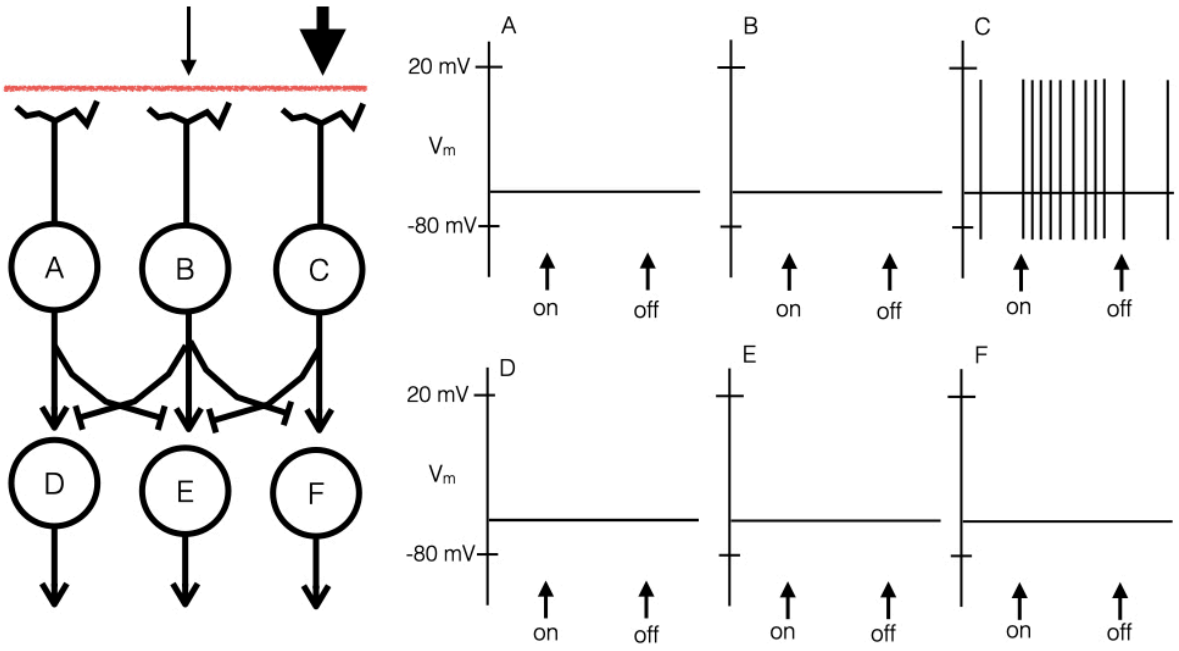
Question 1 (18 marks). Consider the arrangement of sensory systems in the image below. The system depicts first- and second-order sensory neurons that use lateral inhibition. A stimulus is applied that is suprathreshold for cells "B" and "C" but not A. The intensity is greatest for cell "C" (indicated by the size of the arrows). Assume that all neurons have the same action potential size and firing frequency when they are at rest (ie: when there is no stimulus present).
The graphs on the right represent the action potentials (vertical lines) produced by the primary and secondary neurons. Only cell "C" has been completed. Note: the small arrows under the x-axis represent when the stimulus was applied ("on") and removed ("off").



a) Using the action potentials made by cell C as a guide, complete the action potential graphs above by drawing in the action potentials for cells A, B, D, E and F in the top system. I mean, actually draw the action potentials onto the graphs, please. Assume the cells all have the same firing properties (ie: are tonic or phasic), and that they all have the same magnitude of action potentials at rest (ie: comparable to those drawn in C) (5 marks).

A: less than C, but NOT ZERO
B: Higher than A and less than C
D: less than F, and either less than or equal to E (both E and D could be zero)
E: must be less than F
F: must be more than D and E.
All action potentials should be roughly the same size.

b) Explain your drawing for cell E in the top system (ie: with lateral inhibition). Be sure to include how lateral inhibition caused this effect. (2 marks)

The lower # of APs (or none at all!) are a result of less (or no!) NT release from the presynaptic terminal of cell.
Less NT = fewer receptors activated = fewer APs generated

c) Lateral inhibition allows your sensory system to do what? (1 mark)

Locate the stimulus with great accuracy.

d) Where in the body might you expect to find a sensory system with lateral inhibition (like the top image above) compared to a system with a large amount of convergence onto a second-order neuron like the second image below? (1 mark)
Hands/fingers/lips

