Bi/CNS/NB 150 Final Examination

Due: Friday, Dec. 11, at 4:30 pm

You may not read past this cover page before beginning this timed exam.

- The exam covers all lectures and readings and emphasizes material after Oct. 26.
- The exam accounts for 30% of your final grade (7.5% per question).
- <u>Choose only FOUR of the five questions</u> in the exam and indicate them clearly.
- The number of pages is provided for each question. "End of question X" at the bottom of a page indicates the final page for that question.
- The exam has a total of 22 pages. Count the pages before you begin.
- <u>4 hours</u> are permitted for completion of the exam. Use the first 30 minutes to calmly read the exam and choose which four questions you will answer. Use the remaining 3.5 hours to answer these questions.
- If you pass 4 hours, you may place a thick line across the page, complete the exam below that line, and indicate how much time you used beyond 4 hours. Credit <u>may</u> be given for answers completed past 4 hours.

- You may only refer to <u>lecture slides, your notes, this year's problem sets, and the Kandel textbook</u> (including the digital version) to complete the exam.
- You may not use the Internet while taking the exam, but you may use a computer.
- You may not collaborate or discuss questions or answers with anybody before the exam's due date.

- If you think you need to make further assumptions to answer a question, you can provide those assumptions and the reasons for them with the answer. However, no further information should be necessary to answer any questions correctly.
- Include your name and the page number on every page.
- Use a separate page for each question.
- Use complete, grammatically correct sentences.
- Submit with this cover page.

- Type all your answers. Scan or photograph answers that cannot be typed (drawings).
- If you prefer, you may write your answers by hand within the allotted 4 hours, and then type them up exactly as you wrote them by hand afterwards (with no time limit).
- <u>E-mail</u> to the head TA (jcolas@caltech.edu). You may not submit a hard copy as before.
- Note that late submissions will not be accepted without prior approval.

Name:

Time and date submitted:

Total pages (including cover page):

Time spent completing exam:

Question 1 (7.5 points, 4 pages): Functional neuroanatomy

You are ecstatic about going to grad school for neuroscience, but you are also having trouble deciding what to focus on for your thesis. Fortunately, Charles Dickens comes to your rescue with an early Christmas present! Charles introduces you to his old friend the Ghost of Neuroscience Yet to Come, a lesser-known cousin of the Ghost of Christmas Yet to Come. The Ghost of Neuroscience Yet to Come helps you explore three of your many possible futures as a world-renowned neuroscientist.

1.A (3.3 points): Neuroanatomy

In your first future you are a world-renowned neuroanatomist. The Ghost of Neuroscience Yet to Come shows you just how significant neuroanatomy is, considering that structure determines function.

1.A.a. (0.3 points): What is topographic organization? How can topographic organization be distorted relative to the external world it represents? Provide at least two examples of such distortion. Are there any actual advantages of having topographic organization or not? Explain the reasoning behind your answers in one paragraph.

1.A.b. (0.6 points): Which systems among the visual, auditory, olfactory, somatosensory, and motor systems exhibit topographic organization? Provide one-sentence examples for each type of topographic organization, including at least two examples each for the visual and auditory systems. Which regions of the nervous system are characterized by the examples given?

1.A.c. (0.25 points): What do primary visual cortex, primary auditory cortex, primary olfactory cortex, primary somatosensory cortex, and primary motor cortex have in common? Explain in at most three sentences.

1.A.d. (0.3 points): Aside from simply being a part of the motor system, what is unique about the anatomy and connectivity of primary motor cortex relative to the other four primary cortical regions? Explain in at least two sentences.

1.A.e. (0.3 points): Aside from simply being a part of the olfactory system, what is unique about the anatomy and connectivity of primary olfactory cortex relative to the other four primary cortical regions? Explain in at least two sentences.

1.A.f. (0.3 points): Of the aforementioned five primary cortical regions, which two regions are in closest spatial proximity to each other? Which structure(s) divide these regions? Where are these two regions located? You must specify hemispheres, lobes, gyri/sulci, and Brodmann areas. How does this spatial proximity relate to the functional roles of these regions? Explain in one or two sentences.

1.A.g. (0.3 points): Where are the three primary cortical regions other than those referred to in the previous question located? You must specify hemispheres, lobes, gyri/sulci, and Brodmann areas.

1.A.h. (0.25 points): What is association cortex? What distinguishes association cortex from primary cortex? Explain in a paragraph.

1.A.i. (0.3 points): What are striate cortex and extrastriate cortex? Where are striate cortex and extrastriate cortex located? You must specify hemispheres, lobes, gyri/sulci, and Brodmann areas. Which anatomical feature(s) are the names of striate cortex and extrastriate cortex derived from?

1.A.j. (0.1 points): Which system(s) and which functional role(s) are the striatum, globus pallidus, substantia nigra, and subthalamic nucleus all related to? Answer in one or two sentences.

1.A.k. (0.3 points): Which specific emotion(s) have the amygdala, the hypothalamus, and insular cortex each been most strongly linked to?

1.B (1.5 points): Neuropsychology, part 1

In your second future you are a world-renowned neuropsychologist. The Ghost of Neuroscience Yet to Come shows you some of the many things that can be learned from studying patients with damage to the nervous system.

Describe where any lesions or mutations could produce each of the following impairments and describe in one or two sentences how the impairment arises. You must specify hemispheres, lobes, broader regions, gyri/sulci, and Brodmann areas whenever any of these are applicable. Multiple lesions and/or mutations with convergent effects are sometimes possible.

1.B.a. (0.25 points): Achromatopsia, the inability to perceive color. Answer for two types of patients. Both types of patient are unable to see colors, but only one type of patient can imagine or dream in color.

1.B.b. (0.25 points): Prosopagnosia, the inability to recognize faces

1.B.c. (0.25 points): Akinetopsia, the inability to perceive motion

1.B.d. (0.25 points): Visual agnosia, the inability to recognize visually presented objects despite intact visual acuity

1.B.e. (0.25 points): Left hemispatial neglect, the inability to pay attention to and process stimuli in the left visual hemifield despite intact visual acuity

1.B.f. (0.25 points): Loss of the sense of touch in the right leg without paralysis

1.C (1.2 points): Neuropsychology, part 2

The Ghost of Neuroscience Yet to Come asks her sister, the Ghost of Neuroscience Past, to also show you some of the most famous case studies in the history of neuropsychology.

