Molecular CaseNet: Developing case studies using molecular representations for use in introductory chemistry, biology and biochemistry classes

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NSF Award: DUE1323414

Objectives of Molecular CaseNet

1. Assess needs/interests: Use of biomolecular structures in teaching biology/chemistry by identifying/recruiting community members;
2. Analyze challenges/develop solutions: Use of biomolecular structures for teaching biology/chemistry by recruiting interested educators to build the BioEd3D CoP
3. Organize resources/standards: Help and recruit educators to join the BioEd3D CoP and use biomolecular structures in teaching

Conceptual Frameworks

Vision & Change

- Structure and function
- Systems

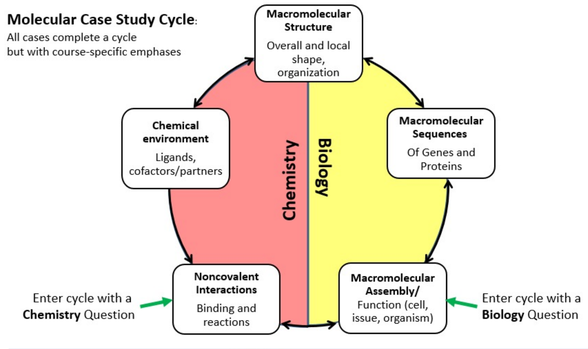
ASBMB: Macromolecule Structure/Function

- Structure and function are related
- Macromolecular interactions
- Macromolecular structure/activity is dynamic and regulated
- Chemistry and physics determines structure/function

Next Gen Science Standards (NGSS) – 3D Learning

- Patterns
- Cause and effect
- Structure and function
- Systems and system models
- Stability and change

Molecular Case Study Cycle

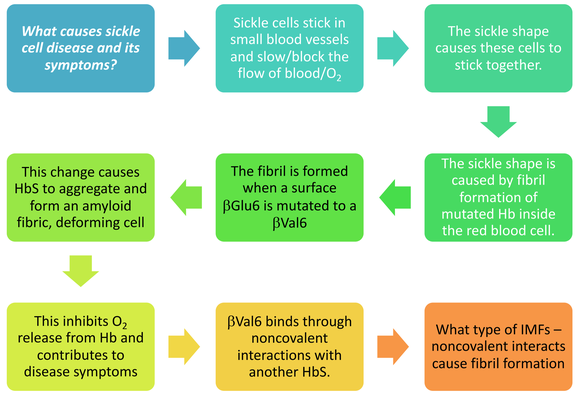


Our 1st Molecular Case Story: Sickle Cell Hemoglobin

A topic that …

- was compelling and emotionally connecting;
- was relevant/interesting to educators/students in biology and chemistry;
- could lead to a clear understanding of structure/function relationships.

A storyboard to link sickle cell disease with introductory chemistry:



Our 1st Case Study – Implementation in Chemistry Courses

Student Learning Objectives

Introductory Chem/Bio Learning goals: Students will be able to …

INTRO CHEMISTRY
- identify non-covalent (IMFs) and covalent interactions between ligand and biomacromolecule
- identify atoms from their CPK colors;
- describe advantages and disadvantages of different types of renderings of biomacromolecules;
- explain how a mutation in a protein can lead to altered protein structure, function and properties

IN COMMON
- describe how the three dimensional structure of a molecule impact its function, including the ability to interact with other molecules.
- describe the binding properties of hemoglobin and oxygen

INTRO BIOLOGY (Molecules/Cells)
- explain how the structure of a cell and its shape impacts its function.
- explain how the sickle cell shape affecting RBC function
- explain how structure constrains function in cellular physiology.
- explain how fibers of abnormal hemoglobin deform red blood cell into sickle shape

Biochemistry/Advanced Biology Learning goals: Students will be able to …

BIOCHEMISTRY
- Describe/compare the structure/properties of T and R states of Hb and their respective binding properties;
- describe cooperative binding and how different allosteric effectors and ligands affect the equilibria between T and R states of hemoglobin;
- Describe and use different mathematical models (Hill, MWC, KNF) that account for cooperative binding of ligand and relate them to structural changes in hemoglobin

IN COMMON
- explain the structure of normal (HbA) hemoglobin,, and the role of hemes in binding oxygen (Level 1)
- explain the cooperative binding and release of O_2 by tetrameric HbA (Level 2)
- Correlate binding of O_2, CO_2 and NO to hemoglobin with graphs of fractional saturation vs pO2;
- describe different allosteric effectors of O2 binding to hemoglobin and how they regulate Hb structure and O_2 binding properties;

ADVANCED BIOLOGY
- explain the structural difference between HbA beta globin and HbS beta globin and the genetic cause (basis) of this difference (Level 1)
- explain why the HbS mutation causes tetrameric polymerization (Level 1)
- explain how HbS polymerization elicits sickle cell disease pathologies
- obtain information on the molecular basis of possible treatments for sickle cell disease

Additional Modeling/Presentation Goals that could be addressed with the Case Study

Basic
- use online interactive web tutorials to display and understand structural features of biomacromolecules, ligands, and their interactions;
- display different renderings of molecules and proteins using web-based molecular modeling programs, given instructions for their use;
- optimally orient molecules to display key feature of structure and function using web-based modeling programs;
- orient 3D printed models of proteins with computer models of the same protein structure
- use PPTX and screen capture to create/complete assignments focusing on structure/function

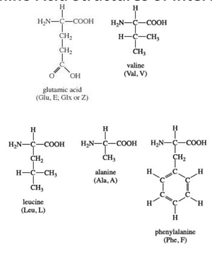
Advanced
- Use specific programs (Jsmol, Chimera, Pymol, etc.), through the command line and/or GUI, to open/render biomolecules to explain structure/function

