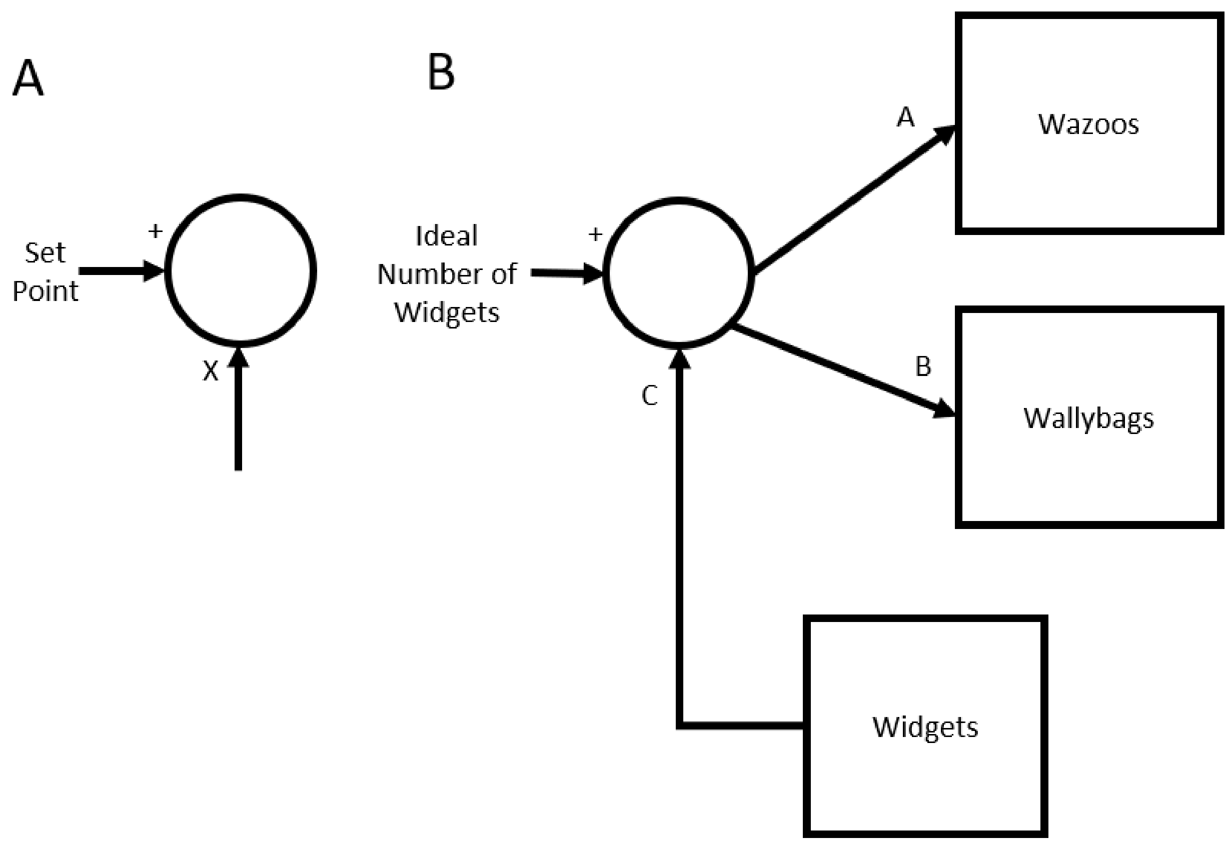
Questions WITHOUT ANY SCIENCE:
Operational Model Basics - Please keep doing these questions until you really understand!
Questions 1- 5: Wazoos! ***Taken From Final Exam, 2023***

The following question will make use of both part A and part B in Figure 1 below. Please note that part B is only representing part of an operational model where some stuff comes out of the Wazoos and Wallybags boxes and goes into boxes not shown (could be several!) and eventually goes into the Widgets box. Panel B is showing part of an operational model from a factory that tries to make the same number of widgets each day. A by-product of widget production is wazoos, which ultimately slow down widget production as they need to be cleared from the equipment. Wallybags are added to the widget production process by factory workers when an alarm indicates that too few widgets are being made.

Figure 1:



1. In panel A, what is the difference in the operational model when X is a minus vs when X is a plus? (That is, what does this operational model symbol mean?)

In Panel B (see details above) what signs should be assigned at:

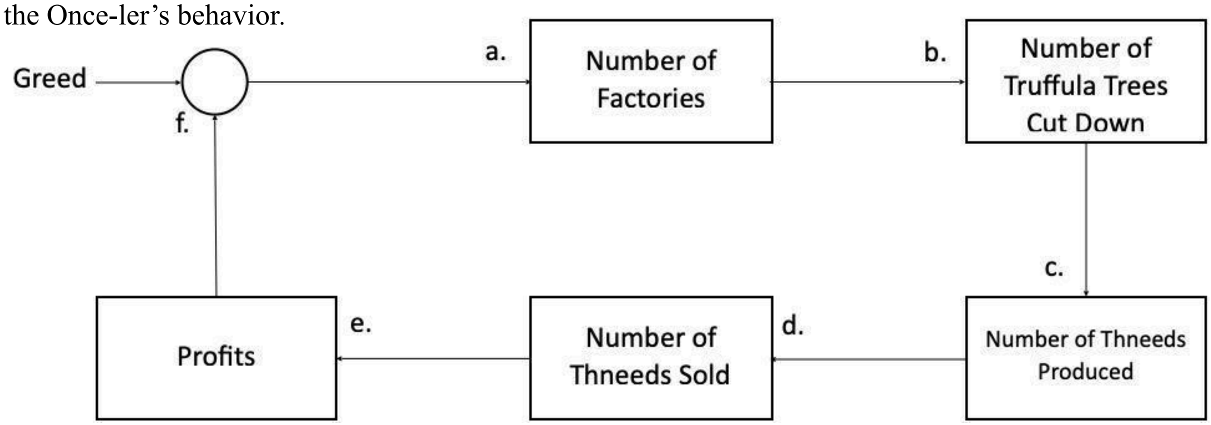
2. A
3. B
4. C
5. Given just what you know in the paragraph above, do you think the full operational model as described for B would include positive feedback loop(s), negative feedback loop(s), neither, or both?

Questions 6-19: Dr. Seuss *Taken From Final Exam, 2014*

These control loop questions are inspired by Dr. Seuss's *The Lorax!* As usual, I'll tell you what you need to know. Go by what I say, not what you might know/recall from the story.

The story is essentially a tale about the environment. It features the Once-ler, a greedy character inspired to maximize his own profits. The Once-ler gets greedier the more profits he has. He uses Truffula trees as the raw materials to create Thneeds (a product "which everyone needs"). Because everyone needs theeds, he can always sell all his theeds for profit. As the Once-ler generates more profits, he is able to expand his operations by building more factories, and thus using more raw materials.

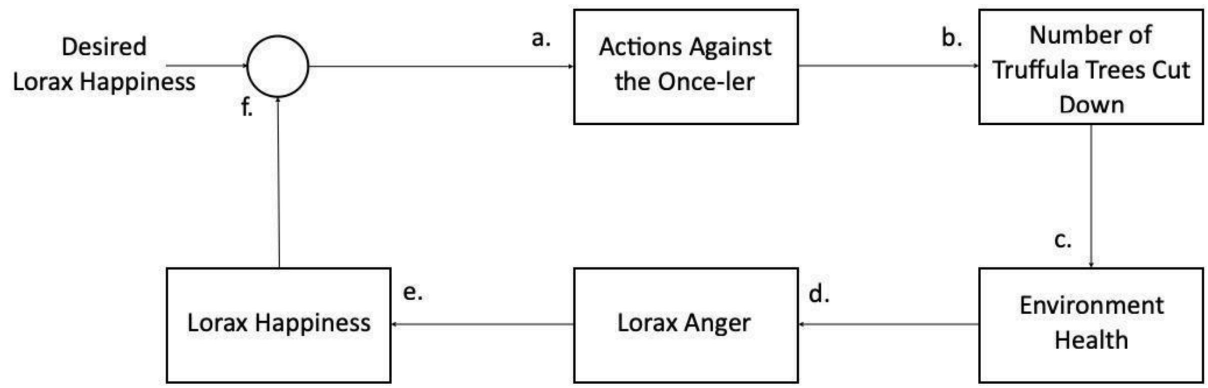
For the next 6 questions, please determine the signs in the operational model to describe these aspects of the Once-ler's behavior.



