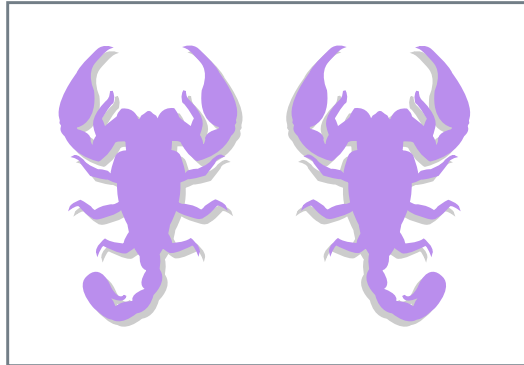


## Question 1

You are a molecular biologist dedicated to preserving rare species from around the world. You recently started a project to clone the rare blue lobster by somatic cell nuclear transfer. This lobster is the same species as the normal purple lobster but has a genetic mutation that gives it a blue exoskeleton.



Figures by MIT OCW.

a) Given that you only have **somatic, differentiated** cells available, what are the **two** traits desirable for an appropriate donor cell? Choose from the choices below.

The best donor cell is.... 4 points

haploid	<b>diploid</b>	a sperm cell	densely packed with mitochondria	<b>in G<sub>0</sub> or G<sub>1</sub> phase</b>
in S phase	multinucleated	in G <sub>2</sub> phase	an egg	in M phase

b) Of these three cell types, which have the ability to give rise to blue lobsters? Cells from the.... (Circle all that apply.) 3 points

**retina**

**nervous system**

**stomach**

c) You find that you are only getting viable clones using the intestinal cells. There is a difference in the success of cloning between these cell lines because the \_\_\_\_\_ is different. Circle **all** that could correctly fill in the blank. 6 points

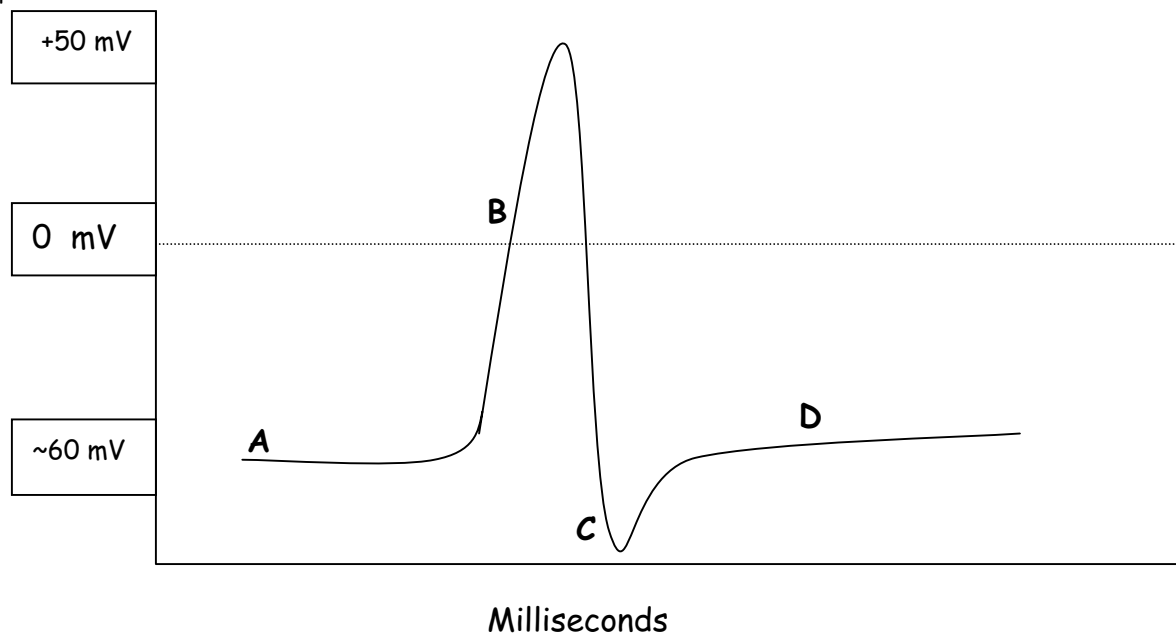
intracellular Ca <sup>+</sup> level	mitochondrial genome	blueness	<b>histone acetylation</b>	actin polymerization
intracellular ATP level	<b>DNA methylation</b>	concordance	integrin level	<b>chromatin structure</b>

d) Of your successful blue lobster clones, most but not all of them have behavioral defects. What is/are the likely reason(s) for this? 3 points

