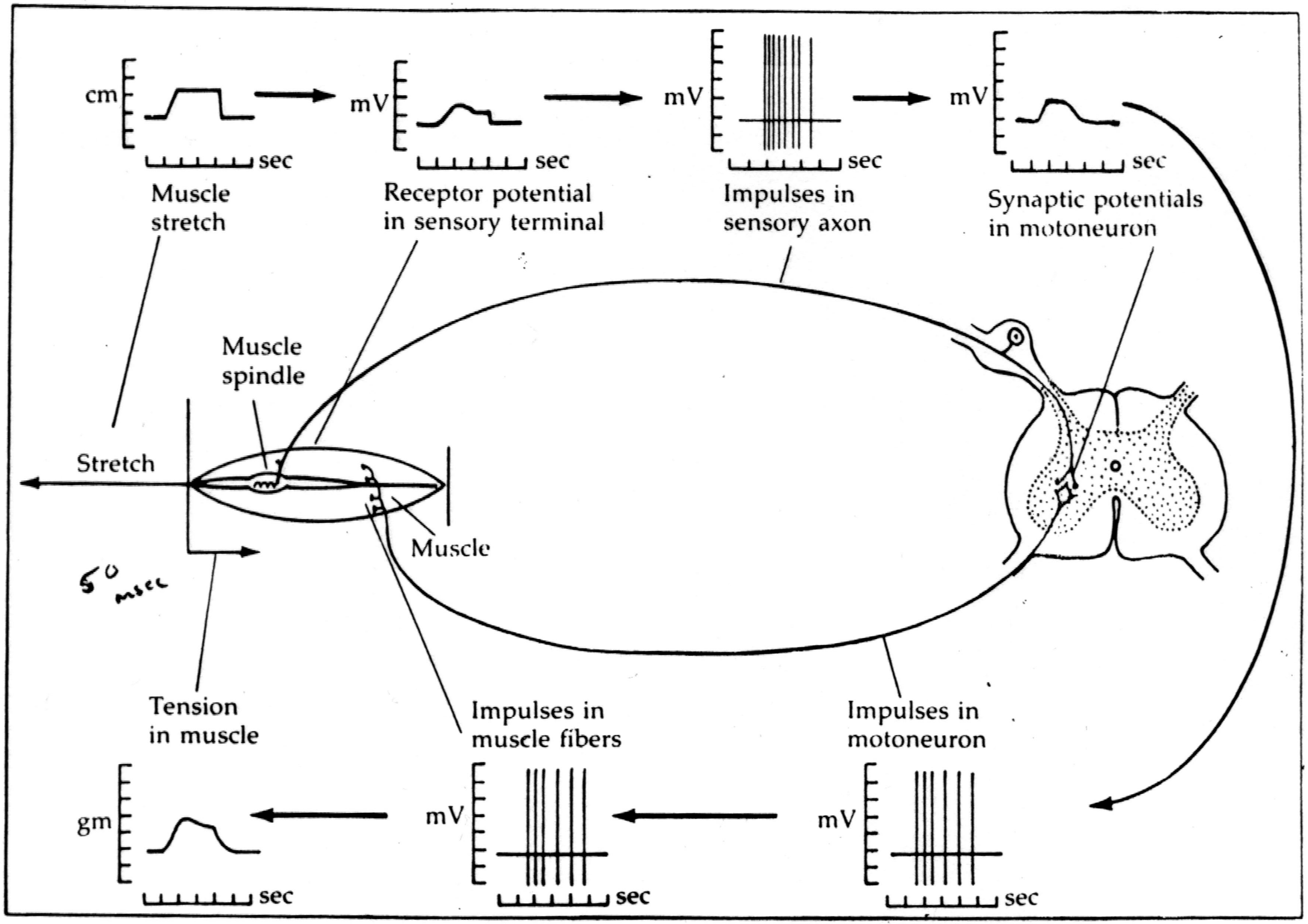
System Introduction to Sensory Physiology: Sensory- Motor System



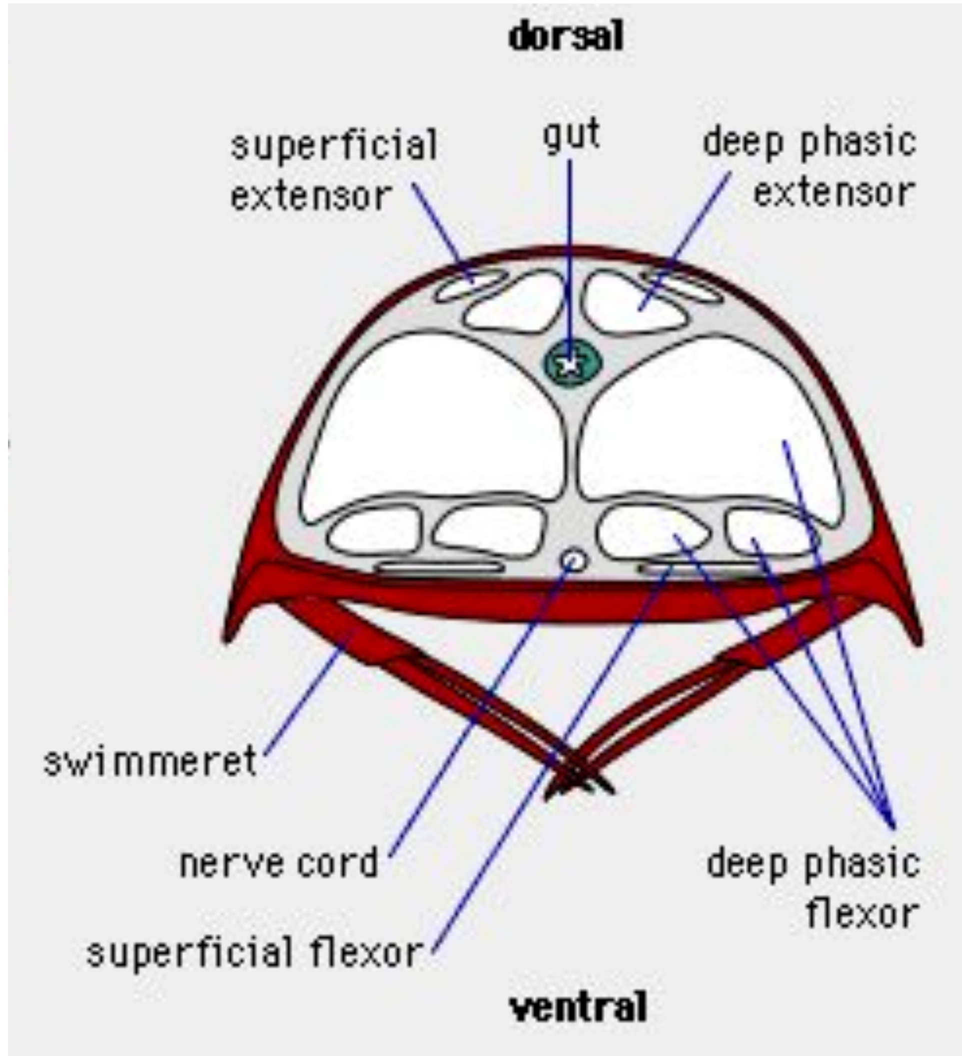
General Properties of Sensory Systems

1. Importance of peripheral structures
3. Adequate Stimulus
5. Range Fractionation
7. Stimulus-Response Relationship
9. Adaptation
11. Efferent Control
13. Higher level processing for perception (what you "see" is not what you get)

Crustacean muscle receptor organs

MROS in parallel with superficial extensors

Device to control muscle length with variable loads
Works like our muscle spindles



See Rydqvist et al 2007

10.2 Stretch Receptor Dissection

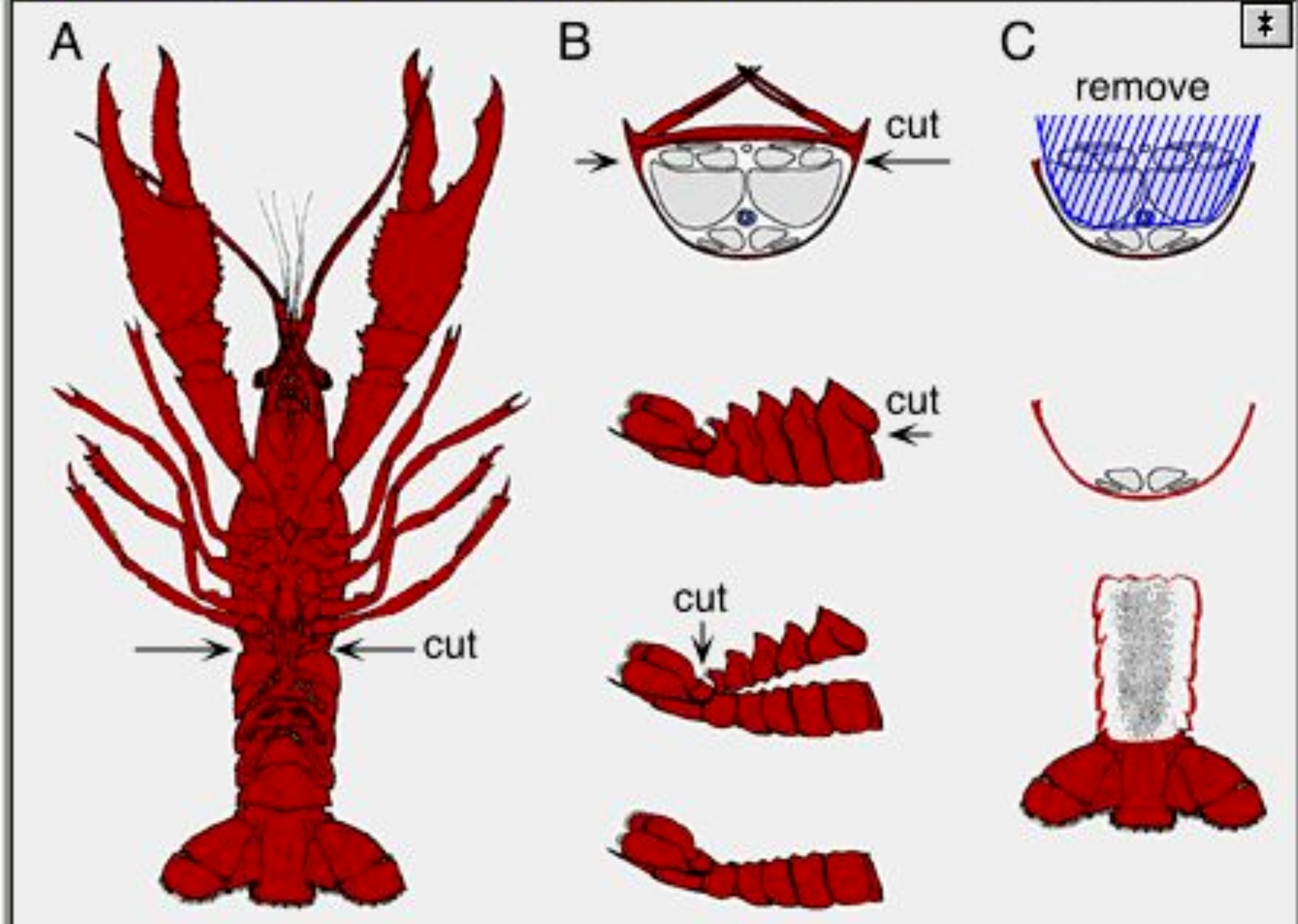


Figure 10.2. Dissection. A. Remove the tail from the crayfish. **B.** Remove the ventral surface of the tail. **C.** Scoop out all the muscles ventral to the gut. Ventral is up in **B** and **C**.