6. a.
7. b.
8. c.
9. d.
10. e.
11. f.
12. Is this an example of a positive or negative feedback loop?

Then the Lorax, who "speaks for the trees," appears and gets angry because the environment is being destroyed. The angrier he is, the less happy he is. When the Lorax isn't happy, he tries to save the environment by pointing things out to the Once-ler, in the hopes that the Once-ler will change his ways. (The story ends poorly for the environment, but just use the information I told you above to fill in the operational model that the Lorax is ideally trying to implement.)

For the next 6 questions, please determine the signs in the operational model to describe these aspects of the Lorax's behavior (+/-)



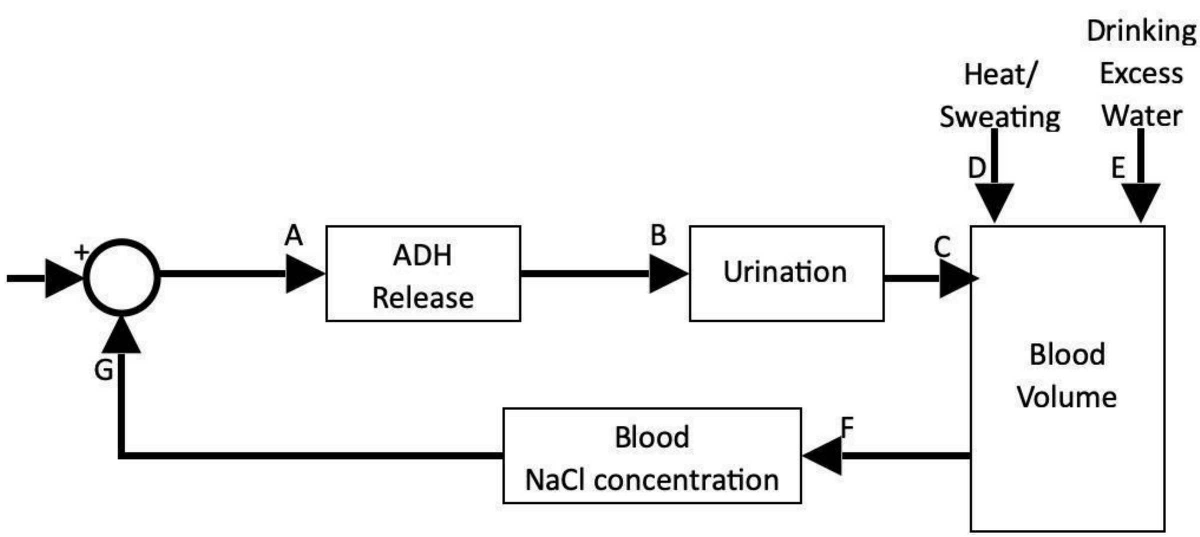
13. a.
14. b.
15. c.
16. d.
17. e.
18. f.
19. Is this an example of a positive or negative feedback loop? (Yes/No)

Questions with SCIENTIFIC CONTEXT THAT IS GIVEN:
Questions 20-30: Osmolarity ***Taken from Final Exam 2015***

One property of the body that has to be carefully modulated is osmolarity, or how salty the blood is. Kidneys play an important role in maintaining osmolarity. (Note: This isn't a physiology class, and this diagram is simplified. Please complete the operational model based on the information provided to you here.)

The set point for osmolarity is in the hypothalamus, which is also where osmoreceptor cells can sense salt level. When salt levels are too high, activity of these cells leads to the secretion of anti-diuretic hormone (ADH) from the posterior pituitary. ADH is carried in the blood and causes the kidneys to increase the amount of water retained by the body, thus lowering the amount of water excreted through urination. Keeping water in the body increases the blood volume in the body, which dilutes the concentration of salts in the blood.

Below is an operational model of this system.



For questions 20-26, fill in the correct sign in the operational model at the location indicated. (+ or -)

20. A
21. B
22. C
23. D
24. E
25. F
26. G

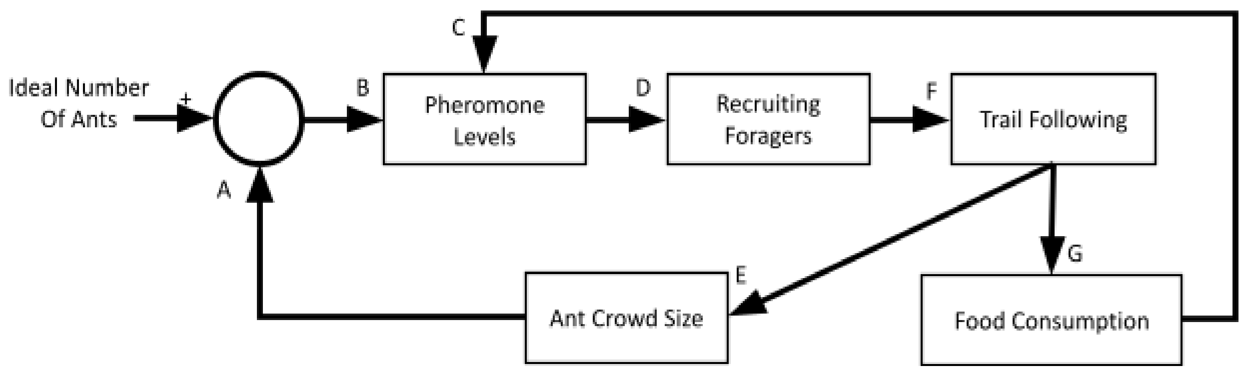
27. Is this model an example of positive or negative feedback? (Positive/Negative)
28. What is the general term for the property of a system in which variables (like osmolarity) are regulated so that internal conditions remain stable and relatively constant?
29. How does a large open-loop gain help to achieve the property of the system described in the above question?
30. What is the drawback to very large open-loop gains?

Question 31-34: Ant Foraging ***Taken from Exam 2, 2020***

This is a simplified description of ant foraging behavior. This is not an invertebrate behavior course, so please base your responses solely on what is included in this description. For simplicity purposes, I have left a lot out of this operational model.

In general, we have looked at negative feedback loops that occur within a single organism. However, an ant colony is also a living system and operational models can describe the behavior of this type of system as well. Ants that find and consume food deposit a pheromone on their way from the food source back to the nest. The more pheromone present, the better able other ants will be to sense the pheromone. Once ants sense the pheromone, they are recruited as foragers. Foragers follow the pheromone trail back to the food. This behavior is best for the overall health of the ant society. At the same time, the more ants that are currently available to be recruited as forgers increases the odds that pheromone sensing will occur. However, if the pathway to the food becomes too crowded, it is not in the best interest of the colony to send more ants on that path, so ants stop depositing the pheromone. Figure 1 shows a simplified operational model describing this system of ant colony behavior. Please note that the "pheromone levels" box is indicating the amount of pheromone and is serving two purposes here – it is indicating how likely it is for a new ant to become a forager by sensing that pheromone, as well as indicating the overall pheromone deposited.

Figure 1



31. On your answer sheet, please number from 31A – 31G, please indicate if the appropriate sign for the operational model is a + or a -. You just need to give us a + or – on the answer sheet.

32. Explain your response to 31B by describing how your response makes sense for ant crowd sizes above the ideal number of ants.

