

Box of lessons:

An Open Educational Resource for Exploring Biomolecular Structure and Function

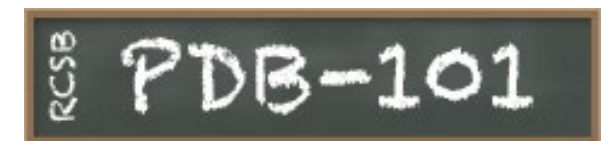
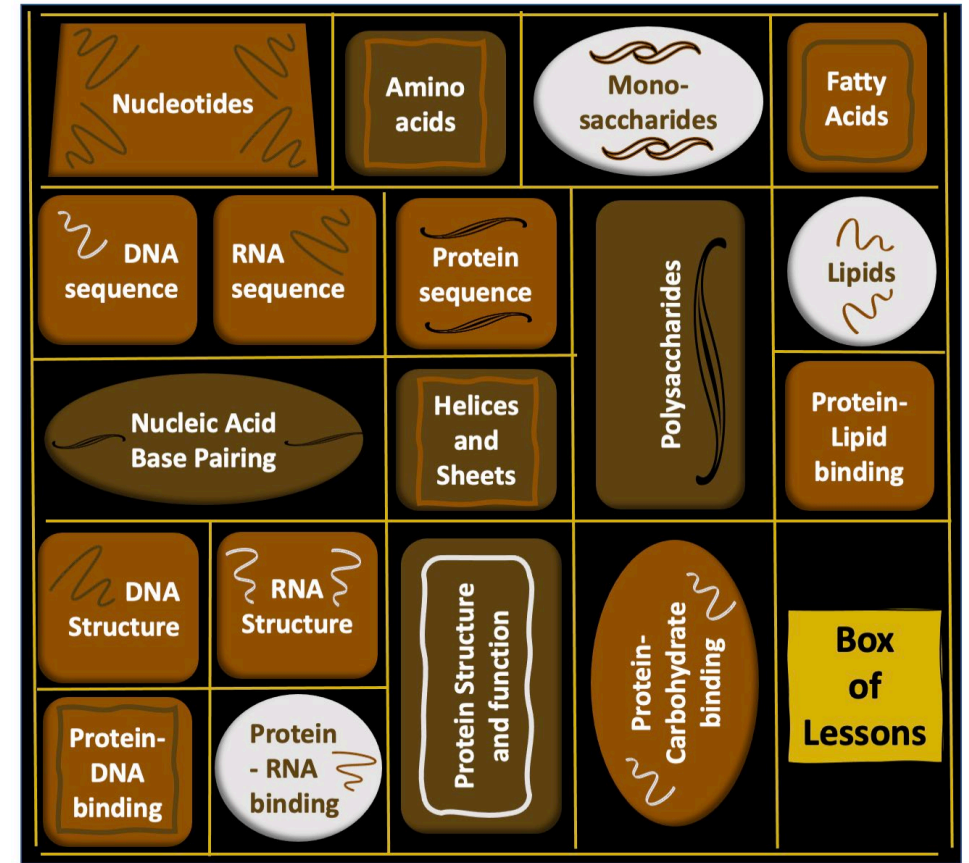
C2 Summit for Pedagogical Advancements in STEM,
Sep 29, 2023

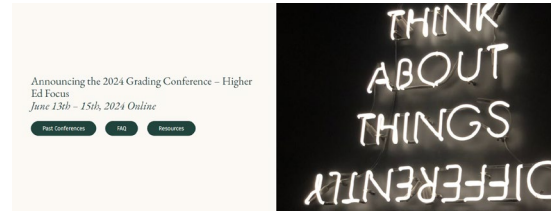
Melanie Lenahan, Ph.D.,

Raritan Valley Community College

Shuchismita Dutta, Ph.D.,

Rutgers University





Melanie Lenahan, PhD

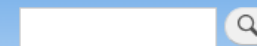
- Open Education
- OER
- Open Pedagogy
- Inclusive Teaching
- Alternative Grading
- Molecular Visualizations



Regional Leaders of Open Education



Case studies at the interface of Biology and Chemistry to learn about structure-function relationships.



[Home](#) [Molecular Case Studies \(S\)](#) [Resources](#) [Events](#) [Publications](#) [About Us](#)

Project, Key Personnel, and Funding

RCN-UBE: Engaging Educators in Developing and Using Molecular Case Studies at the Interface of Biology and Chemistry (2020 to~2025)

Mission: This proposal aims to grow and sustain a community of biology and chemistry educators interested in promoting student understanding and appreciation of the molecular basis of biological phenomena with relevance to real world problems and their solutions.

Funding: NSF Award DBI 2018884 ([Link to NSF](#))

Steering Committee:

Steering Committee



Shuchismita Dutta,
Rutgers University,
NJ



Caleb Trujillo,
University of
Washington, WA



Patricia Marsteller,
Emory University,
GA



David Marcey,
California
Lutherian
University, CA



Henry Jakubowski,
College of St.
Benedict, St.
John's Univ, MN



Melanie Lenahan,
Raritan Valley
Community
College, NJ



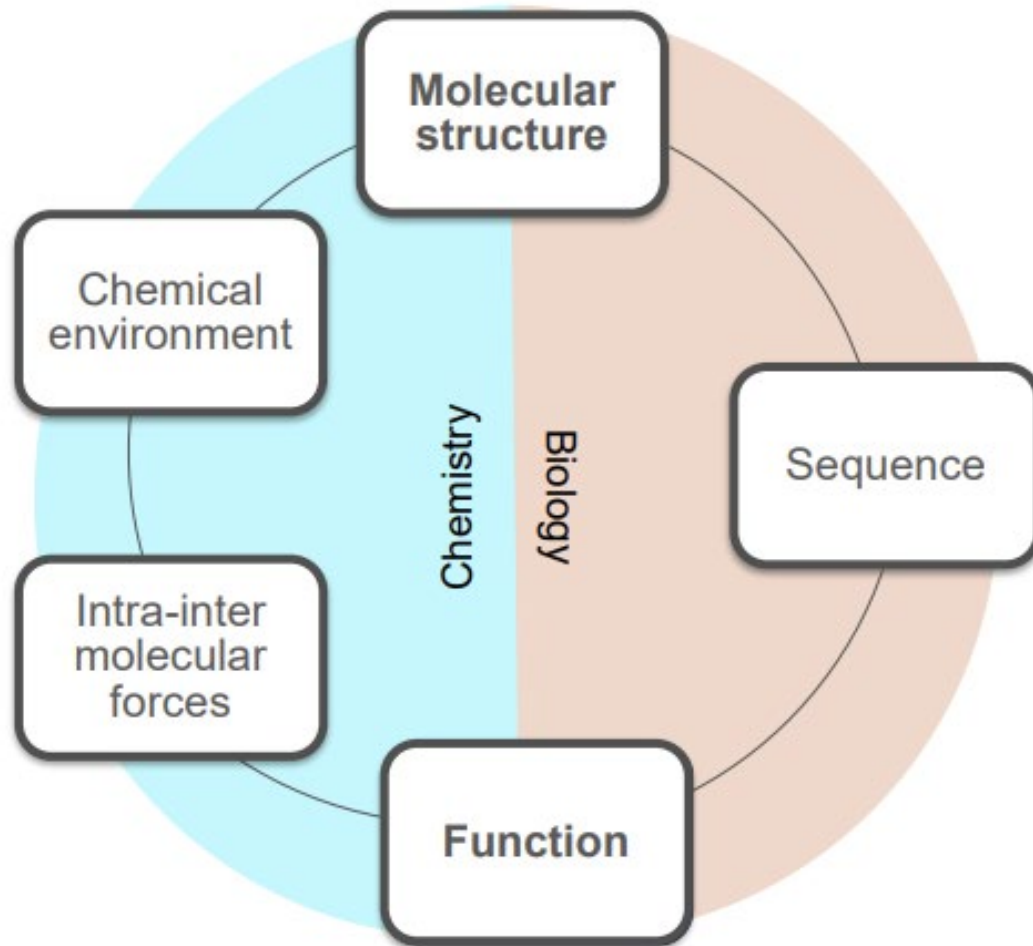
Sondra LoRe,
University of
Tennessee, TN

