Learning Protein Structure-Function with Molecular CaseNet

Laurel D Lorenz[1], Keith A Johnson[2], Anya L Goodman[3], Shuchismita Dutta[4]

[1]Department of Molecular Biology, Princeton University, [2]Department of Biology, Bradley University, [3]Department of Chemistry and Biochemistry, California Polytechnic State University [4]Institute for Quantitative Biomedicine, Rutgers University

Abstract

Molecular CaseNet hosts a library of freely available case studies focused on exploring the relationship between protein structure and function. Each case hooks the reader with a story introducing a specific protein and then leads the reader through a guided inquiry of the protein's chemical structure and biological functions. As students explore the protein structure, they engage with a variety of publicly available bioinformatic resources including the Protein Data Bank, KEGG, Uniprot, and Pubmed. Each molecular case study empowers students and instructors with the knowledge to visualize, maneuver, and annotate a 3D model of the protein. Students communicate their understanding of a protein's structure-function relationship by creating figures that illustrate relevant inter- and intramolecular forces.

Each case study can be adapted to fit biology, biochemistry, and chemistry courses ranging from introductory to advanced levels. For example, in introductory courses, students are told which 3D protein structure to investigate, whereas more advanced students use the scientific literature and bioinformatic sources to find the relevant structure(s). In some courses, students work through a single case study, while in others, they complete multiple case studies and even author new case studies. Instructors interested in incorporating a molecular case study from the Molecular CaseNet in their courses are invited to join the Molecular CaseNet Community through working groups and faculty mentoring networks.

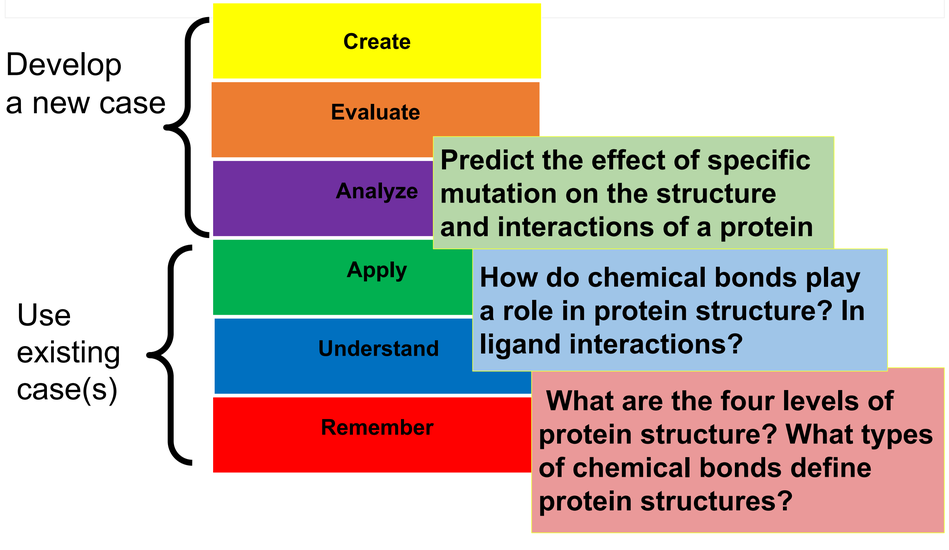

Figure 3. Using Bloom's Taxonomy to illustrate how to use Molecular CaseNet - (a) using published molecular case studies and (b) developing new case studies.

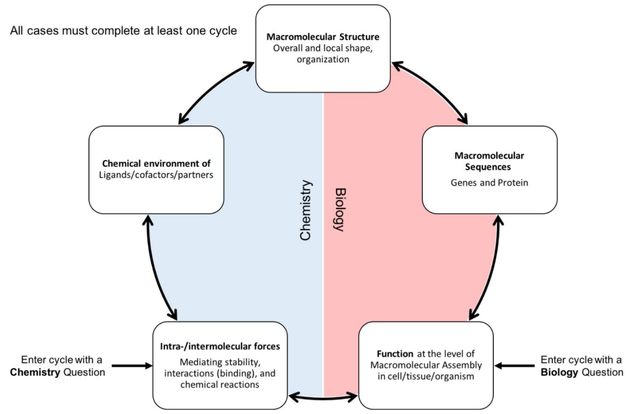

Figure 1. Molecular Case Study cycle at the interface of Biology and Chemistry. Cases are provided with a story (hook) to more effectively engage participants. Some cases provide details for biology or chemistry students while some cases have adaptations for both chemistry and biology students.

1. What is A Molecular Case Study?

These cases for teaching provide guided inquiry to engage students in the exploration of protein structure and function at the interface of Biology and Chemistry. Each Molecular Case Study completes at least one round of the Molecular Case Study Cycle (Figure 1). Each case

- provides a storyline of interest to place the overall concept in context
- incorporates reading scientific literature
- supports the use of online bioinformatics tools and resources to
  - visualize protein structure
  - view chemical bonds within the protein and explore its interaction
- illustrates application of biochemistry to larger issues
  - e.g. human health and disease (Example case about SARS-CoV-2 infection, Figure 2)
  - Protein evolutionary concepts of protein structure.

2. How can You participate?

Instructors have multiple options for using Molecular CaseNet (Figure 3). You can:

1) Use published Molecular Case Studies in your class.
   Note: If you adapt a case in your class, you can publish your adaptation on QUBES Hub.
2) Develop a new Molecular Case Study -
   a) You can become part of the Fall 2021 BIOME working group to develop a case study
   b) You can design an assignment for your students to develop a case. See the poster *Students Authoring Molecular Case Studies.*

3. How do students benefit?

- Learn to use and become confident in manipulating protein structures and identifying inter/intramolecular forces
- Visualize chemical bonds in protein structure(s) and explore its chemical interactions with ligands and other molecules to understand their function
- Gain an understanding of the effect of amino acid substitutions on protein structure/function
- Connect problems relevant to society (e.g. agriculture, health, and disease) to biochemical knowledge

4. How do instructors benefit?

- Learn to use protein visualization tools and become more confident in describing the chemical bonds involved in protein structure and function
- Help students integrate concepts from multiple levels of organization of life including organismal to molecular scales
- Actively engage students in experiential learning opportunities
- Access ready-to-use classroom-tested molecular case studies in curriculum and assessment

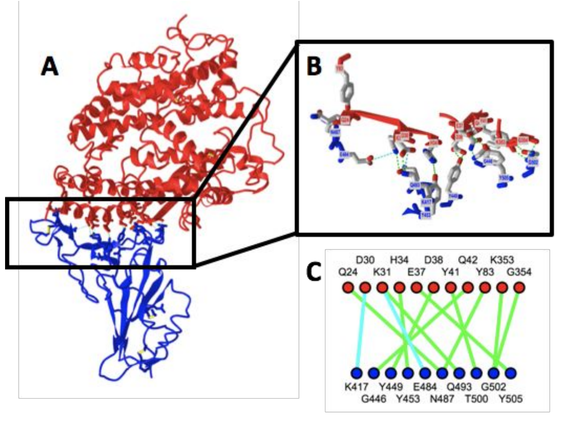

Figure 2. A. SARS-CoV-2 receptor binding domain (blue) interacting with ACE-2 protein (red) (PDB 6M0J). B. The interacting amino acids are shown and labeled in the box. C. Hydrogen (green) and ionic bonds (cyan) interactions between the ACE-2 protein (red) and SARS-CoV-2 receptor binding domain (blue) are shown in 2D.

Acknowledgements

Molecular CaseNet is funded by the National Science Foundation (DBI 1827011; DBI 2018884).