JonDarkow.com Simulations for AP Biology

I created a chart of the simulations I use with my AP Biology students. I organized the chart according to the Big Idea that best applies to each simulation. I organize the narrative of my course around the Essential Knowledge statements of the AP Biology curriculum. However, many of the simulations can apply to many Essential Knowledge statements and Learning Objectives.

Seeing Connections between the Big Ideas:

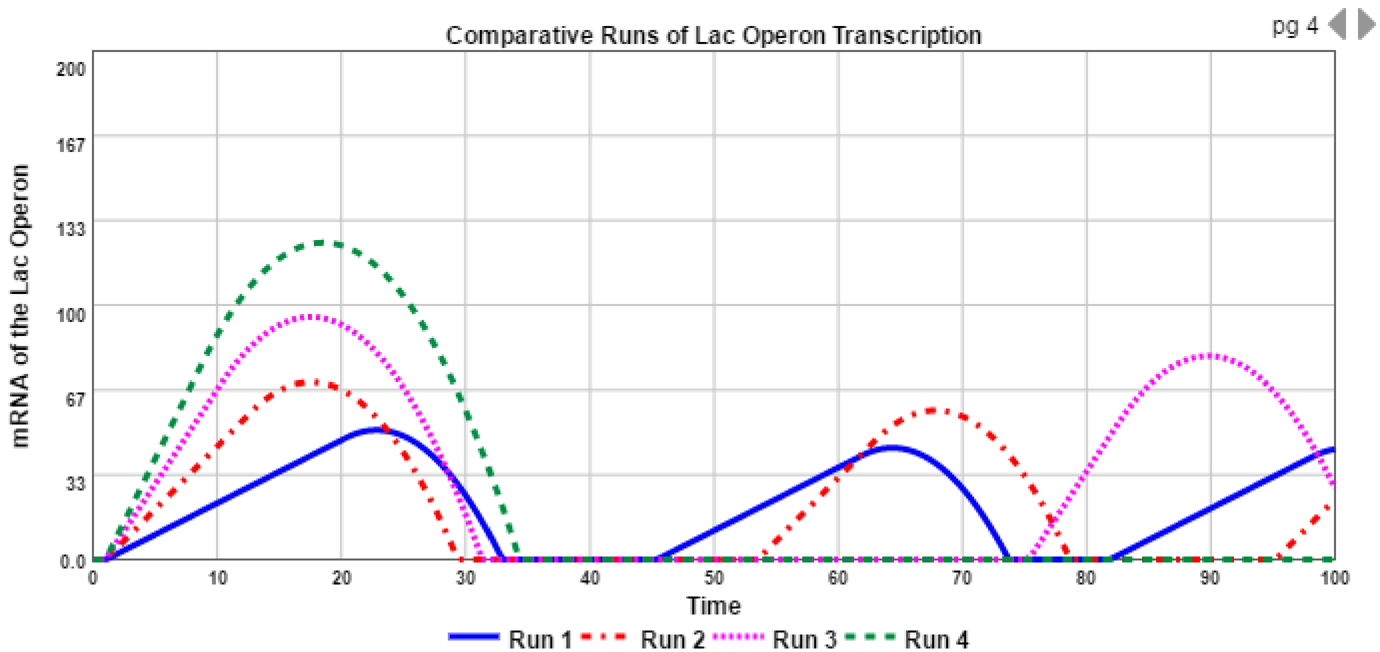
One aspect of my simulations that I am currently excited about, is allowing students to see the connections between the Big Ideas: evolution, use of free energy, information flow, and interactions and complex properties. I have found that this works especially well with the simulations that involve gene regulatory feedback loops. Examples include: Tryptophan Operon: A Repressible System**,** Lactose Operon: An Inducible System**,** Growth Factors, Cyclins, and Cancer**, and** CLOCK Gene Expression and Circadian Rhythms**. The cleanest updated simulation is probably the Lactose Operon simulation. (However, I am hoping to update the CLOCK Gene Expression and Circadian Rhythms simulation soon.)**

Connecting the Big Ideas

By altering the rate of transcription of a gene , like the *Lac* operon, a system's behavior can be altered. Tracking the major factors that influence the system dynamics allows students to see how the Big Idea are interrelated. Because the *lac* operon gene transcription is involved in a negative feedback loop (complex property), increasing the transcription rate of the *lac* operon decreases its own activation. This is very counter-intuitive, and students definitely struggle with negative feedback loops.

The *lac* operon is regulated indirectly by the concentration of lactose. Lactose binding to a protein repressor, inactivates the repressor and the gene turns on, transcription commences. Give a bacteria culture a steady flow of lactose. The lactose will inactivate the repressor, transcription of the *lac* operon will synthesize mRNA, and then the enzymes necessary to hydrolyze lactose. Lactose levels will be reduced to nearly zero. The metabolized lactose will no longer be inactivating the repressor, and the repressor will block the transcription of the *lac* operon. With the operon blocked, and the enzymes degrading, the flow of lactose added to the bacteria culture will again begin to accumulate in the system. Lactose will bind to and inactivate the repressor and the operon will be activated again.

However, when the rate of transcription increases many more enzymes are synthesized. With a high concentration of enzymes, the chance for lactose to accumulate and inactivate the repressor prior to being metabolized is small. The greater amount of enzymes synthesized reduces the amount of lactose in the system, and therefore reduces the chance for the gene to become activated again until the enzymes becoming sufficiently degraded to allow lactose to accumulate again. Increasing the transcriptional rate decreases the time the gene will be activated again if the gene is in a negative feedback loop. Examine the lag times in the graph below. The greater the rate of transcription with continuous lactose, the greater the lag time before the gene is activated again.



transciptional rate of lac mRNAs	0.5	1.0	1.5	2.0

Calories are liberated for metabolism when the gene is activated. Bacteria use the energy from lactose to drive metabolic processes. However, at some point the energy gained from the hydrolysis of lactose will be less then the energy required to transcribe the operon's mRNA and synthesize the enzymes. This is a great opportunity to connect Big Ideas 1 and 2. Organisms that can conserve and utilize the most energy when appropriate will have greater reproductive success.

