In Brief: Key Teaching Points for Molecular Landscapes

Overall Student Learning Objective: Cells are packed full of thousands of proteins, each trying to do their singular job amidst the chaos and jostling of all the others.

- Proteins are not uniformly distributed in cells. Instead, location, location, location! A particular protein will be found in a specific place/compartment, where it interacts with other like-minded proteins to perform a specific function.
- Some proteins are soluble in the watery environment of the cell's cytoplasm. Others are insoluble in water and are therefore embedded in the cell's hydrophobic membranes.
- While most proteins fold up into compact globular 3D structures, some exist as long, flexible chains.
- Many proteins function as multi-protein complexes (machines) rather than as single, solitary proteins.
- These landscape images represent biology at the mesoscale – spanning that dimension between the molecular world as revealed by crystallography, and cellular world as revealed by microscopy.

We suggest that the use of a landscape is highly synergistic with a physical model of a protein. While the physical model focuses attention on the molecular details of a protein's structure, the landscape emphasizes the cellular context in which the protein acts.

Key Point 1

Patterns, **Scale** and **Mechanism/Explanation** are three ***cross-cutting concepts*** described in the framework of the Next Generation Science Standards. These cellular landscapes can be used to call your students' attention to each of these concepts. The close examination of these landscapes requires (1) attention to detail as patterns in the distribution of different proteins are noted; (2) an explicit comparison of the relative scale of a protein, an organelle and a cell; and (3) the explanation (a story) of the molecular basis of some cellular process/mechanism.

Key Point 2

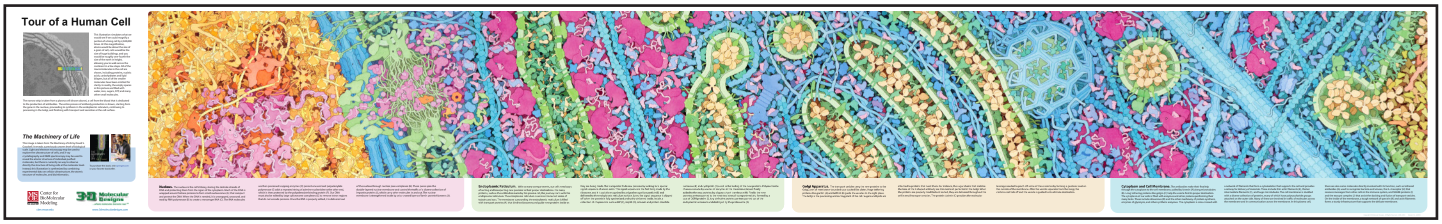
These images provide students with "a model" for how the inside of a cell might look – at the mesoscale. Each student is challenged to reconcile their own mental image of what the inside of a cell looks like with the model provided by scientist, author and artist David Goodsell, PhD.

Key Point 3

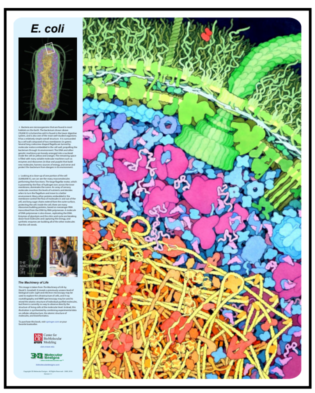
Every shape included in these watercolor landscapes represents a specific protein – illustrated at its appropriate size and shape – at the best current estimate of its concentration in the cell. The molecular structure of virtually every protein can be found in David Goodsell's Molecule of the Month feature at www.rcsb.org.

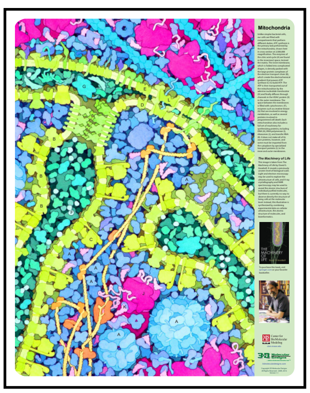
What can you teach with these landscapes?