10.1 Stimulating MROs

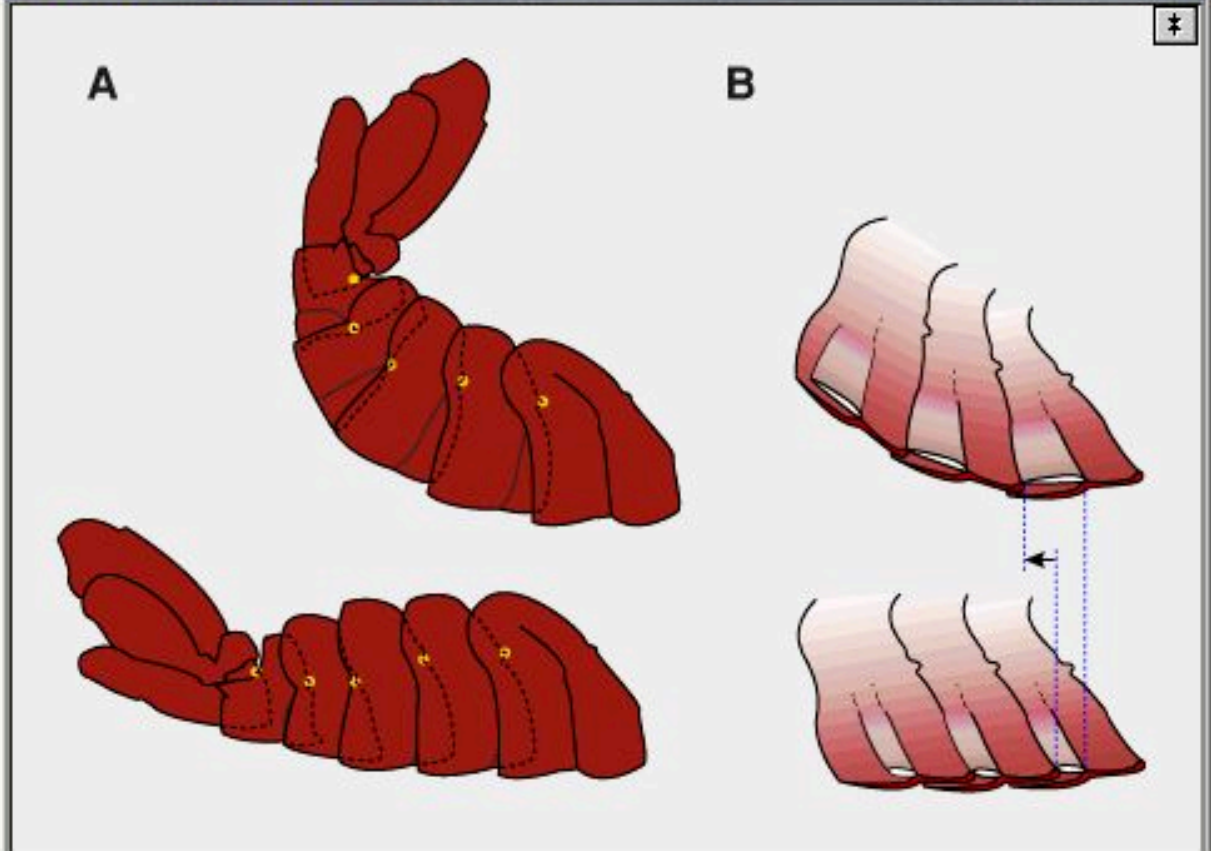


Figure 10.1. Stimulating MROs. A. The intact tail. Yellow dots show where segments pivot when the tail curls; dashed lines indicate hidden parts of each segment. **B.** Section through the first three segments of the tail. Note how the superficial extensor muscle (gray) stretches when the tail curls. Muscle receptor organs (MROs) are embedded in this muscle and are stimulated by the stretch.

10.3 Stimulus Setup

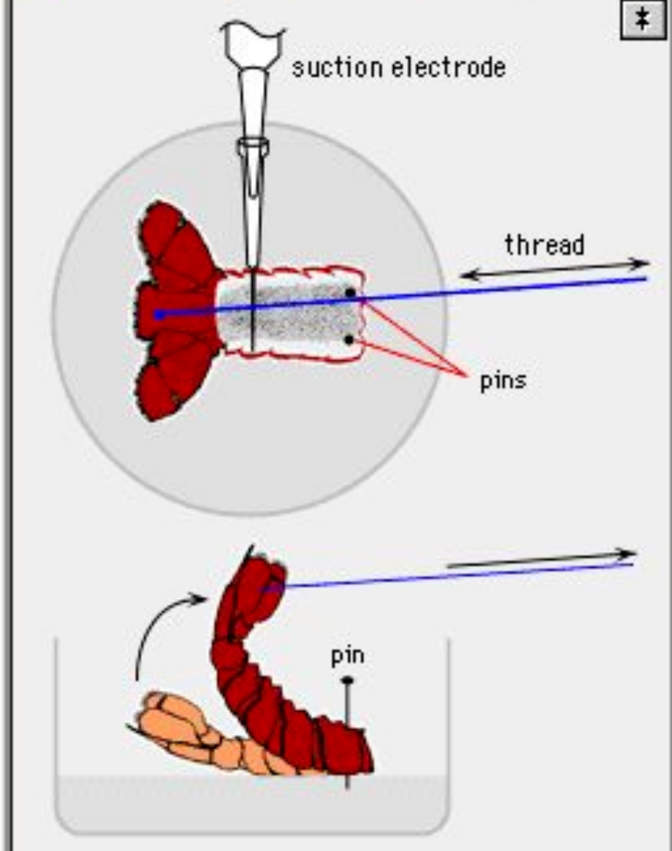


Figure 10.3. Stimulus setup. With the tail pinned at the anterior end in a dissecting dish, attach the thread to a micromanipulator. When the thread is pulled, the tail should curl upwards without hitting the suction electrode.

10.4 Recording Setup

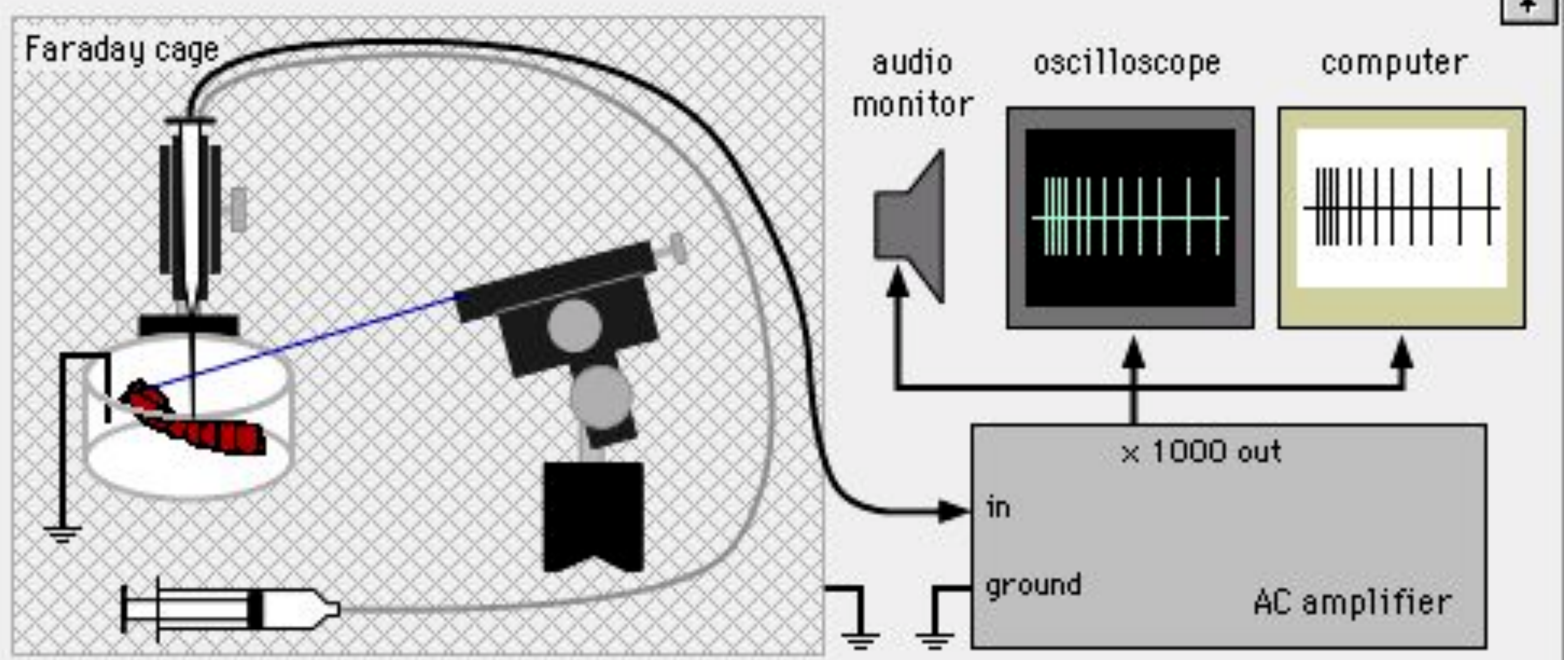
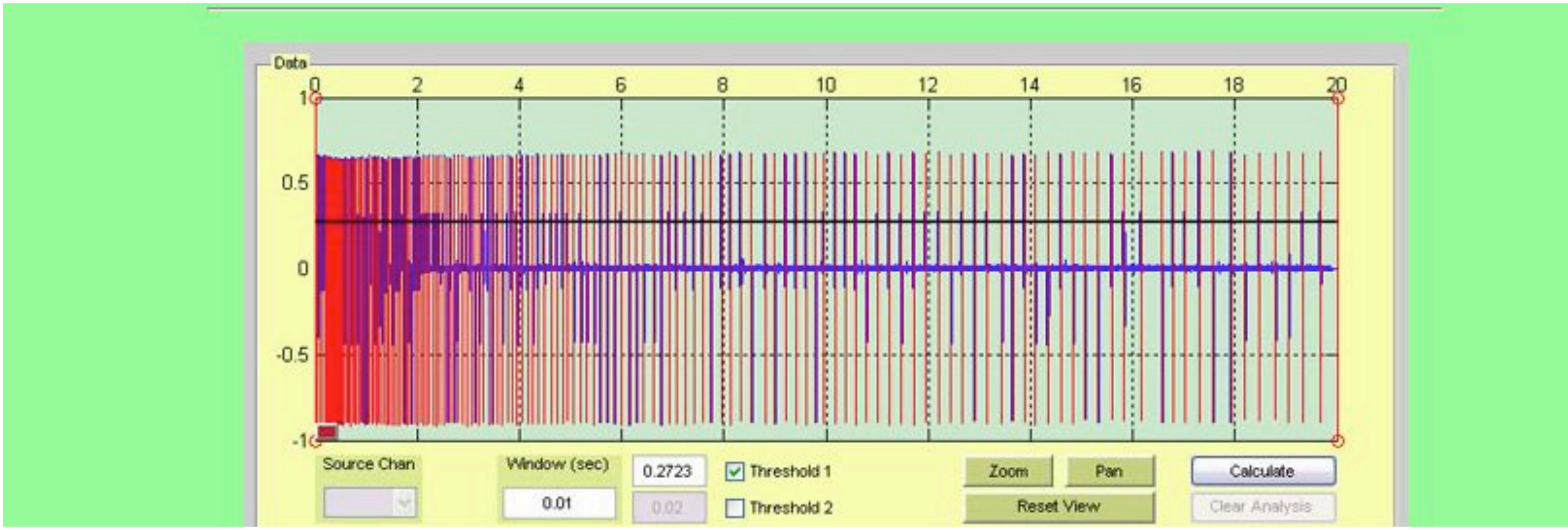


Figure 10.4. Recording setup for the stretch receptor. Recording and stimulation are easiest with the electrode coming from the rear and the thread going to a manipulator at the left or right of the dish. Connect the suction electrode to the amplifier and split the amplifier output between the oscilloscope, audio monitor, and computer.