Evaluator

<https://molecular-casenet.rcsb.org/>

Do you have a learning
outcome that addresses
structure and function in a
course you teach?

It is challenging to integrate these concepts!



Biomolecular Visualization Skills

Student-Instructor visual misunderstanding of protein vs DNA helix (Credit: A. Harvey)

General Biology I (BIOL-101)



Active Learning Classroom

RESEARCH ARTICLE | APPLIED PHYSICAL SCIENCES

Measuring actual learning versus feeling of learning in response to being actively engaged in the classroom

Lois Deslauriers, Logan S. McCarty, Kelly Miller, and Greg Keaton

September 4, 2019 | 116 (39) 19251-19257 | <https://doi.org/10.1073/pnas.1821366116>

348,871 | 211

Significance

Despite active learning being recognized as a superior method of instruction in the classroom, a major recent survey found that most college STEM instructors still choose traditional teaching methods. This article addresses the long-standing question of why students and faculty remain resistant to active learning. Comparing passive lectures with active learning using a randomized experimental approach and identical course materials, we find that students in the active classroom learn more, but they feel like they learn less. We show that this negative correlation is caused in part by the increased cognitive effort required during active learning. Faculty who adopt active learning are



Active learning increases student performance in science, engineering, and mathematics

Scott Freeman, Sarah L. Eddy, Miles McDonough, and Mary Pat Wenderoth

Edited by Bruce Alberts, University of California, San Francisco, CA, and approved April 15, 2014 (received for review December 24, 2013)

May 12, 2014 | 111 (23) 8410-8415 | <https://doi.org/10.1073/pnas.1319020111>

699,960 | 3,077

Significance

The President's Council of Advisors on Science and Technology has recommended an increase in the number of science, technology, engineering, and mathematics (STEM) bachelors' degrees completed per year and recommended adopting validated teaching practices as critical to achieving that goal. This document states that active learning leads to increases in examination average grades by a half a letter, and that failure rates are reduced by 55% over the rates observed under active learning.

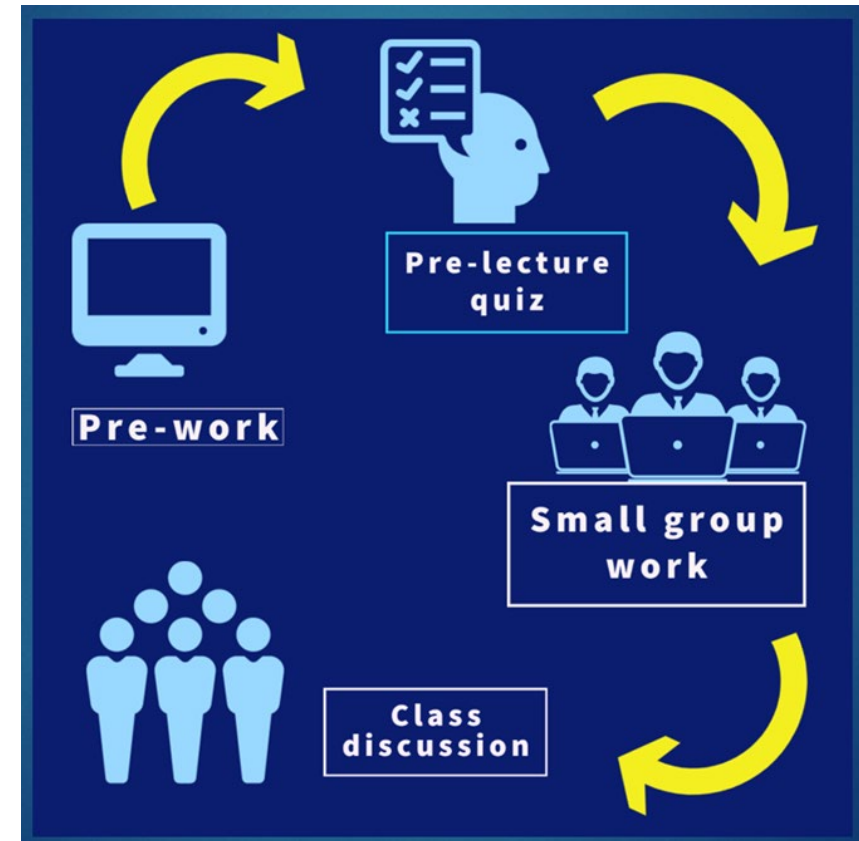
Active learning narrows achievement gap for underrepresented students in undergraduate science, technology, engineering, and math

Ellie Theobald, Mariah Hill, Elise Trapp, and Scott Freeman

Edited by Susan T. Fiske, Princeton University, Princeton, NJ, and approved February 7, 2020 (received for review September 27, 2019)

March 9, 2020 | 117 (12) 6476-6483 | <https://doi.org/10.1073/pnas.1916903117>

81,237 | 235

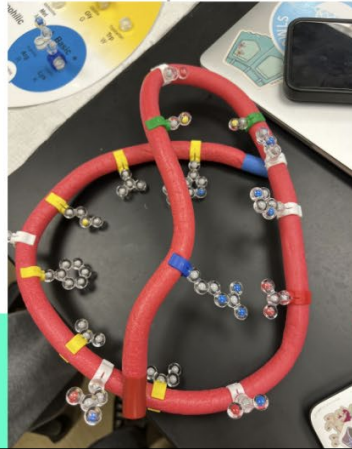


General Biology I – structure/function

Team 3

Covalent

Disulfide bonds



Non-covalent

Hydrogen Bonds
Hydrophobic Interactions
Ionic Bonds
Van Der Waals Interaction

Model 1

Amylose:
3) 2 glucose units
4) α -1, 4 bond
5) 7 pieces, easiest to digest



Model 2

Amylopectin:
3) 3 glucose units
4) α -1, 6 bond
4) α -1, 4 bond
5) 12 pieces, next easiest to digest



