Name: **Key**  Midterm #1  Biology 3330, Fall 2003

1) **6 pts.** You are performing experiments in which you stimulate sensory receptors and record from the corresponding primary afferents. You stimulate the receptors in the following manner and record the responses shown below:

<table>
<thead>
<tr>
<th>Stimulate:</th>
<th>Receptor #1</th>
<th>Receptor #3</th>
<th>Receptors 1 &amp; 3 (concurrently)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Afferent 1:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Afferent 3:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a) What phenomenon could account for the decreased response in primary afferent 1 when you stimulate receptors 1 and 3 together?

- **lateral inhibition.**
- 3 has an inhibitory connection on 1. When you activate 3, it inhibits 1.

b) If you stimulated primary afferents 1 and 3, and recorded from afferent 3, what response would you expect to see?

2 possible answers:

1) Same response as if you stimulate 3 alone. For the case where 3 has inhibitory connection on 1, but 1 has no inhibitory connection with 3.

2) Decreased response. For the case where 3 and 1 have reciprocal inhibitory connections.
2. Using the letters that correspond to the terms on the left, label the CNS regions that the arrows point to.

The three pictures below represent sections through which regions (levels) of the brain?

A) Dorsal column nuclei
B) Ventral horn
C) Colliculus
D) Pyramidal tracts
E) Reticular formation
F) Dorsal horn
G) Red nucleus
H) Substantia nigra
3) (12 pts) For each of the following receptor properties, write I for ionotropic, M for metabotropic, B for both, or N for neither:

- Triggers a fast postsynaptic response
- Acts via phosphorylation of an ion channel

- Triggers a slow postsynaptic response
- This receptor can double as an ion channel itself

- Postsynaptic response is long-lasting
- Is important in mediating reflexive behaviors

- Postsynaptic response is short-lasting
- Is important in neuromodulation

- Binds neurotransmitters such as somatostatin
  and vasopressin
- Acts via a G-protein mediated biochemical cascade

- Binds neurotransmitters such as acetylcholine
- Mediates a physical alteration of an ion channel

4) (10 pts) Match the brain area to the symptoms which could result were you to lesion that area:

- Amygdala
- Occlusomotor Nerve
- Frontal Lobe
- Reticular Formation
- Occipital lobe
- Substantia Nigra/Basal Ganglia
- Lateral Spinothalamic tracts
- Glossopharyngeal Nerve
- Hippocampus

A. Impaired pain sensation
B. Inability to hold limbs in a fixed position; tremors
C. Impaired control of gaze direction
D. Impaired vision (without damage to the eye itself)
E. Emotional ‘flatness’; inability to read emotional states
F. Impaired execution of controlled movements
  (overcorrecting)
G. Inability to consolidate new memories
H. Impaired taste sensation
I. Radical changes in personality and critical thinking
J. Enduring coma

5) (9 pts.) Matching:

- Serotonin
- Dopamine
- Acetylcholine
- GABA
- Tyrosine
- Catecholamine
- Nitric oxide
- Phosphodiesterase
- Adenyly cyclase

a. converts ATP to cAMP
b. sub-class of biogenic amines
c. released at neuromuscular junctions
d. amine with double ring structure
e. retrograde signaling substance
f. inhibitory transmitter in vertebrate CNS
g. lack of this associated with Parkinson's disease
h. produces 2nd messengers IP3 & Diacylglycerol
i. begins synthetic pathway for catecholamines
6) You have a cell in which the following concentrations of ions are present:

\[
\begin{align*}
K^+ \text{ [30mM]} & \\
Na^+ \text{ [400mM]} & \\
Cl^- \text{ [10mM]} & \\
\text{A}^- \text{ [900mM]} &
\end{align*}
\] + uncharged molecules for osmotic balance

\[
\begin{align*}
\text{K}^+ \text{ [400mM]} & \\
\text{Na}^+ \text{ [930mM]} & \\
\text{Cl}^- \text{ [990mM]} &
\end{align*}
\]

a) What are the equilibrium potentials for Na\(^+\) and K\(^+\), respectively?

\[
\begin{align*}
E_{Na} &= 57.5 \log \left( \frac{400}{50} \right) = 52 \text{ mV} \\
E_{K} &= 57.5 \log \left( \frac{30}{400} \right) = -65 \text{ mV}
\end{align*}
\]

b) At a particular excitatory synapse, you find that the conductances for sodium and potassium are equal (gK=gNa). What is the reversal potential of this synapse?

\[
\text{When } g_K = g_{Na}, \quad E_{rev} = \frac{E_K + E_{Na}}{2} = \frac{(52-65)}{2} \text{mV} = -6.5 \text{ mV}
\]

c) You now perform a voltage-clamp experiment in which you hold the membrane potential of the soma at varying voltages and stimulate the presynaptic neuron. You block voltage-gated Na\(^+\) channels and delayed-rectifier K\(^+\) channels with TTX, and TEA, respectively. Draw the current that you would expect to see at -20mV, -6.5mV, 0mV, 6.5mV and 20mV.

