

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

COLLECT proteins

OBSERVE translation

EXPLORE three different genes

ATTACH transcription factors

Gene Expression Essentials | Expression | mRNA | Multiple Cells | PhET

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

Gene Expression Essentials | Expression | mRNA | Multiple Cells | PhET

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.

The screenshot displays the 'Multiple Cells Screen' interface. At the top left, a box labeled 'SEE real protein cells (GFP)' shows a microscopic image of green fluorescent cells. Below it, a box labeled 'OBSERVE the average protein level in real-time' points to a graph titled 'Average Protein Level vs. Time'. The graph shows a fluctuating orange line representing protein levels over 30 seconds, with a vertical bar on the left indicating 'Lots' of protein at the top and 'None' at the bottom. A 'Show Real Cells' button is located above the graph. To the right of the graph, three control panels are visible: 'Concentration' (Positive Transcription Factor and mRNA Destroyer), 'Affinities' (Positive Transcription Factor and Polymerase), and 'Degradation' (Protein). Each panel has a slider from 'Low' to 'High'. A 'Cells' control panel at the bottom left has a slider from 'One' to 'Many'. At the bottom center, there are play, pause, and refresh buttons. The bottom of the screen features a navigation bar with icons for 'Gene Expression Essentials', 'Expression', 'mRNA', and 'Multiple Cells', along with the PhET logo.

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.

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](#).