Answer the following questions in a paragraph with regard to each case study:
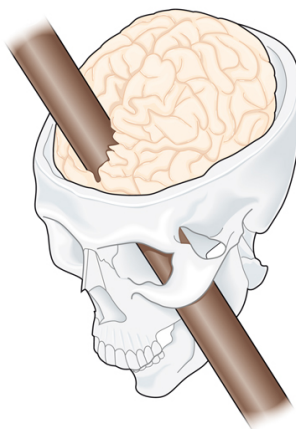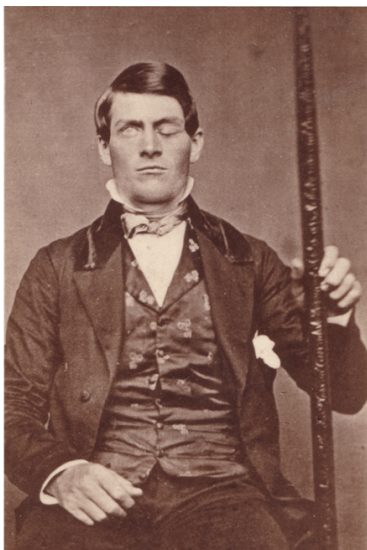
Which area(s) of the patient's nervous system was/were damaged? (You must specify hemispheres, lobes, broader regions, gyri/sulci, and Brodmann areas whenever any of these are applicable.)
What are the consequences of the lesions?
What is remarkable about the specificity of the patient's deficits?
What can be concluded about the area(s) and functions that the patient lacks?

1.C.a. (0.3 points): Railroad worker Phineas Gage, a patient of John Harlow, was the victim of an accident in which a large metal rod was driven through his head.

1.C.b. (0.3 points): Leborgne, a patient of Pierre Paul Broca, had a stroke that affected what subsequently became Broca's claim to fame.

1.C.c. (0.3 points): Patient H.M. suffered from epilepsy that could only be treated with surgical resection of the tissue causing his seizures.

1.C.d. (0.3 points): Patient S.M. has focal brain lesions that developed during childhood as a result of a rare genetic condition.

1.D (1.5 points): Neuroimaging

In your third future you are a world-renowned cognitive neuroscientist specializing in neuroimaging. The Ghost of Neuroscience Yet to Come shows you how powerful of a tool functional magnetic-resonance imaging (fMRI) can be.

1.D.a. (0.5 points): Describe in one paragraph an fMRI experiment that has the goal of identifying the region of the human brain specialized for visually processing human bodies. Where would you expect such a region to be located in the brain?
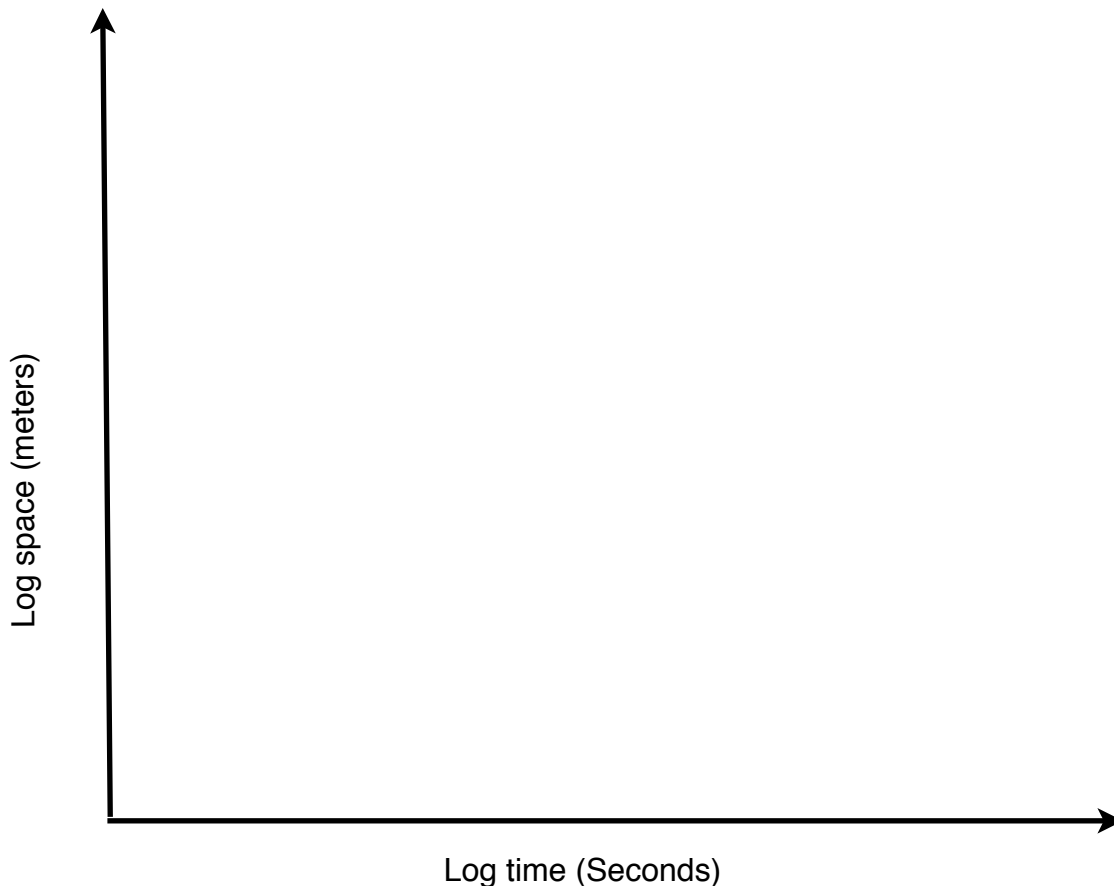

1.D.b. (0.4 points): To what extent could the results of your fMRI experiment demonstrate whether the putative body-processing region is necessary and/or sufficient for visually processing human bodies? Explain in one paragraph that includes a general description of how a region of the brain can be proven to be necessary or sufficient for a given function.