- i) complete reprogramming to embryonic state after nuclear transfer
- ii) mitochondrial incompatibility with in the egg
- iii) improper DNA methylation**
- iv) telomeres could be too short**
- v) intestinal cells do not have the glutamate synthase gene

Question 2

a) Put values in the boxes of the Y axis on the graph below that depicts changes in the membrane potential of a neuron. 2 points

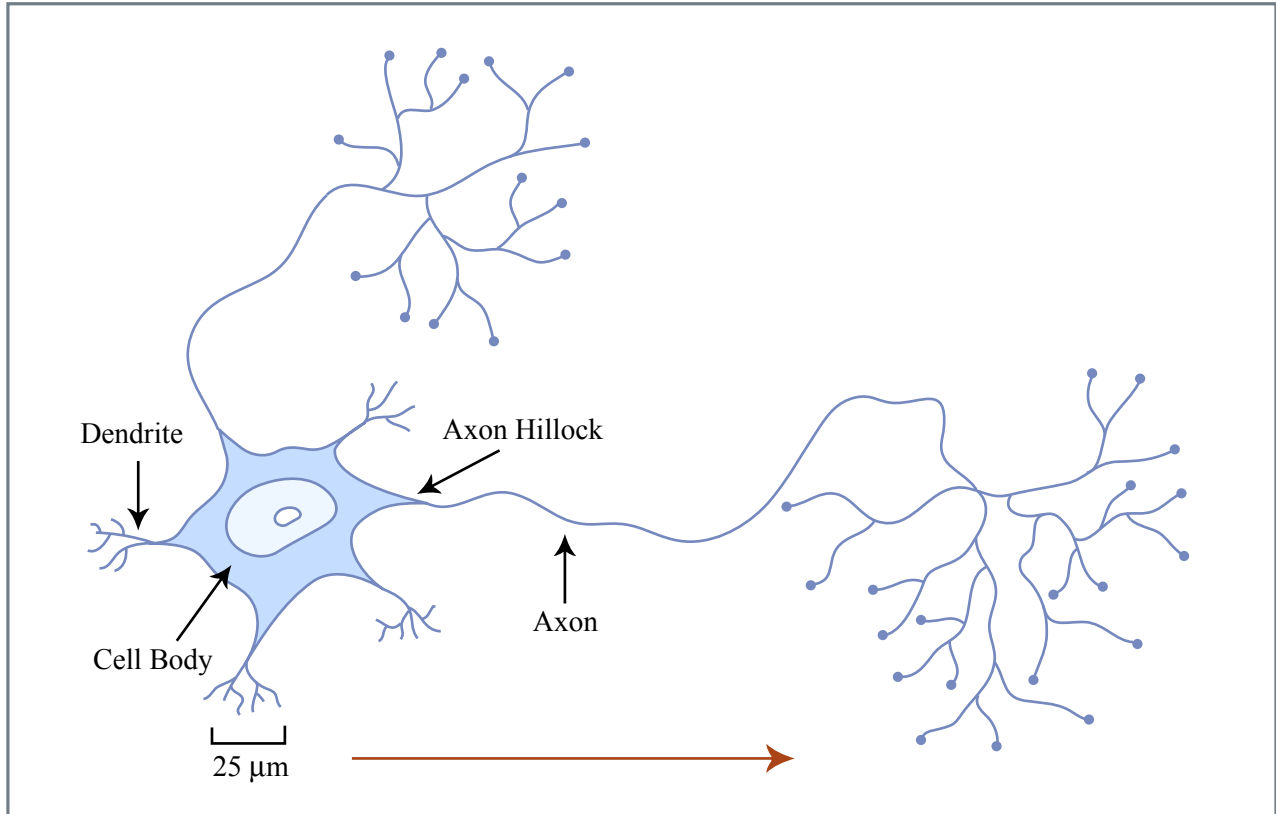


b) Circle all correct corresponding terms that describe the neuron at points A-D depicted on the graph above. 10 points.