33. Does this operational model contain a positive feedback loop, a negative feedback loop, both, or neither? [Just give the answer, no need to explain]

Pheromone signals typically evaporate over time. Weather conditions can lead to different rates of evaporation or loss of the pheromone signal. For example, rain may lead to the pheromone signal washing away quickly. The model in Figure 1 does not account for this.

34. Describe how you would add rain into the operational model. You can either provide a drawing or describe where you would add input and/or connection(s) into and/or out of which box(es) Please also include the sign of the connection(s) [+ or -] and if this would change your response to question 27 [yes or no is sufficient here].

Questions 35-46: Blood Pressure ***Taken from Exam 3, 2014***

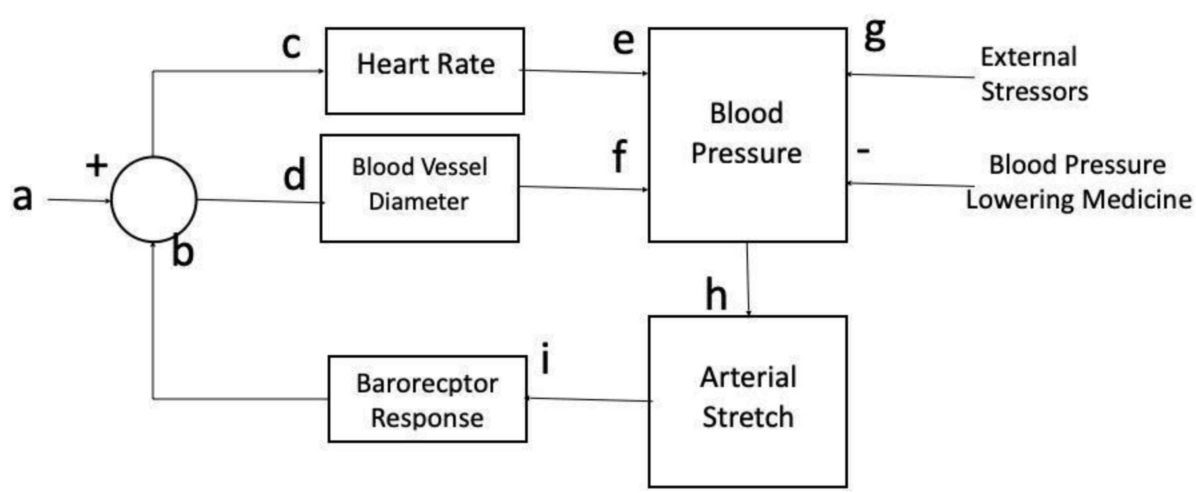
Fun with operational models! (Note: This isn't a general physiology class, so this is grossly simplified. Your answers should reflect what I tell you in the question.)

One important physiological property is blood pressure. It is important to maintain blood pressure levels in a safe range. High blood pressure can be dangerous to the heart, while low blood pressure can prevent oxygen from reaching the organs of the body through the capillaries.

The body's own means to regulate arterial blood pressure (blood pressure in the arteries) is not completely understood. Furthermore, there are multiple aspects to this regulation, some including the kidneys. For this question, we will only consider part of the regulatory system (and ignore the kidneys.)

Blood pressure is sensed by baroreceptors. Baroreceptors are mechanical receptors that can sense the stretch of blood vessels (the higher the pressure, the more stretch, so the larger the response from the receptor). Baroreceptors send their input to the medulla, which connects to the autonomic nervous system to modify heart rate and force and to constrict blood vessels. (Blood pressure increases with increasing blood flow or force, and the force of blood flow increases as blood vessel diameter decreases.)

Let's consider the operational model for this system.



35. The value at point a is the ideal blood pressure. What do we call this value?

36. Where are the neurons that represent your answer to the prior question (a) likely located?

For questions 37 – 44, fill in the correct sign in the operational model at the location indicated. (+ or -)

37. b

38. c

39. d

40. e

41. f

42. g

43. h

44. i

45. True or False: This operational model contains a negative feedback loop.

46. True or False: This operational model contains a positive feedback loop.

Questions 47-58: Tree Frogs *Taken from Exam 3, 2015*

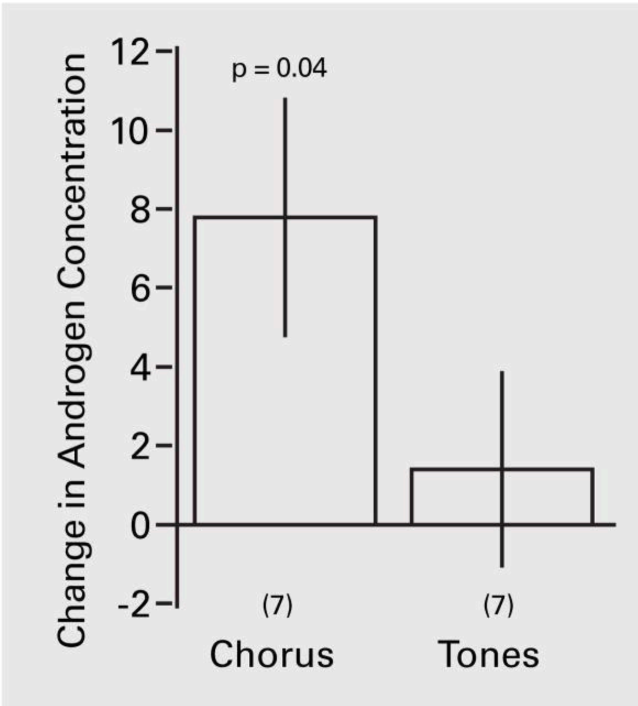
Fun with operational models! (Note: This isn't an endocrinology class, so this question is somewhat simplified. Please answer the question given the information provided to you.)

Burmeister and Wilczynski *(Brain, Behav. Evol., 2005)* sought to understand the interplay between physiological state and external cues in the reproductive behavior of green treefrogs. In the green treefrogs, mating calls are an important regulator of reproductive behavior and physiology.

External cues are used by treefrogs to appropriately time reproduction. These seasonal cues can influence the activity of gonadotropin-releasing hormone (GnRH) neurons to increase GnRH release. Additionally, hearing mating calls from other treefrogs ultimately leads to a change in androgen levels (as released by the gonads – see data below). Androgens, in turn, lead to an increase in the production of mating calls, linking the behavioral output of communication with the regulation of the endocrine system.

GnRH neurons are able to regulate androgen levels because release of GnRH leads to release of gonadotropin (GT) from the pituitary. GT is a hormone that leads to androgen release. GnRH neurons also sense androgen levels, and can decrease their activity when these levels are too high. Furthermore, androgens can directly reduce the release of GT

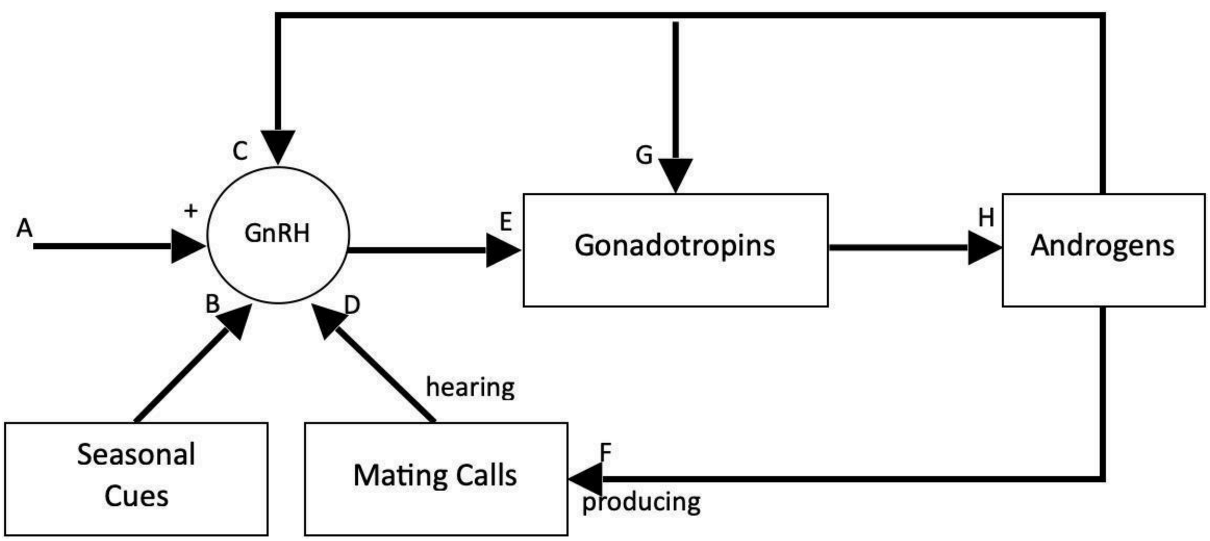
One aspect of this study was to determine the effect of mating calls on androgen levels. Here are the results:



The change in androgen levels in response to the sounds of an actual mating chorus or just pure tones. Sample size indicated in parentheses. The chorus group showed a change significantly different from 0, while the tones group did not show a significantly different change in androgen levels.