1.D.c. (0.6 points): Remarkably, some blind people can echolocate as bats, dolphins, and whales do. You hypothesize that the unique brains of these people actually "see" visual images while echolocating as a sighted person would while looking. Describe in one paragraph an fMRI experiment that tests this hypothesis.

END OF QUESTION 1

Question 2 (7.5 points, 3 pages): Sensory Systems.

A. (i) (2 points) You will remember the plot we had in class of the spatiotemporal resolution of different methods (fMRI, electrophysiology, etc.). Now apply this kind of plot to sensory systems. Plot the resolution in space and time, on the log-log plot below (feel free to expand it, paste it onto another sheet, etc.), of the following sensory systems in humans: dorsal-column medial lemniscal touch system, anterolateral pain system, M-pathway vision, P-pathway vision, auditory system. Begin by labelling your axes with numbers, in log increments, that are in units of meters on the y-axis (so, ... 0.1m, 1m, 10m, 100m etc.) and in units of seconds on the x-axis (so, ...0.1, 1, 10.... seconds). Then indicate with a circle or oval the region of this graph in which the specific sensory modality listed above operates (its resolution in space and time). For instance, for the olfactory system, its resolution in time is on the order of seconds (limited by sniffing, also olfactory transduction is slow), and its resolution in space is centimeters to meters (you basically can only very roughly tell if something is to the left or right of your nose as you move around, very poor spatial resolution). For each of the 5 sensory modalities/submodalities, explain your answer in a few sentences. Grading: if your answer is correct in the drawing and you give a very brief explanation, you get full credit; if your answer is incorrect in the drawing, but you give a good justification in your explanation of it, you will get partial to full credit.

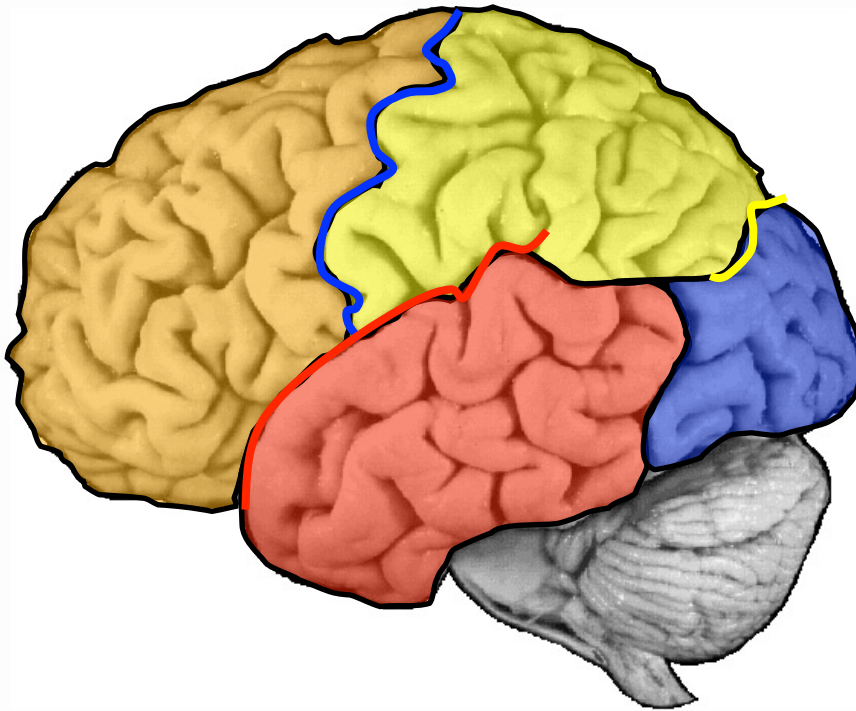Log space (meters)

Log time (Seconds)

(ii) (1point). As you may have noticed in answering the above question, it is somewhat ambiguous, since there is the behavioral resolution possible for humans in psychophysical experiments (e.g., what distance apart of visual stimuli can somebody discriminate above

chance) and there is also the neuronal resolution (what distance apart of visual stimuli is there a neuron somewhere in the visual pathway that can tell them apart).

Think about this distinction and explain which of the two measures, behavioral or neuronal, would have better resolution in time and in space for each of the five sensory modalities/submodalities listed above. Do the neuronal and behavioral resolutions need to be the same? Why or why not? Is it possible for one to be better resolving than the other, and if so, which one is it? Explain each of your answers in 2-3 sentences.

B. (i) (1 point) clearly indicate on the image of a human brain shown below the primary sensory cortices for vision, touch, and audition. (feel free to expand the image or paste it into another page).
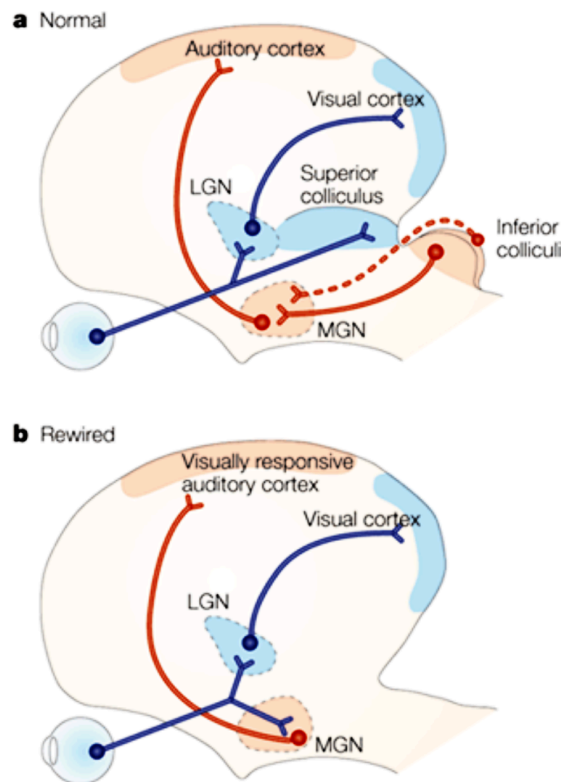

(ii) (0.5 point) Note that the primary sensory cortices are all fairly separated on the diagram you drew above. Why are they separated? That is, since the brain wants to integrate information across sensory modalities, why not put the primary sensory cortices adjacent to one another? Give a functional explanation of this in a paragraph or so.

