Box of lessons:

An Open Educational Resource for Exploring Biomolecular Structure and Function

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

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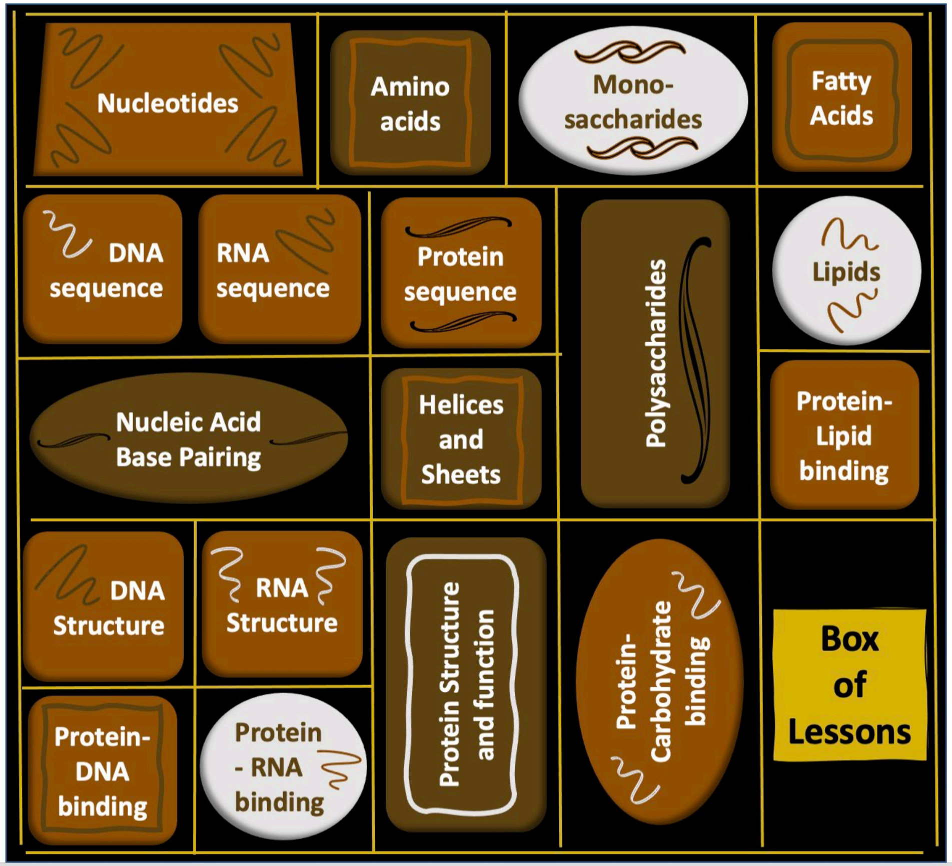
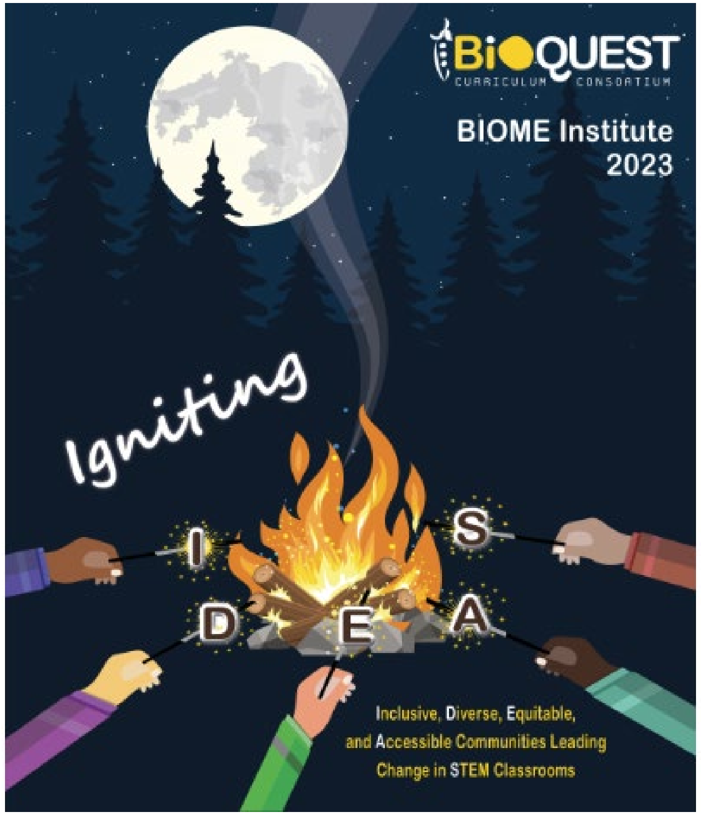
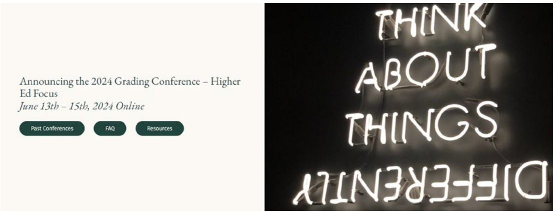






Regional Leaders of Open Education

Melanie Lenahan, PhD

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

Molecular CaseNet

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.