47. Does hearing mating calls from other treefrogs lead to an increase, decrease, or no change in androgen levels?

Let's consider the operational model for this system.



48. While the exact nature of the seasonal cues that modulate this system are unknown, temperature may be one of the important cues. The brain area where these GnRH neurons are located is the same brain area where the temperature regulating neurons we discussed are located. What brain area is this? (You can give the general brain area, the specific sub-nucleus is not necessary.)

49. The value at point A is the ideal level of GnRH. What do we call this value?

For questions 50–56, fill in the correct sign in the operational model at the location indicated. (+ or -)

50. B

51. C

52. D

53. E

54. F

55. G

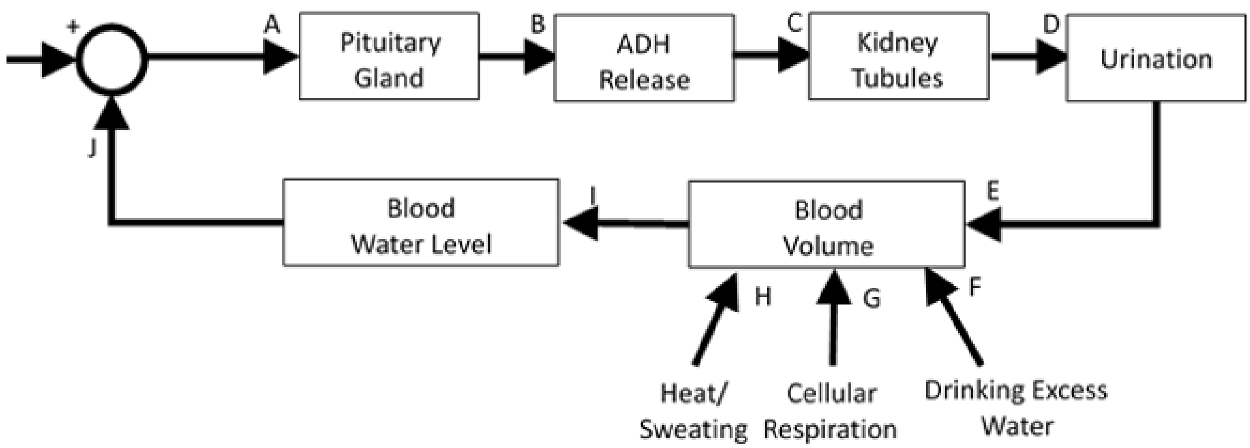
56. H

57. True or False: This operational model contains a negative feedback loop.

58. True or False: This operational model contains a positive feedback loop.

Questions 59-72: Kidneys, Part 2 ***Taken From Final Exam 2019***

The amount of water in the blood must stay relatively constant to prevent cell damage through osmosis. Kidneys play an important role in maintaining water balance. (Note: This isn't a physiology class, and this diagram is simplified. Please complete the operational model based on the information provided to you here. Also note that this looks like an old exam question, but it's not the same as that question!) Water is gained and lost in multiple ways including drinking and eating, the gain of water through cellular respiration, sweating, evaporation, feces and urine. When the hypothalamus senses low water levels, a signal is sent from the hypothalamus to activate the pituitary to release antidiuretic hormone (ADH). ADH travels in the blood to the kidneys where it activates the tubules which results in the reabsorption of water into the blood, decreasing the amount lost through urination.



For questions 59–68, fill in the correct sign in the operational model at the location indicated. (+ or -)

59. A
60. B
61. C
62. D
63. E
64. F
65. G
66. H
67. I
68. J
69. Does this operational model contain positive feedback loops, negative feedback loops, neither, or both? (Positive/Negative/Neither/Both)

70. Where is the set point for blood water content?

71. The drug Ecstasy increases the amount of ADH. Do you expect someone taking ecstasy to urinate more or less? (More/Less)

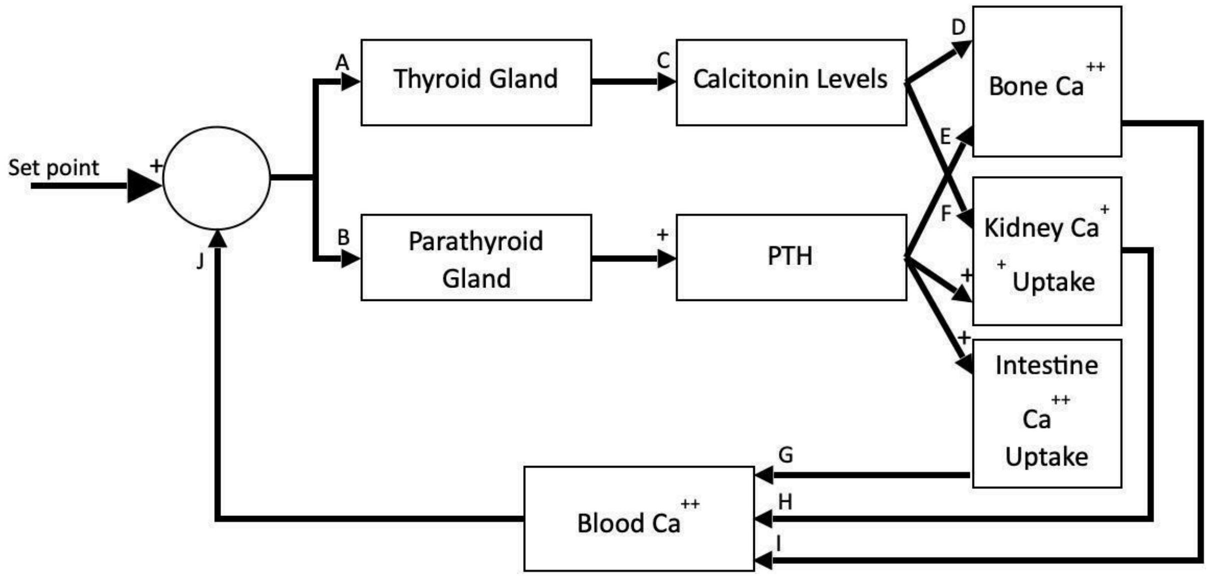
72. Explain your response to the previous question by referring to the operational model.

Questions 73-84: Calcium *Taken from Exam 3, 2016*

(This isn't an endocrinology class, so this question is somewhat simplified. Please answer the question given the information provided to you.)

As we know from neuroscience, calcium is an incredibly important ion for biological function. Our bodies try to maintain a calcium level in the range of approximately 9-11 mg per 100mL of blood. There are calcium sensors in both the thyroid and parathyroid glands. Cells in the thyroid sense calcium and activate the gland when calcium levels are high. This leads to the release of the hormone calcitonin which stimulates calcium storage into bones and controls the kidneys to allow calcium to be excreted through urine. Calcium stored in bones is not in the blood. Cells in the parathyroid also sense calcium and activate the gland when calcium levels are low. This leads to the release of parathyroid hormone (PTH) which causes bones to release calcium back into the blood and increases the uptake of calcium (back into the body, instead of excreted) via the kidneys and intestines.