At Point...	The neuron is... (Circle one.)	The axon's has its... (Circle all that apply.)
A	depolarized hyperpolarized mispolarized <b>at resting potential</b>	Resting (Leaky) Na <sup>+</sup> channels open Voltage-gated Na <sup>+</sup> channels open <b>Resting (Leaky) K<sup>+</sup> channels open</b> Voltage gated K <sup>+</sup> channels open
B	<b>depolarized</b> hyperpolarized mispolarized at resting potential	Resting (Leaky) Na <sup>+</sup> channels open <b>Voltage-gated Na<sup>+</sup> channels open</b> <b>Resting (Leaky) K<sup>+</sup> channels open</b> Voltage gated K <sup>+</sup> channels open
C	depolarized <b>hyperpolarized</b> mispolarized at resting potential	Resting (Leaky) Na <sup>+</sup> channels open Voltage-gated Na <sup>+</sup> channels open <b>Resting (Leaky) K<sup>+</sup> channels open</b> <b>Voltage gated K<sup>+</sup> channels open</b>
D	depolarized hyperpolarized mispolarized <b>at resting potential</b>	Resting (Leaky) Na <sup>+</sup> channels open Voltage-gated Na <sup>+</sup> channels open <b>Resting (Leaky) K<sup>+</sup> channels open</b> Voltage gated K <sup>+</sup> channels open

c) In the image below...

i) ...in the boxes, identify the cell body, a dendrite, the axon hillock, and the axon. 4 points



Figures by MIT OCW.

ii) ...draw an arrow indicating the direction of signal propagation. 1 point

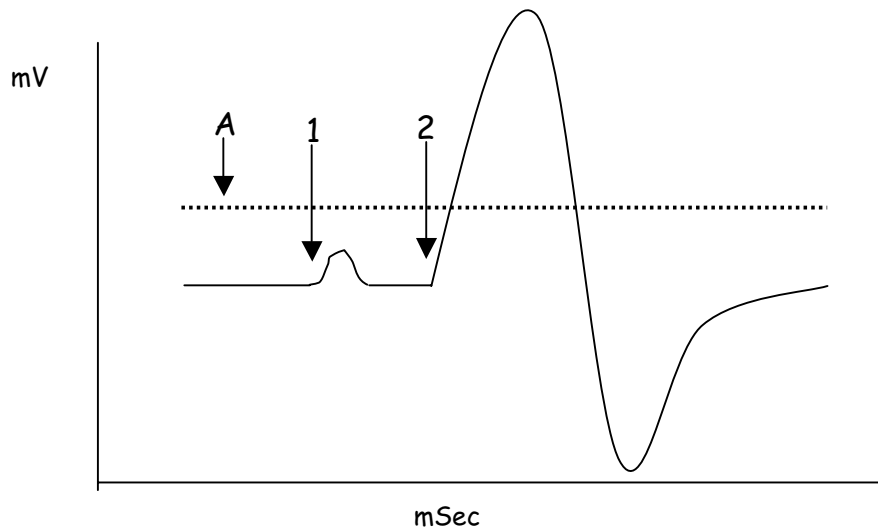
Applying a gradient of Factor X to neurons in a dish causes the axon growth cones to move towards the high concentration of Factor X. This is known to work through a G-Protein coupled receptor.

d) Circle the effect of applying the following specific inhibitors to a neuron near a source of a Factor X. 4 points

Inhibitor of:	Effect on attraction of neuron		
DNA polymerase	Inhibits Attraction	No effect	Promotes Attraction
Actin polymerization	<b>Inhibits Attraction</b>	No effect	Promotes Attraction
Factor X receptor	<b>Inhibits Attraction</b>	No effect	Promotes Attraction
the alpha subunit of the coupled G protein	<b>Inhibits Attraction</b>	No effect	Promotes Attraction

You are researching action potentials, and so you decide to inject a small amount of  $\text{Na}^+$  to the axon hillock of a hippocampal neuron. When you inject 1 nanogram of  $\text{Na}^+$  at time point 1, you see a small change in membrane potential, but by injecting twice as much at time point 2, you see a large change. See the data on the top of the next page.