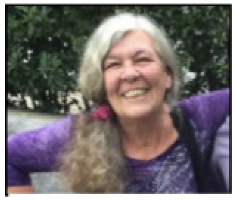
Funding: NSF Award DBI 2018884 (Link to NSF)

Steering Committee:

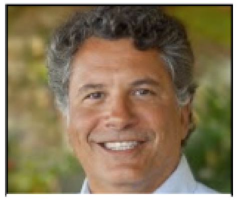
Steering Committee

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

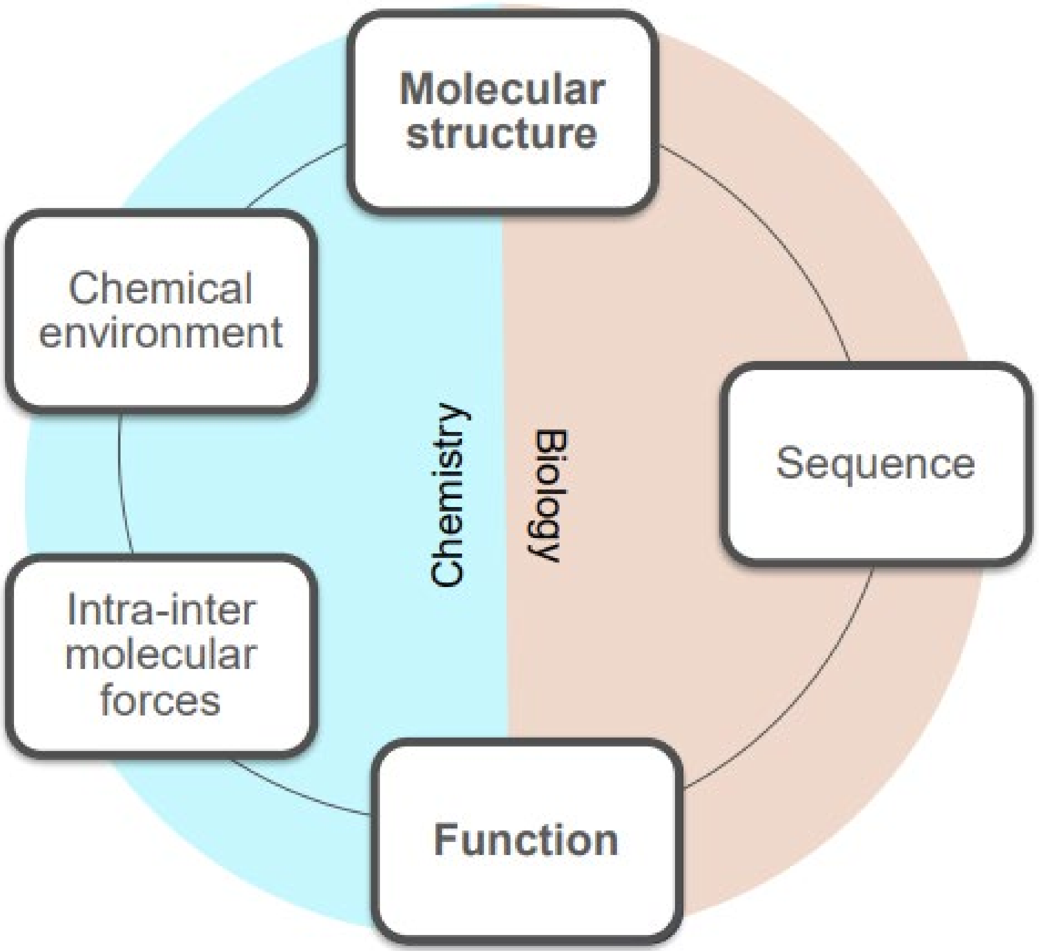
Evaluator

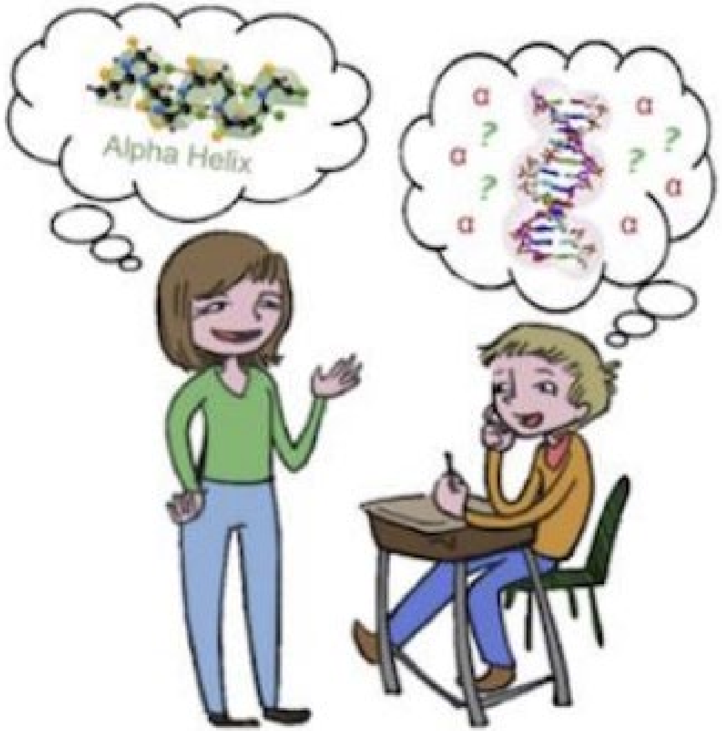
Sondra LoRe, University of Tennessee, TN

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!

