Neural Engineering

Final exam

Name: KEY

REMINDERS

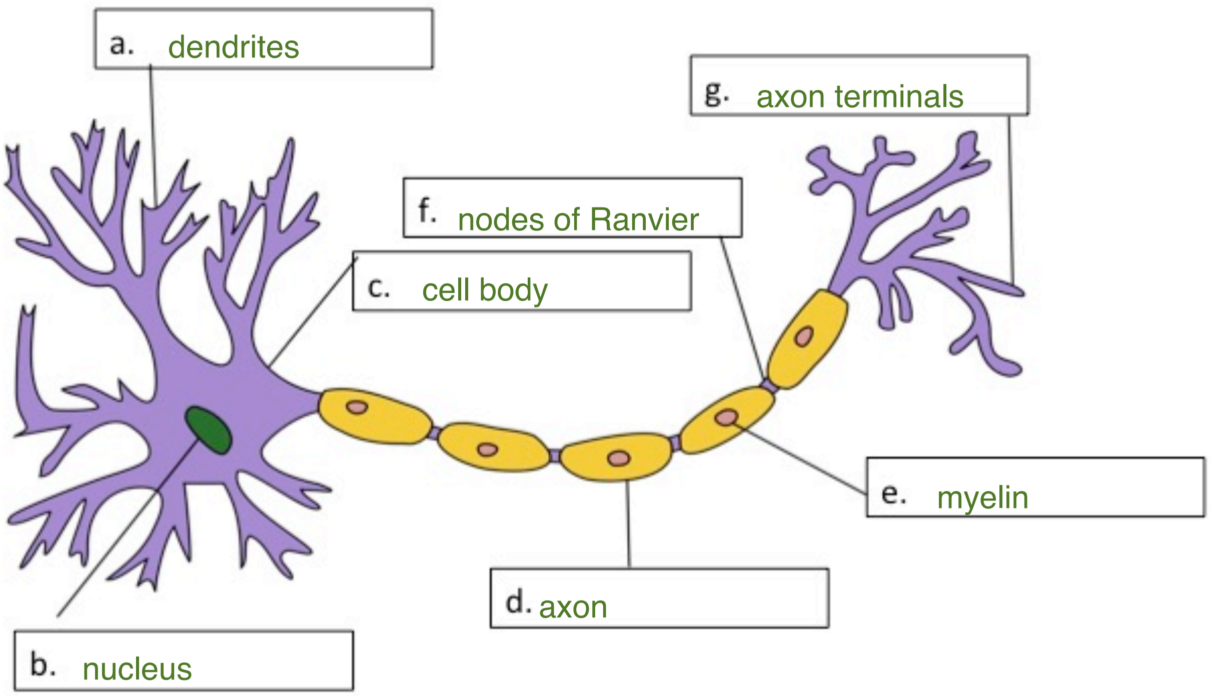
- Short answers should be limited to the space marked. Use the amount of space given for a question as a guide for how much detail to give.
- If a question is confusing, ask.
- Read the questions carefully and make sure you are actually answering what it asks for.
- Partial credit will be awarded for partial or partially correct answers. It's better to make an educated guess than leave it blank.
- A correct answer is a legible answer!

Score: _______/65

Section 1: Basic neuroscience

1. Below is a drawing of a neuron. Fill in the blanks naming each portion of the neuron. **(1 point per label, 7 points total)**

Note: Box D is referring to the entire long, skinny segment of the cell. Box E is referring to the blob surrounding the structure in D, not just the circle in the center. Box F is referring to the gaps between the blobs.