MRO1 response



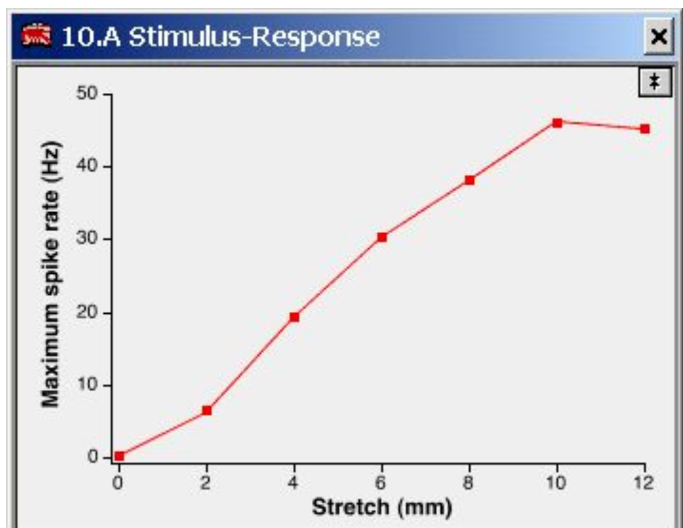
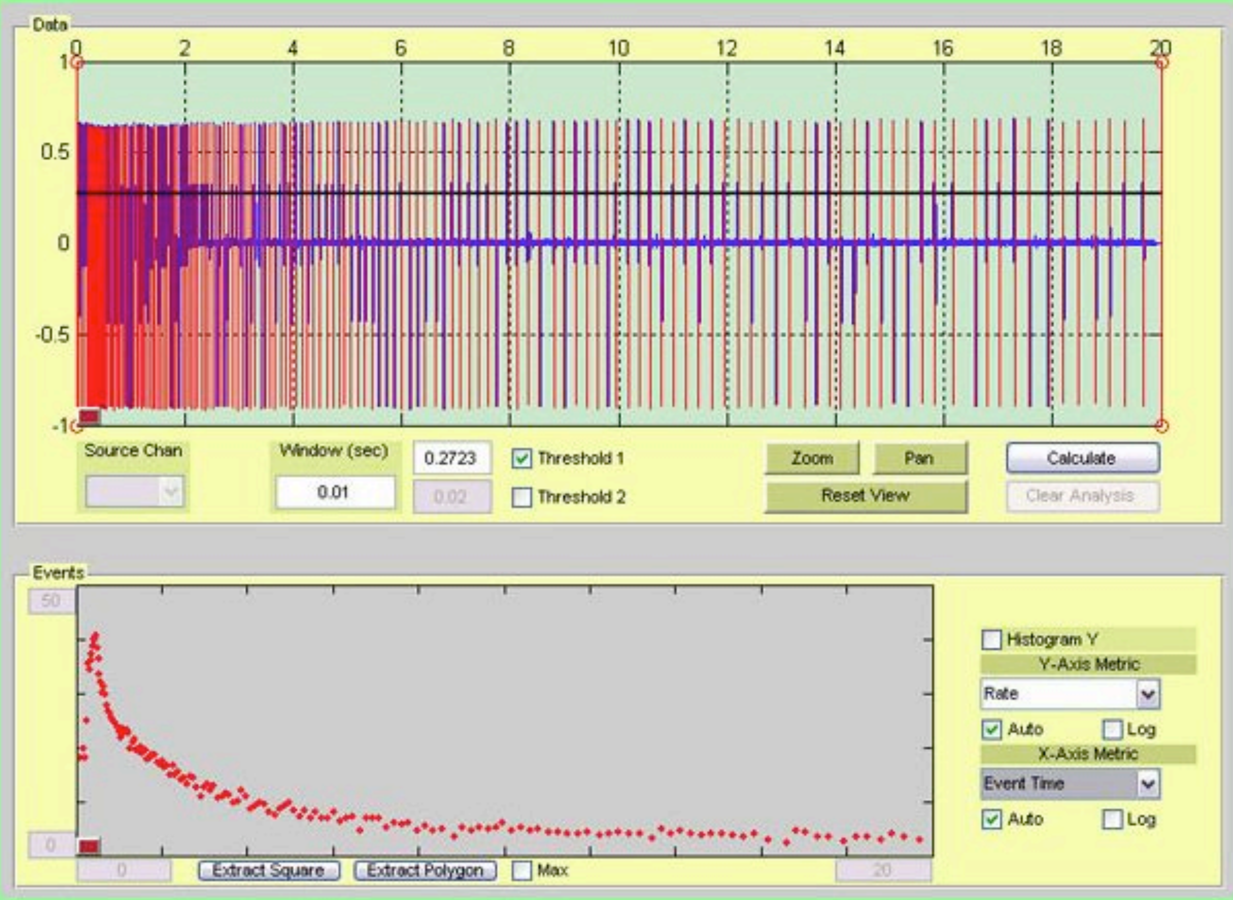


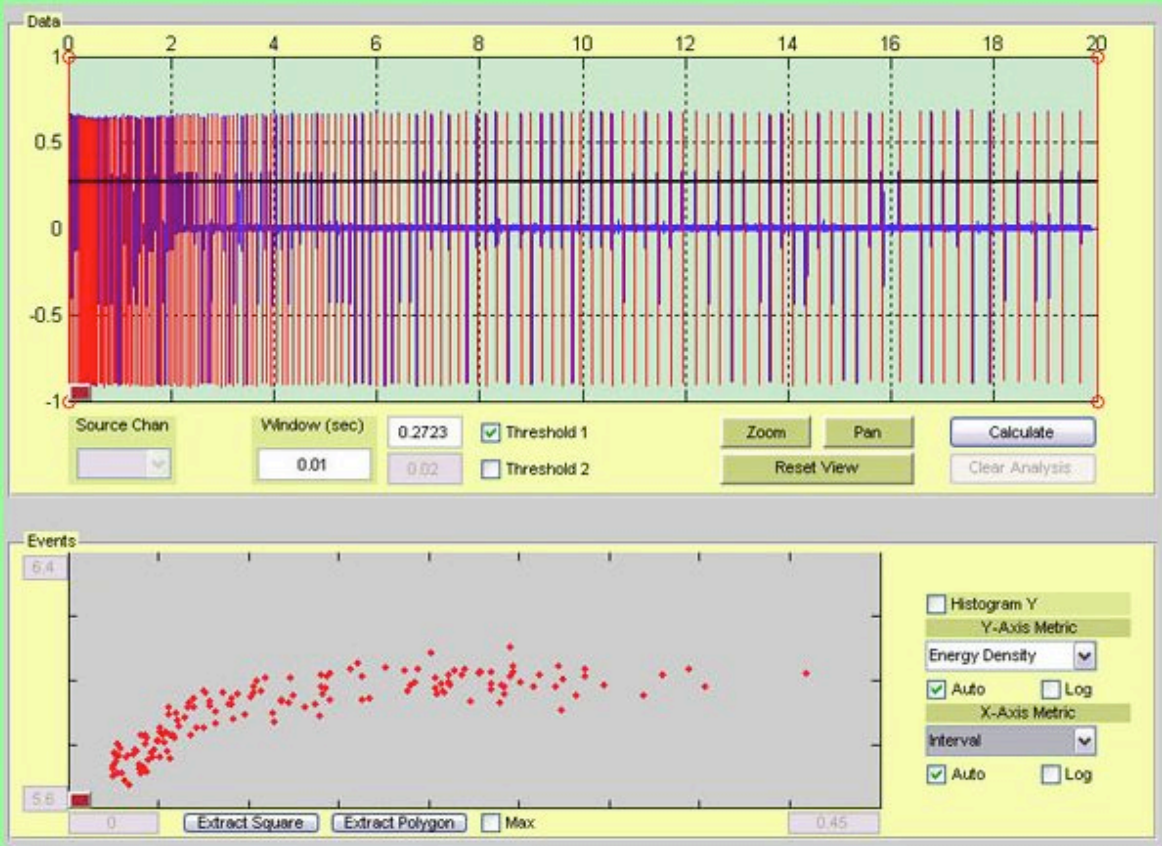
Figure 10.A. Stimulus-response curve for MRO_1. The response is roughly linear between 2 and 10 mm (arbitrary units of stretch).

MRO1 data analysis



This data set contains one spiking neuron adapting to a sensory stimulus (in this case a tail stretch). Selecting "rate" from the "y-axis metric" display in the lower events analysis panel illustrates the rate of adaption of this specific sensory neuron.

MRO1 data analysis



Instead of displaying rate versus time, now, energy density of a spike versus interval since previous spike is illustrated. In this data representation, one can see the response of individual spikes in this neuron to inter-spike-interval. The shorter the interval between spikes, the smaller the subsequent spike is in amplitude. This amplitude saturates at a given inter-spike interval. This illustrates a recovery period for the neuron that inhibits full energy of the action potential. Note that these data points illustrate values acquired after the tail had stopped moving so the change in amplitude is not a funciton of the electrode attaching to the nerve differently. The effect is small but noticable.

Compare tau adaptation at different stretches

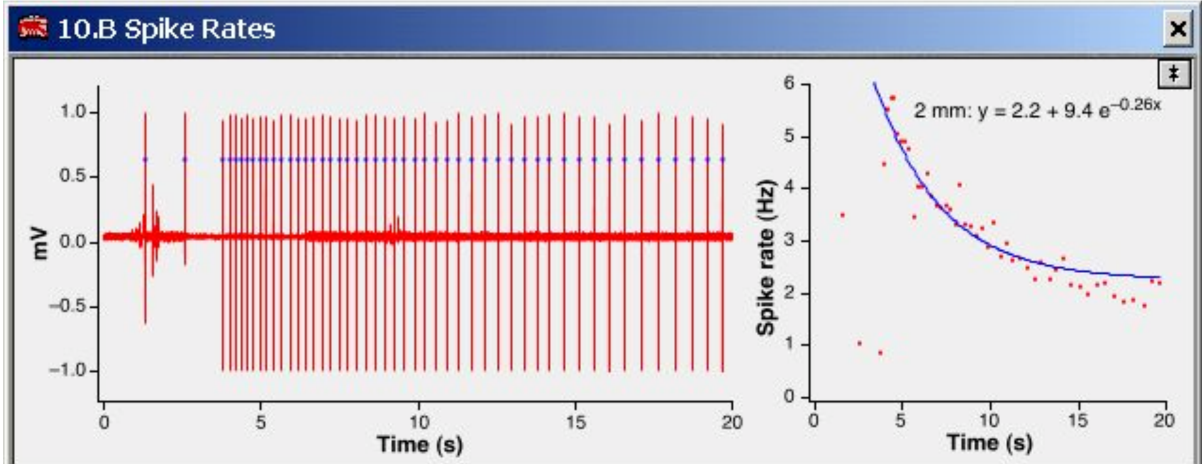


Figure 10.B. Spike rates. On the left, the data have been windowed (marked in blue) and converted to spike rates; on the right, instantaneous spike rate is plotted against time and fit with an exponential equation.