Consider a second-order neuron from a system with lateral inhibition (like the one above) compared to a second-order neuron from a system with convergence.

e) Which second-order cell has a larger receptive field? Why? (2 marks)

convergence
b'c it includes the receptive fields of cells A, B and C, while that of the top system includes the receptive field of sensory neuron A only.

f) Which second-order neuron has better sensory discrimination? Why? (2 marks)

lateral inhibition
b/c it includes only information from cell A, AND the surrounding cells (eg: E) are 'silenced' (or inhibited) by lateral inhibition

g) In the system with convergence, what would be the perception of the person if we applied two stimuli of equal magnitude to cells A and B? Explain, and be specific. (2 marks)

It would be of a single stimulus
It would be (roughly) double the intensity of each individual stimulus.

h) Propose a **mechanism** by which cell C "laterally inhibits" cell B in the top arrangement (with lateral inhibition). (3 marks)

Anything reasonable:
Activate a K+ conductance
Close Ca2+ channels
Open Cl- channels.
Each of these reduces the amount of Ca2+ coming into the terminal, reducing NT release.

- Describe how the nervous system encodes stimulus intensity and duration
- Predict how changes in the intensity and duration of a stimulus are encoded by the nervous system.
- Describe how convergence of sensory neurons affects the size of receptive fields, and how receptive field size affects stimulus discrimination.
- Explain how lateral inhibition increases contrast of incoming stimuli.

Question 2 (15 marks).

a) Fill in the blanks for the following (short-form is fine! Eg: nAChR for nicotinic): (2 marks)
   i. The neurotransmitter released by the preganglionic neuron of the prevertebral ganglion in the sympathetic nervous system is: _____*ACh*_____.
   ii. The receptor on the smooth muscle of the stomach receiving input from the parasympathetic nervous system is: _____*muscarinic AChRs*_____.

b) What would happen to the following organs if we had damage to all of the prevertebral ganglia and only the prevertebral ganglia? **One to five words** should suffice. (4 marks)

bronchioles of the lungs	Nothing
heart (rate)	Nothing
smooth muscle of stomach	Increased contraction.
smooth muscle of blood vessels leading to skeletal muscles of legs	Contraction or constricted or less blood flow or something like that.

c) Someone shows up to a clinic and they have ingested a drug, but they don't know what drug it was. They have the following symptoms: elevated heart rate; constipation (due to relaxation of the smooth muscle of the gut); breathing with ease (due to dilation of the bronchioles). The drug was either a blocker of receptors or an activator of receptors. Based solely on the symptoms above, tell us 1) what receptors the drug targeted, and 2) whether it was a blocker or activator. You do not need to explain WHY at this point. [note: there may be multiple possible answers. I only want ONE]. (1 mark)

Muscarinic blocker (antagonist).
OR
Agonist of all beta receptors. [would have to be ALL receptors explicitly … both 1 and 2]

d) Tell us WHY you selected the response to the preceding question. You should refer to the symptoms in this explanation. (3 marks)

Full points for a drug that would cause ALL of the symptoms noted.

To treat this person, you have the following drugs available that have the following mechanism of action:

Drug	action
A	Blocker of alpha 1 receptors
B	Blocker of all beta receptors
C	Blocker of all muscarinic ACh receptors
D	Blocker of beta 1 receptors only
E	Blocker of beta 2 receptors only

e) Which drug will you use to treat this person and why? You may only pick ONE! (2 marks)

Drug A will lead to relaxation of blood vessels leading to the skin and GI tract; not particularly helpful in this scenario.
Drug B will decrease the heart rate via beta1 receptor blockade, improve GI motility by blocking beta2 receptors on the smooth muscles of the stomach, and constrict the bronchioles slightly by blocking beta2 receptors on smooth muscle of bronchioles. This would work!
Drug C: will decrease parasympathetic tone pretty much everywhere, which is already what we're dealing with. Not helpful!
Drug D: will decrease heart rate (and force of contraction), but not improve GI nor breathing issues.
Drug E: would fix the airway and GI issues, but not the cardiac issues.

f) A colleague chooses to administer a drug that lowers cAMP levels in all smooth muscle and cardiac pacemaking cells. What will this do to the following? circle your answer. (1 mark)

Heart rate: INCREASE NOT CHANGE IT ***DECREASE***

Contraction of smooth muscle of the stomach:
INCREASE NOT CHANGE IT DECREASE
OK if they say "not change", I suppose. It would depend on the state of NS balance.