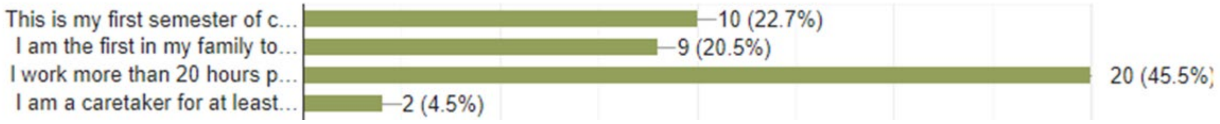


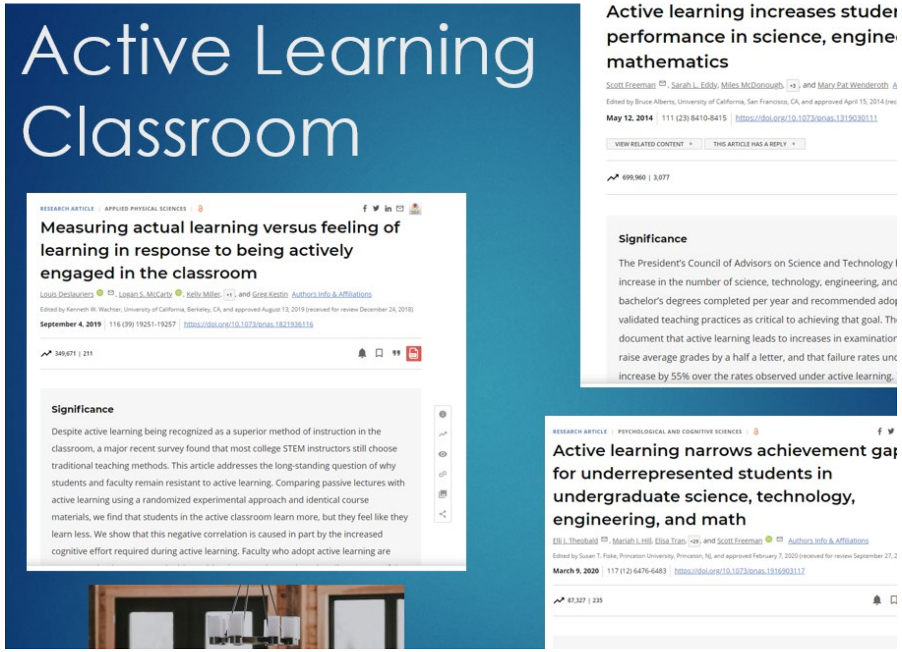


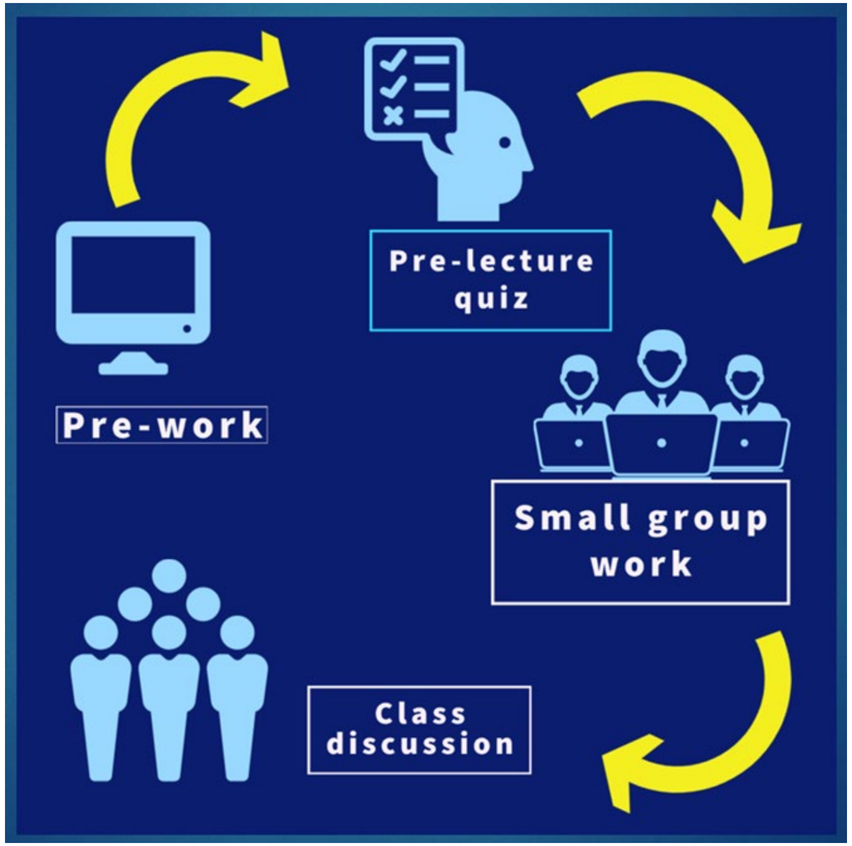
Biomolecular Visualization Skills

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

General Biology I (BIOL-101)





