NEUR0010 Exam 2 Review - KEY
Prepared by Ronnie Li

You have a lot of multiple choice questions to practice from, but do you truly understand the concepts behind what you're studying? Test yourself here, for starters.

Some of these questions are more food-for-thought **(FFT)** questions than test questions, but they do have reasonable and unreasonable answers.

1. **FFT:** Why do you think it makes more sense to have photoreceptors hyperpolarize to light rather than depolarize?

In my opinion, you can get more range with hyperpolarization than with depolarization. Although photoreceptors do not fire action potentials, there's only so much you can depolarize a photoreceptor before it releases glutamate. In contrast, there's theoretically no "limit" for hyperpolarization. This is especially the case with regular neurons that fire action potentials. If a neuron sits at -65 mV, there's no stopping the action potential when the membrane potential reaches the threshold. But again, in theory, you can hyperpolarize it all you want and not have to worry about the all-or-nothing nature of the action potential.

2. Using a diagram, contrast the two signaling pathways from photoreceptor to an ON or OFF bipolar cell to a retinal ganglion cell. Indicate whether each cell depolarizes or hyperpolarizes, what neurotransmitter is released, the relative amount of it that is released, and what kind of receptors are present on each bipolar cell. Indicate in each pathway whether the retinal ganglion cell increases or decreases its firing rate.

This question is important, but unfortunately I just don't have the time to explain it all. I would encourage you to look online. Dr. Paradiso is a vision researcher, and he can probably give you an answer and explanation if you email him and/or go to office hours. However, I hope to get to this concept before the final exam.

3. You're an ophthalmologist, and you see a patient who has blindness in her upper left visual field. Upon receiving her MRI scan, the radiologist tells you that your patient has a lesion in her upper left optic radiation, which is causing this partial blindness. Do you trust the radiologist's interpretation? If not, where do you think the lesion actually is? **FFT:** How do you think other areas of V1 will compensate for this partial blindness?

Remember that the visual world enters your eyes upside-down and backwards. So if the patient has partial blindness in her upper left visual field, the lesion is more likely to be in the lower right optic radiation. Primary visual cortex (V1) is amazingly plastic. If a part of V1 is damaged, nearby areas will essentially "take over" the damaged parts. You might have heard that blind people sometimes have extraordinary senses of smell, hearing, touch, etc. That's because in blind people, their V1 is not getting any input, so other areas of cortex will expand and take over, sometimes giving you greater acuity in other senses.

4. Commissural tracts are collections of axons that cross over from one hemisphere to another. Perhaps oddly, primary visual cortex (V1) and primary auditory cortex (A1) have very few commissural tracts. In other words, the left V1 doesn't have many connections to the right V1, and the same is true for A1. Why might these regions in particular not "need" so many commissural tracts?

Primary sensory regions like V1 and A1 don't "need" as many commissural tracts as other regions of the brain. Regions like V1 and A1 are binocular and binaural, respectively, meaning that they receive input from both eyes and both ears. When you learned about vision, look back at the illustration of the pathway from the eyes to V1. You'll notice that both sides of V1 receive input from both eyes. The same concept is true for A1 and ears. Because V1 and A1 already receive information from both sides of the body, they might not require as many commissural tracts connecting the two.

5. Based on what you learned about the action potential, why is it impossible for a single neuron to encode very high frequency sounds using the phase locking principle?

High frequency sounds usually cannot be encoded by simple phase locking. Recall when you learned about the action potential. The timing is important: It takes about 1 ms to reach the overshoot, and another 1 ms to hyperpolarize and return to resting state. During the falling phase, which lasts about 1 ms, the neuron cannot fire another action potential – you might remember that this is called the "absolute refractory period" because you cannot do anything to make the neuron fire during that period. Therefore, for very high frequency sounds, it's impossible for the neuron to "keep up" with the sound waves just by firing action potentials, simply because the neuron can't fire fast enough.

6. If you cut the right half of the spinal cord at level C3, describe what happens to touch and pain sensation below the level of the cut on both sides of the body. What happens to touch and pain sensation above the level of the cut?

Cutting the right half of the spinal cord at C3 should not affect touch and pain sensation in both sides of the body above the cut. Below the cut, cutting the right half of the spinal cord will result in loss of touch sensation on the right half of the body, and loss of pain sensation on the left half of the body. This discrepancy exists because the pathway responsible for pain decussates (crosses the midline) immediately upon entering the spinal cord. On the other hand, fibers like the DCML pathway responsible for touch sensation tend to run on the same side of the body until it reaches the brain.