Would your colleague's administration of the cAMP-lowering drug alleviate the symptoms of the patient from question c)? Why or why not. (2 marks)

It would work.
cAMP = increased heart rate, which is already fast. Here lowering cAMP = good.
cAMP = decreased smooth muscle tone in GI tract and respiratory tract, which we already have.

- Identify the location of neuron cell bodies in sympathetic and parasympathetic nervous systems.

- Identify the neurotransmitters involved in both sympathetic and parasympathetic nervous systems, and which receptors are involved in mediating their actions.
- Predict the effect of increasing/decreasing sympathetic/parasympathetic action on target organs.
- Predict the effect of damage to the following to the function of the sympathetic NS: paravertebral ganglia, prevertebral ganglia, and adrenal medulla.
- Predict the effect of damage to the following to the function of the parasympathetic NS: cranial nerves III, VII, IX, and X, and the sacral segments of the parasympathetic system.
- Compare and contrast different adrenergic receptor types (eg: α_1, β_1, β_2) with regards to their location, role, and pathway (which GPCR pathway they use).

Question 3 (12 marks).

a) Which of the following classes of hormone have at least one hormone that can bind to receptors in the cytoplasm? (circle all that apply) (1 mark)

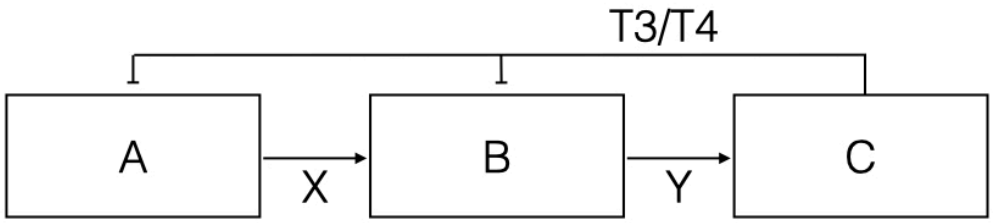
STEROID PEPTIDE *AMINE*

Consider the endocrine pathway below when answering the remaining questions.

b) Identify the following: (2 marks)

Structure B: _____*ant. pit.*_____ Hormone X: ____*TRH*_____

Structure C: _____*thyroid*_____ Hormone Y: _____*TSH*_____



Two people go to their doctor because they have excess (too much) T3/T4 secretion. Both patients are given a drug that suppresses the secretion of Hormone Y. Person A's T3/T4 levels return to normal after receiving the drug, while Person B's T3/T4 levels remain elevated.

c) What anatomical location is most likely the source of the problem for Person A? Explain how you know, or why you cannot tell. (2 marks)

Either hypothalamus or anterior pituitary.
The thyroid is working fine, because restoring hormone Y to normal fixed the problem.
So the elevated level of Y was either caused directly by the ant. pit., or by excess Hormone X from the hypothalamus.

d) What anatomical location is most likely the source of the problem for Person B? Explain how you know, or why you cannot tell. (2 marks)

Thyroid.
Since giving them a drug that suppresses Y has not fixed the problem, the adrenal cortex is not responding to Y appropriately.

e) What were the circulating levels of Hormone X, Y in person A **before** the drug treatment? Explain how you know, or why you cannot tell. (2 marks)
Hormone X:

we don't know. High levels of X would have caused the high Y (and high T3/T4) levels; but if the problem was the anterior pituitary, we'd expect low levels of hormone X.

[NOTE TO IAs: PLEASE BE CONSISTENT WITH WHAT STUDENTS WROTE IN Qs C) and D)]

Hormones Y:
they were high. Suppressing their production fixed the problem, so they must have been too high to begin with.

f) What were the circulating levels of Hormone X, Y in person B **before** the drug treatment? Explain how you know, or why you cannot tell. (2 marks)

Hormone X:
low
T3/T4 exerts a 'negative feedback' onto hypothalamus, so production of Hormone X would go down.

Hormones Y:
low
T3/T4 exerts a 'negative feedback' onto hypothalamus, so production of Hormone X would go down.