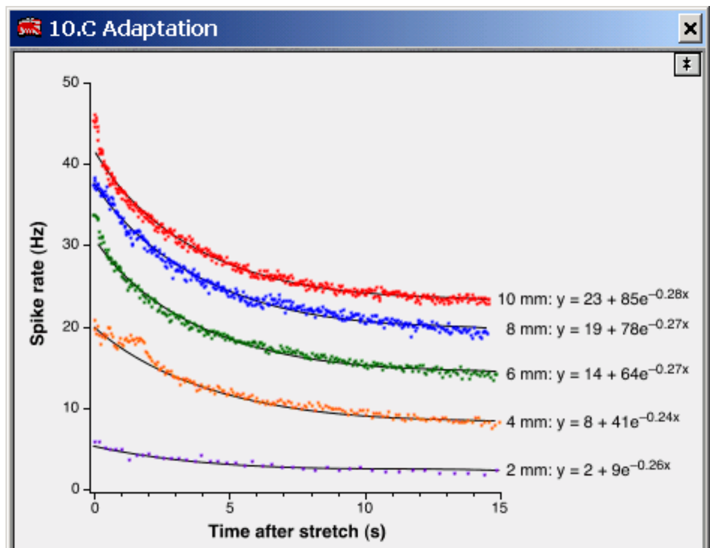
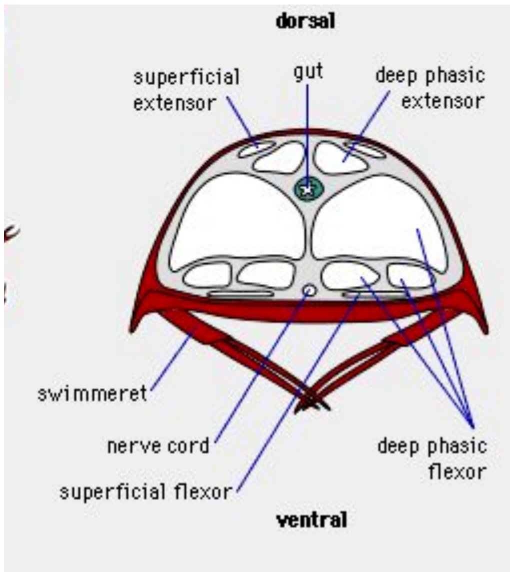
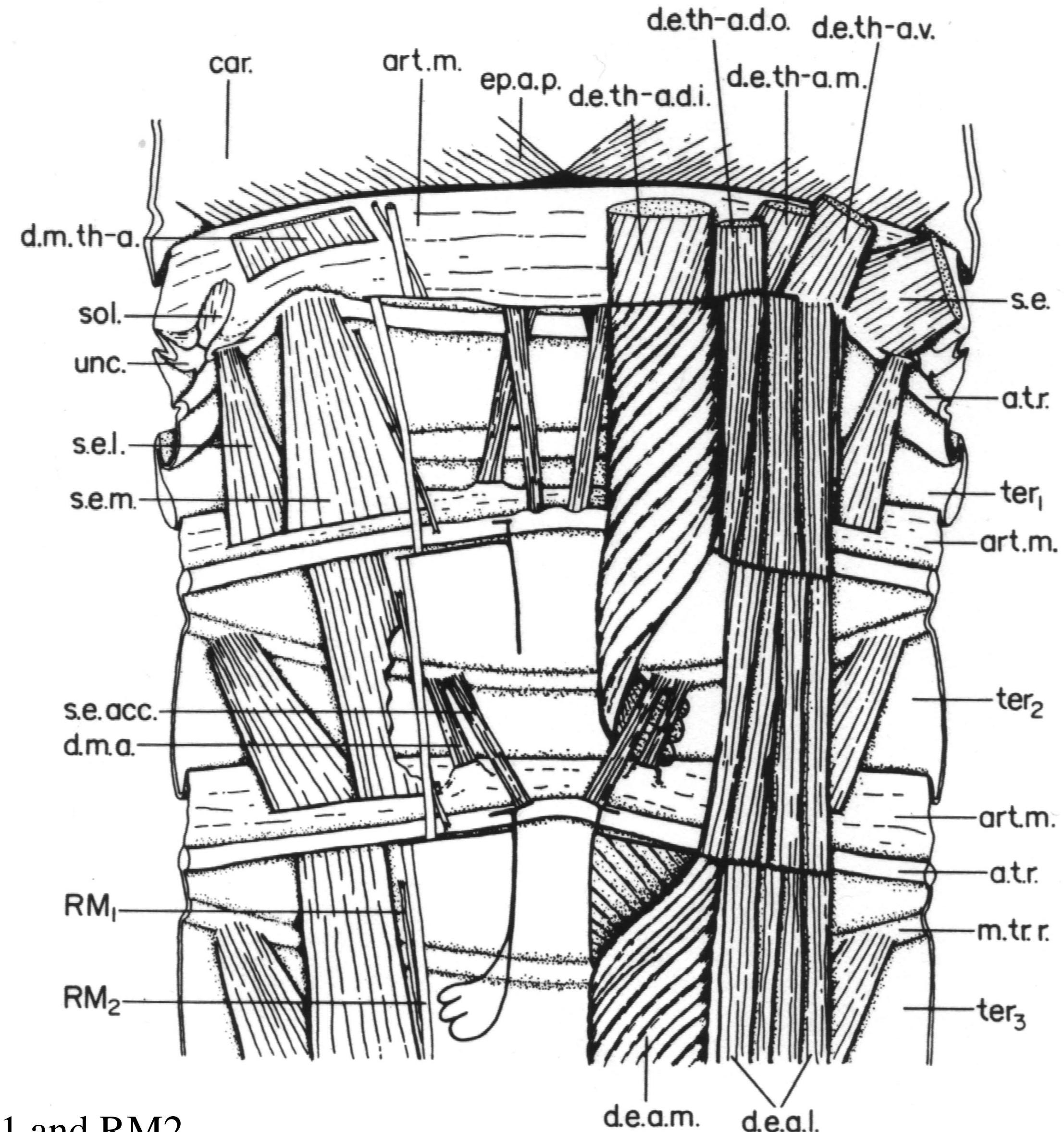


Figure 10.C. Adaptation curves. Data such as those in Figure 10.B have been cleaned up and fit with exponential equations. The inverse of the exponent is the adaptation rate. In this case, the rate was fairly constant (about 4 s); adaptation rate often increases with greater stretch.