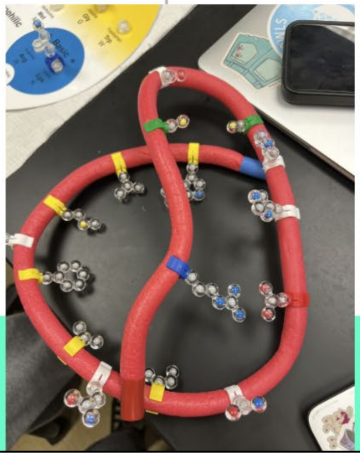


General Biology I – structure/function

Team 3

Covalent

Disulfide bonds

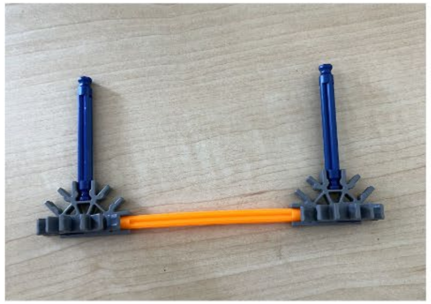


Non-covalent

Hydrogen Bonds
Hydrophobic Interactions
Ionic Bonds
Van Der Waals Interaction

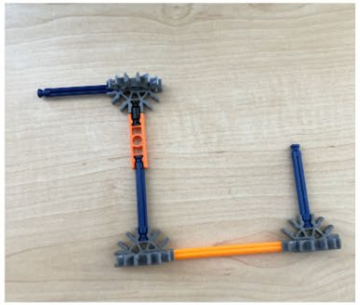
Model 1

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



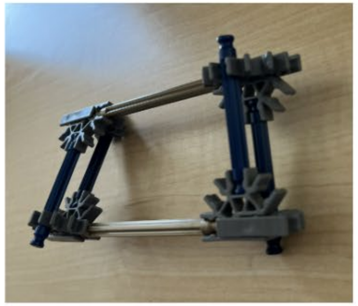
Model 2

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



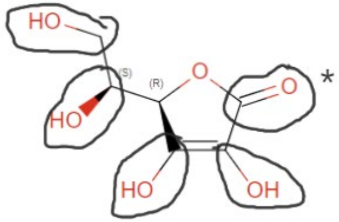
Model 3

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