Name \_\_\_\_\_



e) Why is the response to the addition at time point 1 smaller than at time point 2? Circle all that apply. 2 points

- i) A less intense signal was sent down the length of the axon from time point 1.
- ii) **Not enough  $\text{Na}^+$  was added to trigger an action potential.**
- iii) Generation of an action potential requires the influx of both  $\text{Na}^+$  and  $\text{K}^+$  ions.
- iv) Generation of an action potential requires  $\text{Ca}^{++}$ .
- v) At time point 1, the membrane was hyperpolarized, and thus didn't respond properly.

f) What could the dashed line marked A represent? Circle all that apply. 2 points

- i) Action potential
- ii) Resting potential
- iii) **Threshold potential**
- iv) Moneymaking potential
- v) Gap junction potential

g) A colleague repeats your experiments, but with hippocampal neurons derived from mice from a different colony. He finds that 1 nanogram of  $\text{Na}^+$  is always enough to cause production of the large response that you saw only after adding 2 nanograms. Circle all possible explanations for this inconsistency. 4 points

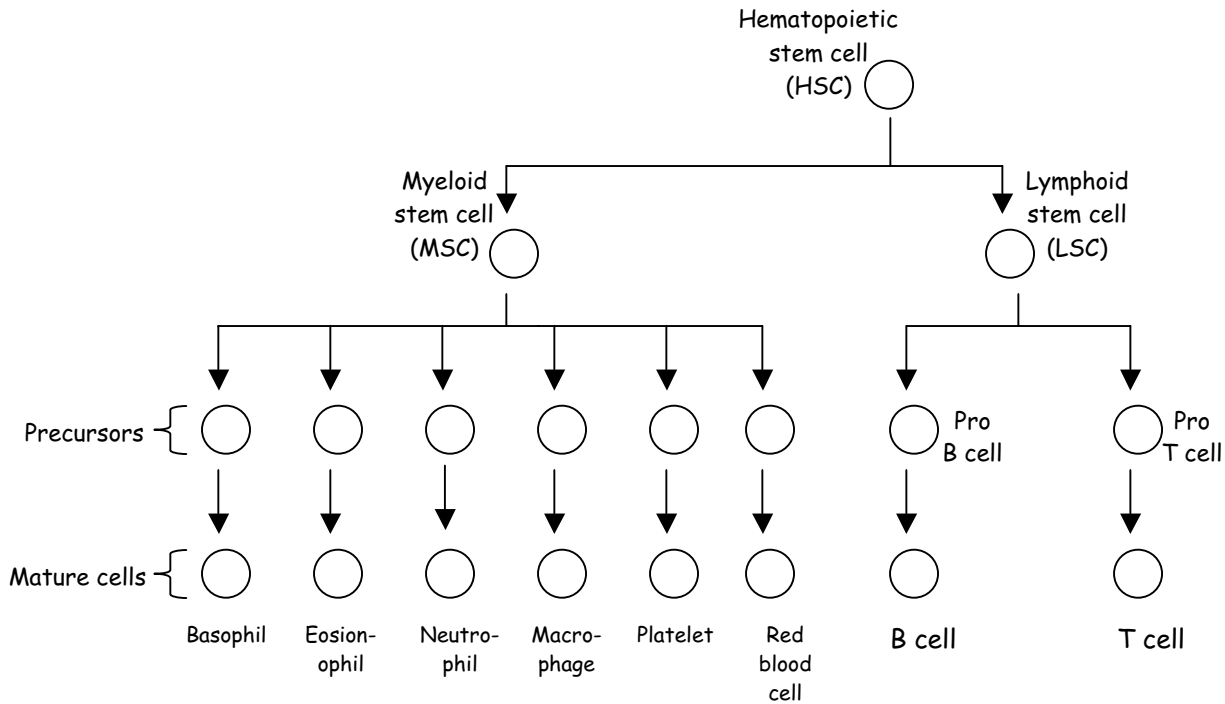
- i) **The neurons of your mice have undergone long term depression of the hippocampus**
- ii) The neurons of his mice have undergone long term depression of the hippocampus
- iii) The neurons of your mice have undergone long term potentiation of the hippocampus
- iv) **The neurons of his mice have undergone long term potentiation of the hippocampus**
- v) The neurons of your mice "ah wicked lame".

