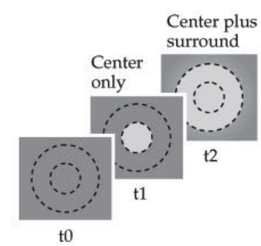
Biology 455 Midterm 2 – Nov 6, 2017 NAME:

Please make sure you have all 5 pages. Answer all of the following questions. You can write in full sentences or in point form, but whatever you write has to consist of coherent thoughts. Calculators are not permitted. There should be enough room to answer each question (ie try to be succinct), but if you absolutely need to, you may write on the back of the pages; however, you must make it absolutely clear which question any extra writing is answering.

Questions (9 total questions; 25 total points Turns out I miss-counted and there were only 24 points available. But then I made everyone's grade out of 23 to boost the average a little bit.):

1. The diagram to the right illustrates a hypothetical progression of luminance changes in the center and surround of a retinal ganglion cell's receptive field.



Describe the change in state at **t2 relative to t1** (e.g. more depolarized/hyperpolarized or increased/decreased activity) for the **on-center retinal ganglion cell** and explain the mechanism for the effect. **(3 points)**

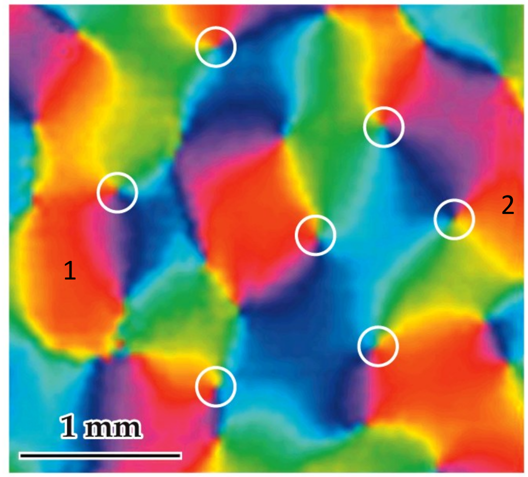
- Increased light in surround causes hyperpolarization of horizontal cells, leading to less GABA release. (0.5)
- Less GABA release causes depolarization of center cone, which releases more glutamate. (1)
- Glutamate binds to mGlur6 receptors on On-center bipolar cells, causing hyperpolarization and less glutamate release (1)
- less glutamate signaling to on-center retinal ganglion cell means less firing. (0.5)

*note: if you had the correct pathway, but everything was reversed, you got 1 point.

2. Name and briefly describe the mechanism used by humans to localize **high frequency** sounds. **(3 points)**

Interaural level difference (ILD) (1 point). The head acts as a shield that deflects high frequency sounds, the ear farther from the sound source will receive less input. Neurons on each side of the lateral superior olive (LSO) are excited by input from the ipsilateral ear, and inhibited (via an inhibitory interneuron) by input from the contralateral ear (1 point). The side of the LSO that receives net excitation signals to the brain which ear is closer to the source, and thus the position of the source. (1 point)

3. The image to the right illustrates a receptive field property of neurons within the primary visual cortex (V1). In the colour version of this picture, position 1 is the same colour as position 2.



I apologize for the poor reproduction of this figure during printing. This is part of the reason why I made the exam out of 23 instead of 24. I hope people weren't too affected by the poor quality of the image.

a) What receptive field property (or "represented parameter") would you expect to be very similar at position 1 and 2? **(1 point)**

Orientation preference.

b) What receptive field property would you expect to be different at position 1 and 2? **(1 point)**

Position in visual field.

4. Imagine that one day you discover that you miss all your calls/texts when your phone is on silent, because you can't feel it vibrate. You worry that you have a defect in touch sensation, so you stretch your skin and feel a bunch of objects, but everything seems normal. Assuming your phone is operating normally, offer a broad explanation for why you may be experiencing this phenomenon. (**1 point**)

Different types of touch sensations utilize different sensory receptors. So loss of vibration sensitivity would not necessarily affect other types of touch.

If you mentioned having a defect in Pacinian corpuscles, that's fine too, but not required.