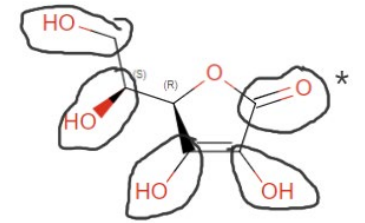
Model 3

Cellulose:
3) 4 glucose units
4) (2) β -1, 4 bonds
5) 14 pieces, hardest to digest



3

1. This molecule is a carbohydrate



2. $C_6H_{12}O_6$

3. Carbon is the backbone

4. 20 bonds

5. hydrophilic

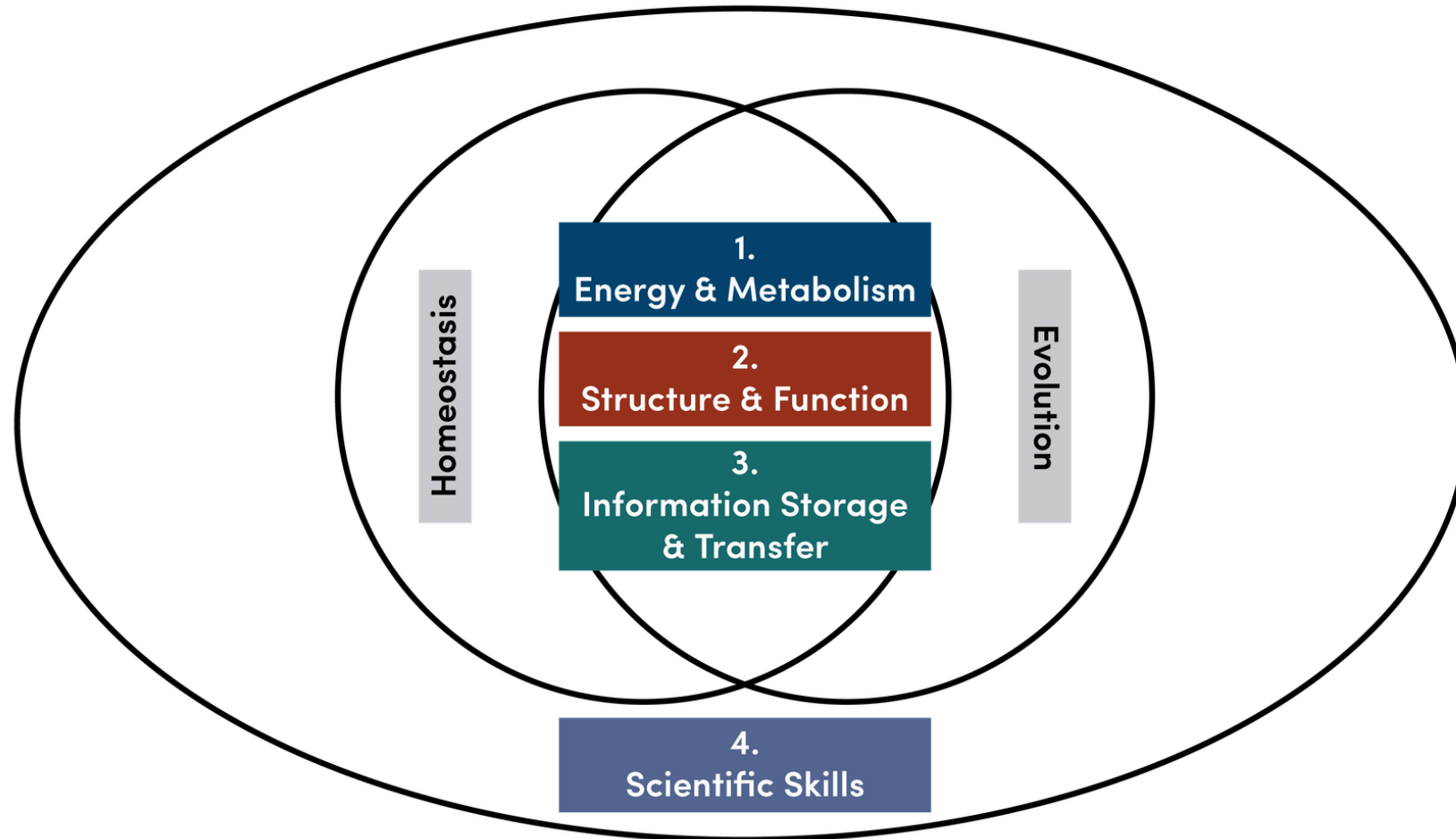
6. Everything circled is either Carbonyl or hydroxyl. The one with the * is the only Carbonyl.

7. 2 chiral atoms

Foundational Concepts



AMERICAN SOCIETY FOR BIOCHEMISTRY AND
MOLECULAR BIOLOGY



<https://www.asbmb.org/education/core-concept-teaching-strategies/foundational-concepts>

Core Concepts of Vision & Change (for Biology)

BioCore Guide

INFORMATION FLOW	Overarching Principles: Organisms inherit genetic and epigenetic information that influences the location, timing, and intensity of gene expression. Cells/organs/organisms have multiple mechanisms to perceive and respond to changing environmental conditions.		
	In most cases, genetic information flows from DNA to mRNA to protein, but there are important exceptions.	Information stored in DNA is expressed as RNA and proteins. These gene products impact anatomical structures and physiological function.	Individuals transmit genetic information to their offspring; some alleles confer higher fitness than others in a particular environment.
	Gene expression and protein activity are regulated by intracellular and extracellular signaling molecules. Signal transduction pathways are crucial in relaying these signals.	Organisms have sophisticated mechanisms for sensing changes in the internal or external environment. They use chemical, electrical, or other forms of signaling to coordinate responses at the cellular, tissue, organ, and/or system level.	A genotype influences the range of possible phenotypes in an individual; the actual phenotype results from interactions between alleles and the environment.
	The signals that a cell receives depend on its location, and may change through time. As a result, different types of cells express different genes, even though they contain the same DNA.		
STRUCTURE FUNCTION	Overarching Principles: Biological structures exist at all levels of organization, from molecules to ecosystems. A structure's physical and chemical characteristics influence its interactions with other structures, and therefore its function. Natural selection leads to the evolution of structures that tend to increase fitness within the context of evolutionary, developmental, and environmental constraints.		
	The structure of a cell--its shape, membrane, organelles, cytoskeleton, and polarity--impacts its function.	Physiological functions are often compartmentalized into different cells, tissues, organs, and systems, which have structures that support specialized activities.	Natural selection has favored structures whose shape and composition contribute to their ecological function.
	The three dimensional structure of a molecule and its subcellular localization impact its function, including the ability to catalyze reactions or interact with other molecules. Function can be regulated through reversible alterations of structure e.g. phosphorylation.	The size, shape, and physical properties of organs and organisms all affect function. The ratio of surface area to volume is particularly critical for structures that function in transport or exchange of materials and heat.	Competition, mutualism, and other interactions are mediated by each species' morphological, physiological, and behavioral traits. Figure 3.
	The structure of molecules or organisms may be similar due to common ancestry or selection for similar function.	Structure constrains function in physiology; specialization for one function may limit a structure's ability to perform another function.	
Molecules → Ecosystems (smaller and faster) → (larger and slower) Biological Scale			

