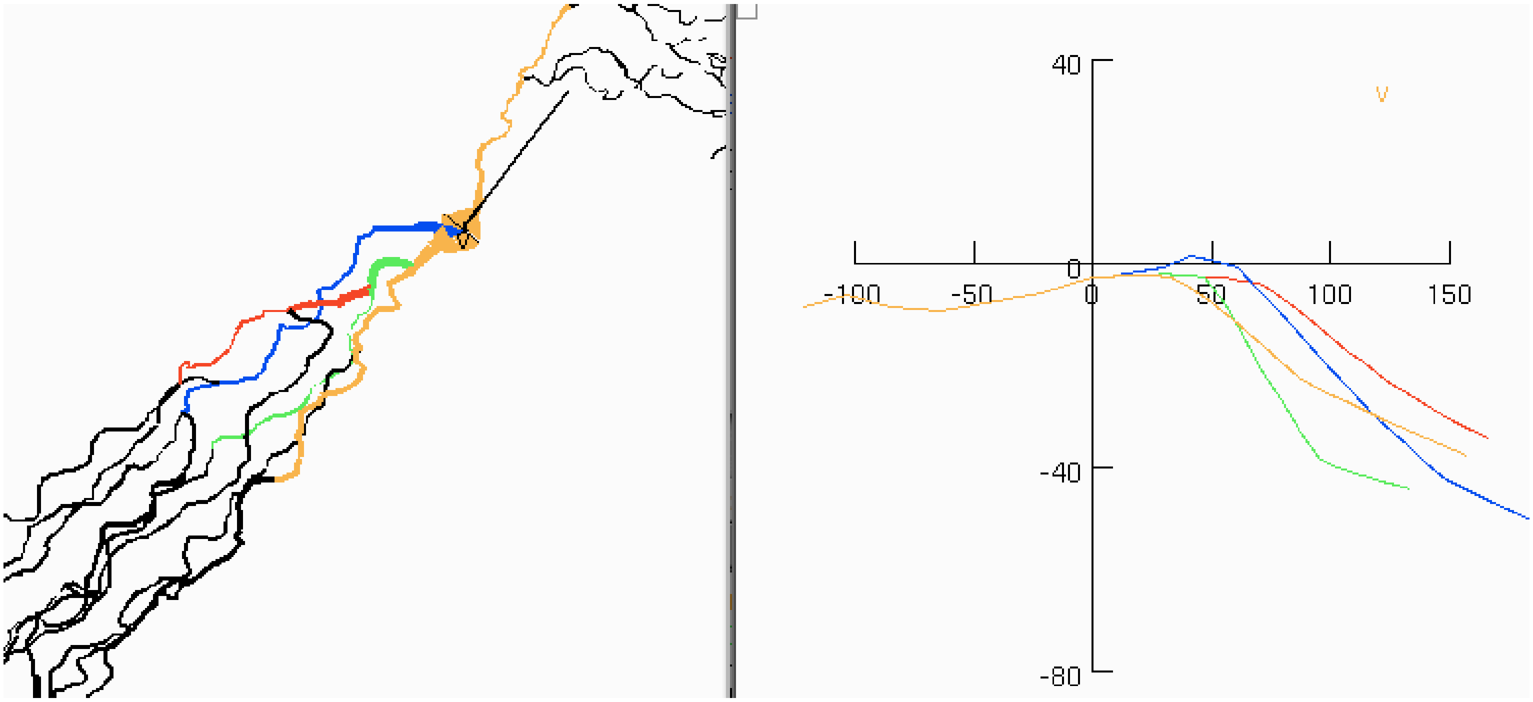
24MG_currents.psd



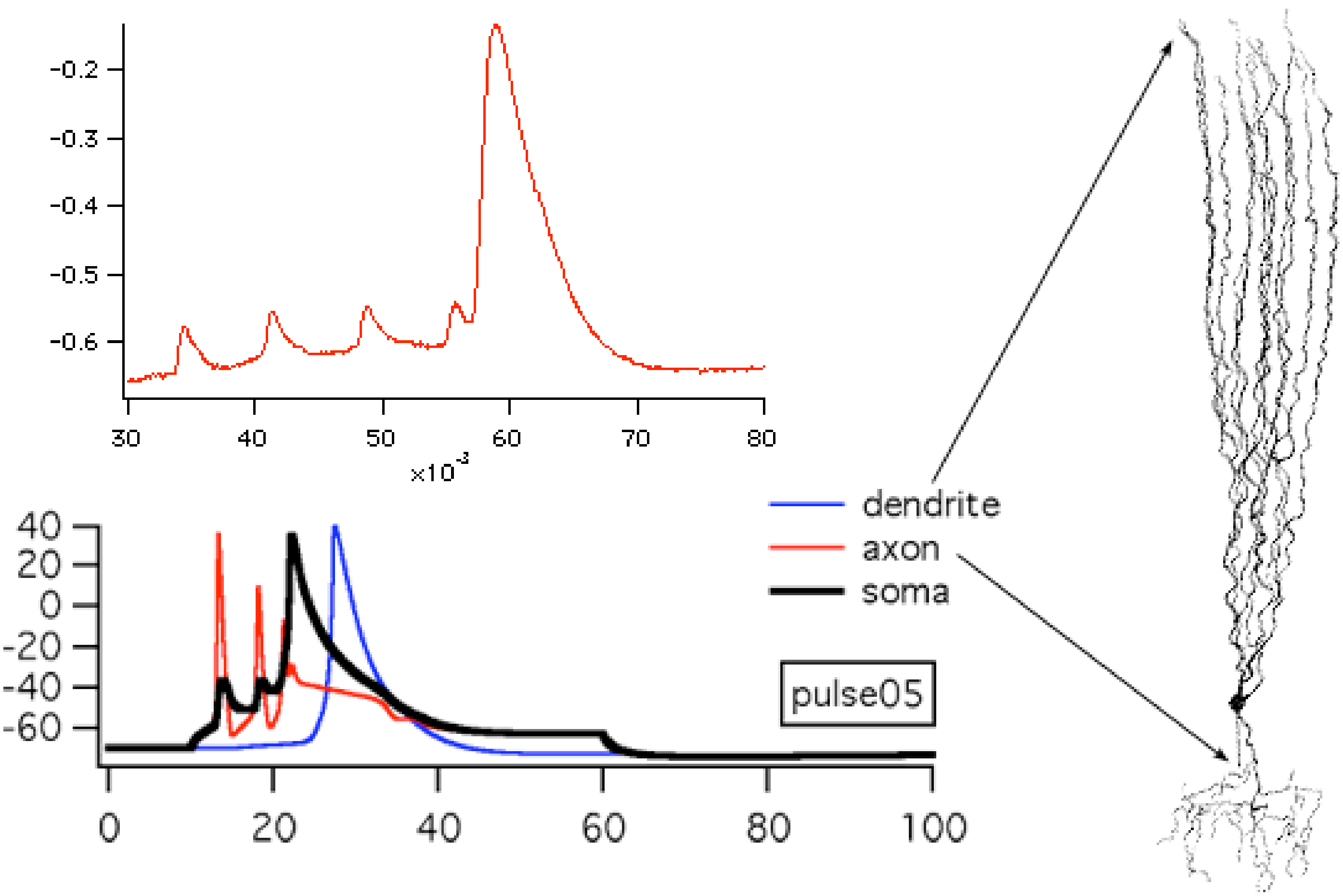
25bs_pulse05.mov



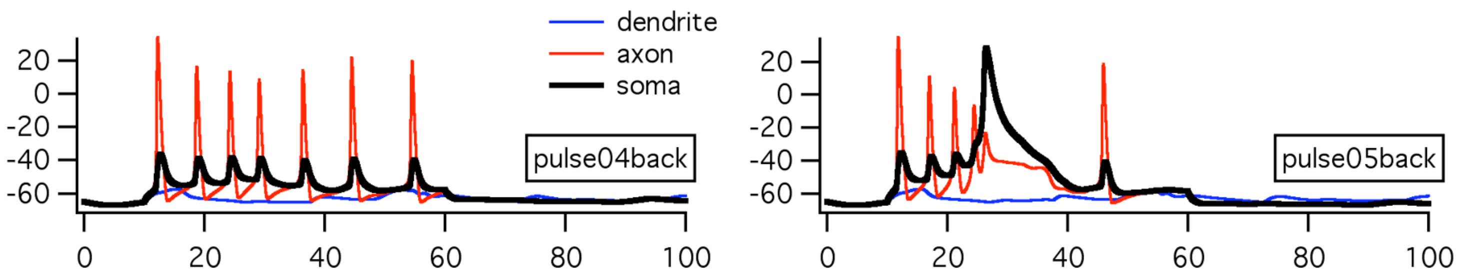