Tour of a Human Cell Panorama© and **Grand Panorama**©



With the **Tour of a Human Cell**© you can teach "your flu shot in action" as you trace the production of an antibody protein from (1) the transcription of its gene in the nucleus, to (2) the translation of the mRNA in the cytoplasm by ribosomes docked onto the endoplasmic reticulum, to (3) the folding of the protein in the endoplasmic reticulum, to (4) its path through the Golgi, to (5) vesicles loaded with mature antibody proteins being walked toward the cell membrane by kinesin motor proteins, to (6) the fusion of the vesicle with the cell membrane to release the antibody into the circulation.



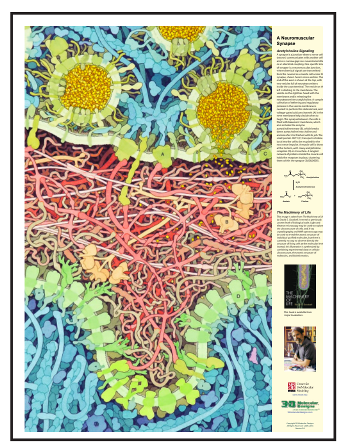


E. coli Poster© and **Mitochondria Poster**©

By comparing the E. coli Poster© and the Mitochondria Poster© you can teach the endosymbiotic theory of mitochondria, as students explore the similarities and differences between these two structures. Especially telling is the extreme expansion of the inner membrane of the mitochondria, with its many copies of the electron transport chain proteins and ATP synthase.

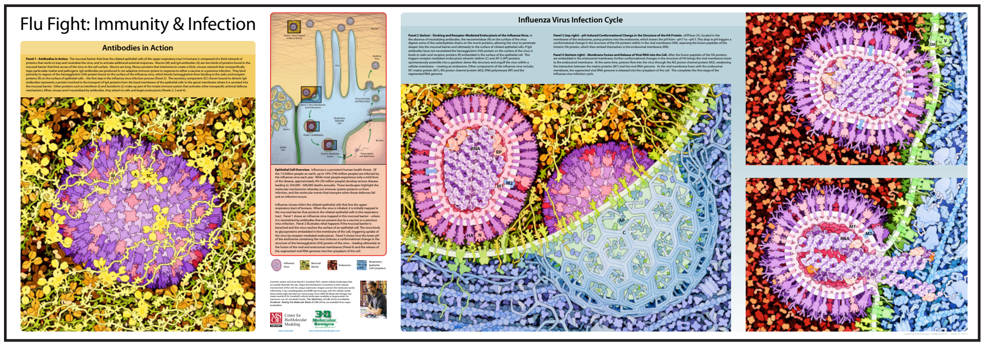
Neuromuscular Synapse Poster©

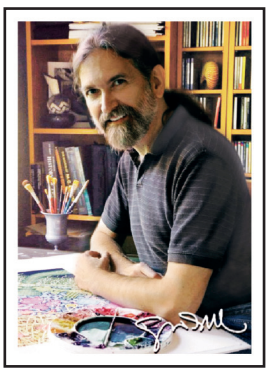
With the Neuromuscular Synapse Poster© you can teach the basic concept of neurotransmission. Vesicles containing acetylcholine fuse with the pre-synaptic cell's membrane to release the neurotransmitter into the synapse, where it diffuses across the synapse to bind to the acetylcholine receptor proteins found on the membrane of the post-synaptic muscle cell.



Key Point 3 Continued

Flu Fight: Immunity & Infection Panorama©
With Flu Fight: Immunity & Infection© you can explore what happens when the molecular defense mechanisms that protect our bodies from the influenza virus *fail*, and infection occurs. You can walk your students from infection of the ciliated epithelial cells that line the upper respiratory tract, through virus neutralization by antibodies in the mucosal barrier. Influenza – in the absence of antibodies – breaches the barrier and binds in the cell membrane before fusing with the endosomal membrane and finally releasing segmented viral RNA genome into the cytoplasm.





Since 2009 3D Molecular Designs has made several of Dr. David Goodsell's cellular landscapes available as large posters for classroom use. His books, *The Machinery of Life* (2010) and *Atomic Evidence: Seeing the Molecular Basis of Life* (2016), are available from major booksellers. Most of the art featured in our posters is from *The Machinery of Life*. Dr. Goodsell also is the author of the Molecule of the Month, a regular feature on the Protein Data Bank's website, www.rcsb.org.

These molecular landscapes can be purchased from 3D Molecular Designs (*3dmoleculardesigns.com*). Find complete lessons and activities for at: *http://www.3dmoleculardesigns.com/Teacher-Resources.htm*.