C. (2 points) There is substantial plasticity for all sensory modalities, especially early in development. In one series of famous studies, Mriganka Sur and colleagues at MIT arranged it such that (in baby ferrets, who are very immature at birth), the auditory cortex on one side of the brain got no auditory input, and instead got visual input. The basic experiment is shown below. In the rewired ferret, there is no auditory input to the MGN of the thalamus. Instead, retinal ganglion cells project not only to the LGN as usual, but also to the MGN. Consequently, auditory cortex gets visual input, and indeed one then finds maps of visual space forming in

auditory cortex as this cortex begins to process visual information. Neurons in auditory cortex, in the rewired ferret, respond to visual stimuli.

An interesting question now is: what is this like for the ferret? Does it hear visual stimuli? Think about this question and come up with an experiment that might test this. Needless to say, the ferret cannot speak, so you need to design a behavioral experiment that would tell you that the rewired ferret treats visual stimuli the same as auditory stimuli. Remember that the manipulation shown below is for one side of the brain, so you could have a ferret in which one side of the brain is rewired as shown, and the other side is normal, allowing you to compare how a ferret behaviorally treats stimuli when they are processed by the normal brain circuitry and also by the rewired brain circuitry. Describe your experiment in ca. 1 page and be as clear as possible. Note that you will not receive credit if you cannot explain your ideas clearly.

D. (1 point). Processing of touch and pain information in the spinal cord is already remarkably complicated. Why not just feed all touch and pain information from the spinal cord straight to the brain for processing, and eliminate any synapses in the spinal cord? Then the spinal cord would contain only axons and no gray matter. Give at least TWO reasons, from what you know about spinal cord processes, for why this would NOT be good. That is, identify at least two features of spinal cord processing that could not be done as efficiently if the information went straight to cortex first. Relatedly, what do you think an animal could still do if it had a spinal cord, but you removed the cortex? (1-2 paragraphs).

END OF QUESTION 2

Question 3 (7.5 points, 7 pages): Neurological Disorders

Part 1- Neurodegenerative diseases (5.5 pts total)

A) Examination (0.8 pts)

You are observing an elderly couple, the Nicholsons, who have been kind enough to volunteer to be subjects for examination in your laboratory (after full IRB approval of course). One of them is in the intermediate stages of Parkinson's disease, while the other is beginning to shows signs of advanced Alzheimer's. To start, you administer a mental status exam to each, while making certain neurological observations. The results are shown in the following two pages.

Based on their responses, **determine** whether Mr. or Mrs. Nicholson has Parkinson's or Alzheimer's, and use 3-4 sentences for each to support your decision in the space below:

Mini-Mental State Examination
Patient: Mr. Nicholson
Date: 12/6/2015

Orientation
What is the date today? (Points for year, season, month, date, or day)
Response: "It's Sunday, December 6th, in 2015"   3/3
Where are we now? (Points for country, city, state, or contextual location)
Response: "Caltech laboratory, in Pasadena"   3/3

Registration
Ask them to remember the following: 'tulip', 'blue', 'honesty'. Ask the patient to repeat all three back to you, and see how many trials it takes for them to name all 3.
Response: Full registration on first trial   3/3

Attention and Calculation.
Ask them to count backwards from 100 by 7 (100, 93, 86, etc.) May stop after 5 answers.
Response: Perfect response   5/5

Recall
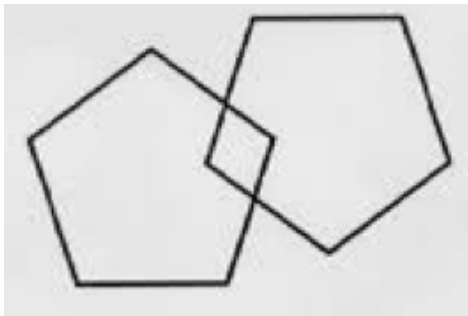**Ask for the three objects from 'Registration'.**
Response: 3/3 recall   3/3

Language
Write the following sentence below:
Mary had a little lamb its fleece was white as snow   2/3

Mary had a little lamb its fleece was as white as snow

Copy the design below in the space provided: 4/5

TOTAL: 23/25

Mini-Mental State Examination

Patient: Mrs. Nicholson

Date: 12/6/2015

Orientation

What is the date today? (Points for year, season, month, date, or day)

Response: "It's morning…" unable to complete   1/3

Where are we now? (Points for country, city, state, or contextual location)

Response: "school in Pasadena"   2/3

Registration

Ask them to remember the following: 'tulip', 'blue', 'honesty'. Ask the patient to repeat all three back to you, and see how many trials it takes for them to name all 3.

Response: could remember 'tulip' and 'blue' after 3 trials   2/3

Attention and Calculation.

Ask them to count backwards from 100 by 7 (100, 93, 86, etc.) May stop after 5 answers.

Response: Could not perform   0/5

Recall

Ask for the three objects from 'Registration'.

Response: 1/3 recall   1/3
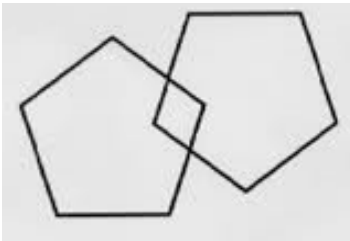
Language

Write the following sentence below:

Mary had a little lamb its fleece was white as snow   2/3

*Note- took considerable time to write the sentence.