Let's consider the operational model. (Note the letter goes with the arrowhead it is closest to):



73. What is the controlled variable that this system is regulating?

For questions 74– 84, fill in the correct sign in the operational model at the location indicated. (+ or -)

74. A
75. B
76. C
77. D
78. E (Calcitonin -> Kidney)
79. F (PTH -> Bone)
80. G
81. H
82. I
83. J
84. Does this operational model contain a positive feedback loop, a negative feedback loop, both, or neither? (Positive/Negative/Both/Neither)

Questions 85-97: pH *Can't figure out which exam this was on*

(This isn't a physiology class, so this question is somewhat simplified. Please answer the question given the information provided to you.)

An important property of blood is its degree of acidity or alkalinity. Acidity and alkalinity are indicated on the pH scale, which ranges from 0 (strongly acidic) to 14 (strongly basic, or alkaline). Blood is normally slightly alkaline, with a pH close to 7.4. The body must regulate blood pH around this value because enzymes, which carry out important biochemical reactions, optimally function at this pH.

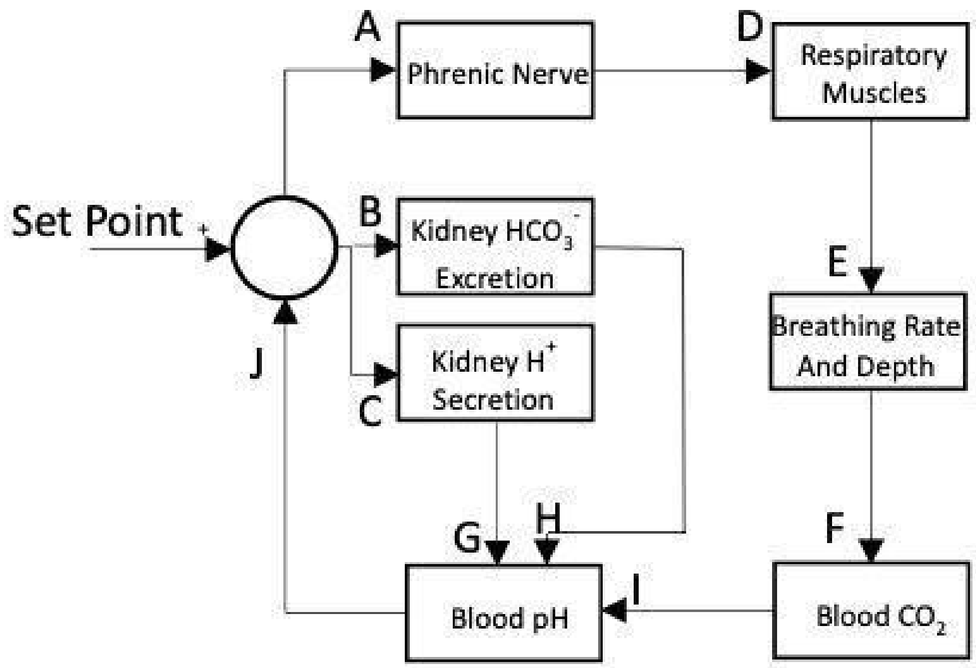
One way to modulate pH is via the phrenic nerve, which controls the muscles involved in breathing. When chemoreceptors in the medulla oblongata sense a pH **above** 7.4, they signal central respiratory centers to decrease activation of motor neurons in the phrenic nerve, which receives contributions from spinal nerves C3 – C5. This reduces respiratory muscle activity, hypoventilating the lungs (slower breaths, smaller air volumes). During hypoventilation, the rate of carbon dioxide (CO2) removal from the blood slows. With more CO2 in blood, more carbonic acid (H2CO3) is produced and pH moves back toward 7.4.

Regulation happens in the kidneys, too. If the kidneys sense a pH above 7.4, they will reduce secretion of H . Secretion is the active removal of H from the blood into the urine. Reduced secretion ultimately results in higher blood [H+], lowering pH, thus returning blood pH closer to 7.4.

Upon sensing a pH above 7.4, the kidneys will also excrete more bicarbonate (HCO3-) into the urine by decreasing HCO3-reabsorption. HCO3- reabsorption from the kidney into the blood increases blood

[HCO3-], raising blood pH since HCO3- is alkaline. Excreting more HCO3- into the urine by reabsorbing less back into blood has the opposite effect, returning blood pH to the desired value.

Let's consider the operational model for this system:



For questions 85-97 fill in the correct sign in the operational model at the location indicated. (+ or -)

85. A

86. B

87. C

88. D

89. E

90. F

91. G

92. H

93. I

94. J

95. Does this operational model contain a positive feedback loop, a negative feedback loop, both, or neither? (Positive/Negative/Both/Neither)

96. Please provide the definition of a set point and what the set point is for this model.

97. In this model, where are the comparators physically located?

Questions 98-112: E. Coli *Taken from Assessment 5, 2021*
When working on this operational model, use the information that I provide. You may know more about this system from a biology or genetics class, but only use what is provided here.

Note that set point is used a bit oddly here (maybe you can figure out what's odd about it). Just go with it, don't overthink.

Operational Model on the Next Page

You will assign the +'s and –'s into the operational model provided on the other sheet to explain the lactose metabolism system in *E. coli* and other enteric bacteria. The basic idea for the control system is that you don't want to produce the enzyme to metabolize lactose if there's low lactose around, or if there is a preferable energy source available, like glucose.

The *lac* gene encodes for a few things including the one we care about here, β-galactosidase (β-gal) which hydrolyzes (breaks down) the lactose. The *lac* gene only transcribes β-gal when the *lac* operon is activated.

To start the process of metabolizing lactose, an allolactose molecule (something similar to lactose) binds to the *lac* repressor protein. The *lac* repressor protein stops the transcription of the *lac* gene, but cannot do this when its bound. When it isn't bound, RNA polymerase can bind to the gene, which turns on the *lac* operon.

If there is any glucose available, *E. coli* prefer to metabolize glucose over lactose. When glucose levels decrease, adenylyl cyclase is active (it is inactive under high glucose levels). Adenylyl cyclase leads to the production of cAMP. cAMP binds to the catabolite activator protein (CAP) creating cAMP-CAP complexes. These cAMP-CAP complexes bind to the CAP binding sites. When this happens, RNA polymerase binds tightly.