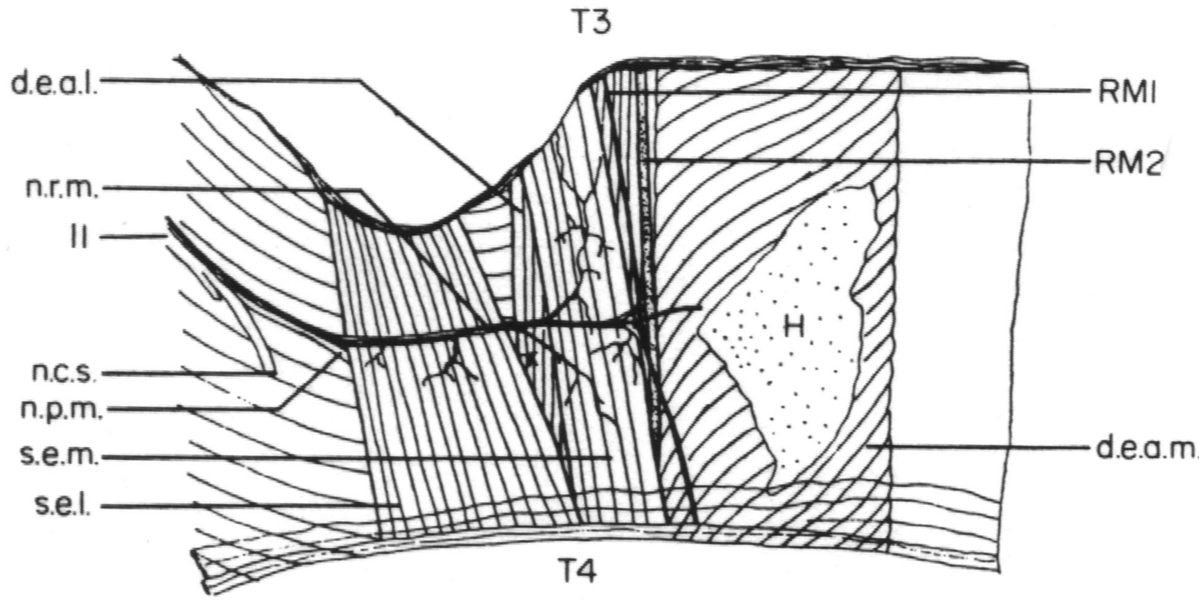
Anatomy of MROs



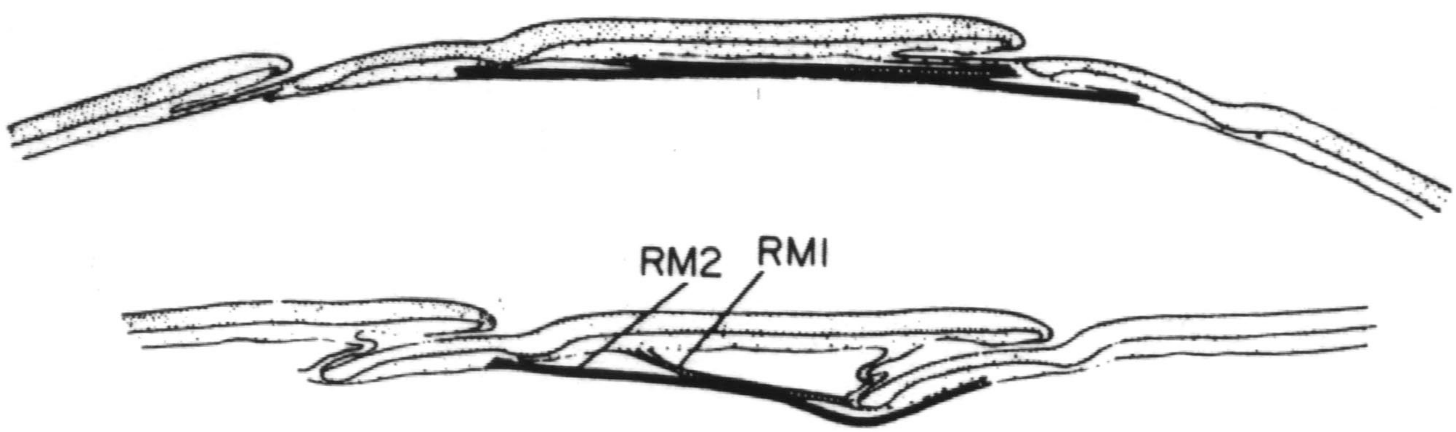


Extensor muscles, especially note RM1 and RM2

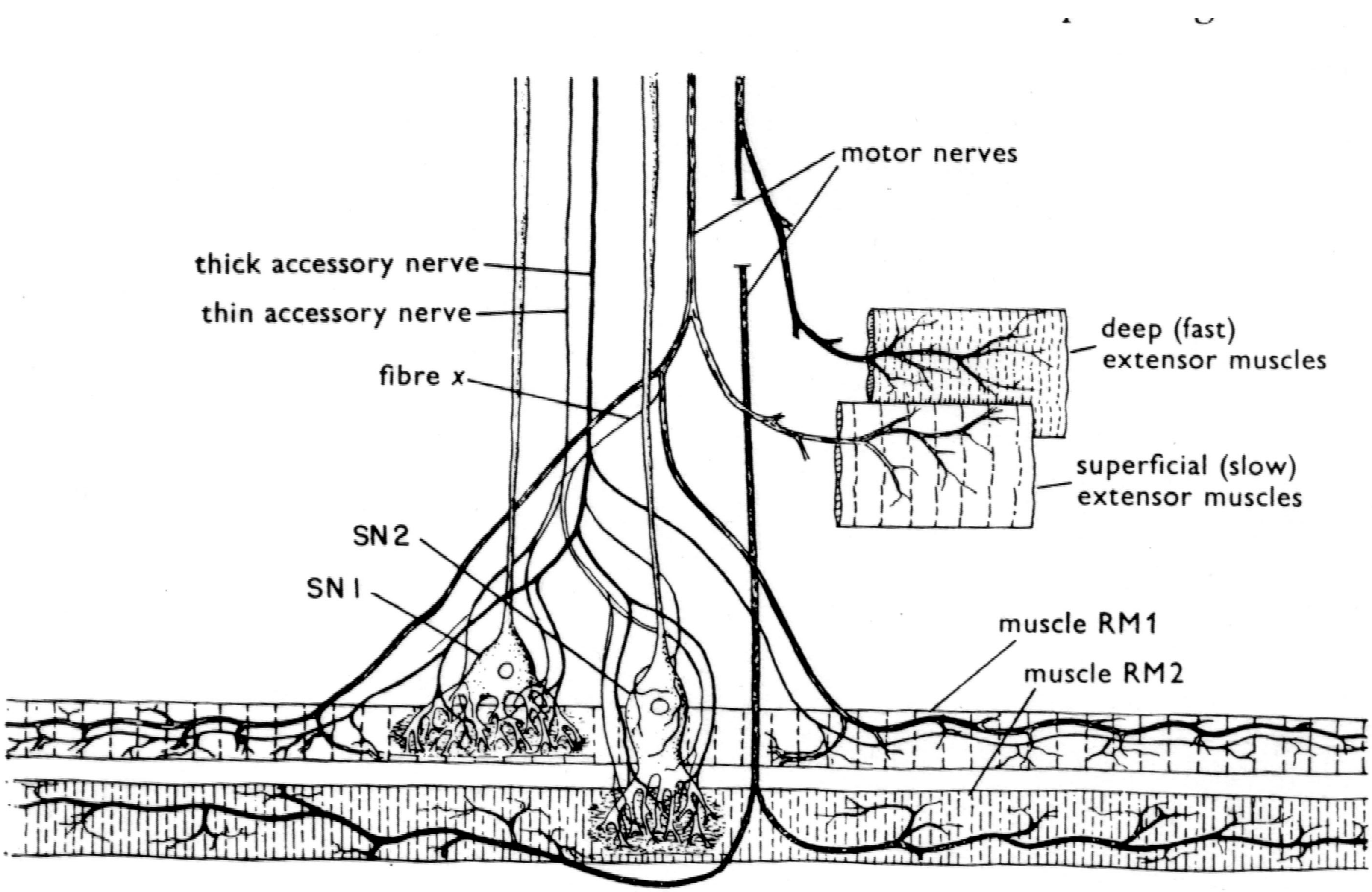
Nerve 2 position



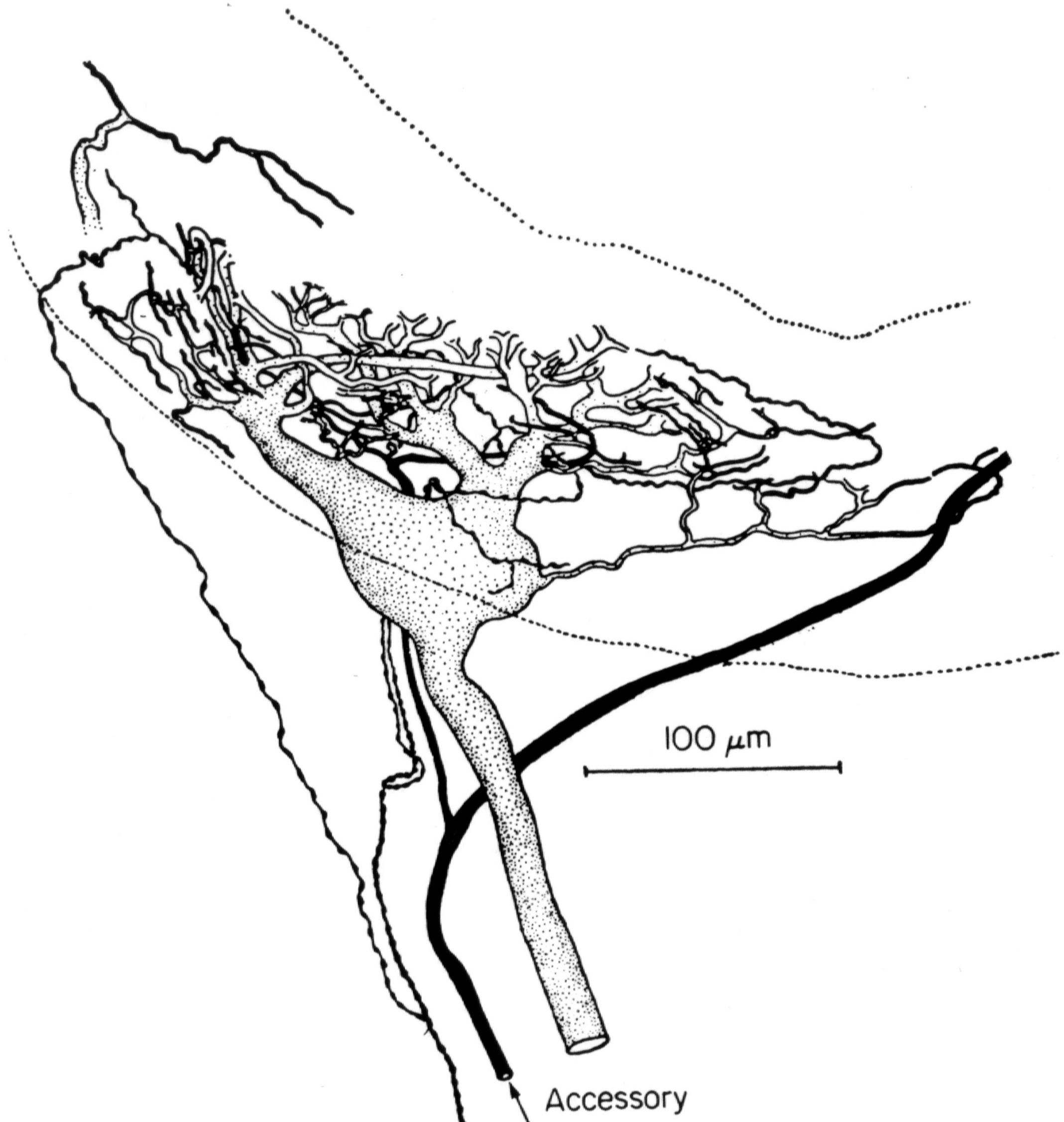
MRO stimulation



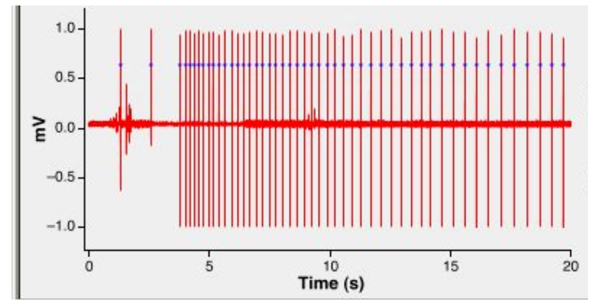
MRO innervation- excitatory mns and inhibition of sensory cell