About the Box of Lessons

Molecular Casenet is supported by the National Science Foundation - DBI 1827011; DBI 2018884



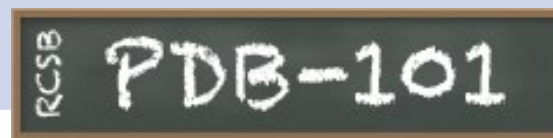
Developed as a collaborative effort of members participating in the Molecular CaseNet Spring 2022 Faculty Mentoring Network



Reviewed by ~30 educators nationwide in Fall 2022



Piloted by ~8 faculty worldwide in Spring 2023.



Published on PDB-101 in Sep 2023



QUBES
A BioQUEST Project

Motivation for the “Box of Lessons”



Free (OER)



Engage students in active learning



Help in teaching/learning introductory level UG courses in Biology/Biochemistry



Literature based examples to explore biomolecular structure and function



Uses data and tools from open access data resources



Variety of lessons to match curricular themes and student needs



Provides a template to develop lessons on new topics (as needed)



Can be used in public, private, and community colleges and universities

How to Use the Box of Lessons

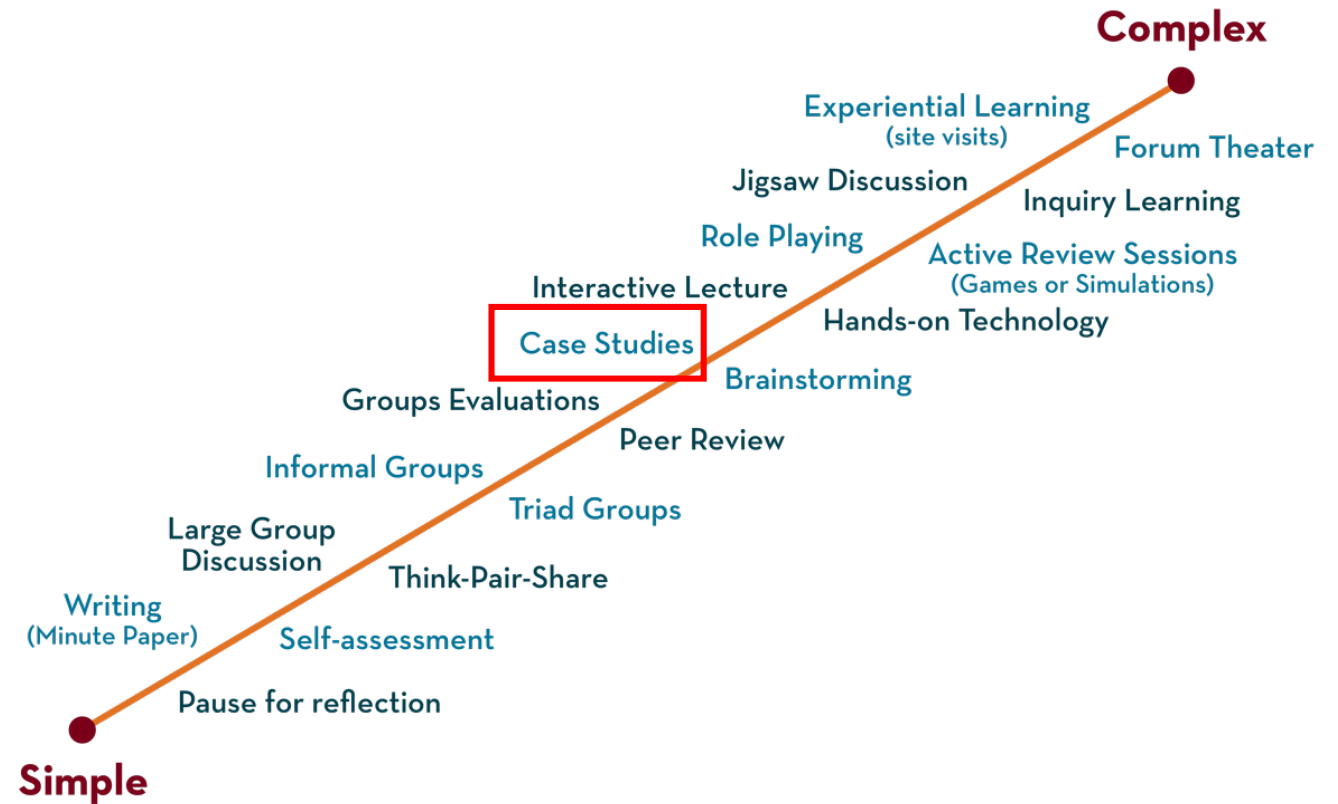


Image - [Active Learning Strategy Spectrum](#)
[University of Minnesota Center for Educational Innovation](#)

How to access the Box of Lessons

RCSB PDB Deposit Search Visualize Analyze Download Learn About Documentation Careers COVID-19 MyPDB Contact us

210,180 Structures from the PDB
1,068,577 Computed Structure Models (CSM)

Advanced Search | Browse Annotations | Help

3D Structures Enter search term(s), Entry ID(s), or sequence Include CSM

PDB-101 PDB PDB-Dev

New: More Computed Structure Models (CSM) available

Welcome

Deposit Search Visualize Analyze Download Learn

RCSB Protein Data Bank (RCSB PDB) enables breakthroughs in science and education by providing access and tools for exploration, visualization, and analysis of:

- Experimentally-determined 3D structures from the Protein Data Bank (PDB) archive
- Computed Structure Models (CSM) from AlphaFold DB and ModelArchive

These data can be explored in context of external annotations providing a structural view of biology.

Explore NEW Features

Virtual Crash Course

Leveraging RCSB PDB APIs for Bioinformatics Analyses and Machine Learning

October 12 | Register Now!