3

1. This molecule is a carbohydrate



2. C6H8O6

3. Carbon is the backbone

4. 20bonds

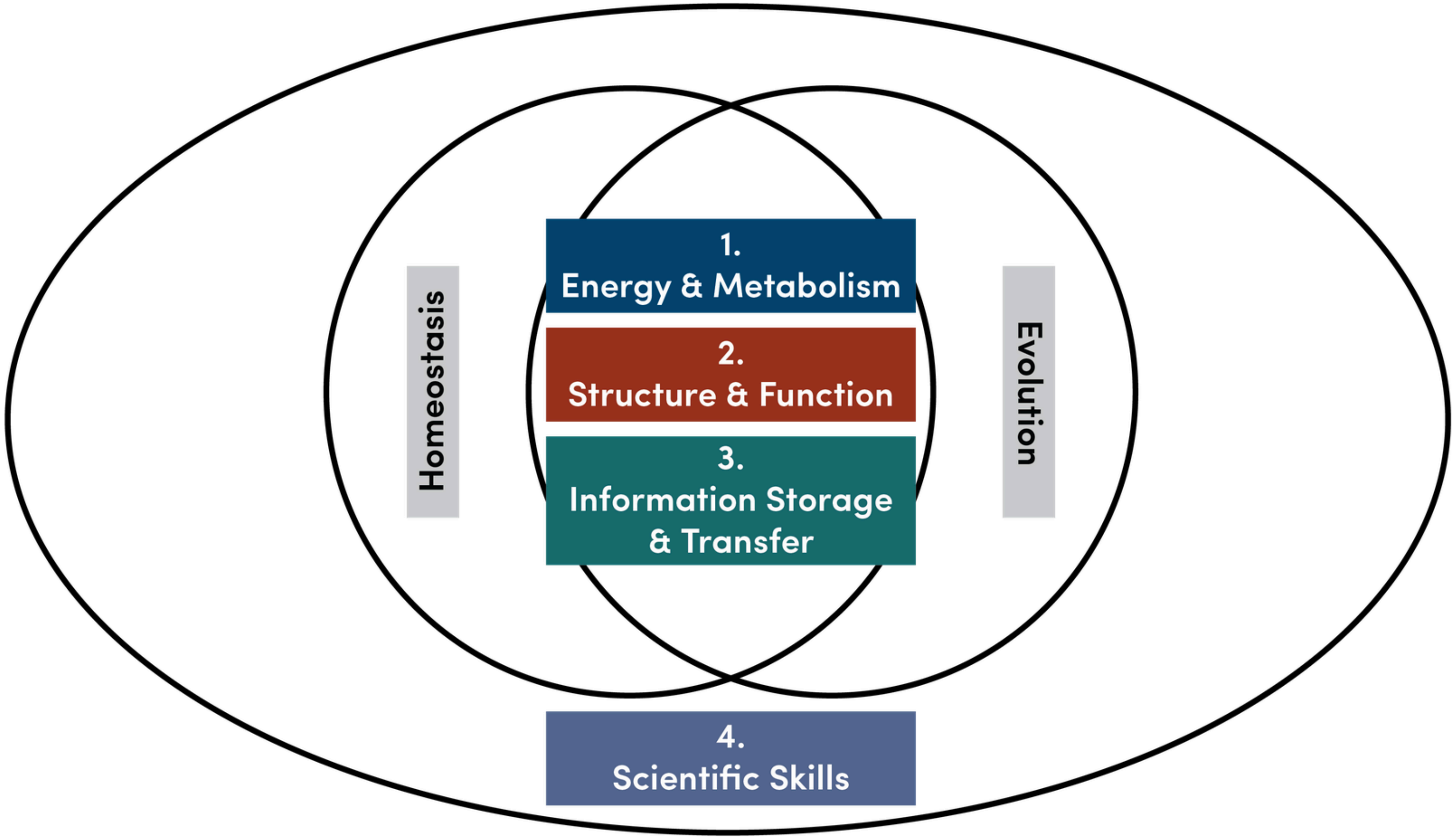
5. hydrophilic

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 (smaller and faster) → **Ecosystems (larger and slower)**

Biological Scale

https://www.lifescied.org/doi/10.1187/cbe.13-12-0233

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

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

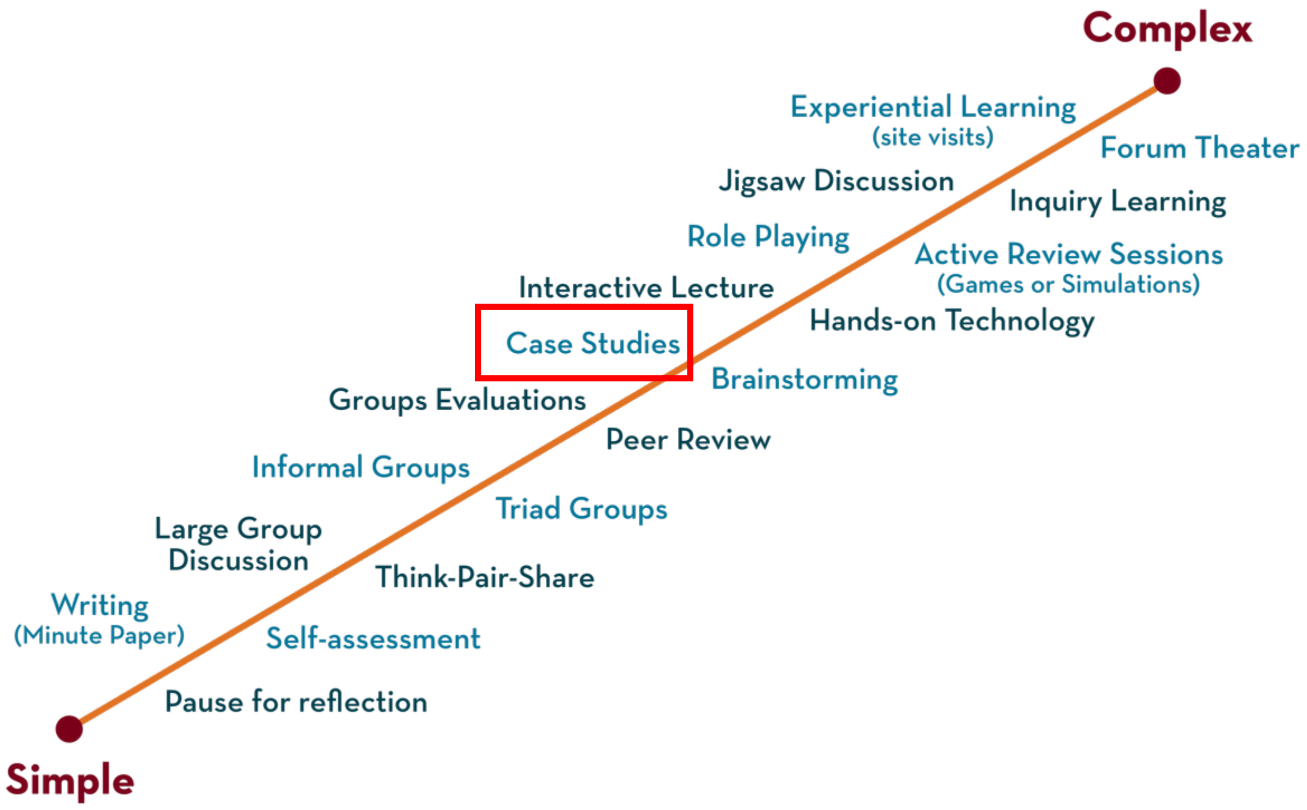
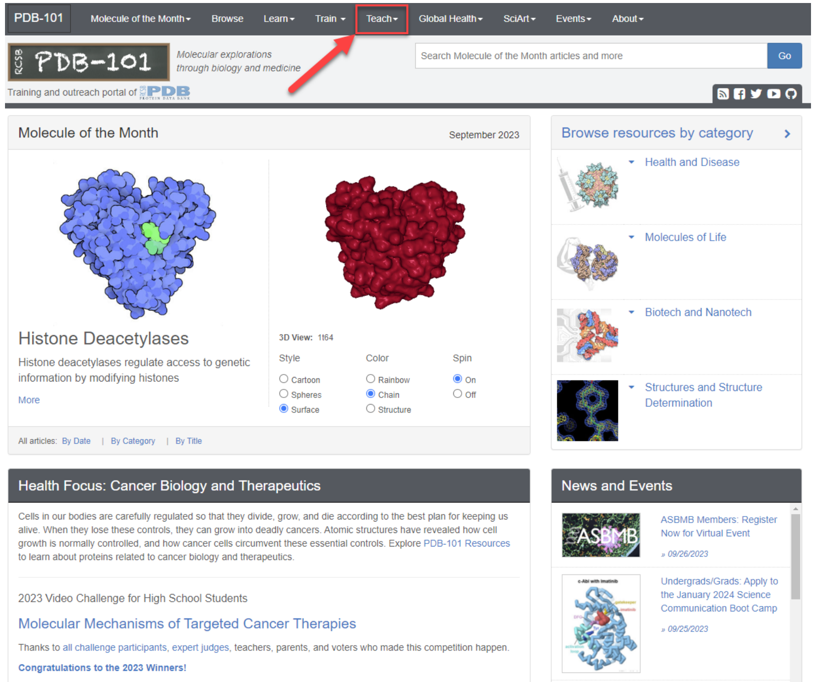


