This is an open book, open notes exam. **Choose any 7 questions (out of 10) to answer.** Each question is worth **15 points.** Typed answers will be appreciated but are not necessary as long as your handwriting is legible.

You may make use of any reference material but may not discuss the questions with anyone.

You may take up to 24 hours to complete this test.

**PLEASE PUT YOUR NAME ON ALL SHEETS.**

The test must be returned to the Biology Department office (77 Klamath) by **10:00 am Friday December 2nd**

(Please note that exams turned in after 11am will not be graded and will receive a failing grade)

This test will not be graded if the following is not signed:

"On my honor, I did not collaborate with any other person, including a fellow student, during this exam."

Signature

Under no circumstances should your answers exceed the space given.

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EXAM SCORE ____________________

EXAM GRADE ____________________

COURSE GRADE ____________________
1. What are the major structural and functional similarities (3 pts) and differences (3 pts) between ionotropic and metabotropic neurotransmitter receptors? What are the advantages of each (5 pts)? Provide two examples of each type of receptor (4 pts).

**STRUCTURAL/FUNCTIONAL SIMILARITIES:** Both are transmembrane proteins, both bind transmitters (ligand gated), both bind transmitter on the extracellular side of the receptor, and both act as transducers of information from the presynaptic cell.

**STRUCTURAL/FUNCTIONAL DIFFERENCES:**
Ionotropic receptors form an ion channel pore and change shape when they bind to a ligand.

Metabotropic receptors do not have an intrinsic channel function; instead they activate second-messenger-mediated pathways that cause a change in cellular function of the postsynaptic cell.

**ADVANTAGES:** Ionotropic receptors generate a faster response than metabotropic receptors but the responses of the latter are often more long lasting. Metabotropic receptors can also activate a wider range of responses than ionotropic receptors.

**TWO EXAMPLES OF EACH:** There are many different possible correct answers.
2. Barnacle photoreceptor cells have a typical neuronal morphology as shown below.

These cells are unusual however in that light produces a generator potential in their dendrites which is able to travel all the way to the terminal and activate transmitter release without producing an action potential. Explain how this is possible using your knowledge of passive properties of neurons (15 pts).

Barnacle photoreceptors are able to transmit the generator potential all the way down their axons to their terminals without the necessity for action potentials because the length constant ($\lambda$) of their membrane is higher than normal (i.e., very long). Using the equation $\lambda = \sqrt{\frac{R_m}{R_i}}$, there are only two possibilities to change $\lambda$, $R_m$ or $R_i$. Either one is acceptable for this answer. However, in reality, the barnacle photoreceptor has these unusual properties because of a substantial increase in $R_m$. 
3. You are recording from a mammalian nerve cell that has never been recorded before. Using patch clamp techniques, you voltage clamp a small patch of membrane that has one or a few of a particular type of channel. The recordings you obtain look like this:

a. Is this channel voltage gated? Why or why not (5 pts)?

**The channel is not voltage gated because it is open at all voltages.**

b. The experimental solutions used to obtain these recordings were:
   Extracellular: 150 mM KGlucolate (glucolate is a large impermeant anion) & 10 mM NaCl
   Intracellular: 150 mM KCl & 1mM MgCl₂

What ion(s) carry the current observed in the figure (5 pts)?

K⁺, because $E_K = 0 \text{ mV}$ and the reversal potential of the current is at $\sim 0 \text{ mV}$. Na⁺ cannot be the current carrier because it is only present in the pipette and thus $E_{Na}$ will be positive.

c. Draw the I-V curve for this channel (5 pts).

**Straight line going through zero with a slope corresponding to -3pA at -50mV, -1.8pA at -30mV etc.**
4. There are several mechanisms by which the strength of a synapse can be altered. List four pre-synaptic and four post-synaptic mechanisms which increase the strength of a synapse and briefly explain why each increases synaptic strength (15 pts).

Presynaptic:
- Increase number of voltage dependent Ca\(^{2+}\) channels
- Change voltage dependency of Ca\(^{2+}\) channels
- Increase total number of vesicles
- Increase fraction of vesicles that are releasable
- Increase amount of transmitter per vesicle
- Decrease intracellular Ca\(^{2+}\) levels more slowly

Postsynaptic:
- Increase number of existing receptors
- Add new type of receptors
- Increase conductance of existing receptors
- Change receptor affinity to transmitter
- Minimize receptor desensitization
- Close leakage channels in post-synaptic membrane
5. Vertebrate dorsal root sensory cells have a Na\(^+\)-dependent action potential. Voltage clamp experiments reveal that the inward Na\(^+\) current is reduced but not eliminated in the presence of TTX. What do you conclude from this results (9 pts)? Describe two experiments to test your conclusion (6 pts).

If TTX does not entirely block the inward Na\(^+\) current, then there must be a second, voltage dependent Na\(^+\) current that is TTX insensitive. Blocking the TTX sensitive current reveals a TTX insensitive current.

There are several possible experiments to test your conclusion. One can show that changing extracellular concentrations of K\(^+\) or Cl\(^-\) ions has no effect on the two Na\(^+\) currents. Another experiment would be to voltage clamp the cell (or patch clamp a small piece of membrane) and demonstrate that both currents have a reversal potential at the Na\(^+\) equilibrium potential.
6. Most terrestrial dinosaurs probably walked with an alternating gait, i.e., the front left and rear right legs stepped in unison followed by the rear left and front right legs. Your task is to draw a hypothetical neural circuit controlling dinosaur walking behavior. Be sure to include 1) the central pattern generator; 2) any pre-motor neurons; 3) all motoneurons; 4) Flexor and extensor muscles for each leg; and 5) the types of synapses (electrical or chemical; inhibitory or excitatory) at each synapse. Explain how your circuit is able to generate multiple cycles of walking.