PLEASE SELECT ONLY ONE CHOICE FOR EACH OF THE FOLLOWING QUESTIONS

98. ☐ + ☐ -

99. ☐ + ☐ -

100. ☐ + ☐ -

101. ☐ + ☐ -

102. ☐ + ☐ -

103. ☐ + ☐ -

104. ☐ + ☐ -

105. ☐ + ☐ -

106. ☐ + ☐ -

107. ☐ + ☐ -

108. ☐ + ☐ -

109. ☐ + ☐ -

110. ☐ + ☐ -

111. As drawn, does this operational model contain a positive feedback loop, a negative feedback loop, both, or neither?

☐ positive

☐ negative

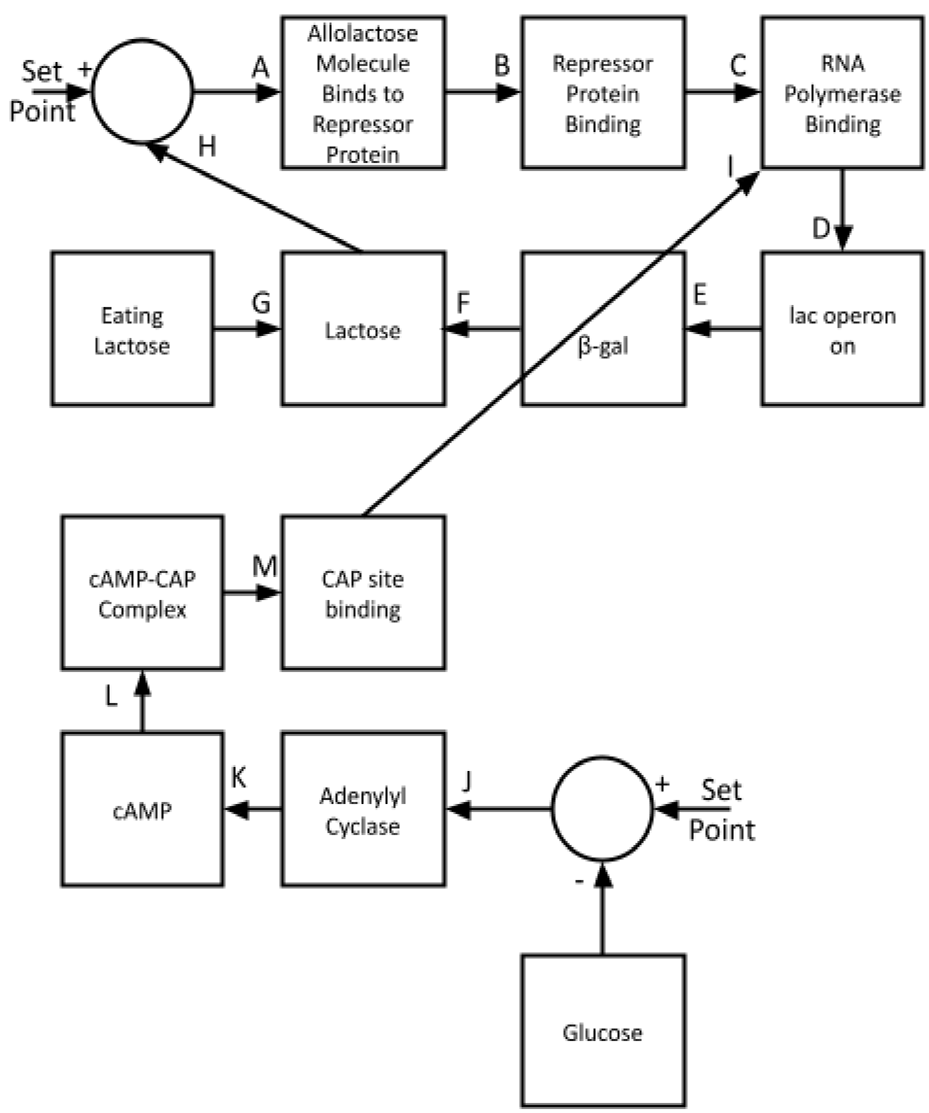
☐ both

☐ neither

112. True or False: High glucose levels lead to a decrease in lactose levels.

☐ True

☐ False



Questions 113-26: Iron ***Taken from Assessment 5, 2022***

When working on this operational model, use the information that I provide. You may know more about this system from a biology class, but only use what is provided here.
You will assign the +'s and –'s into the operational model provided on the other sheet to explain the control of iron levels in the cells of non-graminaceous plants. (Most herbaceous plants, except grasses, are non-graminaceous)

Plant cells use intracellular iron when they engage in important processes like photosynthesis or generating energy from mitochondrial activity. However, too much iron can be toxic to the cells. These cells strive to maintain an ideal, homeostatic level of iron (Fe^{2+}) in the cytoplasm of the cell.

When there isn't enough iron, FIT, a transcription factor, increases the production of an ATPase, which leads to protons (H^+) being secreted from the cell, increasing the extracellular levels of H^+. This leads to Fe^{3+} entering the cytoplasm of the cell. Once inside the cell cytoplasm, the Fe^{3+} can be converted to Fe^{2+}. FIT has other effects, as well. For example, it also activates IRT1 transporters which move Fe^{2+} into the cell. Some researchers think that high levels of intracellular Fe^{2+} lead to a decrease in IRT1 transporters, but the data are inconclusive (so I used a dotted line for this in the operational model).

PLEASE SELECT ONLY ONE CHOICE FOR EACH OF THE FOLLOWING QUESTIONS.

113. ☐ + ☐ -

114. ☐ + ☐ -

115. ☐ + ☐ -

116. ☐ + ☐ -

117. ☐ + ☐ -

118. ☐ + ☐ -

119. ☐ + ☐ -

120. ☐ + ☐ -

121. ☐ + ☐ -

122. ☐ + ☐ -

123. ☐ + ☐ -

124. ☐ + ☐ -

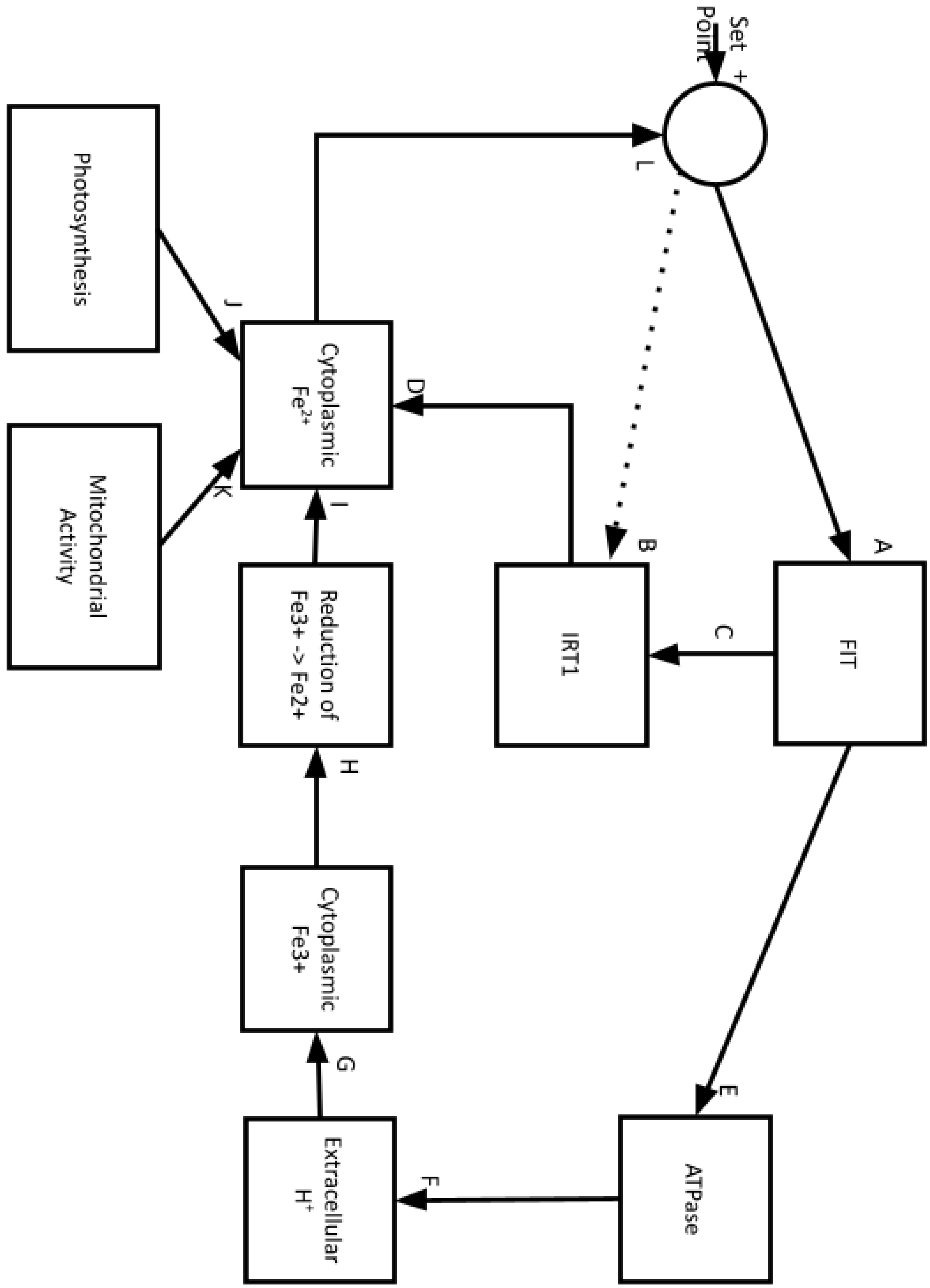
125. As drawn, does this operational model contain a positive feedback loop, a negative feedback loop, both, or neither?