September Molecule of the Month

Histone Deacetylases

Latest Entries As of 10p_Sep_26_2023

Features & Highlights

ASBMB Members: Register Now for Virtual Event

Learn about Teaching enzymology with the Protein Data Bank: from pandemic to Paxlovid on October 19.

Register Now for October Virtual Crash Courses on RCSB PDB APIs

Learn about Leveraging RCSB PDB APIs for Bioinformatics Analyses and Machine Learning. Part 1 will introduce the Data and Search APIs. Part 2 will

News

Publications

Undergrads/Grads: Apply to the January 2024 Science Communication Boot Camp

Limited spaces available for the Science Communication in Biology and Medicine Virtual Boot Camp: January 8-12, 2024. Applications due October 31, 2023. # 09/25/2023

Poster Prize Awarded at ACA 2023

Congratulations to Alexander Paredes for his exceptional presentation of the

PDB-101 Molecule of the Month Browse Learn Train Teach Global Health SciArt Events About

PDB-101 Molecular explorations through biology and medicine

Search Molecule of the Month articles and more

Go

Training and outreach portal of PDB

Molecule of the Month September 2023

Histone Deacetylases

Histone deacetylases regulate access to genetic information by modifying histones

More

3D View: 1154

Style Color Spin

- Cartoon
- Rainbow
- On

- Spheres
- Chain
- Off

- Surface
- Structure
- Off

All articles: By Date | By Category | By Title

Health Focus: Cancer Biology and Therapeutics

Cells in our bodies are carefully regulated so that they divide, grow, and die according to the best plan for keeping us alive. When they lose these controls, they can grow into deadly cancers. Atomic structures have revealed how cell growth is normally controlled, and how cancer cells circumvent these essential controls. Explore PDB-101 Resources to learn about proteins related to cancer biology and therapeutics.

2023 Video Challenge for High School Students

Molecular Mechanisms of Targeted Cancer Therapies

Thanks to all challenge participants, expert judges, teachers, parents, and voters who made this competition happen. Congratulations to the 2023 Winners!

News and Events

ASBMB Members: Register Now for Virtual Event

09/26/2023

Undergrads/Grads: Apply to the January 2024 Science Communication Boot Camp

09/25/2023

PDB-101 Molecule of the Month Browse Learn Train Teach Global Health SciArt Events About

PDB-101 Molecular explorations through biology and medicine

Search Molecule of the Month articles and more

Go

Training and outreach portal of PDB

Curriculum Modules Overview Discussion Forum Contact Us Teacher Log In

Curriculum Modules

Curriculum Modules

- Biomolecular Structures and Models
- COVID-19 in Molecular Detail
- Diabetes at a Molecular Level
- Molecular Immunology
- Molecular View of HIV/AIDS
- Box of Lessons

Overview

RCSB PDB Curriculum Modules include authentic data from existing public resources, hands-on activities, teaching materials, individual and group activities and assessment suggestions. They were developed through the collaboration and participation of scientists, curriculum design experts, educators, clinicians and local teachers.

Take a Video Tour of the Curriculum Modules

<https://www.rcsb.org/>

<https://pdb101.rcsb.org/>

Link: <http://bit.ly/3LGa1zY>



Box of Lessons

Biological Macromolecules >

Proteins >

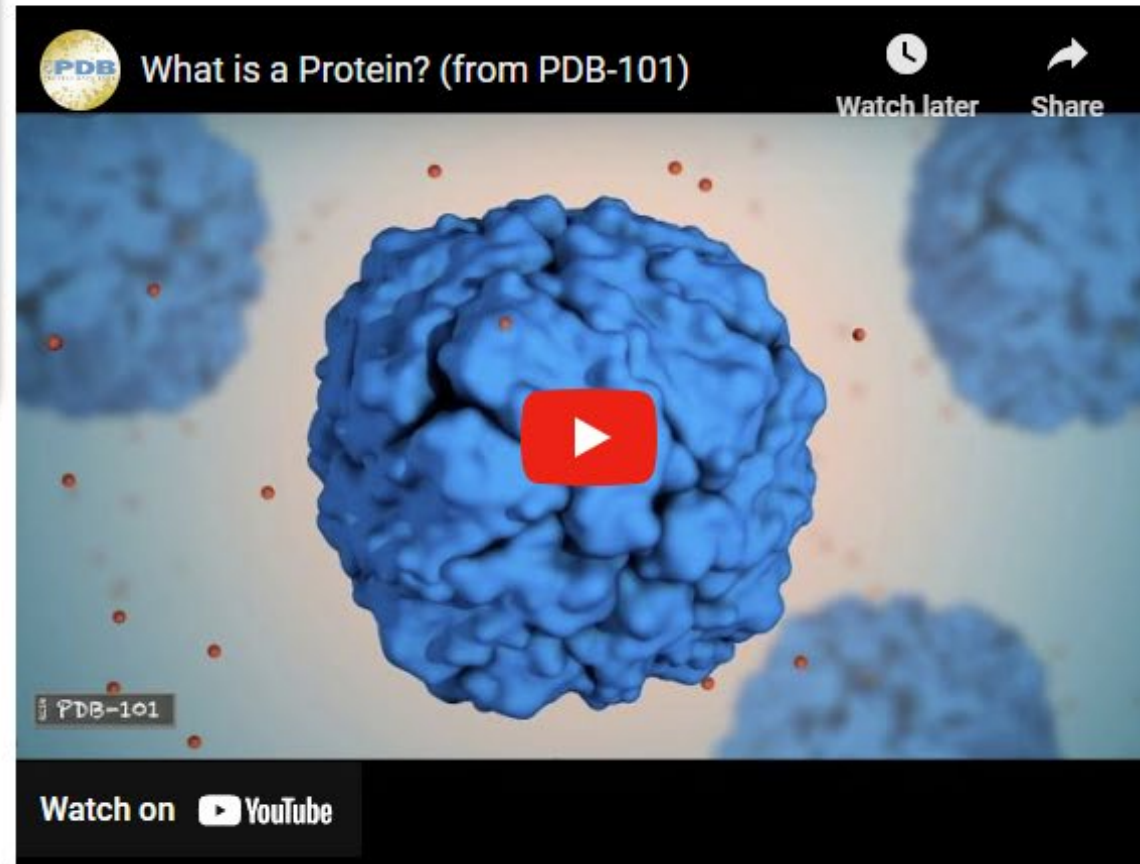
Nucleic Acids >

Carbohydrates >

Lipids >

Includes a total of **21 ready-to-implement activities** for students and **9 associated learning materials**

Proteins



Learning Materials

- [Amino Acids in the PDB](#)
- [Exploring Levels of Protein Structure in the PDB](#)
- [Handedness and Twist](#)

Activities

- [Exploring Amino acids-Ex](#)
- [Protein Sequences-Ex](#)
- [Helices and Sheet-Ex](#)
- [Insulin Structure & Function-Ex](#)
- [Hemoglobin Structure and Function-Ex](#)

Activity Key & Teaching Notes

- [Exploring Amino acids-key](#)
- [Protein Sequences-key](#)
- [Helices and Sheet-key](#)
- [Insulin \(a hormone\) Structure and Function-key](#)
- [Hemoglobin \(a transporter\) Structure and Function-key](#)

What does an activity look like?

