Midterm I 2003:

1. An action potential triggers transmitter release from the presynaptic nerve terminal (bouton). What is the second messenger that couples the action potential to secretion? What target protein does the second messenger activate? Which other proteins are essential for the fusion process?

2. Following the arrival of a presynaptic action potential in the never terminal there is a period of time of about 500 ms that the probability of transmitter release by a second action potential is increased. What is the mechanism for this?

3. Two identical amounts of transmitter are released onto a postsynaptic cell separated by a 10 ms interval. The first release evokes an action potential, but the second does not.
   a) Where in the cell is the action potential initiated? Why there?
   
   b) What kind of ion channels in the postsynaptic cell are responsible for the failure to evoke the second action potential? Describe two contributing mechanisms for this failure.
4. A cell has a resting potential of $-70 \text{ mV}$, $E_K = -100 \text{ mV}$, $E_Cl = -70 \text{ mV}$, $E_Na = +60 \text{ mV}$, $E_Ca = +120 \text{ mV}$, and three classes of ligand-gated channels: NMDARs, AMPARs, and GABARs. Explain what happens to the membrane potential and intracellular Ca++ under the following conditions.

a) You wash on GABA (Opens ligand gated Cl channels)

b) You wash on NMDA, a specific ligand for NMDARs.

c) You wash on glutamate

5. Axons from three presynaptic neurons synapse onto the same dendrite, close to the cell body (“near input”), far out on the dendrite (“far input”), and in the middle (“middle input”). The three have an equal probability of fusion of vesicles. “far input” and “near input” release glutamate, while “middle input releases GABA. Respond to the following questions and explain your answers.

a) compare the size of the voltage response recorded in the postsynaptic cell body in response to a single action potential in the “near” versus “far” glutamate input? Explain and illustrate.

b) How will the size and shape (rise and decay rates) of the EPSP differ if “near” and “far” inputs fire at roughly the same time instead of at different times as in a)? How about if “far” and “middle” fire together? Draw the responses and explain your logic.
6. Acetylcholine (ACh) released by an axon activates two classes of receptors in the postsynaptic cell: 1. A ligand-gated ion channel that is cation selective, and 2. Another class of receptor that leads to the G-protein activation of a K⁺ channel. What will be the relative time delay between the binding of ACh to the two receptors and the gating of the two channels? Explain.

7. What are the molecular mechanisms of ion selectivity and voltage sensing in voltage-gated K⁺ channels? Support your explanation with a membrane topology cartoon of a voltage-gated K⁺ channel, where you label the functional parts and explain how they operate.