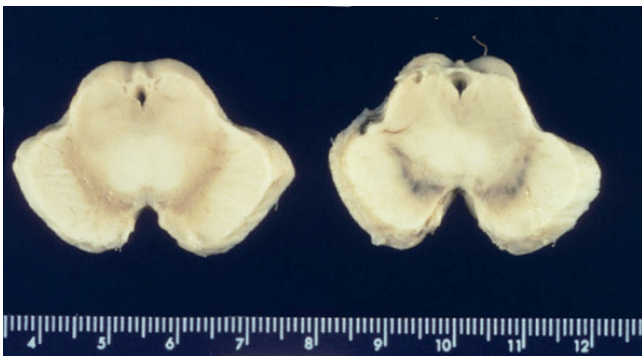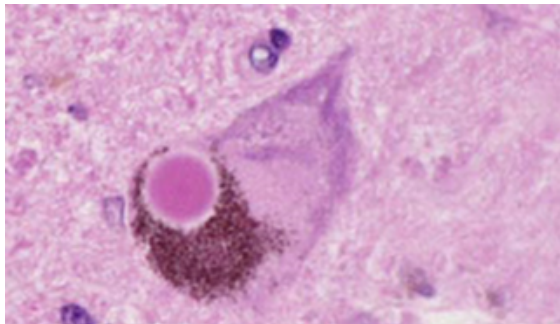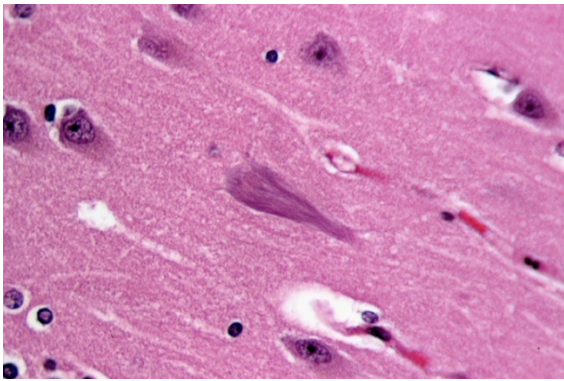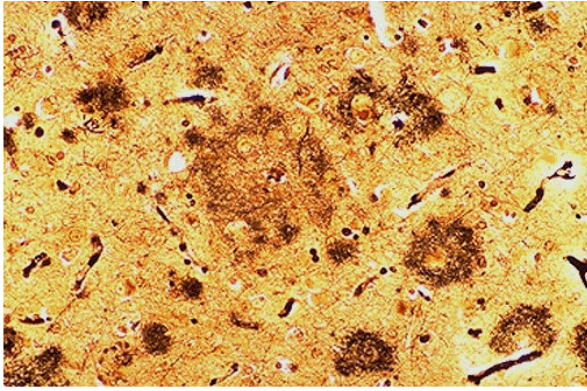**Copy the design below in the space provided:**   3/5

TOTAL: 11/25
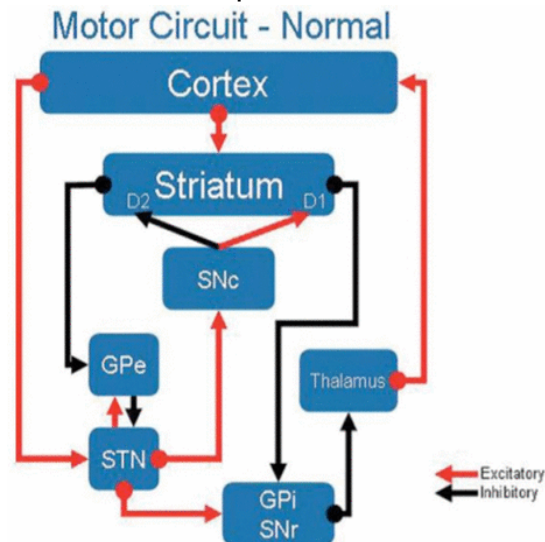
11

B) Pictures (2 pts)

For **each** of the following images:

-**State** what pathological abnormality is being shown

-**Draw** an arrowhead to one example of said pathology

-Briefly **describe** the molecular or cellular changes that produce these abnormalities

-**State** whether it's more likely to be present in Mr. or Mrs. Nicholson

C) Short answer (2.7 pts)

i. The key circuit that is primarily affected in Parkinson's disease includes regions of the basal ganglia and cortex. The normal circuit is provided below:
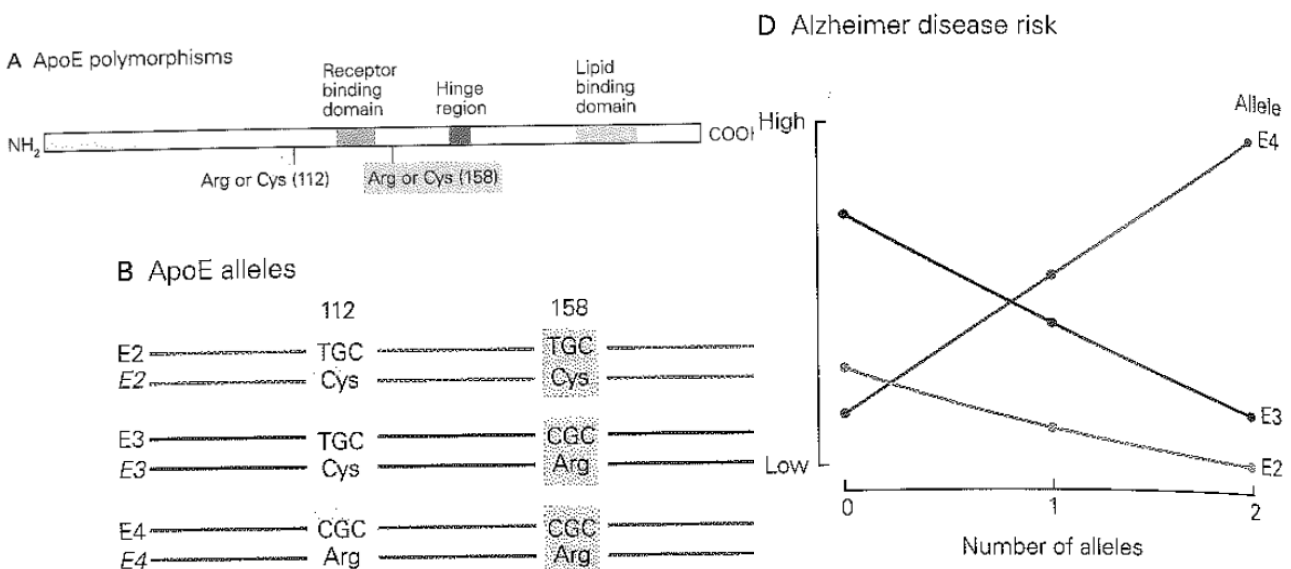

