**Part 1 - Simulating how Gene Expression works**

1. Google “phet gene machine”. Open the flash program. **Click on the “Lactose Transport” tab on the top of the simulation.**

Done.

1. On the screen you should see two floating blue molecules, these are RNA polymerase. There is also an incomplete DNA gene beneath them. You can turn on the legend in the lower right and that will help you identify the molecules. Click the “show legend” box in the lower right.

Done.

1. Drag the lac promoter into place. What happens to the RNA polymerase? Are any new molecules created?

RNA polymerase can now bind to the DNA and it "rides" along the DNA molecule, which looks like a string in this simulation. Despite movement by the RNA polymerase no new molecules, like RNA polymers (aka strings) are created at this time.

1. Drag the lacZ gene into place. What happens? What molecule is represented by the black line? What is the name of the process that converts the lacZ DNA gene to the black line?

RNA polymerase still binds to the DNA but now the RNA polymerase produces a black string when it "rides" along the DNA. This black string is messenger RNA, mRNA. The process by which DNA is read and made into RNA molecules is called transcription.

1. Eventually, arrows appear from the black line and purple circles appear from it. What type of molecules do the purple spheres represent? What is the name of the process that converts the black line to the purple spheres?

The purple spheres represent the final protein encoded by the lacZ DNA gene. The process by which RNA is converted to protein is called translation.

1. Turn the lactose injector onto “Auto” mode. What happens to the lactose? Can it enter the cell?

Lactose accumulates outside of the cell and cannot enter.

1. Drag the lacY gene into place. What happens to the lacY protein? What is the role of the lacY protein?

The lacY protein, green boxes, end up the membrane, by a process called membrane insertion, and functions to allow lactose to enter into the cell.

1. Now that lacY is letting lactose into the cell, we can see the function of lacZ. What happens to the lactose once it is inside of the cell? What is the function of lacZ?

Now with the lactose into the cell, it is possible to see that lacZ protein functions to cut lactose in half, breaking the disaccharide into monosaccharides. These monosaccharides disappear which represents the individual monosaccharides entering cellular respiration.

**Part 2 - Simulating how Gene Expression can be turned off and on**

1. Drag the lac operator into place. Does anything happen because of it?

No. Not at this point. Dragging the lac operator onto the DNA causes no change in the molecules that are produced or their actions (properly described as molecular function).

1. Switch the lactose injector to “Manual” mode and wait for all lactose to disappear. Drag the lacI promoter into place. Can the RNA polymerase bind both promoters? Is the RNA polymerase able to make the lacI gene now?

RNA polymerase, either molecule of it, can bind to both promoters but as we haven't placed the lacI gene in yet, no lacI mRNA nor lacI protein is produced.

1. Drag the lacI gene into place. Does this allow for the creation of new proteins? To what does the lacI protein bind to? What effect does the lacI gene have on transcription of the LacZ and LacY genes?

With the lacI gene present, the lacI protein can now be produced. The lacI protein binds to the operator. The lacI protein acts as a "road block", which prevents RNA polymerase from transcribing the lacZ and lacY genes.

1. Remove the lac operator. Wait for lacY to return to the membrane. Turn the lactose injector onto “Auto” mode and wait for lactose to enter the cell. Drag the lac operator back into place. What happens now to the LacI protein? Does the presence of lactose in the cell alter its ability to repress translation?

Lactose binds to the lacI protein. After which that lacI protein can no longer bind to the lac operator on the DNA. So lactose blocks lacI from blocking transcription, basically lactose stops the protein that stops RNA polymerase from transcribing the lac genes.

1. If the ​lacZ​ protein breaks down lactose, is it worthwhile to make it when there is no lactose around? How does the bacteria use this system to efficiently control the production of the lacZ protein?

No, it is inefficient to make lactose digesting proteins when they are not needed. This entire system functions as an "on/off" switch to "intelligently" or efficiently control the expression of the lac operon, so that the cell only uses energy to make proteins when those proteins are needed.