Image - Active Learning Strategy Spectrum
University of Minnesota Center for Educational Innovation

How to access the Box of Lessons

https://www.rcsb.org/



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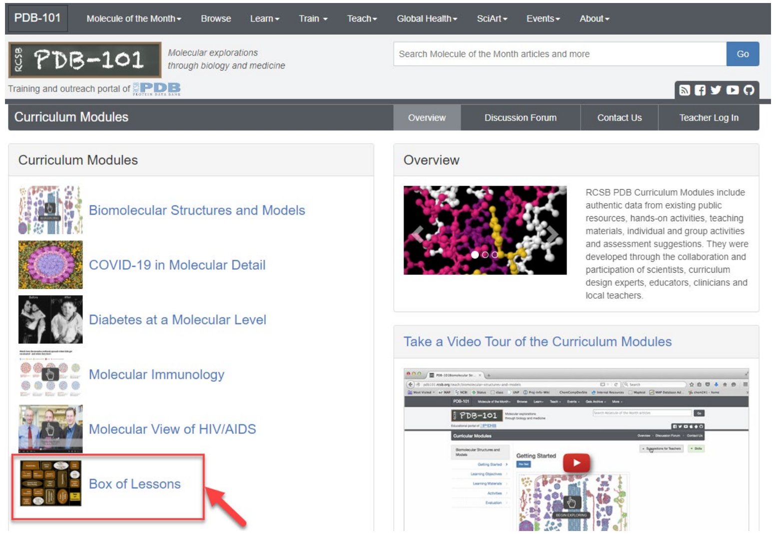