Overproducing the *lac* enzymes would utilize a greater percentage of the flow of lactose, but would waste free energy producing a large amount of enzymes unnecessarily. To increase reproductive success, more is not always better. More energy is better, but not necessarily a greater transcriptional rate, or enzyme concentration. Natural selection does not just act on the types and shapes of proteins produced, but also on the rate of their production.
https://docs.google.com/document/d/1DRVD2GhYBSwLsbh9gfAz_lG6f-T1_7lwm2vyreZUDUQ/pub

Simulation	**Big Idea 1:** The process of evolution drives the diversity and unity of life.	**Big Idea 2:** Biological systems utilize free energy and molecular building blocks to grow, to reproduce and to maintain dynamic homeostasis.	**Big Idea 3:** Living systems store, retrieve, transmit and respond to information essential to life processes.	**Big Idea 4:** Biological systems interact, and these systems and their interactions possess complex properties.
Evolution of Populations, Genetic Drift, and Mutations	A gene pool of alleles A and B in a population evolves or remains at equilibrium over 50 generations.		Three genotypes (homozygous AA and BB, and heterozygous AB individual) randomly mate each generation using the Hardy-Weinberg formula.	
Lactase Enzyme Simulation		Enzymes rate of reaction changes in response to pH, temperature, and substrate concentration.		
Cellular Respiration Simulation		The products and reactants of glycolysis, the Citric Acid cycle, and the electron transport chain change during the metabolism of glucose. ATP production can be manipulated by changing		

		the pH in the mitochondria, thereby changing the proton motive force.		
Dynamics of Photosynthesis		By varying light intensity, light wavelength, temperature, pH and the herbicide atrazine the dynamics of photosynthesis in the photosystems and the Calvin cycle are compared. Like in the cellular respiration model, changing the pH can artificially boost ATP production. In this model manipulating initial NADPH and pH can generate glucose without light.		
Neurophysiology and Information Processing	Neurotoxins, TTX, sarin gas, and botulinum, affect the movement between neurons and the movement of ions across the cell membrane affecting the action potential along a neuron.		Using two common neurotransmitters, glutamate and GABA, information is processed differently as one neuron activates another neuron	
HPV and Adaptive Immunity			Vaccination to HPV and primary and secondary response to HPV are and how the humoral immune system stores memories	

			of prior infections to confer resistance to future resistance.	
Drosophila Genetics - White Eyes			Choose between white-eyed or wild type mother and father. About 1,000 offspring are generated to investigate the sex-linked pattern of inheritance.	
Gene Linkage and Recombination			Select the distance between two genes to determine how the proximity of two genes affect the pattern of inheritance in a testcross, or an F2 cross.	
Transformation Experiment			Add *E. coli* to the experiment and transform to ampicillin resistant *E. coli.* Determine what causes the transformation of the *E. coli*: DNA, RNA, or proteins.	
Tryptophan Operon: A Repressible System				
Lactose Operon: An Inducible System			Lactose inhibits the repressor, activating the operon gene transcription. The	

			enzymes metabolize the lactose, and without lactose the lac operon genes become inhibited again. A mutated lac repressor transcribes the gene continuously showing that the direct cause of the lac operon gene transcription is NOT lactose, rather the inhibition of the lac repressor.	
Catastrophic Regime Change in Aquatic Ecosystems		High amounts of nitrogen and phosphorous (and also increases in temperature) leads to exponential growth of cyanobacteria causing the lake to become eutrophic.		Feedback between trophic levels leads to dynamic homeostasis. Reduction in one of the trophic levels destabilizes the community dynamics.
Extinction Vortex of the Greater Prairie Chicken			Genetic diversity increases the resilience of the population. Low genetic diversity makes the population more susceptible to population decreases.	
Population Dynamics of the White-Footed Mouse			Abiotic and biotic factors affect population growth. Density-dependent factors, like habitat size, competitors, and food affect carrying capacity.	

			Density-independent factors, like temperature, affect the constant rate of growth.	
Growth Factors, Cyclins, and Cancer			Growth factors induce cyclin-CDK complexes to pass through checkpoints of the cell cycle. DNA in humans has a count per cell of 46 during G1 of cell cycle, increases to 92 during S-phase, 92 during G2, and reduced from 92 to 46 during mitosis.	Cyclins are an example of a negative feedback loop. Growth factors increase G1 cyclins, which increase S-phase cyclins, which increase M-phase cyclins, which DECREASE G1 cyclins. This negative feedback loop regulates the timing and coordination of the phases of the cell cycle.
CLOCK Gene Expression and Circadian Rhythms	Circadian temporal isolation can be manipulated by changing the rate of transcription of the genes that regulate the circadian clock.		Transcription factors promote gene transcription and transcripts are translated into proteins. Some proteins repress gene transcription by blocking RNA polymerase on the regulatory region of a gene.	Timing of the circadian clock is maintained by the transcriptional translational negative feedback loop. Transcription can be altered by sunlight (entrainment).
Phenology of the Endangered Karner Blue Butterfly				In a community predator-prey relationships can be temporally interdependent on the lifecycle of each other. Climate change can disproportionately shift the timing of the life

				cycle of predators and prey lifecycles. The asynchrony between interdependent species can lead to population declines.
Water Potential and Osmosis		Differences in concentrations, pressure, and temperature across a cell membrane can increase the free energy across the membrane.		