7. You are using the tip of your index finger to read a long horizontal sheet of braille so that your finger is continuously receiving mechanosensory input. Based on what you know about the anatomical and physiological properties of the four different mechanoreceptors covered in class, which mechanoreceptor would be able to convey the information from the braille dots most faithfully and accurately? Which mechanoreceptor would be the worst at conveying this information?

The properties of mechanoreceptors of interest are the receptor's receptive field size (small or large) and its adapting behavior (fast-adapting or slow-adapting). Because the indentations on a Braille sheet are small, a mechanoreceptor with small receptive fields would be better at reading Braille compared to a receptor with a large receptive field. In other words, small receptive fields allow you to detect things with higher resolution. Regarding mechanoreceptor adaptive behavior, we would want a mechanoreceptor that is slow-adapting because it will allow us to

convey more accurate information about the sheet of Braille, which is essentially a continued indentation. If we relied on a fast-adapting mechanoreceptor like the Pacinian corpuscle, we would lose the tactile input quickly because the Pacinian corpuscle would have already adapted to the Braille. Therefore, the Merkel's disc will be best because it has a small receptive field and is slow-adapting. It's not surprising that Merkel's discs are good for sensing continuous indents like Braille, while Pacinian corpuscles are good for sensing things like vibration. Mechanoreceptors like the Pacinian corpuscles will perform the worst at scanning Braille because they adapt quickly and have large receptive fields.

As another add-on, it's also important to think about how deep in the skin these mechanoreceptors are. In this situation of reading Braille, the ideal mechanoreceptor must be close to the surface of the skin, whereas mechanoreceptors deeper in the skin will have larger receptive fields and won't be able to scan the Braille with the same resolution as a more superficial mechanoreceptor can achieve.

8. **FFT:** Diffuse noxious inhibitory control (DNIC) is one mechanism by which the central nervous system, through the caudal medulla, can inhibit pain transmission. In one experiment, researchers pinched one hindpaw of a rat to induce pain, and they recorded from that nociceptor. While that hindpaw was pinched, they submerged the rat's tail in very hot water, and they found that the firing of that initial nociceptor decreased substantially. What do you think is the purpose of having this DNIC system?

In my view, the DNIC system helps the organism to direct its attention to the most recent and/or most severe injury. As an example, if you step on a Lego, that really hurts. But if you then got shot in the face, chances are you'll probably forget about that Lego piece hurting your foot. There is some speculation that acupuncture relies on this principle, although to my knowledge there is no concrete evidence to support that.

9. As you might know from the news, there is a major opioid crisis happening in our country. People are dying from opioid overdose. One of the common drugs people take is fentanyl, which is about 100 times more potent than morphine. Fentanyl heavily stimulates the periaqueductal gray (PAG), specifically the mu receptor. Based on this information alone, would you expect fentanyl to produce powerful analgesia or hyperalgesia?

Stimulation of the mu receptor by opioid drugs produces powerful analgesia (an = not, algesia = pain). This might explain how people on opioids recklessly endanger themselves and do things that would be incredibly painful if they were not using the drug.

10. Humans have two major types of motoneurons that innervate different muscle fibers. Our alpha motoneurons innervate extrafusal fibers, and our gamma motoneurons innervate intrafusal fibers. However, some species have a "beta system," in which their alpha motoneurons innervate both extrafusal and intrafusal fibers. Why might it be advantageous for humans to have these two separate systems in terms of motor control?

Recall that extrafusal muscle fibers are responsible for generating tension and causing movement. On the other hand, intrafusal fibers respond to changes in muscle length. Having two systems could be advantageous because it allows us to fine-tune our movements more easily. If you have ever used a microscope, you'll probably remember that there is a coarse

adjustment knob and a fine adjustment knob. Having these two separate systems would be like using both knobs on the microscope to get your specimen in focus, compared to using only one knob.

11. In lecture, you learned that the basal ganglia generally has an excitatory output to the cortex to generate movement. The basal ganglia actually projects to the thalamus, which sends the excitatory output to cortex. Lesioning the output nuclei of the basal ganglia results in excessive, uncontrolled movement. Based on this information alone, are the connections from the output nuclei of the basal ganglia to the thalamus excitatory or inhibitory?

This simply requires a bit of logic. The pathway is generally like this: Basal ganglia → Thalamus → Cortex. We are told that lesioning the output nuclei of the basal ganglia results in more movement. Therefore, the basal ganglia output nuclei must exert an inhibitory effect on the thalamus. The thalamus has an excitatory output to the cortex, especially primary motor cortex M1. If we got rid of the basal ganglia nuclei, we also get rid of the inhibition that's affecting the thalamus. With decreased inhibition coming in, the thalamus is now more active, increasing its excitatory output to the cortex and thus facilitating movement. In other words, the thalamus is therefore *disinhibited* (double negatives are annoying, I know).