Hemoglobin Structure and Function

Authors: Shuchismita Dutta, Rutgers University, NJ

Lesson Overview:

This lesson introduces the structure and function of a molecule (hemoglobin). It begins by reviewing the RCSB Molecule of the Month article on the molecule and explores the ready-made static and interactive models of the structure. Subsequent parts of the lesson use RCSB PDB tools and resources to visualize and analyze the molecular structure to learn more about the structure and function of the protein.

Note: *There are several sections in this activity. Feel free to select and use parts of the exercise aligned with your curricular/course learning goals.*

ASBMB Learning Objectives (<https://www.asbmb.org/education/core-concept-teaching-strategies/foundational-concepts/structure-function>)

2. Several factors determine structure

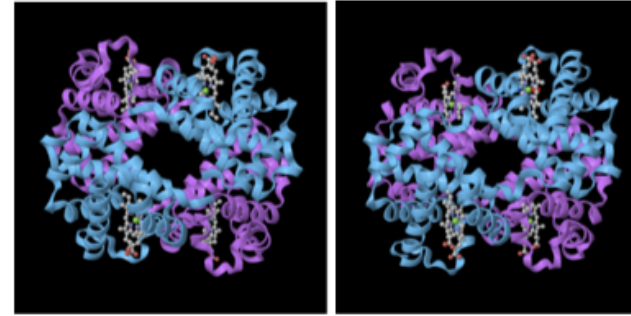
- Students should be able to **recognize the repeating units** in biological macromolecules and discuss the **structural impacts of the covalent and noncovalent interactions involved** (*Introductory*).
- Students should be able to compare and contrast the **primary, secondary, tertiary, and quaternary structures** of proteins (*Intermediate*).
- Students should be able to **use various bioinformatics approaches to analyze** macromolecular primary **sequence and structure** (*Intermediate*).

What does an activity look like?

Details:

Go to the “Exploring the Structure” section in the article and analyze the structures shown in detail. Examine the static images and JSmol interactive views, where available.

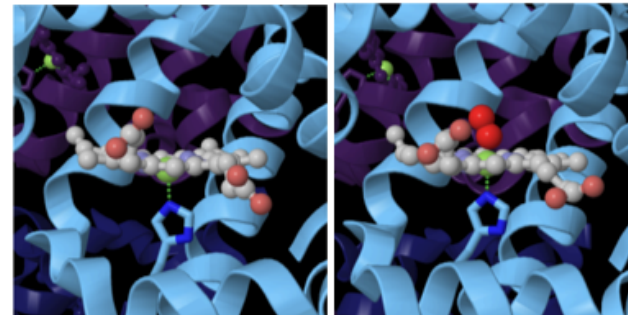
2. Take screenshots of two views of the entire hemoglobin protein (in JSmol) - **oxy and deoxy states** and include them in your answer. Describe any one structural feature that is different in these images. Upload your screenshots to Jamboard.



Deoxy state

Oxy state

3. Create two images showing a closeup of the Heme groups in the oxy and deoxy states. Describe the interactions stabilizing the heme group and the oxygen binding (in the oxy state). Note that the CPK colors used for the heme group show carbon in gray, nitrogen in blue, oxygen in red, and sulfur in yellow. Upload your screenshots to Jamboard.



Deoxy state

Oxy state

Let's try
an activity....

<https://www.rcsb.org/structure/2HHB>



Go to the [RCSB PDB home page](https://www.rcsb.org), enter the hemoglobin PDB code 2hhb in the top search box, and click on it to open the Structure summary page for deoxy human hemoglobin or go to the page (<https://www.rcsb.org/structure/2hhb>).

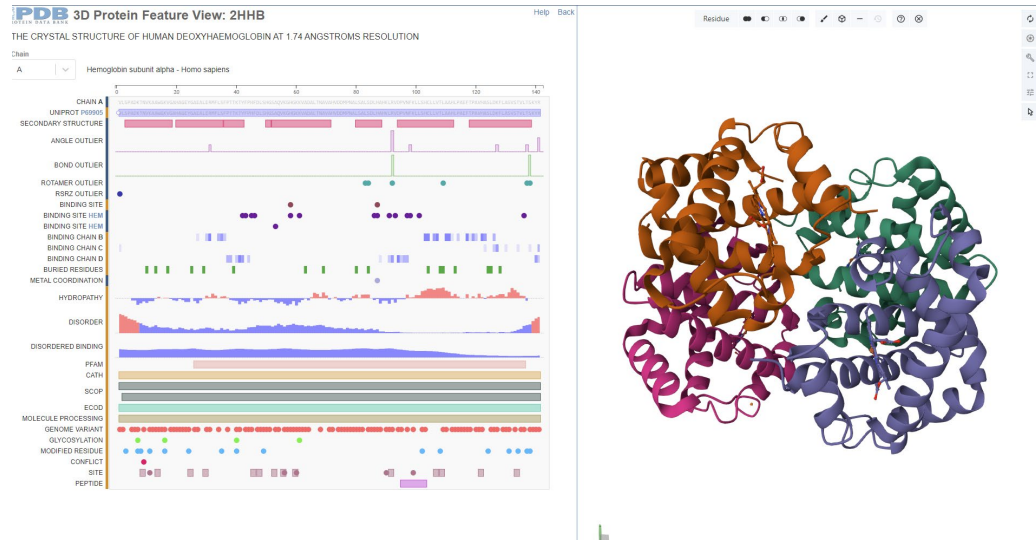
On the top left corner of the page, there is an image showing the molecule's structure.

A screenshot of the RCSB PDB structure page for PDB ID 2HHB. The main image shows a 3D ribbon representation of the deoxy-hemoglobin molecule, composed of four subunits: two alpha subunits (colored green and orange) and two beta subunits (colored pink and violet). Below the image is a navigation menu with links for '3D View: Structure', '1D-3D View', 'Electron Density', 'Validation Report', and 'Ligand Interaction'. The '1D-3D View' link is highlighted with a red box. Below the menu, there are sections for 'Global Symmetry: Cyclic - C2 (3D View)', 'Global Stoichiometry: Hetero 4-mer - A2B2', 'Pseudo Symmetry: Dihedral - D2 (3D View)', and 'Pseudo Stoichiometry: Homo 4-mer - A4'.