\[
\text{E}_{rev} = -6.5 \text{ mV} \text{ is the clamping potential at which no current flows. It is also the potential at which current 'reverses' direction.}
\]

\[
\text{So } V > E_{rev} \text{ out, } V < E_{rev} \text{ in}
\]
7) EPSPs of equal amplitude are generated on two different dendrites (A and B) of the same neuron. The membranes of the two dendrites have the same specific membrane resistivity and specific membrane capacitance. However, the diameter of dendrite A is 4 times as large as that of dendrite B.

\[ \text{diameter (A)} = 4 \times \text{diameter (B)} \]

\[ \lambda = \sqrt{\frac{r_m}{r_i}} \quad r_m = \frac{R_m}{2\pi r} \text{ radius } R \]

a) Plot the amplitudes of EPSP_A and EPSP_B as a function of distance, and explain your drawing. PSP decays from 100% to zero over distance. \[ A \to \text{A travels further due to bigger } \lambda. \]

b) Which EPSP (A or B) would you expect to make a greater contribution in depolarizing the soma? Cite two reasons why you think this would be the case.

\[ \text{EPSP_A, because:} \]

1) A travels further before decaying, so has a better chance of reaching the soma with a larger amplitude.

2) Because EPSPs are same amplitude, EPSP_A must be carrying more current \( V = IR \). So there is more current available to charge the membrane capacitance, according to \( \frac{dV}{dt} = i/c \).

3) EPSP_A has a higher conduction velocity due to increased diameter. So will reach soma faster, before \( \lambda \) becomes too large according to time constant \( \tau \).
8) 10pts The resistive and capacitive properties of a cell can be modeled as an RC circuit, where \( E_{\text{rev}} \) is the reversal potential, and \( \tau = C_m R_m \) is the time constant of the circuit.

Consider the 2 cells shown below, which receive synaptic input from the same neuron. You stimulate this presynaptic neuron, and record the results. The time courses of the channels at each synapse are similar; however, the cells themselves differ in their resistive and capacitive properties, and in \( E_{\text{rev}} \).

\[
E_{\text{rev}} = E_{\text{revA}}, \quad \tau = \tau_A
\]

\[
E_{\text{rev}} = E_{\text{revB}}, \quad \tau = \tau_B
\]

You observe that PSPs A and B have the same amplitude, but very different shapes. PSP A rises quickly, but returns to baseline very slowly, while PSP B is symmetric in its rising and falling phases. Given what you know about these cells, what can you say about the relative differences in \( E_{\text{rev}} \) and \( \tau \) that would account for these findings?

PSP A and B rise at same rate and to same amplitude, but come down at different rates because...

\[ E_{\text{revA}} > E_{\text{revB}} \]. It has higher \( \tau \) but doesn’t rise faster than B because \( \tau_A > \tau_B \). When they both reach 20mV, channel closes. They both discharge according to \( e^{-t/RC} \). But B comes down faster because it was closer to its \( E_{\text{rev}} \) when channels closed.
9) Consider the following situation: You have treated a neuron with TEA to eliminate K⁺ currents. Normal resting potential for this cell is -70 mV. You then voltage clamp the axon at various clamp potentials and observe the Na⁺ currents as shown to the right.

What do the shapes and relative amplitudes of these current traces tell you in terms of the properties of Na⁺ channels?

1. Channels are voltage-gated (they do not open as well for more negative voltages, i.e., < -40).
2. They activate with a particular time course (i.e., do not open immediately).
3. They inactivate (current stops flowing), and this is time-dependent.

10) 4 pts. The stellate ganglion and giant axon of the squid have played critical roles in enabling the early neurobiologists to understand basic mechanisms underlying synaptic transmission and action potential generation. A) What features of these two aspects of the squid nervous system made them so amenable to experimental analysis. B) What is the neuroethological principle that is revealed here?

A) The prep was large enough to insert electrodes
   - you could voltage-clamp axon and depolarize
   - terminal

B) A specialized system can be the easiest and most useful way of addressing general questions
11) 10 pts. In your neurophysiological studies of the neural circuit shown below, you discover that the synapses that neuron 1 makes onto neuron 2 show facilitation if presynaptic action potentials occur within 10 ms of each other. Synaptic depression, however, occurs at the synapse between neuron 2 and 3 when action potentials arrive at intervals less than approximately 5 ms. To better understand the function of this neural circuit, you stimulate neuron #1 in various temporal patterns while recording intracellularly from neurons #2 and #3.

![Synaptic Circuit Diagram]

a) The spikes elicited in neuron #1 are shown below. Above each of the spike recordings shown below, draw the pattern of postsynaptic potentials and, in some cases, action potentials that you would expect to see in neuron 2 and 3 in response to the patterns of spike activity in neuron 1. Explain your drawings in terms of the effects of synaptic plasticity.

- neuron #3
- neuron #2
- neuron #1 spikes

10 ms

b) How would the output of this circuit i.e., the responses of neuron 3, differ if synaptic depression occurred at the first synapse and facilitation was present at the synapse between neuron 2 and 3?

- neuron #3
- neuron #2

(c) Would you expect that lowering the calcium concentration in the extracellular fluids might alter the output properties of this circuit? If so, explain what changes would occur and why?

It would take even more than 4 spikes to trigger A.P.'s in neuron 2. (Ca^2+ is responsible for NT release. Less Ca^2+, less NT release, smaller post-synaptic response.)