Re-draw the diagram with new arrows to reflect the changes in the strength of these connections in Parkinson's. Then **explain** in 4-5 sentences how degeneration of the SNc changes the behavior of this circuit to produce the physical manifestations of resting tremor and bradykinesia/akinesia.

ii. Dopaminergic neurons in the SNc are both excitatory and inhibitory. **Explain** in 2-3 sentences how the release of one neurotransmitter can produce both types of effects.

iii. A very interesting observation that has been made is that those with Down syndrome (trisomy 21) almost universally exhibit early signs of Alzheimer's disease by the age of 40. Down syndrome patients have an extra copy of chromosome 21, and subsequently an extra dose of all genes present on that chromosome. In 5-6 sentences, **discuss** how that information fits with the current leading hypothesis on the etiology of Alzheimer's disease.

iv. The following diagrams show that particular alleles for ApoE, a lipoprotein, are associated with increased risk of Alzheimer's disease (taken from Kandel, Fig. 59-15). Lipoproteins in general are responsible for trafficking fats, cholesterol, and other hydrophobic/insoluble components in the bloodstream.

A ApoE polymorphisms

Receptor binding domain   Hinge region   Lipid binding domain

NH$_2$ — COOH

Arg or Cys (112)   Arg or Cys (158)

B ApoE alleles

	112	158
E2	TGC	TGC
E2	Cys	Cys
E3	TGC	CGC
E3	Cys	Arg
E4	CGC	CGC
E4	Arg	Arg

D Alzheimer disease risk

Allele
E4
E3
E2

High / Low

Number of alleles: 0 1 2

Propose a role for ApoE proteins in the context of neuronal function, consistent with the observation that the ApoE4 allele greatly increases ones' risk for developing Alzheimer's disease while the ApoE2 allele does not. Your theory does not need to be supported by literature, but it cannot break any known laws of the natural world.

Part 2-Psychiatric Illnesses (2 pts total)

A) Evaluation

This part of this question explores four psychiatric disorders: Schizophrenia, Autism, Major Depressive Disorder, and Bipolar Disorder. While the DSM-V details guidelines for placing patients into distinct categories, the truth is that many of these disorders blur into one another, and often can occur together. The following are excerpts from transcripts of psychiatric interviews or psychiatric assessments. After each, **describe** which deficits or symptoms (i.e. lack of energy, delusion, hallucination, obsessive behavior, pressured speech) are being illustrated, and **discuss** which of the four disorders the transcript or assessment would be consistent with (it may be consistent with more than one). Using 6-8 sentences should be more than sufficient.

i.   A patient displays a distinct lack of energy and flat affect. Responses to questions had to be coaxed out little by little. He did not seem interested in talking, and suggested that he wasn't doing anything worth talking about. Said of his job: "I don't really do much work anymore, and what I do get done, you know…just not that great." Facial expressions often did not match what you would expect based on the content of his answers. Continually unbuttoning and rebuttoning the sleeves on his jacket.

ii. Interviewer: So how would you describe your life recently?
Patient: You know what, it's been great. Really great. You know why? I'll tell you why. I had the greatest idea the other for a project. You know how we're on cell phones all the time? Day in, day out, day in, day out, hour after hour after hour. All those signals, radio waves bouncing around an inch from your head, those can't be good for you. So I'm making this headband that you wear, it'll protect you from all of that. I'll make millions and millions-they'll go like hotcakes. Know why? Best part is, it'll get rid of those signals trying to blend in with the other signals. You know the ones, the bad ones. Trying to gunk up your brain and get you to do things. They try to hide them, but I can hear them. I don't know where they're coming from or who's sending them, but this'll stop them dead.

END OF QUESTION 3

Question 4 (7.5 points, 5 pages): Learning and Memory

a) In 1911, John Watson conducted an (in)famous experiment known as the Little Albert experiment. In the experiment, a one-year old child was presented with different animals that he had never seen before (e.g. rat, monkey, dog, rabbit). His initial response to these animals was in the form of curiosity – he tried to touch them and understand what they were. He was then trained to be fearful of the rat by pairing the presentation of the rat with a loud noise. The training also made him scared of other animals and furry objects (e.g. a furry mask). For the following questions, your answer can be as brief as 2 or 3 words in most cases.

   i. What form of learning was used in this experiment? Be as specific as possible. **(0.25pt)**

   ii. Which region of little Albert's brain would you have selectively ablated prior to Dr. Watson's experiment in order to prevent the form of learning in (a)(i) from taking place? **(0.25pt)**

   iii. After the experiment, little Albert was released from the hospital where the study took place. It is highly likely that his fear of furry things persisted for a long time even after the experiment was over. Imagine you were a graduate student working with Dr. Watson. Briefly describe a training procedure you would have used to remove poor Albert's fear of furry objects before letting him leave the hospital. **(0.25pt)**

   iv. You agree to take care of your friend's cat for a week. During your first night of cat-sitting, you feel a furry paw of fury slapping the side of your face at around midnight. You groggily give the cat some treats and she lets you proceed peacefully with your slumber. This sequence of events occurs every night over the course of the week. Based on this scenario, answer the following questions:
   - What form of learning has your friend's cat undergone? Is your answer the same as in (a)(i)? Explain why or why not. **(0.5pt)**
   - Name a region in the human brain that is involved in the form of learning experienced by the cat. **(0.25pt)**

   v. After one week of waking up in the middle of the night to a hungry cat slapping your face, you find that you stop waking up in response to the physical abuse from your friend's cat. However, you know that the cat has still been consistently hitting you during those nights that you have not woken up (thanks to a hidden camera you have set up in the room to record the cat's behavior during the night). Based on this scenario, answer the following questions:
   - Is the form of learning you have undergone a type of associative memory, or a type of non-associative memory? **(0.25pt)**
   - In your answer to the above question, consider the different, specific types of associative or non-associative memory we discussed in class. Name the single most specific type of memory involved? **(0.25pt)**

b) Synaptic plasticity is the ability of synaptic strength to change over time depending on the level of activity at the synapse. Long-term potentiation (LTP) results in the strengthening of chemical synapses in response to brief, high-frequency stimulation of the pre-synaptic neuron. For the following questions, assume that the synapse in question is located in the Schaffer collateral pathway.