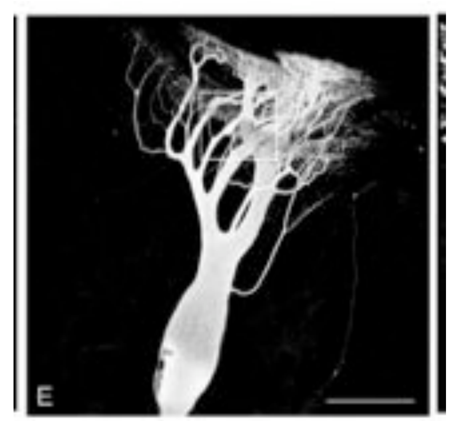


MRO1- diffuse dendritic arbor



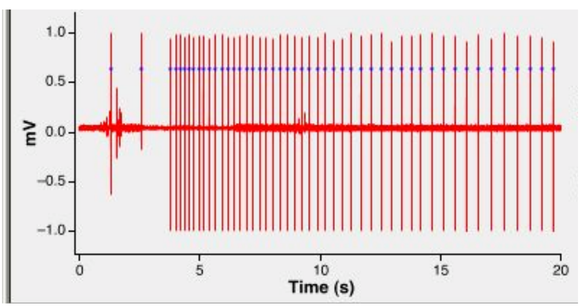
Fires throughout stimulation

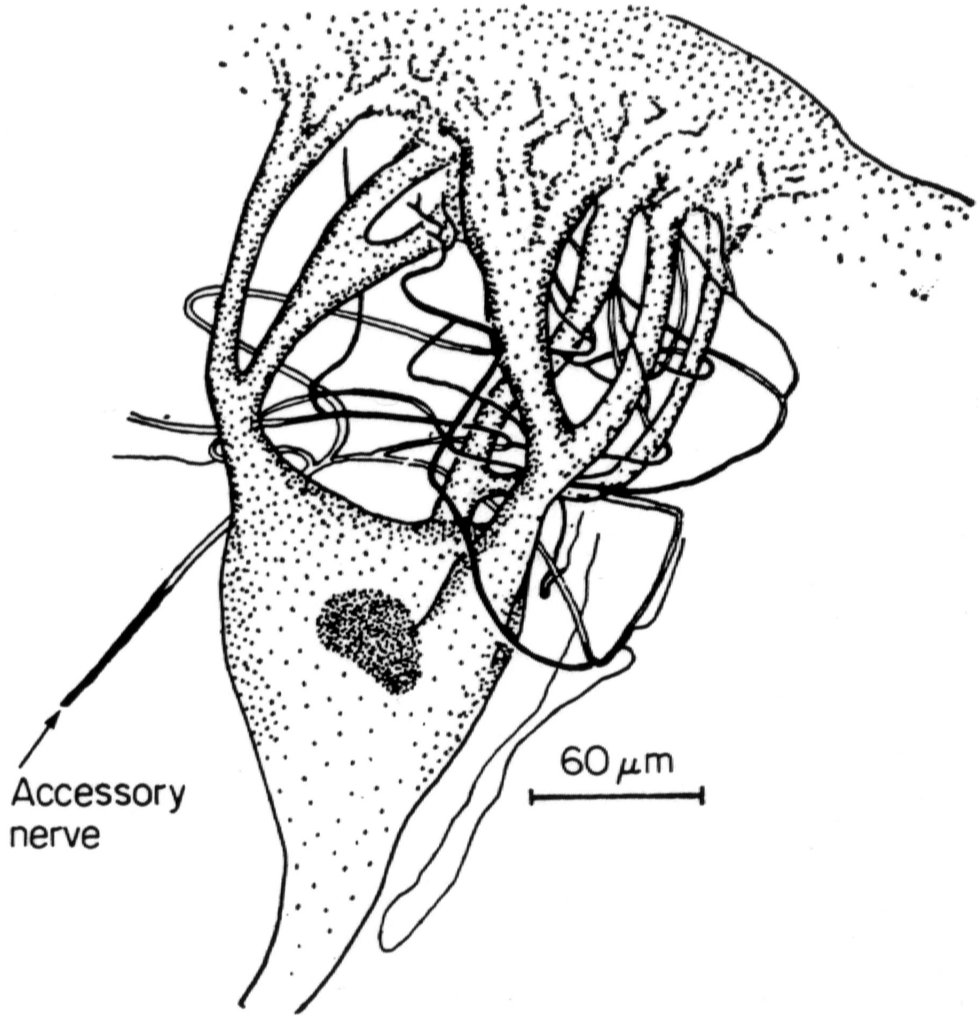


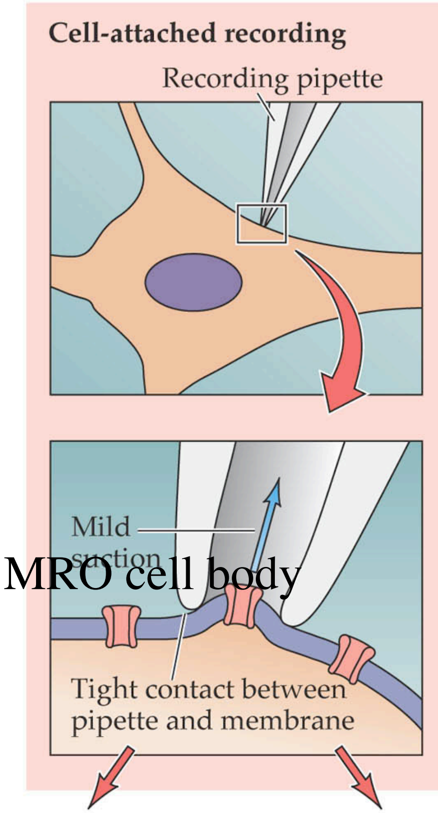


MRO2- clumped dendritic arbor

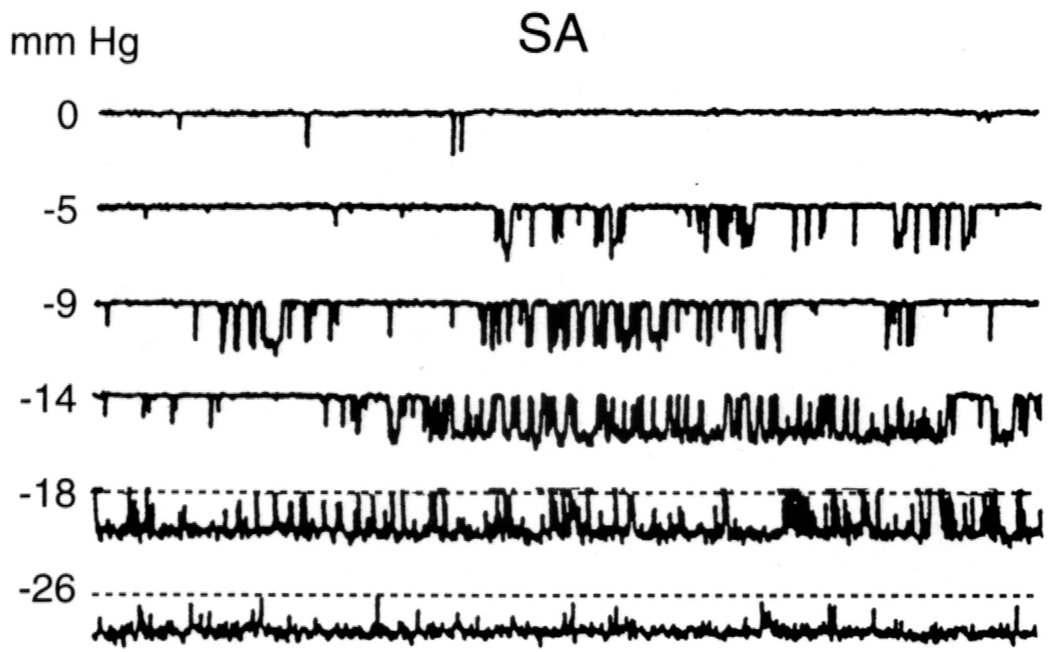
Fires only a few spikes at beginning



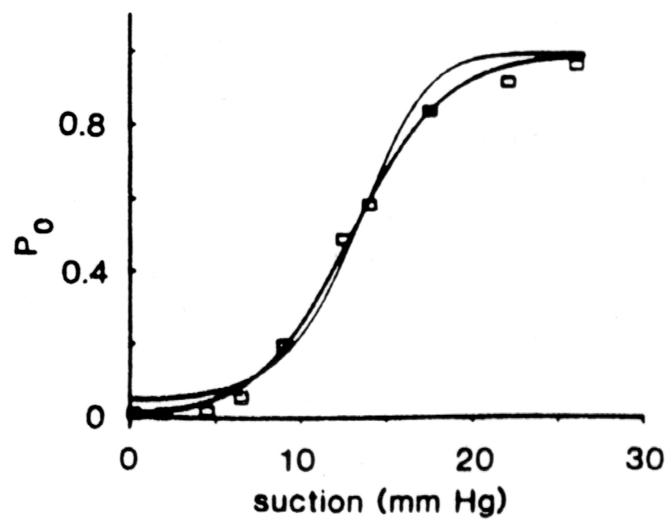




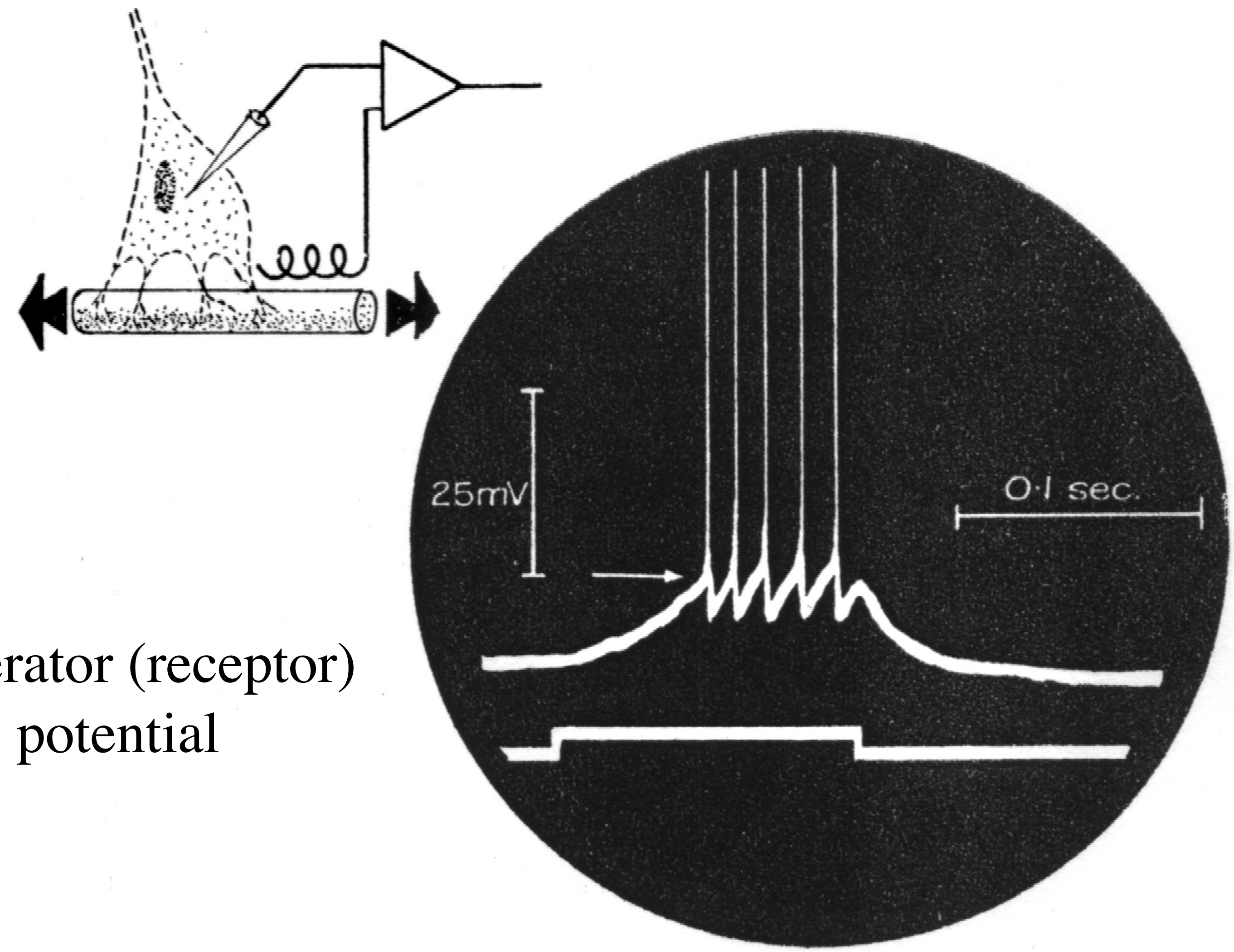
stretch



Stretch channel open probability



Response to stretch

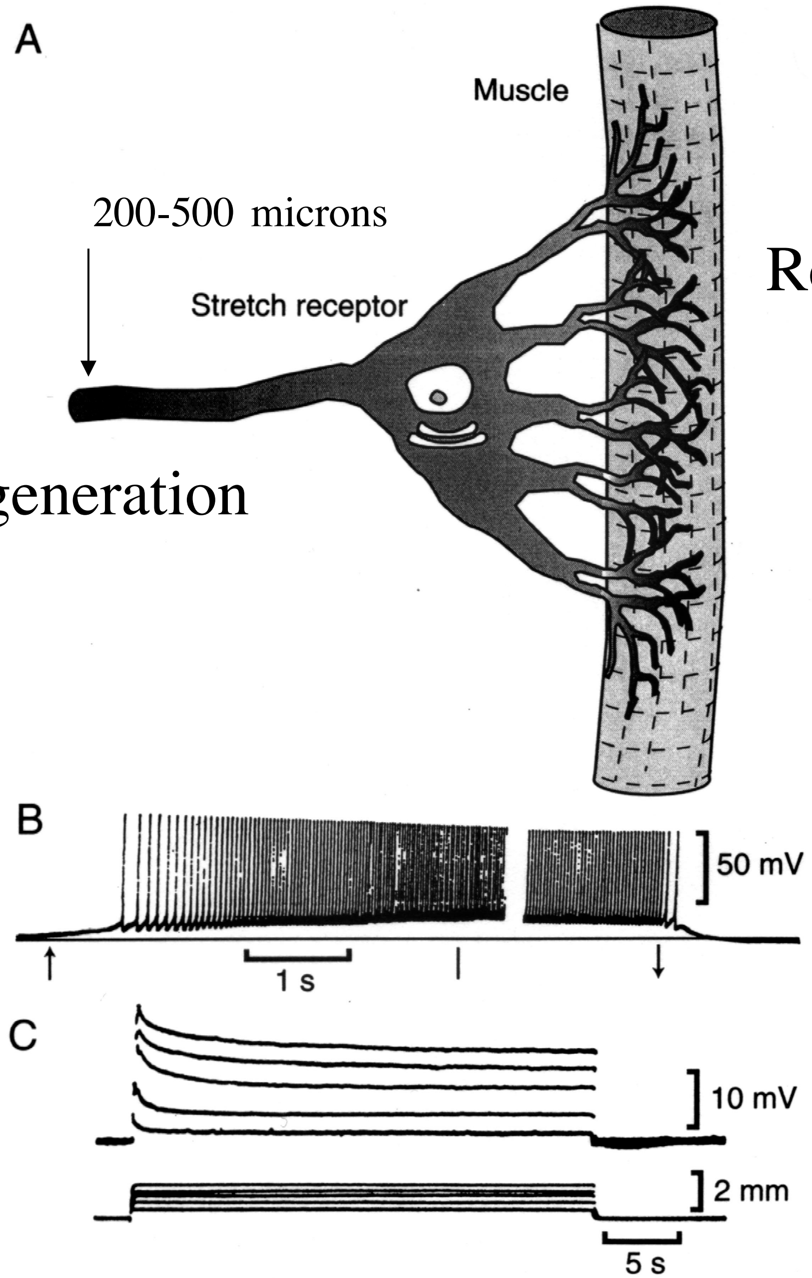


Generator (receptor) potential

200-500 microns

Receptor potential

AP generation

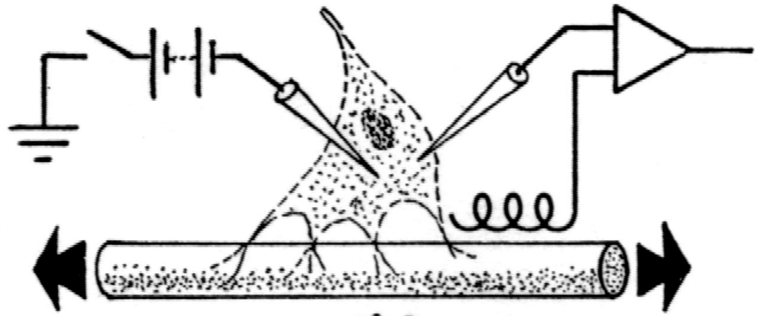


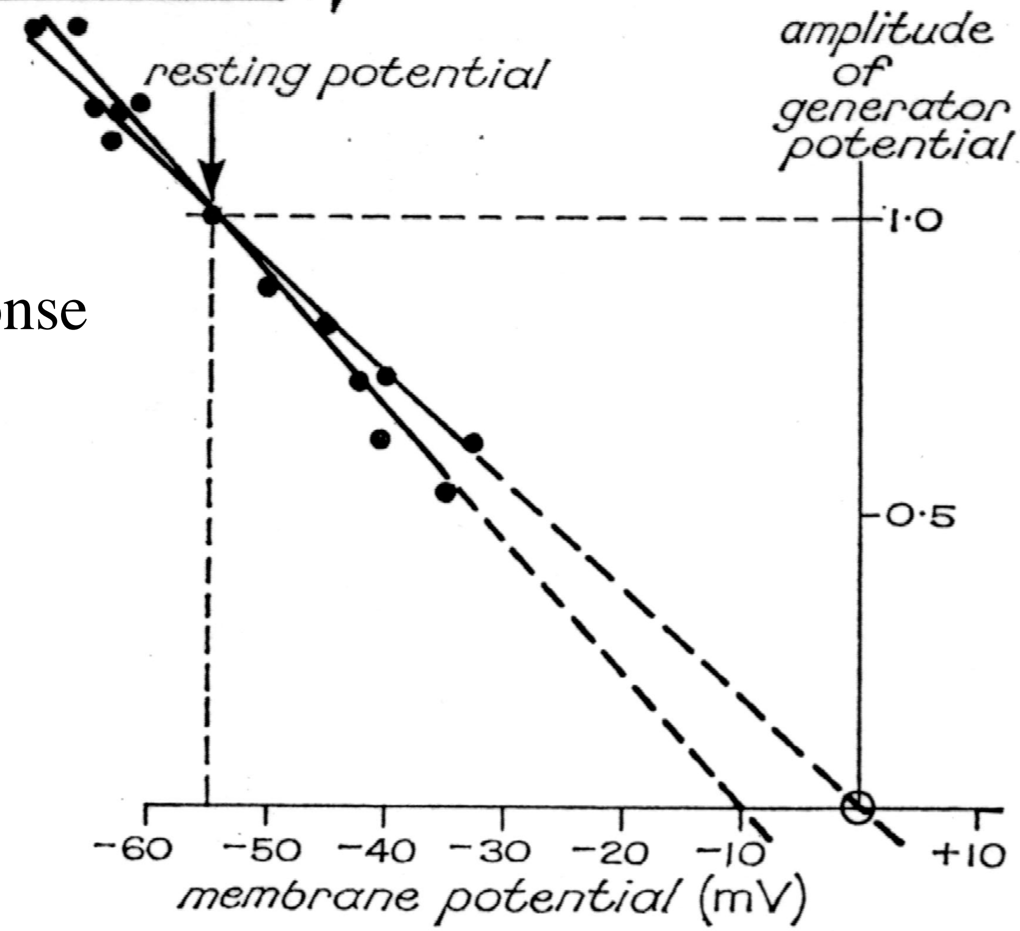
Linear relationship between generator potential amplitude and impulse frequency