i) If you are right about your explanation, what has been adjusted in your and/or your colleague's mice? Circle all that apply. 2 points

- i) Action potential
- ii) **Resting potential**
- iii) Threshold potential
- iv) Moneymaking potential
- v) Gap junction potential

Question 3

Shown below is the development of multiple blood cell lineages from a hematopoietic stem cell (HSC).



a) What two properties does the HSC possess to make it a stem cell? 4 points

Self-renewing

Gives rise to at least one other cell type

b) Which of the following terms is conventionally used to correctly describe the HSC? 2 points

- i) Unipotent
- ii) Totipotent
- iii) Impotent
- iv) Nanopotent
- v) Quasipotent
- vi) **Pluripotent**

c) Which of the following terms best describes the macrophage labeled at the bottom of the figure? 2 points

- i) Unipotent
- ii) **Stem cell**
- iii) **Differentiated**
- iv) Loss of heterozygosity
- v) Quasipotent
- vi) Pluripotent

d) Answer True or False. 4 points

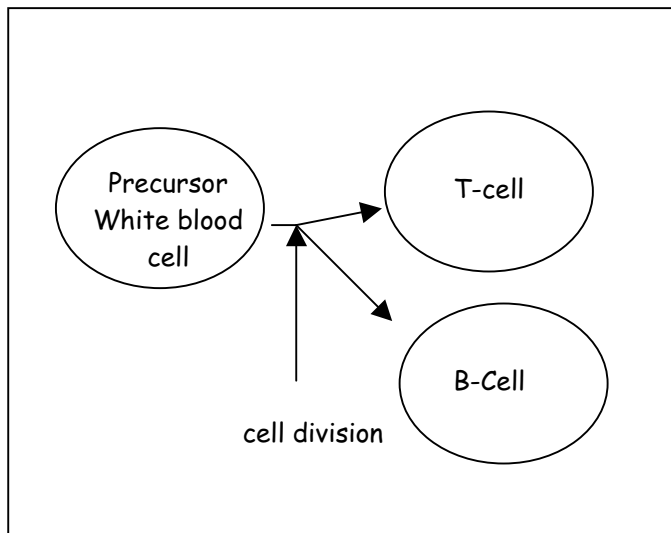
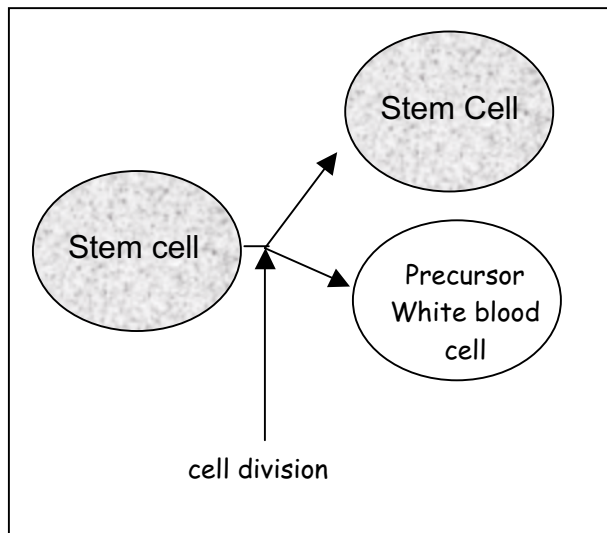
T	F	The HSC already expresses all of the proteins eventually found in the red blood cell.
T	F	The MSC is less potent than the LSC.
T	F	The pro B cell is determined.
T	F	MSC's normally give rise to T cells.

e) Which of the following cellular mechanisms could mediate the development of a pro-B cell into a mature B cell? Circle all that apply. 8 points

- i) Diffusible ligand binding to membrane receptor in pro-B cell
- ii) Transcription of specific genes in pro-B cell
- iii) Fusion between pro-B cell and another cell
- iv) Activation of a C-protein
- v) Activation of a G-protein
- vi) A kinase cascade

Question 4

A stem cell goes through a division once a day to produce another stem cell and a precursor white blood cell. The precursor white blood cell then divides after one day to give rise to two differentiated cell types, the T-cell and the B-cell.