Consider a completely new situation separate from the Person 1 and Person 2 scenario above. In our new case, a patient has a complete blockage in the portal veins leading into the pituitary from the hypothalamus. Vessels leaving the pituitary are fine (ie: not blocked).

g) What would this do to circulating levels of the following: (circle your choice) (1 mark)

ACTH:	INCREASE THEM	*NO CHANGE*	DECREASE THEM
Oxytocin:	INCREASE THEM	NO CHANGE	*DECREASE THEM*

- Predict the outcome(s) of disrupting different parts of a feedback loop.
- Compare and contrast steroid, amine and peptide hormones, including site of receptors and consequences of receptor activation.
- Know the anatomy of the hypothalamic/pituitary pathway.
- List hormones secreted by the posterior pituitary, and the effects they have on target organs.
- For all the anterior pituitary hormones, know: the hormones that caused their release; their targets; the hormones their targets release; the impact of the target's hormones on the body.

Question 4 (10 marks).

a) At rest, the length of the A-band is 4.0 μm. The H-zone is 0.5 μm. The thin filament (from z-line to filament tip) is 2.0 μm. What is the length of the sarcomere at rest? (1 mark)

2 + 2 + 0.5 = 4.5 um

b) Compared to a normal muscle cell, what will happen to the number of cross-bridges under each of the following circumstances. For each, state WHY you think so. (2 marks each = 4 marks)

(i) We add a drug that increases the amount of time that RyRs are open (once they are activated normally), then stimulate the muscle cell.

Increased cross bridges
Longer open time = more Ca2+ entering cytoplasm = more troponin bound… more crossbridges.

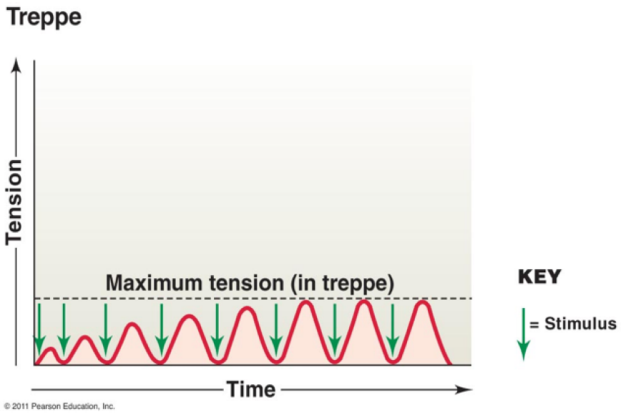
(ii) We add a drug removes the connection between troponin and tropomyosin, then stimulate the muscle cell.

Fewer cross bridges
Ca2+ can still bind troponin, but it will not move tropomyosin out of the way, so the active sites on actin remain covered.

c) You are holding one book in your hands. A friend asks you to hold more until you are creating as much tension as possible in your whole muscle. What Type(s) of muscle are you using when the muscle is maximally contracting? Explain with specific reference to skeletal muscle types. (2 marks)

All of them (Type 1, Type 2A and Type 2X).
When we add more demand to our muscles, we increase the number of motor units contributing (this is recruitment), going from Type 1 to Type 2A and finally Type 2X.

d) In a condition called “treppe”, the amount of tension in a single muscle cell increases with subsequent stimulation, but the cell is allowed to *fully relax* each time (see figure below). Can you predict what is happening to allow the muscle to increase tension with subsequent stimulation while being allowed to relax fully between each stimulation? Your answer should include a discussion of how tension is generated. (3 marks)



If the muscle is relaxing fully, all the Ca2+ is coming off troponin, and the # of cross-bridges is zero.
Somehow, subsequent stimulation produces more tension, so we're getting more cross bridges presumably due to increased Ca2+.
There are several possibilities to explain this, including:
before all the Ca2+ is sequestered into the SR (but after it has left the troponin), the second stimulation arrives, so we add newly released Ca2+ to the amount of Ca2+ that was left-over from the previous stimulation.
Ca2+ actually potentiates RyRs, leading to greater Ca2+ release.

- Know the anatomy of the neuromuscular junction including pre- and post-synaptic components, and ligand receptor types.
- Outline the sliding filament theory, and identify which region(s) (ie: I, A, or H "bands") get shorter during contraction.
- Outline the sequence of events between AP reaching the axon terminal of the motor nerve and the increase of cytosolic [Ca^{2+}], leading to contraction of the muscle (excitation-contraction coupling).
- Specifically, identify the roles of L-type calcium channels, ryanodine receptors, and SERCA pumps.
- Describe the processes underlying summation of skeletal muscle.
- Describe the functional differences between summation and tetanus.