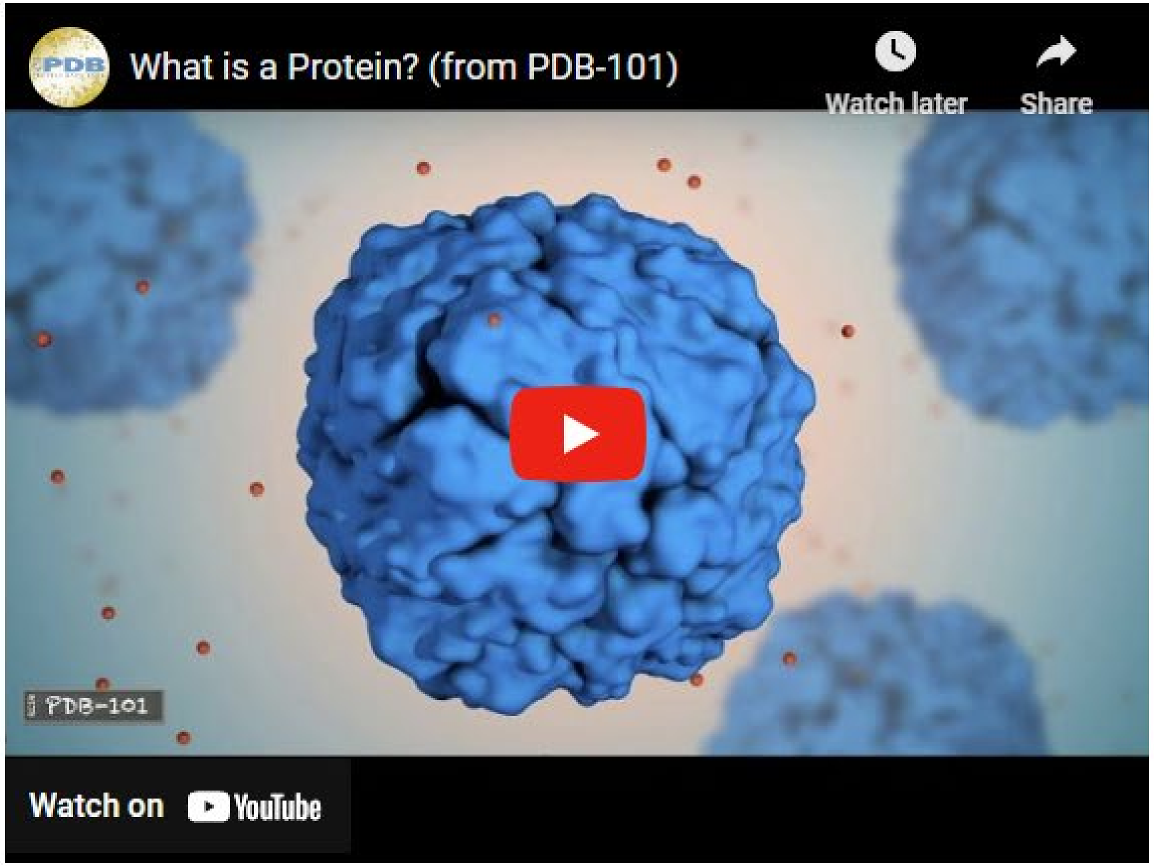
Link: http://bit.ly/3LGa1zY

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

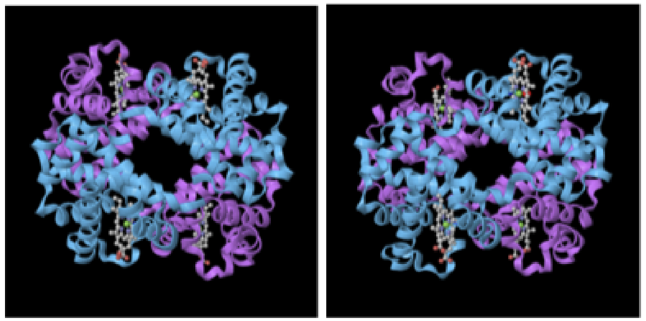
- Students should be able to **recognize the repeating units** in biological macromolecules and discuss the **structural impacts of the covalent and noncovalent interactions involved** *(Introductory)*.
- Students should be able to compare and contrast the **primary, secondary, tertiary, and quaternary 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:

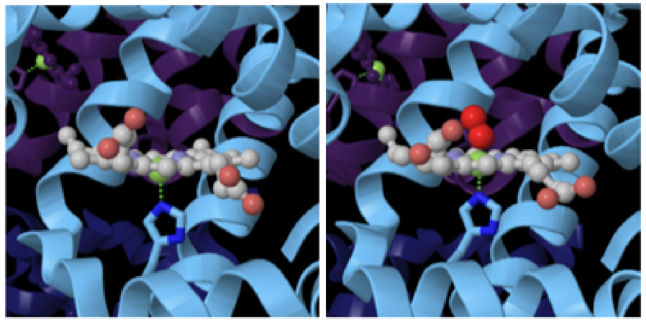
Go to the "Exploring the Structure" section in the article and analyze the structures shown in detail. Examine the static images and JSmol interactive views, where available.

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, 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.

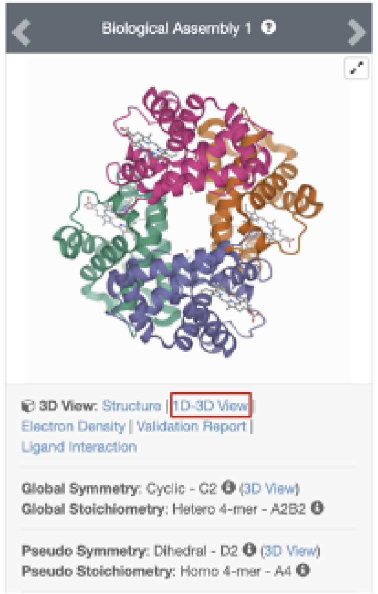
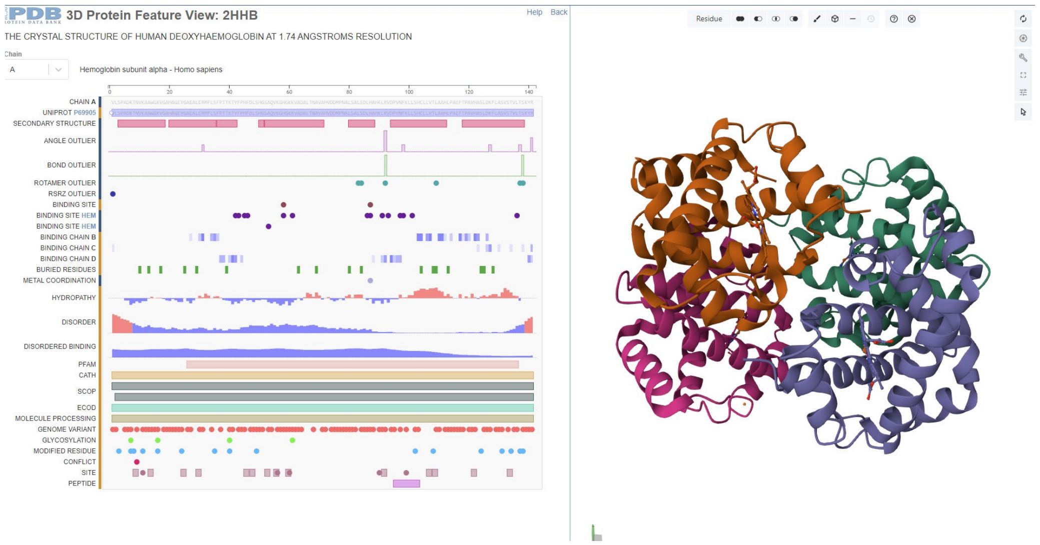