☐ positive ☐ negative

☐ both ☐ neither

126. Researchers have created plant cells that overexpress (have too much) IRT1. We would expect high levels of iron in these cells.

☐ True ☐ False


Set Point
+
L
A
B
C
D
FIT
IRT1
Cytoplasmic Fe2+
Photosynthesis
J
K
Mitochondrial Activity
I
Reduction of Fe3+ -> Fe2+
H
Cytoplasmic Fe3+
G
Extracellular H+
F
ATPase
E

Questions 127-140: Iron Part 2 ***Taken from Final Exam 2018***

(This isn't a physiology class, so this question is somewhat simplified. Please answer the question given the information provided to you.)

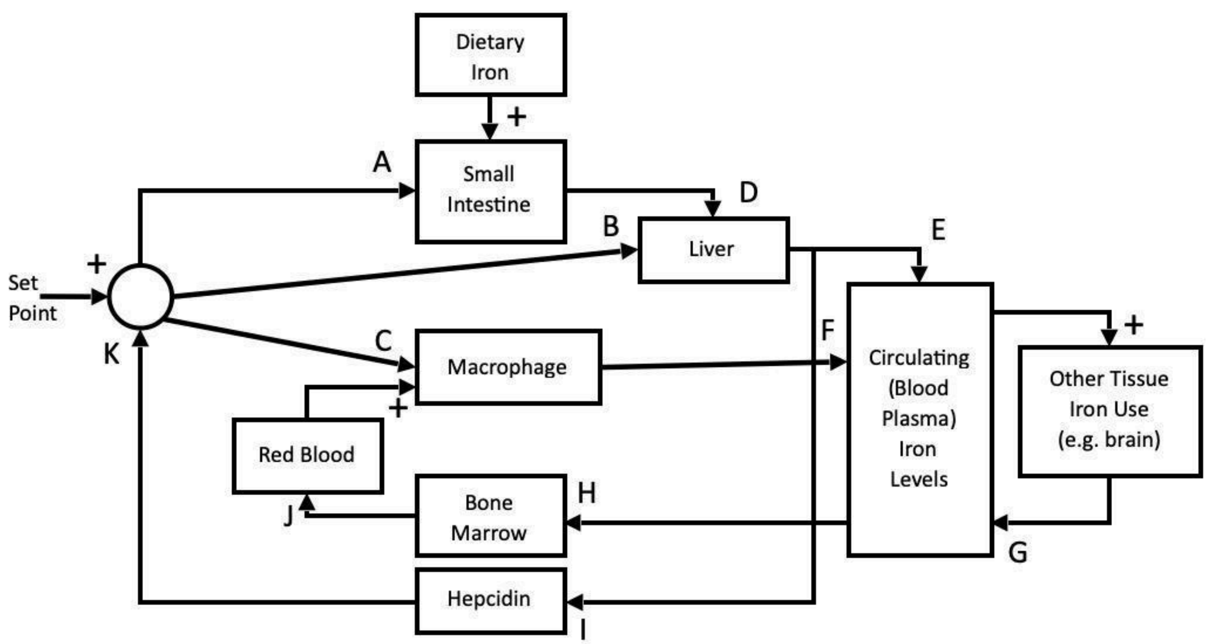
Maintaining appropriate levels of iron is important for bodily function, including brain function. Iron comes from the diet. Activity in the small intestine absorbs the iron, which leads to activation of the liver. The liver allows iron to bind to blood plasma, and be available in the circulatory system for use by various organs, including the brain.

When blood is available in the plasma, activation of bone marrow tissue allows for hemoglobin production, leading to red blood cells. These red blood cells can subsequently be broken down by macrophages to release iron back into the plasma.

Hepcidin is regulated by iron demand from the tissues of the body, as sensed by the liver. (What the liver does to blood plasma levels is the same as what the liver does to hepcidin levels for our purposes).

Figure 1 shows the operational model:

Figure 1:



For questions 127 – 137, fill in the correct sign in the operational model at the location indicated. (+ or -)

127. A
128. B
129. C
130. D
131. E
132. F
133. G
134. H
135. I
136. J
137. K

138. Does this operational model contain a positive feedback loop, a negative feedback loop, both, or neither? (Positive/Negative/Both/Neither)

139. Please provide the definition of a set point and what the set point is for this model.

140. In this model, where is the comparator physically located?

Questions with COURSE CONTENT
Questions 141-156: Feeding Behavior ***Taken from Exam 3, 2016***

(Please note that this is not a physiology class. This model is based on several theories related to bone formation, and is not meant to be an exhaustive description of the process. It is highly simplified so that you can answer the questions. Please use the information provided here to develop the operational model.)

Originally proposed by Frost (*Anat. Rec.,* 1987 – reviewed in Rauch and Schoenau *Ped.. Res.,* 2001), bones may be subject to regulatory feedback to maintain bone strength.

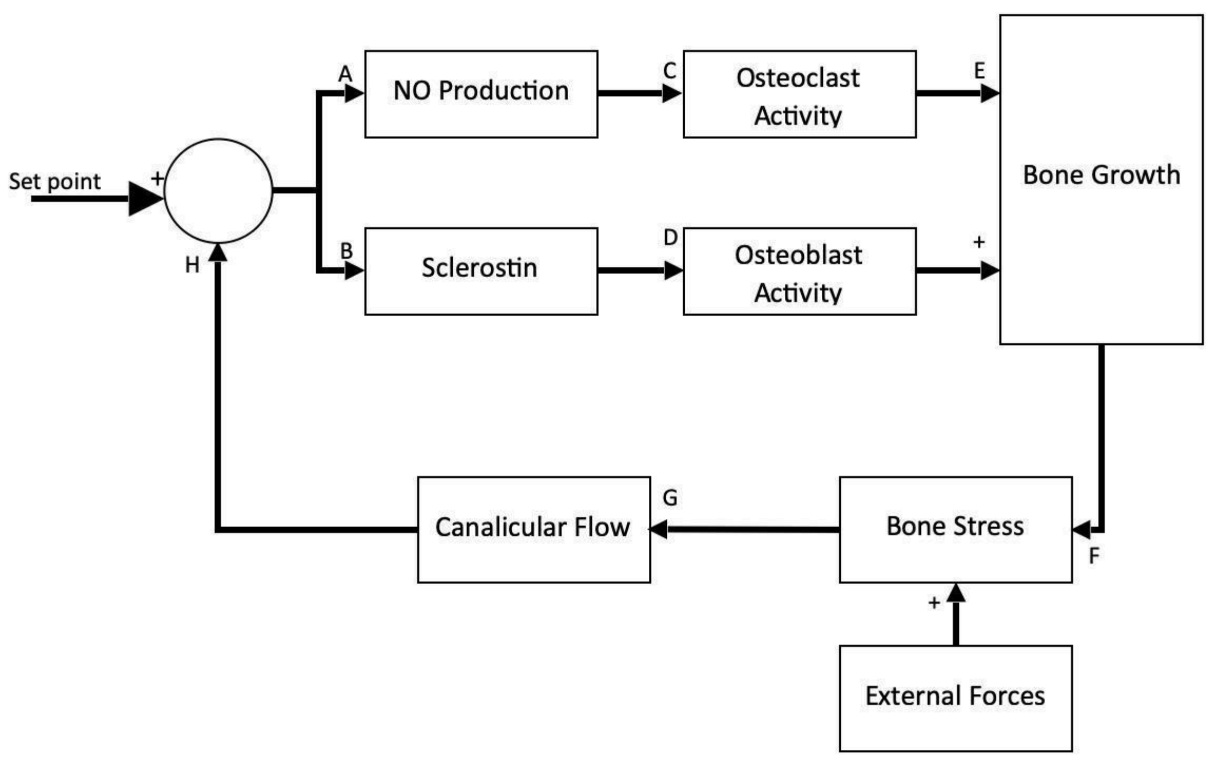
141. Frost's theory is called a "mechanostat" theory. Why do you think it is called that? (HINT: what is the "stat" referring to?)