There are many possible correct answers. All however must include motoneurons controlling flexor and extensor muscles for each leg, a set of pre-motor neurons that alternately activate the flexors and extensors for each leg and a group of central pattern generator neurons that synchronize the movements of the front left and rear right legs followed by the rear left and front right legs.
7. You have recorded the responses of 10 mitral cells to 4 different scented oils: clove, wintergreen, rose and spearmint. The mitral cells’ responses are shown below.

a. What can you conclude from these data about the specificity of the mitral cells to these odors (7 pts)?

Each mitral cell has a different and unique specificity to the 4 odorants.

b. Do these data support the labeled-line or across-neuron hypothesis of sensory coding, and why (8 pts)?

The data presented above supports the across neuron hypothesis since all but one mitral cell respond to more than one odorant. Thus, specific odorant coding must be contained in the output of the ensemble of mitral cells.
8. How did the book by Oliver Sachs influence your understanding of neuroscience? Which story (stories)/case study (studies) had the greatest impact and why (15 pts)?

A correct answer to this question focuses on several general issues raised by the book (neural deficits; plasticity; behavioral abnormalities; etc) with an emphasis on one story.
9. It is important to know the relative sizes/rates of various neural components. Circle the best answer.

<table>
<thead>
<tr>
<th>Component</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
<th>Option 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synaptic cleft width</td>
<td>0.2 nm</td>
<td>2 nm</td>
<td><strong>20 nm</strong></td>
<td>200 nm</td>
</tr>
<tr>
<td>Fast Axonal Transport Rate (per day)</td>
<td>0.2 mm</td>
<td>2 mm</td>
<td>20 mm</td>
<td><strong>200 mm</strong></td>
</tr>
<tr>
<td>Intracellular $[\text{Ca}^{2+}]$ in terminal at rest</td>
<td>0.1 µM</td>
<td>1 µM</td>
<td>10 µM</td>
<td>100 µM</td>
</tr>
<tr>
<td>Intracellular $[\text{Ca}^{2+}]$ during vesicle release</td>
<td>0.1 µM</td>
<td>1 µM</td>
<td><strong>10 µM</strong></td>
<td>100 µM</td>
</tr>
<tr>
<td>Diameter of a single acetylcholine vesicle</td>
<td>0.4 nm</td>
<td>4 nm</td>
<td><strong>40 nm</strong></td>
<td>400 nm</td>
</tr>
<tr>
<td>Vesicles released per MEPP</td>
<td>1</td>
<td>10</td>
<td>100</td>
<td>1000</td>
</tr>
<tr>
<td>Acetylcholine molecules in a single vesicle</td>
<td>10</td>
<td>100</td>
<td>1000</td>
<td><strong>10,000</strong></td>
</tr>
<tr>
<td>Thickness of the myelin sheath of a vertebrate motoneuron</td>
<td>0.4 nm</td>
<td>4 nm</td>
<td>40 nm</td>
<td><strong>400 nm</strong></td>
</tr>
<tr>
<td>Lipid bilayer thickness</td>
<td>.05 nm</td>
<td>0.5 nm</td>
<td><strong>5 nm</strong></td>
<td>50 nm</td>
</tr>
<tr>
<td>Synapse width (length of active zone)</td>
<td>50 nm</td>
<td><strong>500 nm</strong></td>
<td>5000 nm</td>
<td>50,000 nm</td>
</tr>
<tr>
<td>Diameter of a vertebrate CNS axon</td>
<td>1 µm</td>
<td>10 µm</td>
<td>100 µm</td>
<td>1000 µm</td>
</tr>
<tr>
<td>Diameter of NMDA receptor protein</td>
<td>1 nm</td>
<td><strong>10 nm</strong></td>
<td>100 nm</td>
<td>1000 nm</td>
</tr>
<tr>
<td>Synaptic delay</td>
<td>0.1 ms</td>
<td><strong>1 ms</strong></td>
<td>10 ms</td>
<td>100 ms</td>
</tr>
<tr>
<td>Diameter of a squid giant axon</td>
<td>1 µm</td>
<td>10 µm</td>
<td>100 µm</td>
<td><strong>1000 µm</strong></td>
</tr>
<tr>
<td>Slow Axonal Transport Rate (per day)</td>
<td>0.2 mm</td>
<td><strong>2 mm</strong></td>
<td>20 mm</td>
<td>200 mm</td>
</tr>
</tbody>
</table>
10. You undoubtedly studied one aspect of nervous system function you regarded as important but was not covered on this exam. So that all that studying was not a total waste, pose a question that covers a topic from any part of this course not addressed by other questions on this exam, and then answer your own question. You’ll be graded both on the quality of the question (7.5 points) and on the quality of the answer (7.5 points). In particular the question should not be too trivial (e.g., name two kinds of cells in the nervous system), and it should not just be a twist on one of the questions already on the exam. Your question ought to reflect your judgment of what a fair yet relatively difficult exam question should be.

Many correct answers are possible. Points were awarded on the basis of the originality and quality of the experiment and answer.