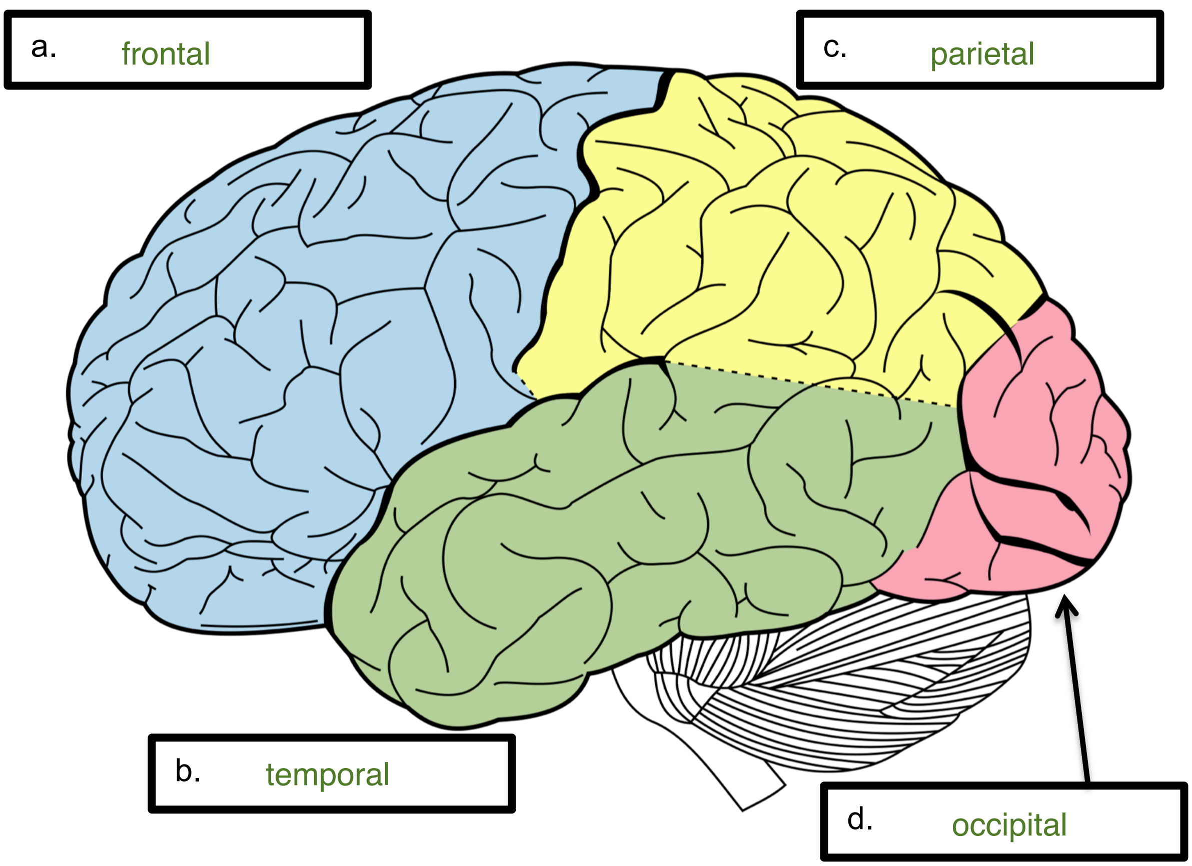
2. Which letter is at the location where a *chemical* signal is converted to an *electrical* signal? (Hint: not where the *electrical* signal is converted to *chemical* signal.) Circle answer**. (1 point)**

a b c d e f g

3. When the brain changes (due to learning, stimulation, or other processes), neuroplasticity occurs. Which of the following features of a neuron or synapse changes as a result of this process? Choose all that apply. **(1 point)**

a. Change in number of neurotransmitter receptors
b. Change in amount of neurotransmitter released
c. Growth of a new neuron
d. Growth of a new synapse between existing neurons
e. All of the above
f. None of the above

4. Label the four major lobes of the brain on the diagram below. **(1 point each, 4 points total)**



5. **(1 point each, 2 points total)**
Motor control functions are located in which lobe? ___frontal___

Somatosensory processing is located in which lobe? ___parietal___

6. What is the name of the lobe, not visible on this view, that processes pain and emotion? (**1 point**) ___insula___

7. You are working in a clinic. A patient in their 70s comes in who has difficulty starting movements and has a noticeable tremor in their hands, but no cognitive symptoms.

a. What disease does this patient likely have? **(1 points)**

Parkinson's disease

b. What area of the brain is damaged in this disease? What group of areas is this area part of? **(2 points)**

Substantia nigra

Basal ganglia

c. What is ONE treatment you could prescribe this patient? Broadly, what does this treatment do? Pharmacologic and engineering solutions are both options. **(3 points)**

Acceptable answers include:
L-dopa, a dopamine precursor oral medication that helps supplement dopamine levels normally maintained by the substantia nigra
Deep brain stimulator, an implanted device that delivers stimulation to either the subthalamic nucleus or globus pallidus (depending on individual case), which is thought to help restore balance to the inhibition/excitation circuits of the basal ganglia regions

8. There are three different types of muscle. Name them. How are they different (in location or function)? **(1 point)**

Skeletal muscle, voluntarily controlled by somatic nervous system. Smooth or visceral muscle, involuntarily controlled by autonomic nervous system. Cardiac muscle, some autonomic control and includes internal pacemaker.