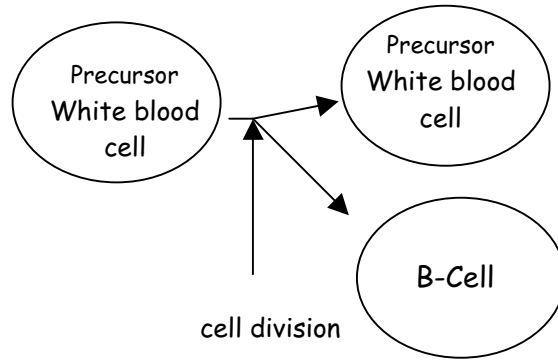


a) You start with a single stem cell. Fill in the chart indicating how many of each cell type will there be on the days listed. 6 points

Assume the time for the cell cycle and cell division is one day.  
How many of each cell type will there be on the days listed?

Cell Type\ Day	Day 0	Day 1	Day 2	Day 3	Day 4
Stem cells	1	1	1	1	1
Precursor white blood cells	0	1	1	1	1
T-cells	0	0	1	2	3
B-cells	0	0	1	2	3

You discover a stem cell that has acquired a *de novo* mutation that prevents it from differentiating into T-cells. As a result, the precursor white blood cells produced from this stem cell divide to form one precursor white blood cell and one B-cell. See below.



b) Starting with a single mutant stem cell how many of each cell type will there be on the successive days? Assume the time for the cell cycle and division is one day. 8 points

Cell Type\ Day	Day 0	Day 1	Day 2	Day 3	Day 4
Mutant Stem cells	1	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>
Precursor white blood cells	0	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
T-cells	0	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>
B-cells	0	<b>0</b>	<b>1</b>	<b>3</b>	<b>6</b>

d) Given that the population of mature B-cells and T-cells have finite life spans whereas stem cells and precursor white blood cells do not, after several months which cell type(s) will be predominate in the experiment described in b)? 2 points

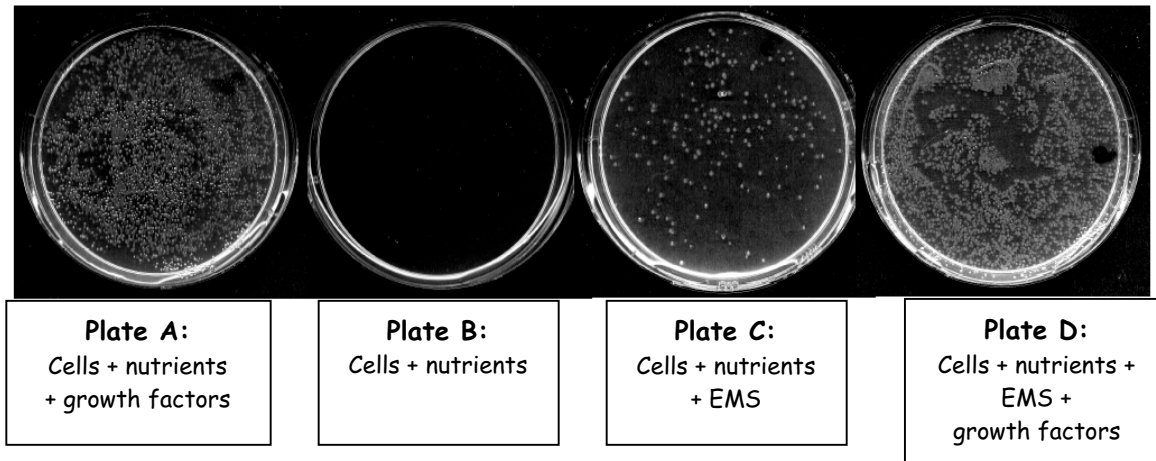
Stem cells                      Precursor white blood cells                      T-cells                      B-cells

e) This condition if it were in an animal it would be called...2 points

Adenoma                      Carcinoma                      Leukemia                      Myosarcoma



