PhET Tips for Teachers

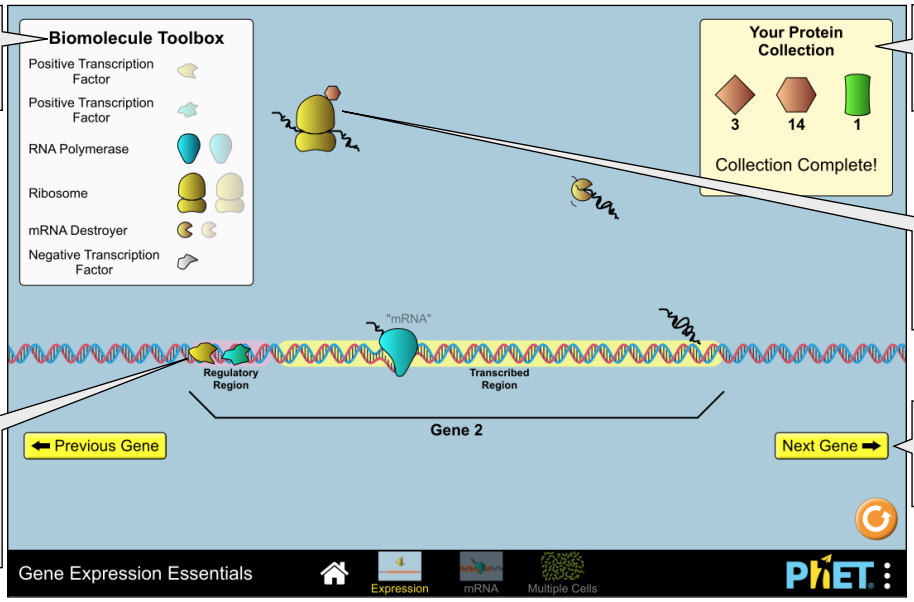
Gene Expression Essentials

Expression Screen

Explore the main sequence of events that occur within a cell that leads to protein synthesis. Generate and collect three types of protein.

EXPERIMENT with biomolecules

ATTACH transcription factors



COLLECT proteins

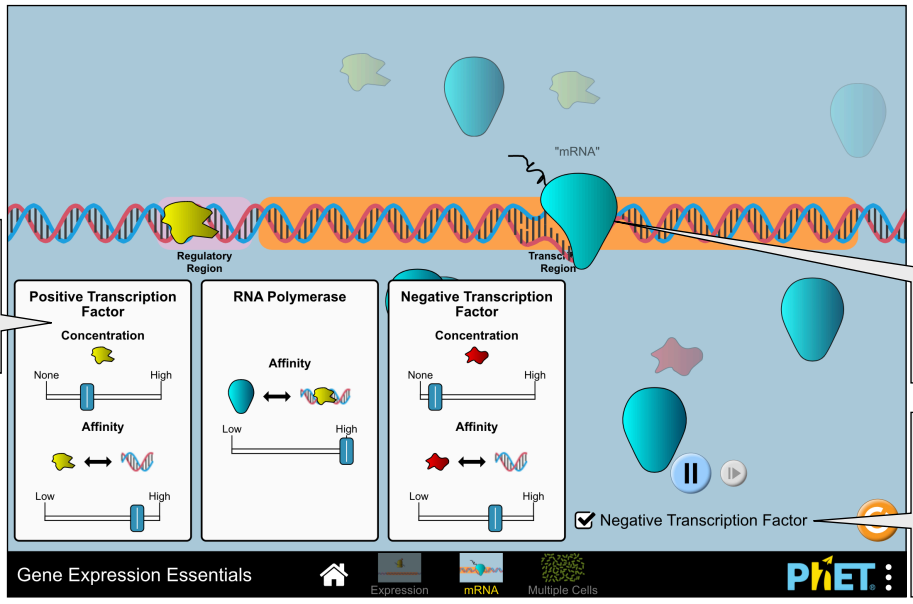
OBSERVE translation

EXPLORE three different genes

mRNA Screen

Explore the factors that affect transcription, including positive and negative transcription factor concentration and affinity, and RNA polymerase affinity.