Figure 2: Structure of the deoxy-hemoglobin molecule (PDB ID 2hhb) - composed of four subunits - two copies each of the Hemoglobin alpha protein (colored in green and orange), and two copies of the Hemoglobin beta protein (colored in pink and violet). The four subunits interact with each other through non-covalent interactions.

Click on the hyperlink “1D-3D View” to launch a view of this molecule.

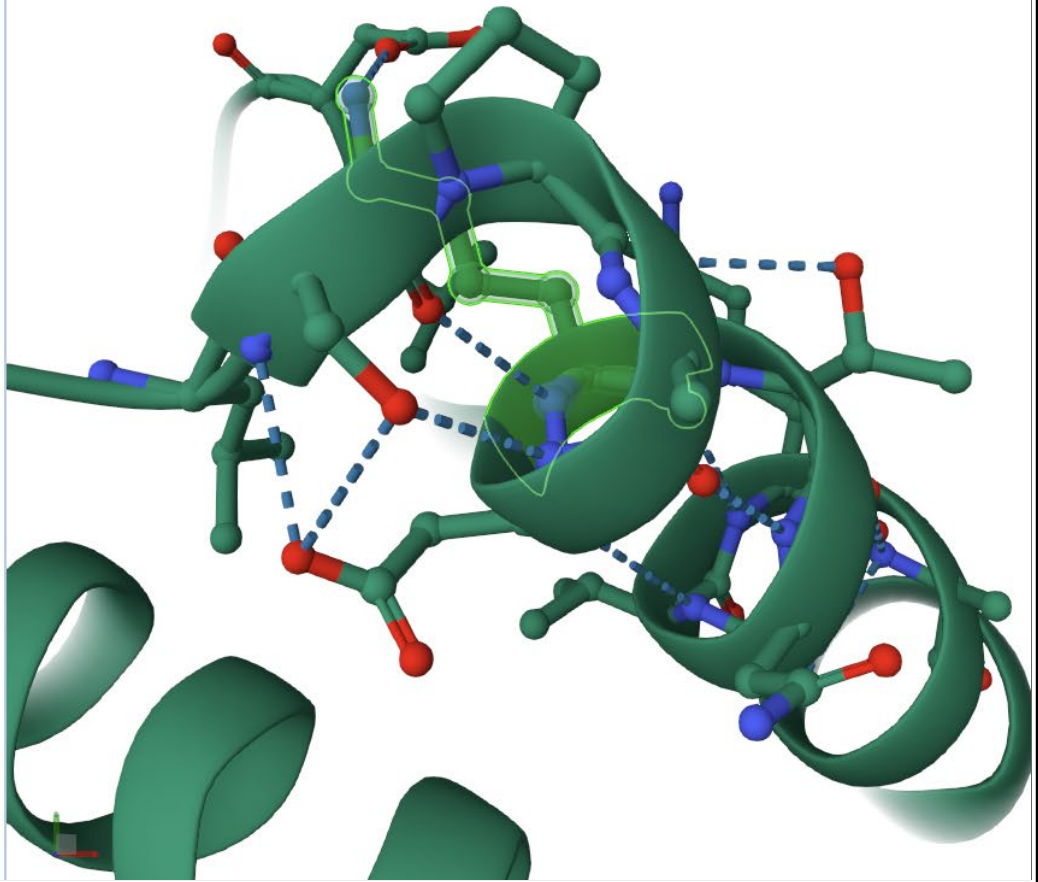
- In this view, one panel shows the (1D) sequence of the protein chains in hemoglobin, and the other shows its 3D structure.
- The two panels are connected, so clicking on a specific amino acid in the 1D panel selects and centers the 3D structure view on the same amino acid and displays the interactions around the specific amino acid.
- The 1D sequence panel also displays various annotations about it (e.g., secondary structure, hydropathy, metal binding)



Let's try
an activity....

G. Tertiary structure:

- a. Identify the **amino acid #7** in Chain A (Hemoglobin alpha) - what is it?
- b. Click on this amino acid to focus (zoom in and center) on it, display the amino acids within 5Å, and show non-covalent interactions among them. List the **amino acid(s) forming non-covalent interactions** with the side chain of the amino acid #7. List the type of non-covalent interaction. Support your answer with an image of the interaction.