Minimal modeling skills
Maximal guidance
Macromolecule Specific

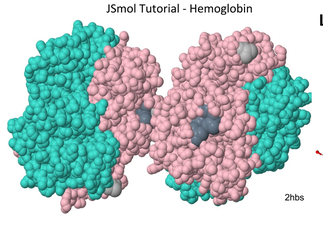
Maximum modeling skills
GUI/command line
For any macromolecule

Modeling PDB Hemoglobin Structures

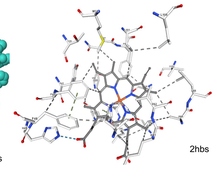
Amino Acid Structures of Interest



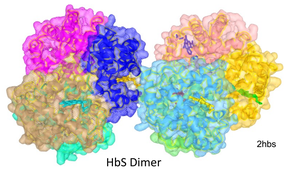
THE ONLINE MACROMOLECULAR MUSEUM
David Marcey, Cassidy R. Terrell
JSmol Tutorial - Hemoglobin



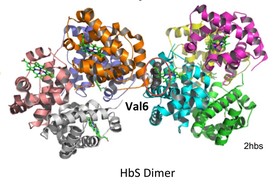
Ligand Interaction PDB



NCBI - iCn3D modeling software



PyMOL



Sickle Cell Hemoglobin (HbS): Beta-tested Classroom Experiences

General Chemistry I

- 48 students at Kennesaw State University
- Goal: Provide biological context for IMF
- 20 min of a 50 min class to show application of IMF
- Used first 2 minutes of video to introduce context.
- Instructor used OMM model as demonstration to highlight important aspects.
- Drew Lewis structures of amino acids on board to have students predict interactions.
- Used OMM to compare their predictions using the Lewis structures to what happens in the protein.

Intro to Chemical Structure and Properties

- 23 students at College of St. Benedict-St. John's University
- Goal: Understanding IMFs in a biological/medical setting
- Pre-class group assignment in flipped classroom activity where students watched video along with 2 videos describing sickle cell
- Each group is assigned a different PDB ID to investigate different aspects of Hb-ligand binding interactions.
- Students model using: Ligand PDB (heme); NCBI - iCn3D for HbS dimer
- Students present their portion of the Hb story to create a class story of Hb
- Class concludes with a discussion of how structure of Hb impacts function in the form of sickle cell.

A compelling and emotionally-charged story that links structure/function

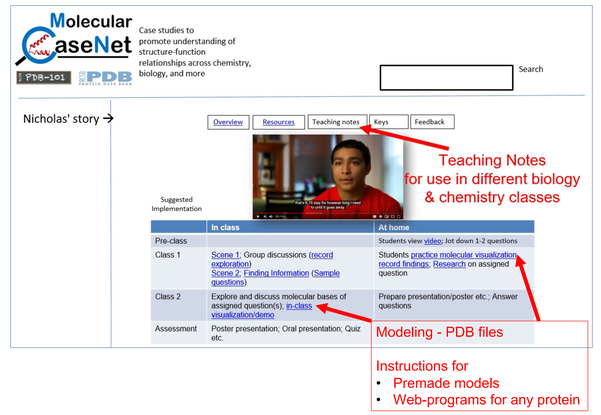
https://www.youtube.com/watch?v=iKQmQHh4E2w

Biochemistry (1 semester survey)

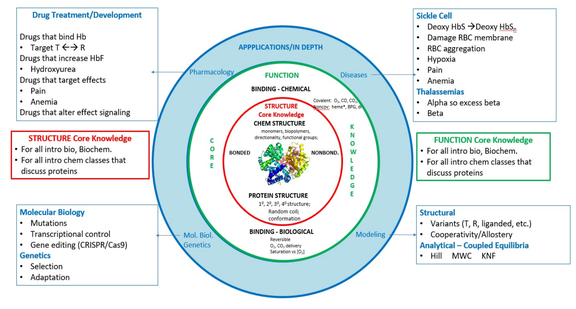
- 72 students at Kennesaw State University
- Goal: Structure impacts function of Hb ligand binding
- Pre-class videos and quiz in flipped classroom format
- 2 class periods used OMM to explore HbA structure and HbS structure
- Students self-guided exploration of the OMM to explore HbA structure
- Guided activity with questions to explore HbS structure with occasional whole-class guidance by instructor

Future Directions for Molecular CaseNet

A Planned Searchable Web Repository



Additional Case Studies Under Development



Sickle Cell Disease – continued
- Pain in Sickle Cell Disease
- Hydroxyurea treatment
- Thalassemia

New Molecules, New Cases
- COXI and COXII drugs
- LSD and serotonin
- Influenza and the MHC
- C-Si bonds & directed evolution

We would love to hear from you!

- What challenges do you face in connecting chemical concepts to biological concepts?
- Which part of the molecular case study cycle do you find to be most difficult to connect in your class?
  - Place a sticker next to the part of the cycle you find to be most challenging
- What challenges do you face in teaching how to develop and use models in your classroom?
- Are there other cases or systems you would like to have included?

- **Molecular CaseNet Workshop**
  - May 4, 2019
  - Emory University Atlanta, GA

Register Now!

- Join our group
- Use/evaluate case studies
  Contact - sdutta@rcsb.rutgers.edu

References

Hemoglobin A Structure, Sickle Cell Anemia, and Carbon Monoxide Toxicity. Marcey and Terrell. http://earth.callutheran.edu/Academic_Programs/Departments/BioDev/omm/jsmolnew/hemo/hemoglobina.html

Vision and Change: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4041499/

ASBMB Learning Goals: https://www.asbmb.org/education/teachingstrategies/foundationalconcepts/MacromolecularStructureFunction/

Next Generation Science Standard (NGSS) – 3D Learning. https://www.nextgenscience.org/three-dimensions