26jln05partial.mov



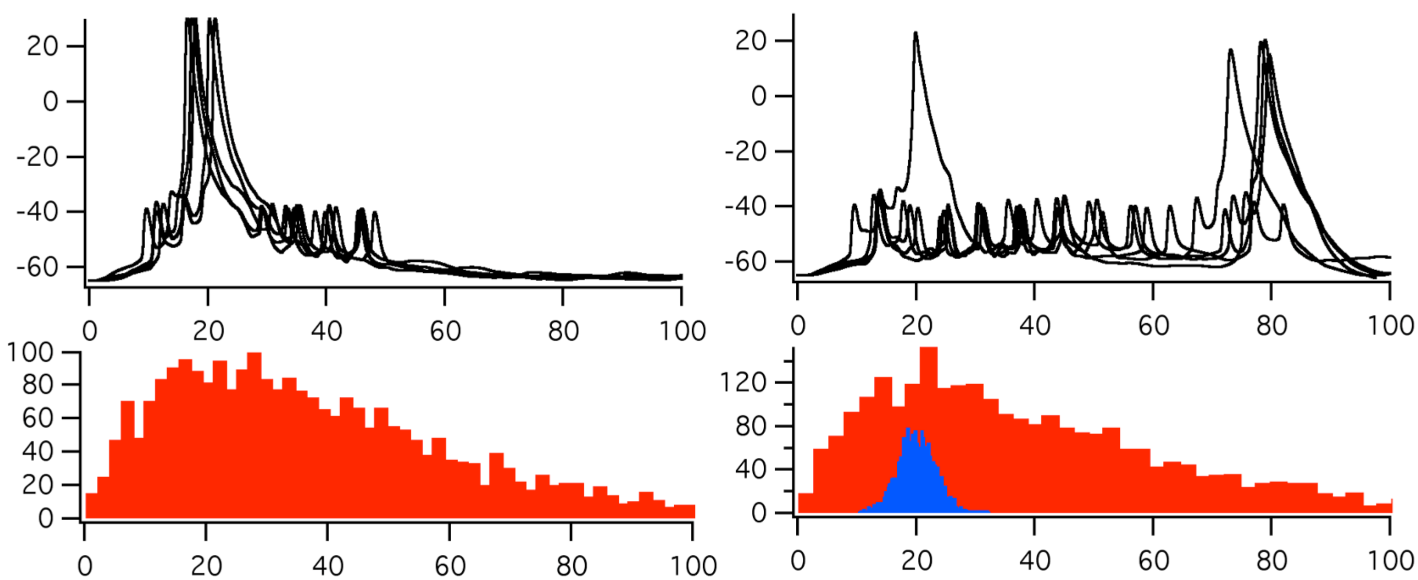
27bsInitZone.png



28firstMG1_BS.psd

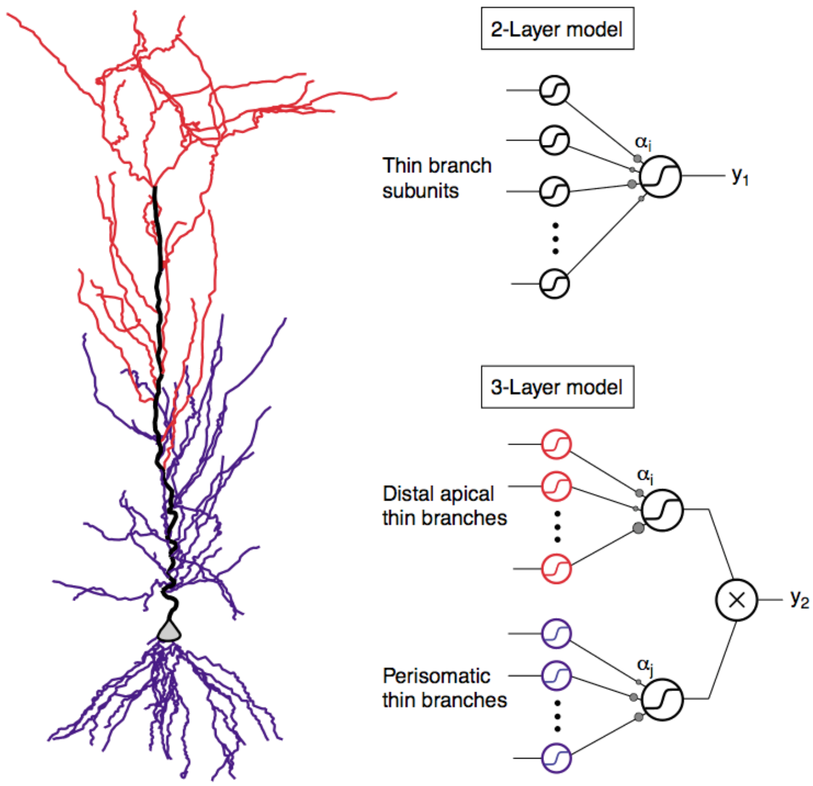


29pulseBackground.psd



30vlm_inhib.psd

What are the functional units of a neuron?



Hausser and Mel (2003) "Dendrites: bug or feature?" Curr Opin Neurobiol, 13:372-383

31_functUnit.psd