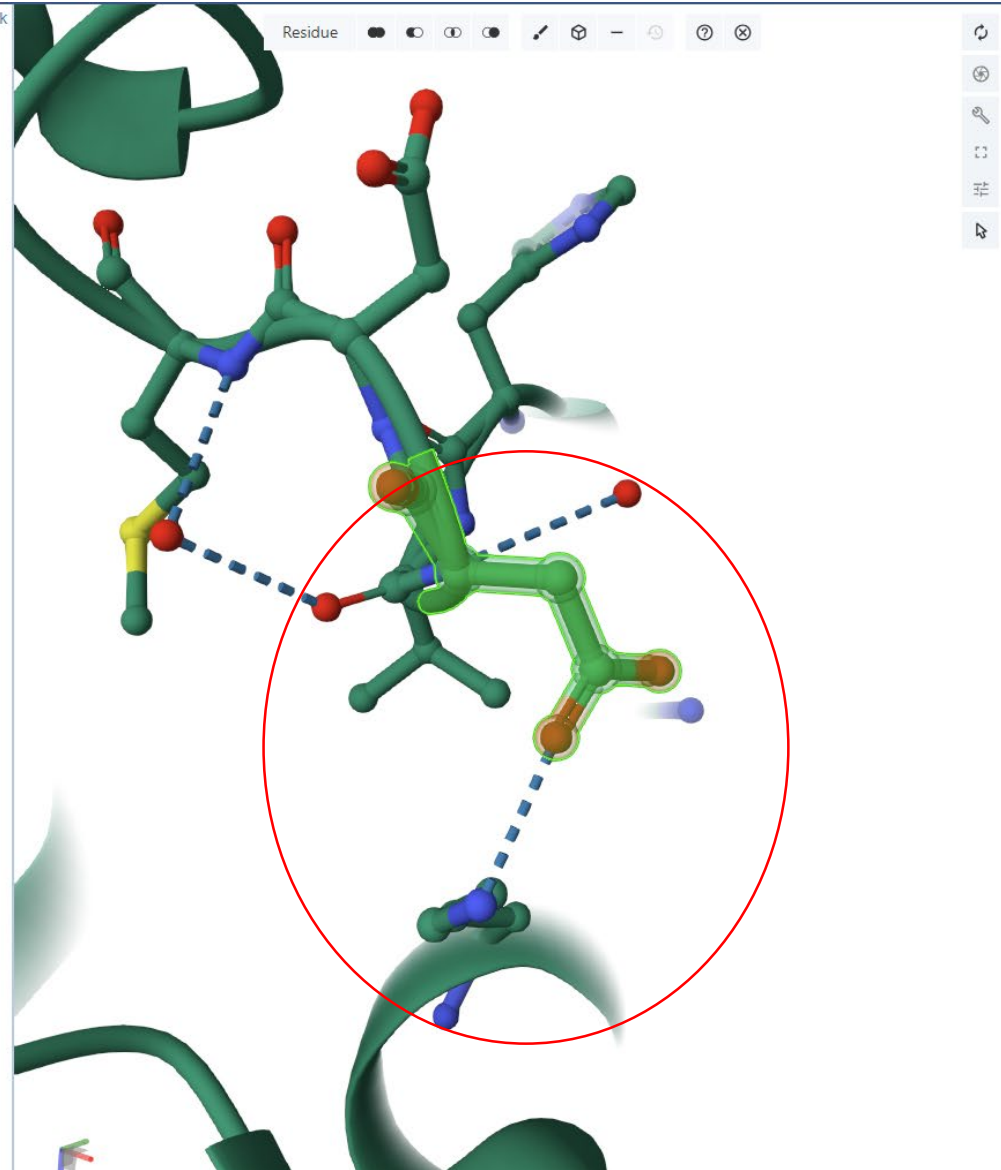
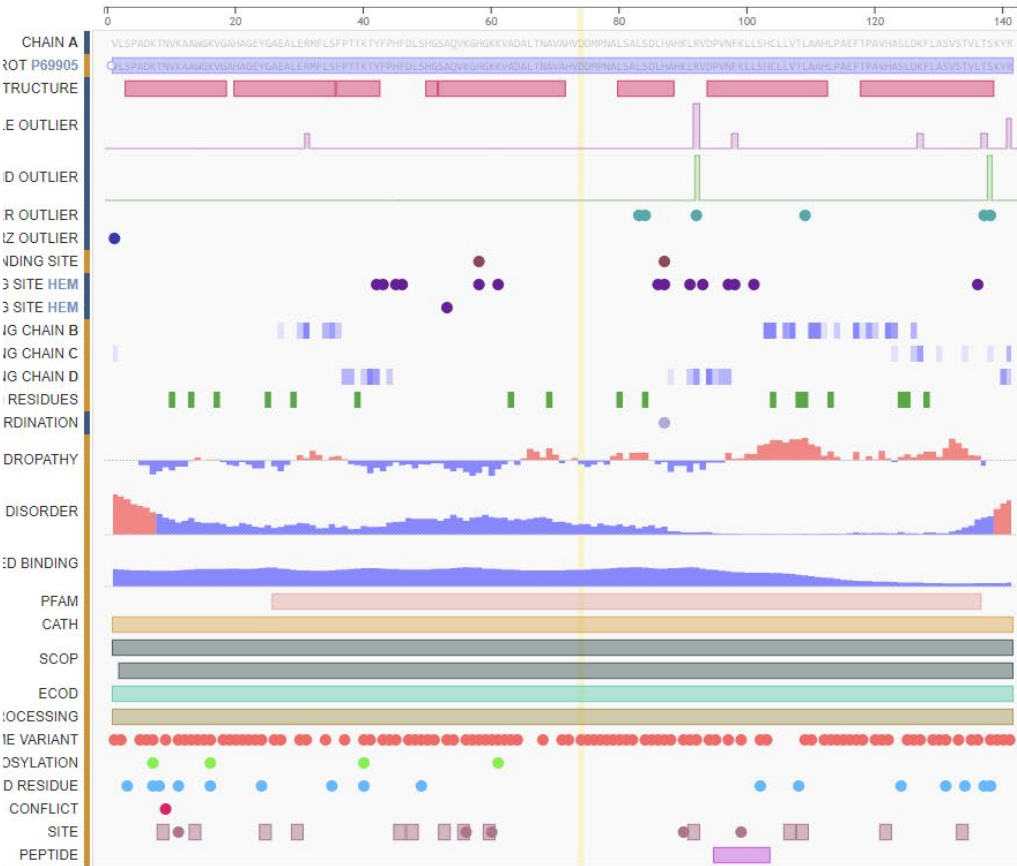
Let's try an activity....

3D Protein Feature View: 2HHB

Help Back

STRUCTURE OF HUMAN DEOXYHAEMOGLOBIN AT 1.74 ANGSTROMS RESOLUTION

Hemoglobin subunit alpha - Homo sapiens



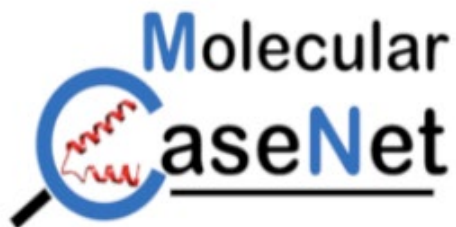


Could engaging your student in exploring biomolecular structural data enhance their learning experience in your course?

How could you use these resources to do so?

Are there other lessons you would like to see added to the collection?

Want to learn more about
Molecular Case Studies?



Visit Website:

<https://molecular-casenet.rcsb.org/>

Write to Shuchi Dutta at
sdutta@rcsb.rutgers.edu

Molecular CaseNet

Molecular Case Studies ▾



Molecular CaseNet is ...

A community of educators and scholars developing and using Molecular Case Studies (MCS), promoting exploration of the molecular basis of biological phenomena, understanding real world problems, and developing solutions at the interface of biology and chemistry.

Molecular Case Studies can help introduce students (and teachers) to molecular visualization and analysis, and engage them in using authentic research data from open access biological databases, and mainstream bioinformatics tools. Each case is modular, interdisciplinary, adaptable to different curricular contexts, and completes at least one [Molecular Case Study](#) cycle. Explore examples.

How to connect with Molecular CaseNet?

Browse through the [Molecular CaseNet website](#) to access molecular case studies for free

To develop new case studies or share adaptations

- Join a Molecular CaseNet Cohort - write to [Shuchi Dutta](#).
- Join an QUBES Faculty Mentoring Network (FMN) or a Biome working group.

Why connect with Molecular CaseNet?

Educator Benefits:

- Free access to MCS (this is an OER)
- Opportunities to engage students in exploring molecular structures (PDB) and a variety of open access data resources
- Connect with a community of educators developing and participating in Professional Development

Student Benefits:

- Introduction to authentic data resources
- Opportunities to experience the scientific method (including authoring molecular case studies for submission to Molecular CaseNet)
- Engaging and real-world examples of concepts and skills from multiple disciplines



Thank you!

- Contact:
- Melanie Lenahan
- melanie.lenahan@raritanval.edu

Acknowledgements

- Molecular Casenet is supported by the National Science Foundation - DBI 1827011; DBI 2018884
- All members of the Molecular CaseNet Spring 2022 QUBES FMN inspired and contributed towards the development of the “Box of Lesson”
 - Several members are still engaged in refining and evaluating the BOL
- The RCSB Protein Data Bank team works to bring data, tools, and resources to researchers, educators, students, and the curious public.