Section 2: Principles of engineering

1. Give any ONE reason why arm/hand control is a more difficult engineering problem than leg/foot control. **(2 points)**

More degrees of freedom (joints), requires greater precision of movements

2. Name two areas of engineering that are involved in neural engineering. What is one contribution of each? For example, materials engineering contributes battery designs. (You can reuse materials engineering with a different specific contribution if you wish.) **(2 points each area, 4 points total)**

NOTE: MANY other fields and/or contributions may be answers! These are examples.

Area A: Electrical engineering

Contribution: Circuit design, electrode design

Area B: Mechanical engineering

Contribution: Advanced prosthetic, orthotic, wheelchair designs

Section 3: Sensory systems

1. How do cochlear implants transduce sound to a signal that human users can understand? **(1 point)**
   a. Mechanically bend the inner hair cells
   b. Electrically stimulate the spiral ganglion neurons
   c. Vibrate the tympanic membrane
   d. Amplify the sound wave as it travels through the ear canal

2. The density of sensory receptors is different in different parts of the body, and is especially high in the fingertips. Why does this matter for prosthetic design? How would you use this knowledge in your design? **(4 points)**

If we want our prosthetic design to capture as much naturalistic function as possible, we will want to have especially high density of touch sensors in the fingertips, even more than the rest of the hand. This is because the density of touch cells is higher in the fingertips than elsewhere on the body, in order to help with dextrous finger movements. There are also multiple types of receptors sensitive to different kinds of touch (e.g., light touch, vibration, firm touch) and other sensation (temperature, pain). We would want to have the highest possible density of touch sensors in our prosthetic hand's fingertips, and those sensors would need to be able to detect multiple different kinds of touch, in order to have naturalistic dextrous movement.

3. Most neural engineering devices include, or should include, a method of providing stimulation and feedback to the nervous system. Describe the following elements of feedback:

EXAMPLE ANSWER: other senses follow same general pattern

Sensory system affected (circle):

vision hearing vestibular touch/proprioception

Specific sensory organ/receptor targeted **(2 points)**: peripheral somatosensation - touch receptors, proprioceptors

Goal of stimulation – what perception does the device TRY to provide? Be specific. **(3 points)**: The device replicates complex touch and proprioception sensations from the body, including light touch, firm touch, vibration, pressure, and joint/limb position. It needs to communicate the intensity, type, and location of sensation. We want a user to actually be able to use the sensation to complete tasks of daily living.

What is a drawback or limitation of this system? What can it not do (or not do yet)? **(3 points)**: Currently existing systems of this type cannot provide multiple types of sensation (such as vibration vs. pressure), do not distinguish between locations on the body very well, and are very bulky.

Name any one ethical consideration related to the use of this system **(4 points):**

Examples include but are not limited to: equitable access, longevity of system, maintenance (by user, care provider, company), safety concerns, dependability, and more

Section 4: Motor systems and BCIs

1. You are working with a tetraplegic patient who will receive a BCI of one of three designs. List any two biological and/or engineering challenges, and briefly how you would solve them. Example for a hand orthotic:
Challenge: detect and exert the desired level of pressure
Solution: detects muscle contraction level in the bicep, calculates fraction of maximum output, provides grip assistance

EXAMPLE ANSWER: other options follow same general pattern

Design choice: exoskeleton muscle stimulation robotic arm

Challenge 1 (**2 points**): Replicating as much dexterity (including number of joints, range of motion, strength) of natural arm as possible

Solution 1 (**2 points**): Develop prosthetic that can be upgraded with modular new components that can be easily replaced as improvements become available

Challenge 2 (**2 points**): Naturalistic motor control, patient can use robotic arm as intuitively as own arm would be

Solution 2 (**2 points**): Place electrodes used to create control signal over motor cortex so arm is controlled just like real arm, provide sensory feedback so user does not have to stare at whatever they are doing

2. Name any one ethical issue related to the use of this system. **(3 points)**

Examples include but are not limited to: equitable access, longevity of system, maintenance (by user, care provider, company), safety concerns, dependability, and more

3. List, in any order, four necessary and SPECIFIC components of any bidirectional brain-computer interface device. Example: protein-resistant electrodes implanted in brain.

Component 1 (**2 points**): Electrodes for recording intent to move from brain (or peripheral nerves)

Component 2 (**2 points**): End effector - what user actually controls, such as a prosthetic or computer cursor

Component 3 (**2 points**): Power source - embedded/integrated or external

Component 4 (**2 points**): Sensors for detecting information from environment

EXTRA CREDIT:

What is one thing you wish we had either 1) covered more of, 2) covered earlier, or 3) did not talk about and you wish we had? **(Up to 2 points)**

What is your favorite fact or idea you learned in this class? **(Up to 3 points)**