+ TTX

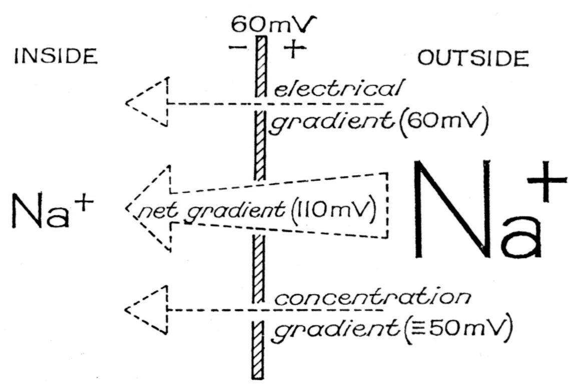
Excitatory conductance increase

$I = g\ (Em - E\ ion)$





Na entry dominates response



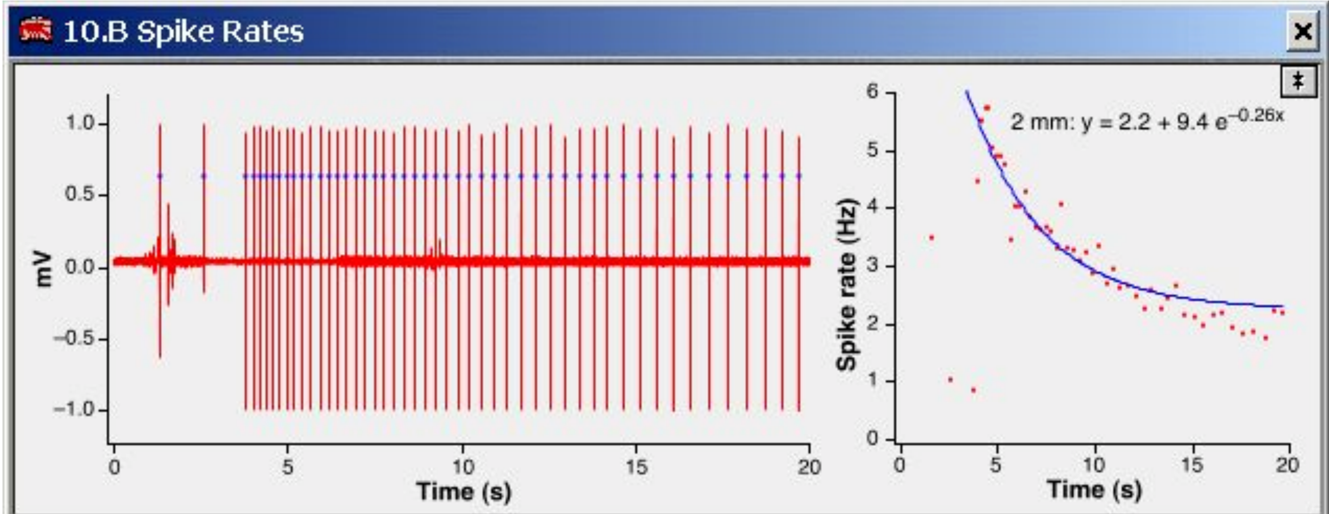
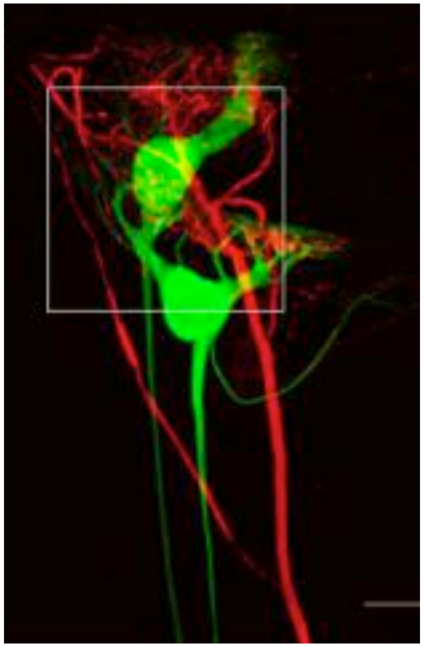


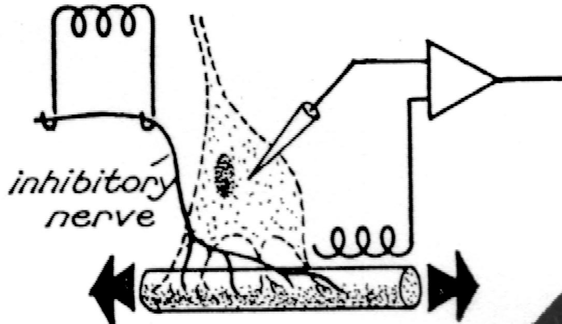
Figure 10.B. Spike rates. On the left, the data have been windowed (marked in blue) and converted to spike rates; on the right, instantaneous spike rate is plotted against time and fit with an exponential equation.

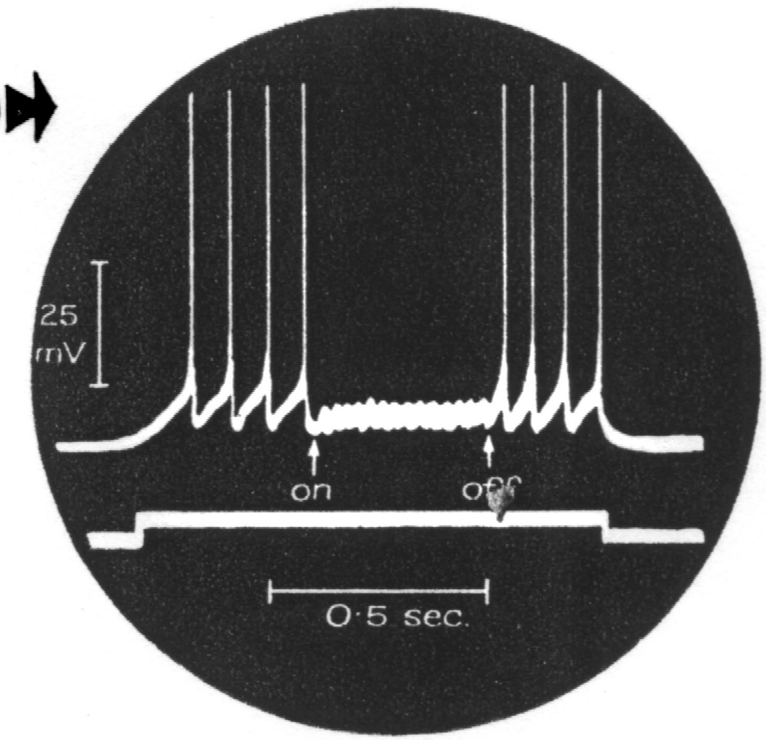
Adaptation:

1) Series-elastic properties of muscle
2) MRO1- slow adaptation- $I_{K\ (Ca)}$, Na/K pump
3) MRO1 and MRO2 have similar generator potentials
4) MRO2 adapts more quickly to depolarization