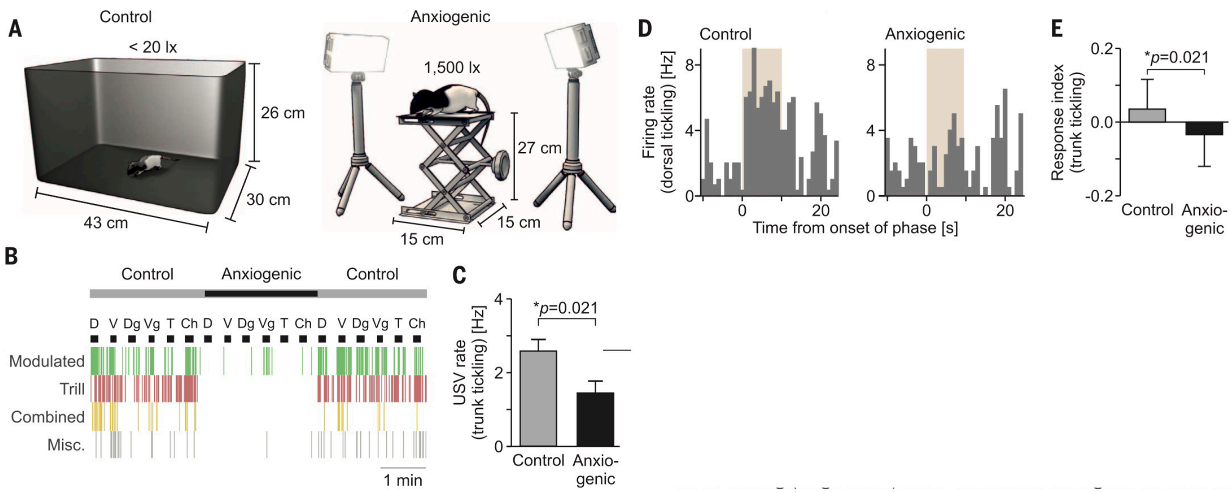
5. a) What protein is thought to act as the mechanically-gated channel in Merkel cells? **(1 point)**

Piezo2

b) Briefly describe how the family of channels that it belongs to was originally discovered. **(2 points)**

Piezo was originally discovered by an RNAi screen in mechanically-sensitive cells (N2A cells). The researchers screened through many candidate genes and found that knockdown of piezo caused a loss in the mechanically-gated currents in N2A cells.

6.



The figure above comes from the paper we discussed in class on rat tickling.
a) Briefly described what was done in the experiment. (**1 point**)

Rats were tickled either in a control condition (normal cage) or in a stressful situation (high platform, bright lights.) (0.5). The researchers recorded their vocalizations as well as the activity in somatosensory cortex. (0.5)

b) State one part of the results that **was not** surprising, given the current knowledge in the field, and explain why it wasn't surprising. (**1 point**)

It wasn't surprising that the rats "laughed" less, because mood is known to regulate the behavioral response to tickling in many species, including rats.

c) State one part of the results that **was** surprising, given the current knowledge in the field, and explain why it was surprising. (**1 point**)

The difference in activity in the somatosensory cortex under the two conditions was surprising, because mood-dependent modulation of sensory cortex has rarely been reported.

7. Imagine that one day you discover a new species of flies, living in a bag of baby carrots in your cupboard. They are unrelated to *Drosophila*, so you call them veggie flies. You examine the veggie flies' brain, and find that, like fruit flies, their antennal lobe has about 60 glomeruli. However, after extensive behavioral testing, you discover that unlike fruit flies, which can discriminate between thousands of odours, veggie flies can only discriminate between about 60 odour classes. Importantly, the veggie flies can detect all the same odours as fruit flies, but essentially lump them into 60 groups instead of being able to tell them all apart. What could be different about the **olfactory receptor neurons (ORNs)** of the veggie flies, compared to fruit flies, that would account for this behavioral difference? Explain your answer. (**2 points**)

The most likely situation is that odours activate only a single class of veggie fly ORNs (single OR), whereas in fruit flies we know that odours generally activate multiple ORs. This would eliminate the combinatorial coding capacity of the olfactory system, and make it code more like taste. With only 60 possible patterns of activation in the antennal lobe, the flies can then discriminate between only 60 types of odours. Note that in this model, you'd expect each ORN to still respond to many odours, giving the veggie fly the ability to detect thousands of odours. This is very much like the taste system can only discriminate between modalities, but cannot discriminate within a modality (e.g. tell the difference between two bitter compounds).

