**Final essay questions for BIONB 2220**

On the final portion of your exam, we will choose three of the following prompts to present to you. These prompts may be modified slightly on the exam, so read carefully. You will then choose to answer **two** of the three presented questions in a 1-2 page essay. Your answers will need to be well reasoned, clearly written, and address the question directly. You should be able to answer most questions in one page of focused content, but you will be given space to write as much as two pages in response to each question. You should formulate your own answers rather than have others write possible answers with, or for, you in advance. Discussion is okay; joint answer writing is not. **The study group leaders and graduate student TAs will be told NOT to help with these essay questions.**

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1. You want to use a mouse model to test which brain areas are involved in a behavior. You may choose to test a behavior relating to *parenting* or a behavior related to *motor control (e.g. locomotion or supervised learning or reinforcement learning)*.
   a) First, explain how you would **measure** one behavior in your mice. Be sure you specify the behavior and how you will quantify it.
   b) Second, identify a candidate brain region to study and **justify** why you think it is likely to be important for this behavior.
   c) Third, describe an experimental manipulation you could perform to *reversibly* modify activity in this brain region and see how the behavior is affected. Describe your predicted result and draw a hypothetical figure of your result (bar graph, line graph, scatter plot). Make sure your design includes a control.

2. A person comes into the emergency room with a spinal cord injury. The cord has been crushed at the middle of the thoracic region (mid-back).
   a) Do you expect this person's knee jerk reflex to be affected and why?
   b) Do you expect there to be a deficit in digestive function and why?
   c) A colleague suggests implanting an electrical stimulation device below the injury site to restore locomotor function. Do you think this technique could work, and why or why not? Justify your answer, including a description of what cells or regions you would target for stimulation and why.

3. A patient comes to your clinic who can barely stand and walks slowly in a poorly coordinated way. The individual has not suffered a recent injury, so there must be some basic problem with neuronal function.
   a) Present **three neuronal deficits** that might be responsible for these symptoms, including one deficit at the **ion channel level,** one at the **synaptic level,** and one at the **circuit level** and **explain** why each might lead to the symptoms.
   b) For **one** of the three deficits, describe a test you could run on your patient to determine if your hypothesis is correct. Justify why this test would be useful and describe the result that would validate your hypothesis

4. *"Proper functioning of the nervous system depends on organization at all levels, from ion channels, synapses, and circuits to neuronal activity patterns in populations."* Use the phenomenon of **learning/memory in the hippocampus** to defend the statement above. Include an explanation of the role of each in proper learning/memory:

a) Describe the neuronal connections, or "wiring pattern" of a circuit necessary for forming one type of memory (e.g. recalling your grandmother's kitchen, but you may choose any learning paradigm).
b) Explain the role of one particular type of **ion channel** at this synapse (specify which ion channel is necessary and what property makes it so important).
c) Explain the role of one particular type of **synaptic receptor** at this synapse (specify which synaptic receptor is necessary and what property makes it so important).
d) Describe the pattern of population activity of the cells in the circuit you describe during the formation and during the recollection of the memory.

5. You learned that stimulating AgRP neurons in the arcuate nucleus of the hypothalamus makes mice eat and lowers their metabolic rate. You are interested in learning more about how these neurons work, so you do some experiments.

a) How would you test whether AgRP neuron stimulation **only** affects eating behavior and metabolic rate, but not other behaviors?
b) You record the activity of an AgRP neuron in a hungry mouse. Describe how food consumption would change the activity of this AgRP neuron.
c) How would you expect water consumption to affect the activity of this neuron? Explain your answer.
d) Do you think that this mouse would voluntarily stimulate its own AgRP neurons? Why or why not? For this question, assume that there is no food available to the mouse.
e) Is there a way that you could stimulate AgRP neurons and promote eating behavior without reducing metabolic rate? Explain how you could do this (in theory is ok).
f) You notice that AgRP neural activity rapidly changes when the mouse gains access to food - before the food is consumed! Did you expect this to happen? Explain why or why not. What does this new data imply about how AgRP neural activity is controlled?

6. a) Describe what it means to have critical periods during brain development.
b) Provide **two** possible advantages and **two** possible disadvantages of having critical periods and explain *why* they would be beneficial, or harmful, to the organism.
c) Describe and discuss a specific critical period in one system and explain whether the advantages and disadvantages you provided in part (b) apply in this system.
d) In your example system, identify one specific synapse that will undergo LTP or LTD during development and explain why the synaptic strength must change to produce a functional neural circuit.

7. Two of your patients complain of muscle weakness. You test muscle contraction and discover that their muscles are working properly, so the problem must be with the neural activation of the muscle. Both patients feel stronger with cholinesterase inhibitors like physostigmine, but present weakness in different muscles and give other indications that they don't have the same disease. Your neurobiologist friend discovers that patient A's motor nerve terminals release smaller than usual amounts of neurotransmitter, while patient B has normal amounts of transmitter release.

a) Describe the experiments that your friend carried out to determine whether the site of disease action was pre- or postsynaptic for each patient.
b) Hypothesize what the mechanism of synaptic disease action for each patient was, and design experiments to test your hypothesis. Consider the process of transmitter release from the AP entering the nerve terminal to the EPSPs generated postsynaptically, including presynaptic AP properties, transmitter release steps, and passive electrical properties of the pre and postsynaptic membranes.
c) Why did cholinesterase inhibitors help both patients?

8. You are recording from the hippocampal structure in a rat while it is performing a spatial orientation task.

a) Propose a hypothesis about how the firing properties of cells in this brain area would correlate with the spatial location of the rat.
b) You find that the firing properties of the cells in this area change slowly over time. Describe how you expect them to change as the animal becomes more familiar with its surroundings and why.
c) A colleague of yours suggests that the changes in cell responses with respect to the spatial task depend on a specific receptor type located on these neurons that allow plasticity to happen. Suggest a receptor type and **two** ways to test your colleague's hypothesis.
d) You notice that when the rats are stressed and noradrenaline (NE) is released, they learn the spatial task much faster and the changes you observe in cell responses also happen faster. Knowing that NE depolarizes the cells' membrane, suggest why this increase in learning and plasticity would happen and explain the specific synaptic learning rule you are using in your reasoning.

9. Design an experiment to test the physiology and function of NMDA receptors in a circuit you have learned about in this course.

a) Describe **three** different techniques you will use and why each will be useful. At least one technique must involve voltage clamp.
b) Describe the exact manipulations you will perform with the three techniques and your expected result. Make sure your designs include appropriate controls.
c) Draw a hypothetical figure of the data from **one** of your predicted results (e.g. bar graph, line graph, scatter plot, voltage trace).