Bone strength can be measured as a weak bone will deform less than a strong one. Bones grow to become stronger and resist strain. Enhanced strain and loading on a bone leads to canalicular fluid flow in a weak bone. Canalicular fluid flow refers to the movement of fluid through the small spaces within a bone. Osteocytes are bone cells that can monitor the canalicular fluid flow within the bone.

Low flow reduces the production of nitrous oxide (NO) by osteocytes, leading to their death. Death of osteocytes attracts osteoclasts, which break down bone. Enhanced canalicular flow causes osteocytes to increase NO production, which reduces osteoclast activity. Increased strain on bone (and thus an increase in fluid flow) leads to a decrease in the release of sclerostin. Sclerostin leads to decreased activity of osteoblasts. Osteoblasts are cells that grow bone.

Figure 1 shows the operational model.

Figure 1



For questions 142 – 149, fill in the correct sign in the operational model at the location indicated. (+ or -)

142. A

143. B

144. C

145. D

146. E

147. F

148. G

149. H

150. Does this operational model contain a positive feedback loop, a negative feedback loop, both, or neither? (Positive/Negative/Both/Neither)

151. In this model, the set point and comparator are in the same cells. Which cells are these?

It turns out that leptin has a role in bone development as well as appetite.

152. What role does leptin play in regards to appetite? (Increase/Decrease/None)

Leptin inhibits serotonergic neurons that synapse in the ventromedial hypothalamus.

153. What role does the ventral medial hypothalamus play in regards to appetite? (Increase/Decrease/None)

The neurons in the ventromedial hypothalamus also decrease activation of the sympathetic nervous system and stimulate osteoblasts.

154. Do you expect *ob/ob*mice (as described in class) to have increased or decreased bone density relative to controls? (Increased/Decreased)

155. Explain your response to the previous question. In your explanation, please describe the deficit in *ob/ob*mice and the neural pathway beginning with that deficit that explains your response.

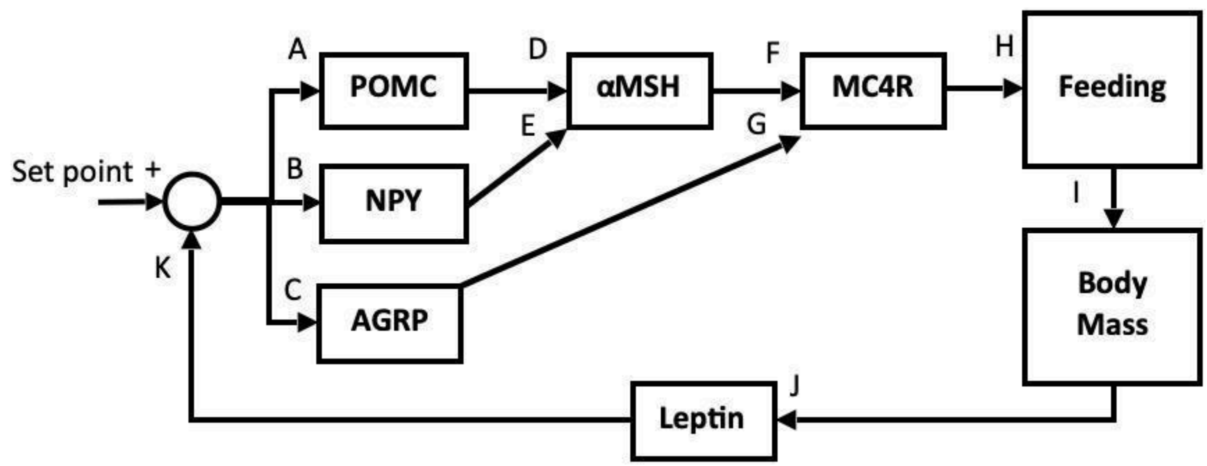
156. Describe what you would expect in terms of bone density if you created parabiotic mice using one *ob/ob*mouse and one control mouse. In your response, explain why you expect to observe this.

Questions 157-174: Feeding Behavior 2 ***Taken from Exam 3, 2018***

As we discussed in class, feeding behavior is quite complex, and there is no easy answer when it comes to obesity. One reason for this is that there are a multitude of other molecules involved in the feeding circuitry. In this question, we are going to elaborate on the operational model for feeding to understand how some of these molecules are involved. **To understand this model, you will need to incorporate what you already know about feeding with some additional information**(model originally from Mutch and Clément, *PLOSGenetics,* 2006).

Leptin (along with other signaling models, not pictured in Figure 1) act on several neuron types including proopiomelanocortin (POMC) neurons, neuropeptide Y (NPY) neurons, and neurons expressing agouti-related protein (AGRP). The POMC neurons are activated by leptin and produce αMSH, which activates the MC4R receptor. Activation of MCR4 acts as a satiety signal. NPY and AGRP are orexigenic molecules.

Figure 1:



For questions 158 – 167, fill in the correct sign in the operational model at the location indicated. (+ or -)

157. A

158. B

159. C

160. D

161. E

162. F

163. G

164. H

165. I

166. J

167. K

168. Does this operational model contain a positive feedback loop, a negative feedback loop, both, or neither? (Positive/Negative/Both/Neither)

169. Based on this model, is αMSH also orexigenic, or is it anorectic?

170. Based on what you learned in class, in which part of the brain do you expect to find the POMC, NPY and AGRP neurons?

Recent research (Ghamari-Langroudi et al., *Science Advances,* 2018) has shown that αMSH, acting through a different receptor (MC3R) can have another role in feeding regulation.

Figure 2:

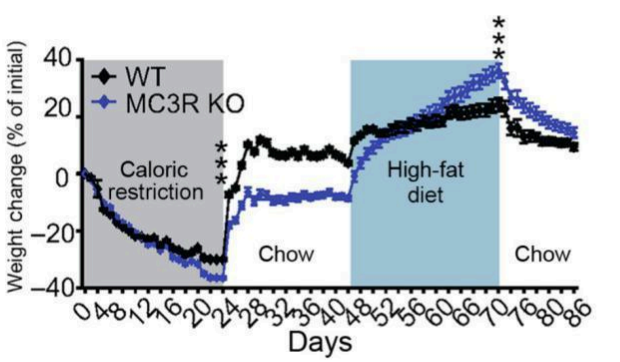


Figure 2 shows an experiment very similar to one we saw in class. "Chow" refers to times when the animal had free access to as much chow as it desired. MC3R KO (knock-out) refers to mice that have been genetically engineered such that they do not have the MC3R receptor. WT refers to mice who have not been genetically manipulated (wild-type).

171. Describe the experiment that led to the data shown in Figure 2.

172. Identify what you see in Figure 2. Be sure to describe both the WT and KO data during each phase of the experiment. Please include any differences between the WT and KO groups.

173. Interpret the data in Figure 2 by drawing a conclusion regarding the role of αMSH acting through the MC3R receptor.

174. On the axes provided below (x axis = day, y axis = weight), use a solid line to indicate the data you would expect from an ob/ob mouse, and use a dotted line to indicate the data you would expect from an MC4R KO (no functional MC4R) mouse (based on the operational model in Figure 1).