Note that this is different than suggesting that each ORN/glomerulus responds to only one odor. In this case, the fly would only be able to <u>detect</u> at most 60 different odors, and this also does not rule out some combinatorial code since in this model odours could still activate more than one ORN type.

8. In class we talked a lot about convergence and divergence. Name two neural circuits discussed in class that involve <u>convergence and divergence</u> of a set of presynaptic neurons on their postsynaptic target neurons. In each case, explain the functional consequence of the convergence/divergence on information coding/processing in that system. (**4 points**)

The two clearest examples are:

1) the somatosensory system. In this case, sensory cells exhibit convergence and divergence in their connections with the second-order neurons in the DCN. Here, convergence serves to increase signal-to-noise, by pooling the inputs of multiple sensory cells. This means that the DCN neuron will only spike when coordinated input occurs from multiple sensory cells, which typically only happens when a true stimulus is present. The downside of convergence and divergence is that it also reduces spatial acuity, something that is offset by lateral inhibition.

2) The connections between projection neurons (PNs) and Kenyon cells (KCs) in the fly olfactory system. In this case we see a similar phenomenon to the somatosensory system, in that coincident activity from multiple input PNs is required to cause the KC to fire. However, in this case, the main effect is to sparsen the representation of olfactory information, by causing only a small portion of the KCs to fire to a given odour. The difference from this situation and the somatosensory situation is that in the case of the olfactory system, you wouldn't necessarily expect coincident activity of PNs on KCs for every stimulus – it only occurs when a particular odour is present that happens to activate that set of PNs.

There is a lot of leeway in the acceptable answers here. I was looking for some level of understanding of the ideas from above. If you used convergence of rods onto bipolar cells in the visual system, you get part marks for that example. This system doesn't exhibit divergence in addition to convergence. A few people came up with other examples, which were judged individually.

9. In class, I presented two partially conflicting ideas about the organization of the primary gustatory cortex. Briefly describe these two ideas, and how they conflict. Then, compare each to the coding of odours in the piriform cortex by stating which gustatory coding scheme is more similar to the model for odour coding in piriform, and in what way. **(3 points)**

The Zuker model is that each taste modality is represented by spatially segregated populations of neurons in the gustatory cortex, forming a gustotopic map – i.e. there is a sweet patch, a bitter patch, etc.

The conflicting idea/result boils down to two things: 1) not all gustatory cortex neurons are tuned to a single modality; and 2) the cells responding to different modalities are not spatially segregated.

The second model for gustatory coding is much more similar to how the piriform cortex is thought to encode odours in distributed, partially overlapping sets of neurons.

I'd like to make a couple general comments on the answers people gave for this question. First, it's very important to read the question and really think about what it is asking. This question is all about the gustatory cortex, yet many people felt compelled to talk about receptor expression in TRCs and the responses in afferent neurons. I assume this is because the labelled line model I showed in class depicted these two populations. But we spent at least half a lecture on the gustatory cortex, so this shouldn't be unfamiliar. The second, and related, point is that quite a few people gave the example of high salt activating sour and bitter TRCs as a conflicting example, but this doesn't relate directly to the gustatory cortex (this is going on in the tongue – we never discussed high salt in the cortex). I think that this is because people remembered a question from an old exam where I asked for an example from the Zuker lab that goes against the labelled line. You have to be very careful about applying the answers you've seen on old exams to current exam questions. It's a dangerous strategy because things change from year to year, and it's like that the focus of the question is different. So please, try to answer the question as directly as possible, given what you've learned, rather than trying to conform some other answer to fit the question.