ADJUST the concentration and affinity



OBSERVE transcription

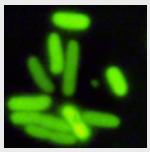
SHOW/HIDE negative transcription factor

Rouinfar & Dalton, December 2017

Multiple Cells Screen

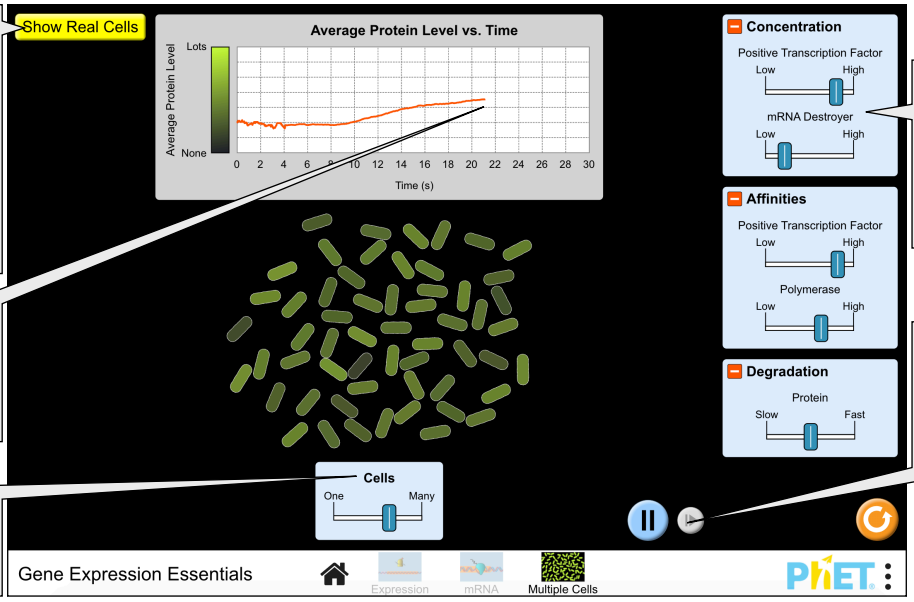
Explore the factors that affect protein synthesis in a cell, and relate protein production in a single cell to the quantity produced by a collection of cells.

SEE real protein cells (GFP)



OBSERVE the average protein level in real-time

ADJUST the number of cells



CONTROL concentration, affinities, and degradation

PAUSE and advance frame-by-frame

Insights into Student Use

- One of the learning goals of the Multiple Cells screen tries to lead students to see the difference between the average protein level expressed by a single cell and multiple cells. Students will likely need to pay attention to the level of fluctuations on the dynamic protein level graph to make sense of this connection.
- On the mRNA screen, consider asking students to describe the factors that affect mRNA production, or first challenge them to produce mRNA as quickly as possible.

Model Simplifications

- The process being portrayed does not show the mRNA moving out of the nucleus, and is thus essentially showing a prokaryotic cell, rather than a eukaryotic cell.
- The RNA polymerase and transcription factors have pseudo-random movement which tends to drive towards the gene region.
- Ribosomes are available to the user in "pre-assembled" form, meaning that the large and small subunits are already together, rather than having the subunits come together as mRNA transcription begins.
- The genes being transcribed are significantly shorter (in terms of the number of base pairs) than real-life genes. On average, a real gene in a prokaryotic organism is 1000 base pairs, whereas the genes in this simulation contain less than 100 base pairs.
- For simplification, some facets of gene expression/protein synthesis are not depicted — including individual amino acids, protein folding, and tRNA.
- On the Multiple Cells screen, the protein production being modeled is green fluorescent protein (GFP).
- The sizes and shapes of the biomolecules were inspired by the illustrations in "The Machinery of Life" by David S. Goodsell.

Rouinfar & Dalton, December 2017

Suggestions for Use

Sample Challenge Prompts

- Synthesize and collect all three types of protein.
- Compare and contrast the three genes.
- Explain what happens when a negative transcription factor binds to a gene.
- Predict how changing the concentrations and affinities of biomolecules affects protein production.
- Determine a way to (a) synthesize lots of mRNA, (b) synthesize a little mRNA, and (c) completely block mRNA synthesis.
- Maximize the average protein level in a group of cells.

See all published activities for Gene Expression Essentials here.
For more tips on using PhET sims with your students, see Tips for Using PhET.

Rouinfar & Dalton, December 2017