  i. What temporal relationship between presynaptic and postsynaptic spikes will result in:
   * Long term potentiation (LTP)? **(0.25pt)**
   * Long term depression (LTD)? **(0.25pt)**
   * Neither LTP nor LTD? **(0.25pt)**

  ii. Describe the roles of AMPA receptors, NMDA receptors, and Ca^{2+} ions during the induction of LTP. That is, describe what they do, in order to result in the induction. **(0.5pt)**

  iii. LTP consists of two phases – early and late. In the table below, compare and contrast both phases of LTP by filling in the empty slots with the appropriate answers from the following list: **(1pt)**
   * PKMζ
   * 1-3 hours
   * Phosphorylation of AMPARs leading to increased channel conductance
   * Synthesis of new AMPA receptors
   * Growth of more synapses via reshaping of the actin cytoskeleton
   * Adenylyl cyclase
   * PKC
   * Up to 24 hours
   * CaMKII
  Insertion of AMPARs into the post-synaptic membrane

	Early LTP	Late LTP
Temporal Length of Phase		
Enzymes activated during LTP expression		
Resultant changes at the synapse		

  iv. You are interested in how the density of NMDA receptors in the postsynaptic membrane prior to stimulation will affect future LTP and LTD production. You prepare mouse hippocampal slices with three types of postsynaptic neurons - neurons that have either very high densities, very low densities, or zero density of NMDA receptors.
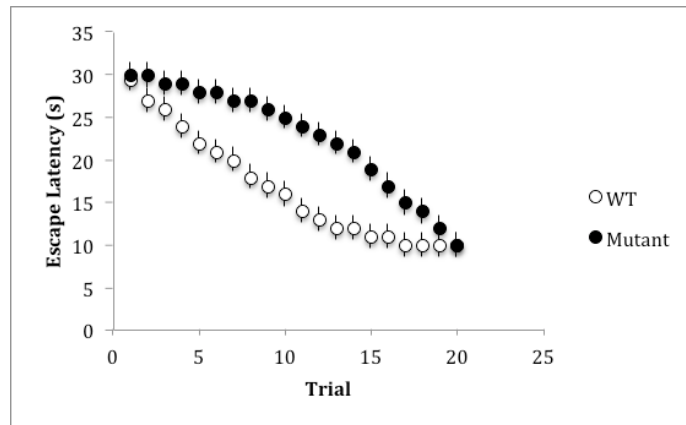
You stimulate the neurons presynaptic to these different types of postsynaptic neurons using a brief, high-frequency stimulation protocol (100 Hz) or a prolonged, low-frequency stimulation protocol (10 Hz). You then record whether an LTP or LTD was produced. Match the different NMDA receptor densities in the first column with the expected LTP/LTD occurrences in the second column of the table below: **(0.75pt)**

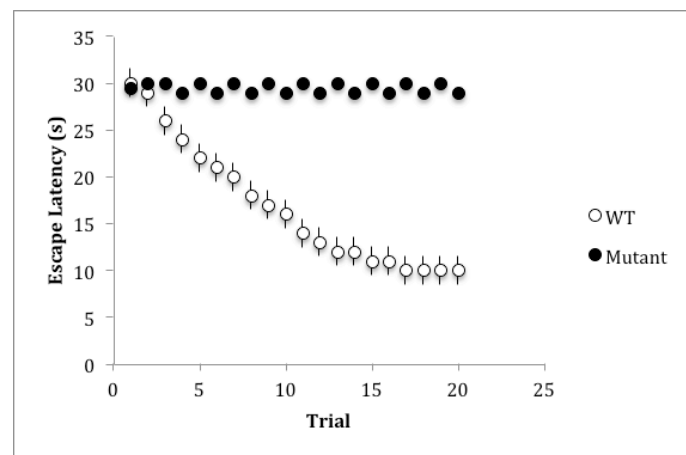| NMDA Receptor/Channel Density Before Stimulation	Results
1. Very high	A. No LTP during brief, high-frequency stimulation. No LTD during prolonged, low-frequency stimulation.
2. No NMDA receptors	B. No LTP during brief, high-frequency stimulation. LTD during brief, high-frequency stimulation.
3. Very low	C. No LTD during prolonged, low-frequency stimulation. LTP during prolonged, low-frequency stimulation.

For each pairing in your answer above, explain why a particular NMDA receptor density led to the result you chose rather than another one of the listed possibilities. **(0.75pt)**

c) As a neuroscientist interested in the molecular mechanisms that underlie learning, you conduct a screen of candidate genes that might be involved in learning. You generate single-gene knockout mice and subject them to the Morris water maze assay. For each gene, you conduct 4 behavior trials per day for 5 days using 10 wild-type (WT) mice and 10 knockout mice. The following are the behavioral results you obtain when you knock out gene X, gene Y, and gene Z (black dots –mean for mutant mice, white dots – mean for WT mice, bars represent ±1 S.E.M.):
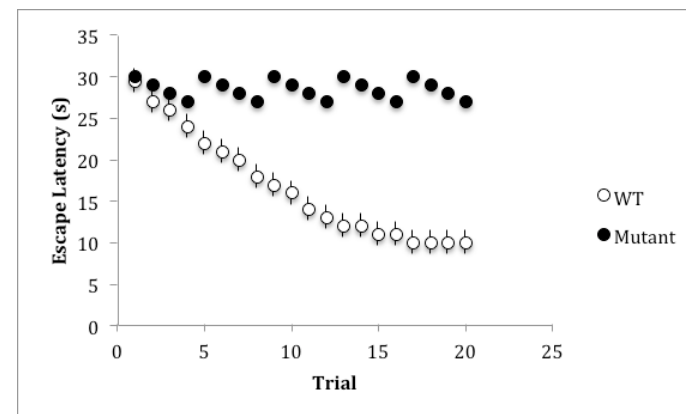
- Gene X knockout:

- Gene Y knockout:
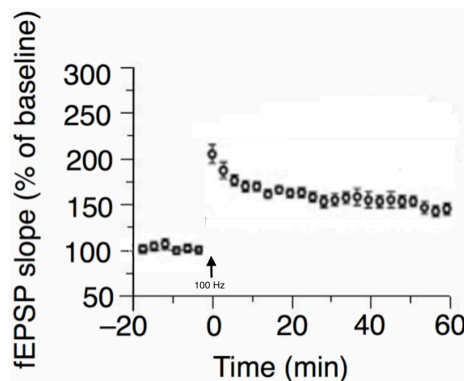

- Gene Z knockout:

i. Based on the plots above, match each of the genes X, Y, and Z to one of the following learning/memory deficits when the gene is knocked out:
   - Decreased rate of learning **(0.25pt)**
   - Impairment in consolidation of spatial memory **(0.25pt)**
   - Impairment in the encoding stage of spatial memory **(0.25pt)**

ii. Although your focus was on genes involved in learning and memory, you in fact do not really know what proteins these genes code for. Given this possible nonspecificity, describe one alternative explanation each for the behavior seen in the graphs for gene X and gene Y shown above. **(0.5pt)**
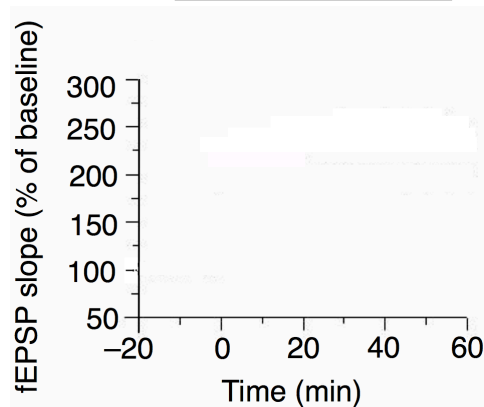
iii. To investigate the synaptic mechanisms underlying your behavioral observations, you stimulate hippocampal slices derived from WT and mutant mice with a high-frequency protocol (100 Hz) and record the resultant field potentials.
The following is the fEPSP slope vs. time plot for the wild-type mice:
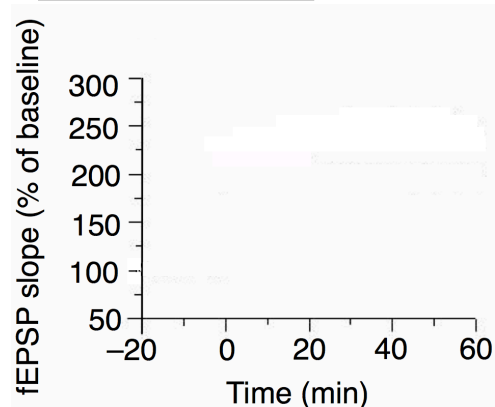

On two separate plots (axes provided below), draw the expected fEPSP slope vs. time plot that you expect to obtain for:
   - Slices from gene X knockout mice **(0.25pt)**
   - Slices from gene Y knockout mice **(0.25pt)**

Gene X Knockout: **Gene Y Knockout:**

END OF QUESTION 4

Question 5 (7.5 points, 2 pages): Neural Circuits

On your way home for winter break, you are abducted by alien neuroscientists. As an ambassador of terrestrial neuroscience, you agree to participate in an experiment in exchange for a slice of surprisingly delicious alien fruit cake.

5.a) In each trial of the experiment, you are presented with a picture of either [A] Prof. Henry Lester's face or [B] Prof. Ralph Adolphs' face. You are instructed to push a button with your left hand in case A and push a button with your right hand in case B, as quickly as possible. Locate and describe 8 stages of neural processing that causally link a pattern of light hitting your retina to your finger pushing the correct button as you perform this task. For each of the 8 stages you describe, please state:

- The location of each stage, which can be any set of related cells (e.g. "mechanoreceptors", "primary somatosensory cortex", or "the ventral posterior nucleus").
- how those cells in the location you describe transform information (e.g. "Meissner's corpuscles transform pressure changes into electrical spike trains via mechanically-gated ion channels").
- how this stage participates in linking perception to action: what are the inputs, where do the outputs go, and how is this stage causally involved in the task described above?
- Also describe what would happen to your performance on the task if you lesioned this specific stage of processing, and why.
- There are multiple correct answers, because there are multiple ways to divide this system into 8 components.

Respond with a succinct paragraph for each stage of processing. (4 points)

5.b) The aliens are surprised that your brain is spatially organized into functional regions (theirs are not; all their functionally different neurons are distributed evenly throughout their brains). In a short paragraph, explain why organization into functional regions is advantageous. Specifically, what would you expect to be the main difference between your brain and the alien brains, if they have to process the same information? (0.5 points)

Since you're done with finals and you don't have much else to do, you agree to help the aliens develop experiments to further their understanding of human neurobiology. The aliens can non-invasively

- record electrical activity from single neurons in multiple brain regions simultaneously, and
- "shut down" any given brain region temporarily and selectively, preventing electrical activity in that region.

5.c) The task described in 5.a requires your ventral visual stream. Let's now turn to the dorsal visual stream, which involves extrastriate cortices in the parietal cortex. Name 2 functions of the *dorsal* visual stream (1-2 sentences). (0.5 points)

5.d) In 2-4 sentences, describe how you could utilize the aliens' technology to localize these

two functions (your answer to 5c above) in your brain. For each function, describe an experiment to determine whether a given region is necessary and/or sufficient for the function – or state that no such experiment is possible with the specific alien technology described above. Thus, please provide 4 clear answers: for each of the two functions, what is the experiment to show that a region is necessary, and to show that a region is sufficient. (1 point)

5.e) In 5.a, you described feedforward processing (how a stimulus is transformed into a response, without considering closed-loop dynamics). In 1-2 sentences, describe a possible role of feedback (recurrent) connections in visual perception. That is, what is the functional role of such feedback, what might it do and contribute to information processing? (0.5 points)

5.f) In 1-2 paragraphs, how could you utilize the aliens' technology to test your hypothesis from 5e above? Describe an experiment for how you could use the specific methods available from the aliens described above, to test a functional role for feedback in the brain. (1 point)

END OF QUESTION 5
END OF EXAM