Swimmy Lecture 1

I. Advantages of Swimmy

A. Faithful simulation of neural activity

1. Swimmy is based upon *Neuron*, a research-grade neural simulation system

2. Eliminates technical problems & technical proficiency necessary for conducting real electrophysiological experiments

B. Indication of realistic nature of *Neuron* & *Swimmy* is that action potentials during bursts decrease in amplitude

1. This occurs when action potentials occur during the relative refractory period of preceding action potentials

a) Caused by decreased membrane resistance during this period

II. Basic synaptic physiology

A. Temporal summation occurs when a single presynaptic neuron is repetitively active

1. Individual postsynaptic potentials (PSPs) sum together if PSPs occur at a rate where subsequent PSPs occur prior to the decay of a previous PSP

B. Spatial summation occurs when more than one presynaptic neuron becomes active around the same time, allowing summation of PSPs

1. Spatial summation can involve the combination of excitatory postsynaptic potentials (EPSPs) or inhibitory postsynaptic potentials (IPSPs) or both

C. The true nature of neural inhibition

1. Most introductory physiology or physiological psychology textbooks present the nature of neural inhibition incorrectly (!)

a) The summation of EPSPs and IPSPs is presented as an algebraic summation - WRONG!

2. During activation of inhibitory synapses, the opening of chloride channels reduces membrane resistance

a) Produces a shunting of excitatory current (from EPSP) that reduces the amplitude of EPSP

b) During the IPSP, the membrane potential will move towards E_{Cl}, regardless of if E_{Cl} is positive to, negative to, or right at the resting potential

(1) IPSPs can be depolarizing, but still inhibitory (if E_{Cl} is positive to V_m)

(2) In Swimmy, E_{Cl} will be negative to resting potential, so IPSPs will be hyperpolarizing - but with one big caveat

(a) If you hyperpolarize a cell below E_{Cl} (you'll do this a lot), the IPSP will appear depolarizing

(b) Polarity will flip at the reversal potential (i.e., the equilibrium potential for chloride)

III. Synaptic facilitation & depression

A. Synaptic depression occurs when a single synapse is repetitively active & PSP amplitude decreases (could be EPSPs or IPSPs)

1. Most likely cause is synaptic terminal runs out of neurotransmitter (can't reload fast enough between spikes)

B. Synaptic facilitation occurs when the PSP amplitude increases

1. Most likely cause is residual calcium in presynaptic terminal (sums with calcium influx from next incoming spike – higher calcium levels = more neurotransmitter release)

C. To demonstrate either synaptic depression or facilitation you need to make sure that the second PSP occurs following the end of the previous PSP

1. If you don't, you could be seeing temporal summation or shunting of currents

2. Facilitation or depression could be occurring during this period, but you can't unequivocally demonstrate it during this period

D. Synaptic depression and facilitation are presynaptic events, while summation is a postsynaptic event

IV. Endogenous properties of neurons

A. Some neurons may be endogenously active, or they may be driven by others

1. How do you figure this out?

B. If you hyperpolarize one cell so it doesn't spike, cells downstream will stop spiking if they aren't endogenously active

C. Temporal correlation between spikes in one cell and PSPs in another cell do not show that there is a connection (direct or indirect) between the two cells

1. Both cells 8 & 26 are driven by cell 7

a) The relationship between the spikes in 8 & 26 and the PSPs in cell 9 are identical

b) You need to come up with an experiment to demonstrate that the circuitry on the slide is correct (remember, next time you won't have the circuit diagram)

D. Some cells in Swimmy are endogenous bursters, they'll fire bursts of spikes without input

1. We won't see any of them today, but they might be in the swim oscillator

V. Quiz (turn in before lecture)

A. Your experience in lab & Section 4.1 of Swimmy manual should allow you to answer questions

VI. Homework! (bring to next lab)

A. Determine which neurons are involved in the circuit

B. Determine the cells that have direct (monosynaptic) inhibitory and direct (monosynaptic) excitatory input into Cell 1 and Cell 2 (the motor neurons)

VII. Strategy for determining if a neuron is involved in the circuit

A. Any neuron that is part of the circuit should exhibit rhythmic activity in phase with the activity in the motor neurons (Cells 1 & 2)

1. In real circuits, this may not be true

a) Trigger and gating neurons do not oscillate in phase with the main circuit

B. Swimmy contains neurons that are not part of the circuit

VIII. Strategy for showing synaptic connections

A. In all of Swimmy's synapses, there is a 1 ms synaptic delay & another 1 ms delay to the peak of the spike

1. This won't be true in real circuits, so we look for a constant synaptic delay

a) This isn't an infallible criterion for showing a direct connection, but circuits with interposed neurons will often have jitter in the synaptic delay

B. Dale's law – a neurons only releases one neurotransmitter (or combination of transmitters) from all of its synapses

1. In Swimmy, this means that a particular neuron should always produce similar effects in postsynaptic cells (excitation or inhibition)

a) May not be true in real world because there are often several types of receptors for a single neurotransmitter molecule

C. Induce "extra" spikes or prevent spikes to see effect on other neurons

1. In your lab report (due after week 2), be sure you include control records so I can see what "normal" activity looks like