These mutant cells, when they arise, are normally found in the bone marrow, where they are exposed to an abundance of growth factors. When they are removed from the bone marrow and placed in a plastic dish in the absence of growth factors, they cannot grow and they die, even though all the nutrients they need are present. However, in the presence of the mutagen EMS, a small number of colonies of cells begin to divide. Adding growth factors, with or without EMS, allows extensive growth.



e) You determine that many cells that grow on plate C have a mutation in one copy of the *kylE* gene, encoding the KYL-E protein, a monomeric G-protein. Is *kylE* an oncogene or a tumor suppressor gene? Circle one. 1 point

*kylE* is an oncogene.

*kylE* is a tumor suppressor gene.

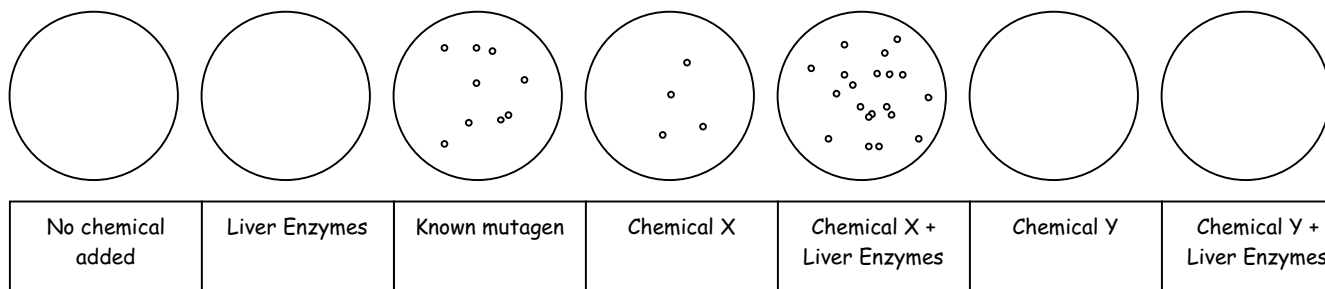
f) It is known that the receptor, associated with the KYL-E protein, binds to cell growth factors, and that signaling through this pathway causes cell growth and division. Which of the following is a **direct mechanism** for the mutant KYL-E protein to be affecting this pathway? Circle all that apply. 4 points

- i) Mutant KYL-E protein binds to cGMP.
- ii) Mutant KYL-E protein cannot hydrolyze GTP.
- iii) Mutant KYL-E protein cannot be activated by the growth factor.
- iv) Mutant KYL-E protein can no longer bind growth factors.
- v) Mutant KYL-E protein is always activating adenylate cyclase.
- vi) Mutant KYL-E protein cannot replace it's GDP for a GTP.

Name \_\_\_\_\_

Question 5

To determine whether two common chemicals are carcinogens, you perform an Ames test with each of them. All of the following minimal medium plates are spread with bacteria that have a point mutation in the gene required for synthesis of histidine. Additions to the plates are shown below the plate. After incubation the plates look like this:



a) Which is more mutagenic, chemical X or chemical Y? 2 points

**Chemical X**                                      **Chemical Y**                                      **Cannot be determined.**

b) Which of these chemicals might be modified by liver enzymes? Circle one. 2 points

**Chemical X**                                      **Chemical Y**                                      **Both**                                      **Neither**

c) A colleague tries to do the same test and gets colonies growing on each plate, including the negative control plates. What could be wrong? Circle all possible correct answers.

- i) She is using medium that contains histidine.**
- ii) She works too close to a significant source of radiation, which is causing mutations.**
- iii) She accidentally added ampicillin to the medium.**
- iv) She is using a strain of bacteria that contains a deletion of the entire histidine synthesis gene.**
- v) She is using a strain of bacteria that isn't mutant for histidine synthesis.**