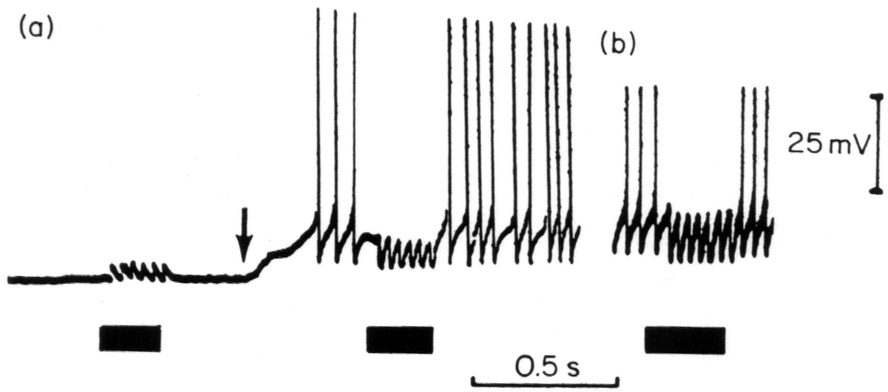
Inhibitory, efferent control of MRO

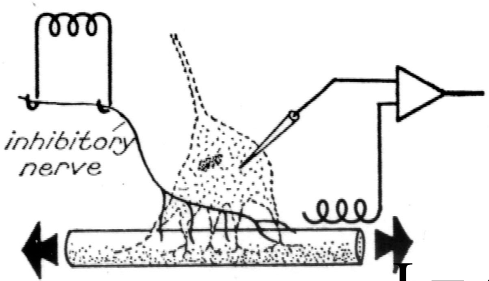




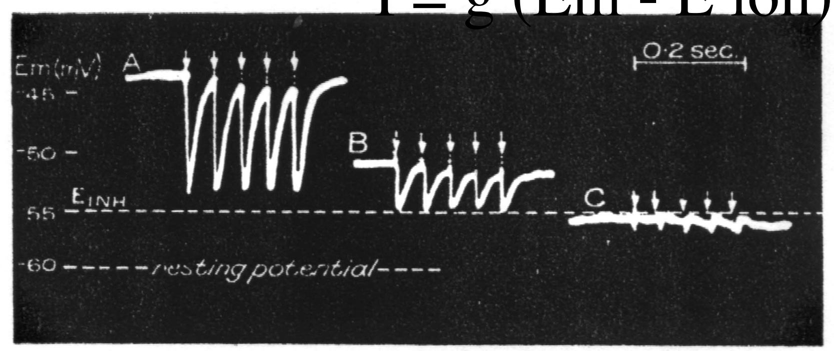


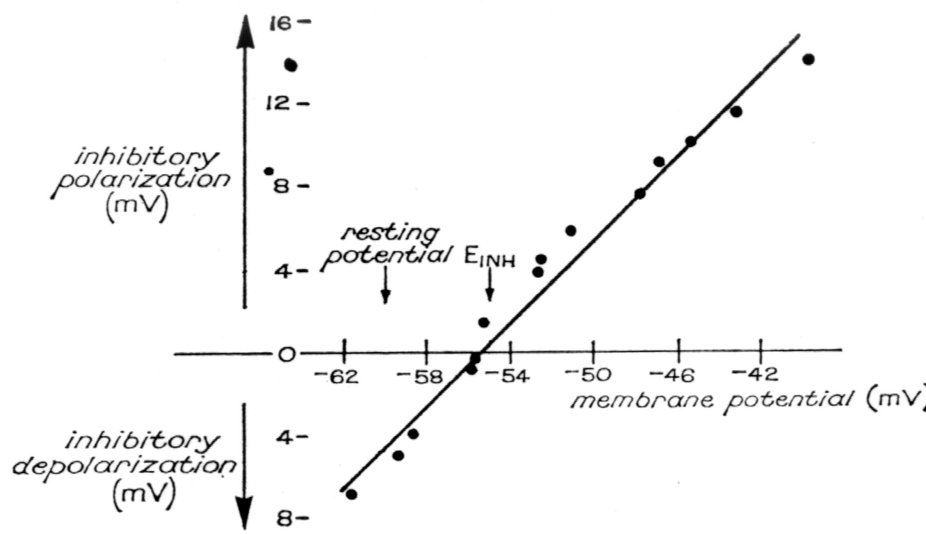
Inhibitory conductance increase





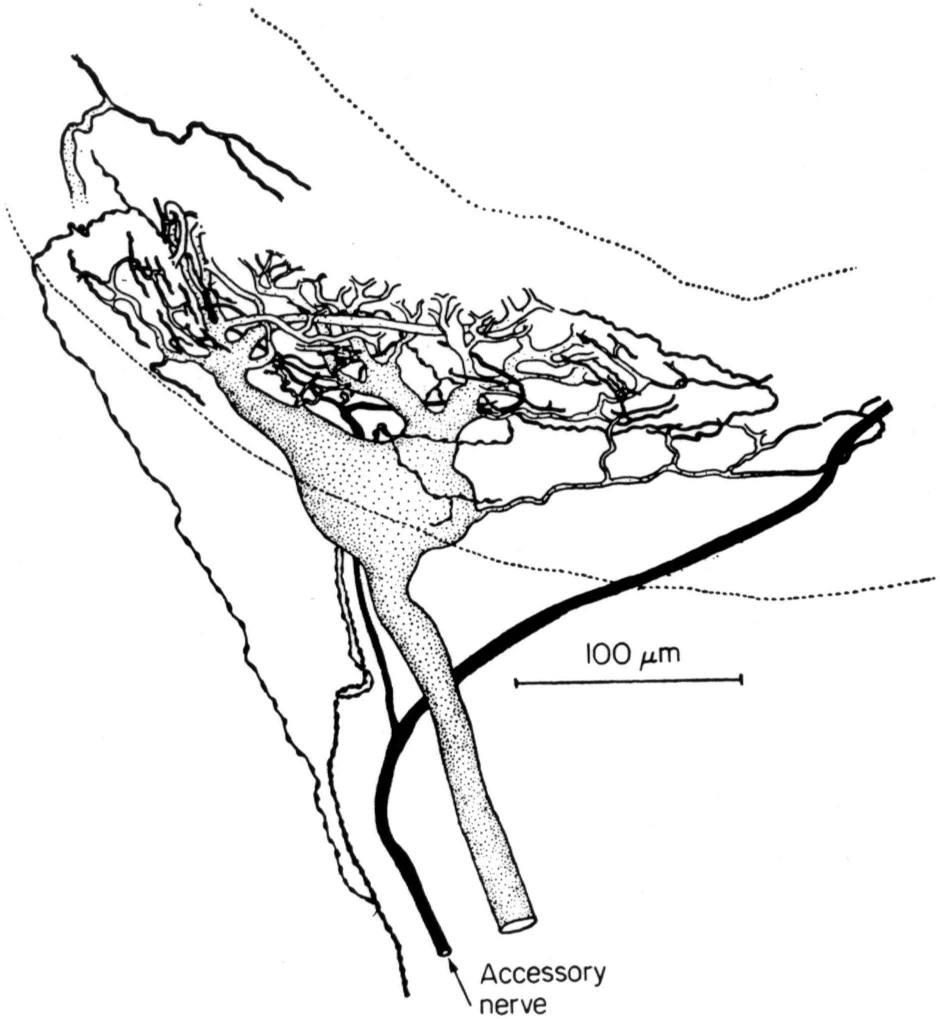
I = g (Em - E ion)

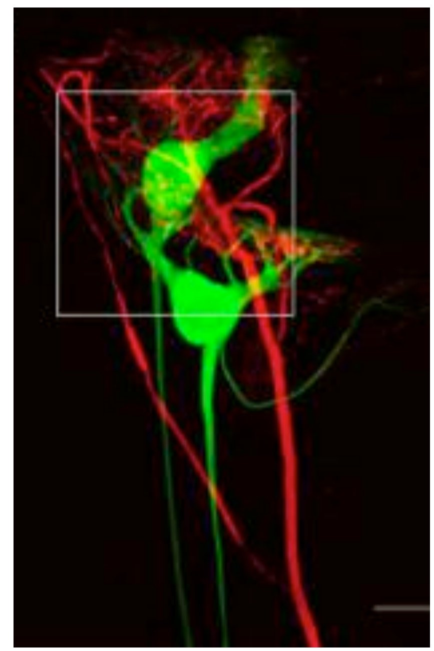




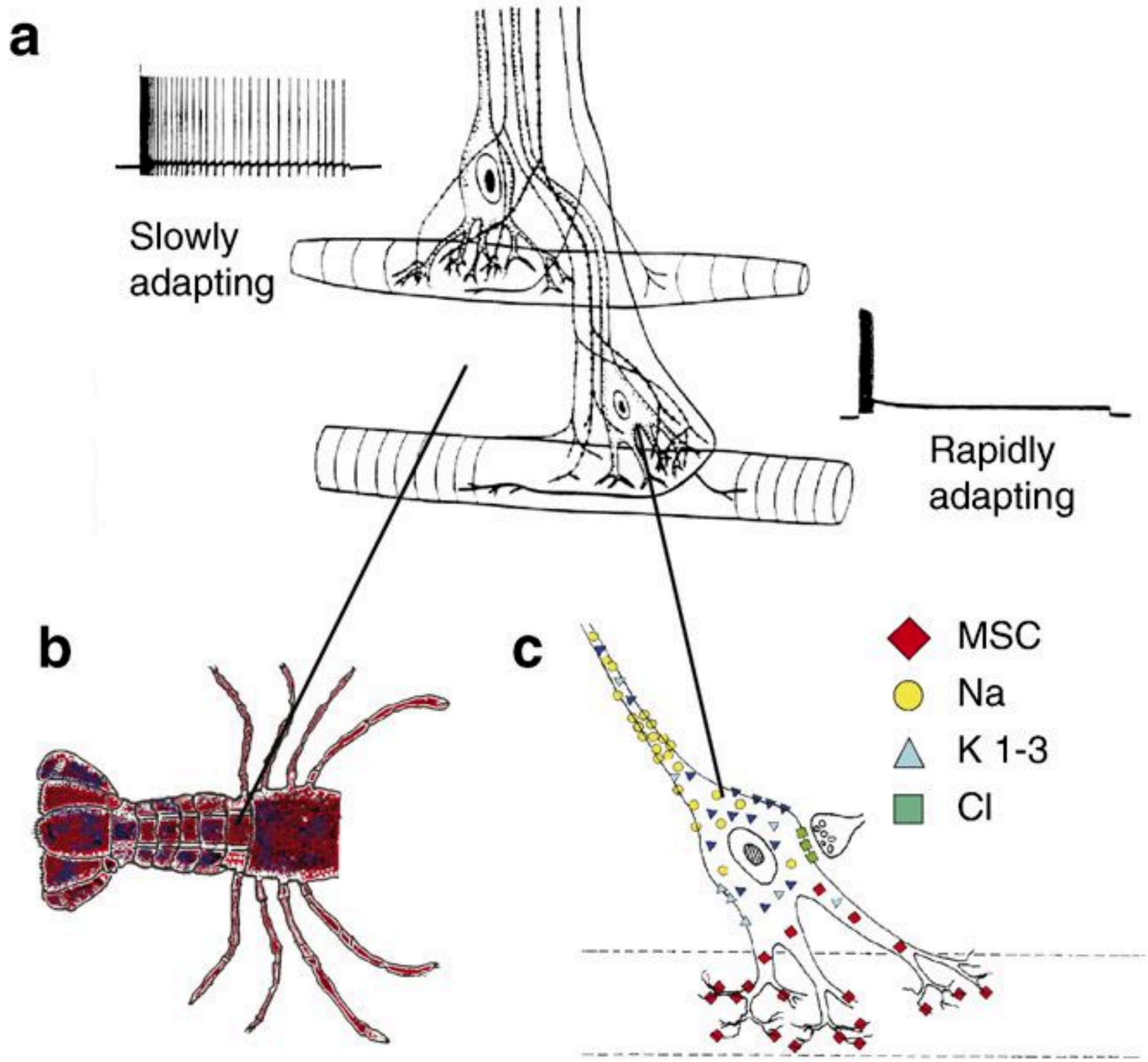
I = g (Em - E ion)

Mechanisms of inhibition?
Reduce AP generation by:
1) Algebraic summation of excitation and inhibition
2) Reduction of space constant





Summary of MRO



Rydqvist,et.al 2007

Control system summary of MRO activity