Figure 2: Structure of the deoxy-hemoglobin molecule (PDB ID 2hhb) - composed of four subunits - two copies each of the Hemoglobin alpha protein (colored in green and orange), and two copies of the Hemoglobin beta protein (colored in pink and violet). The four subunits interact with each other through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

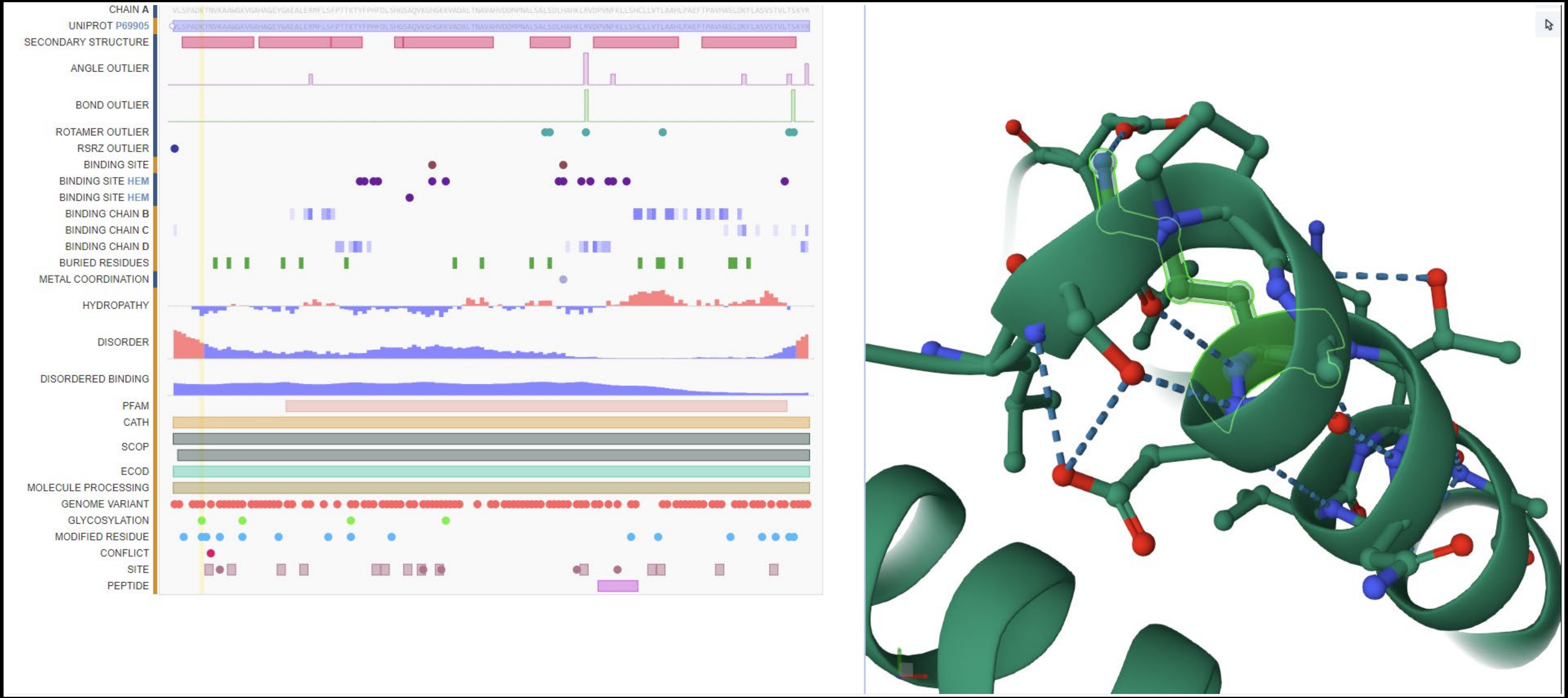


G. <u>**Tertiary structure:**</u>

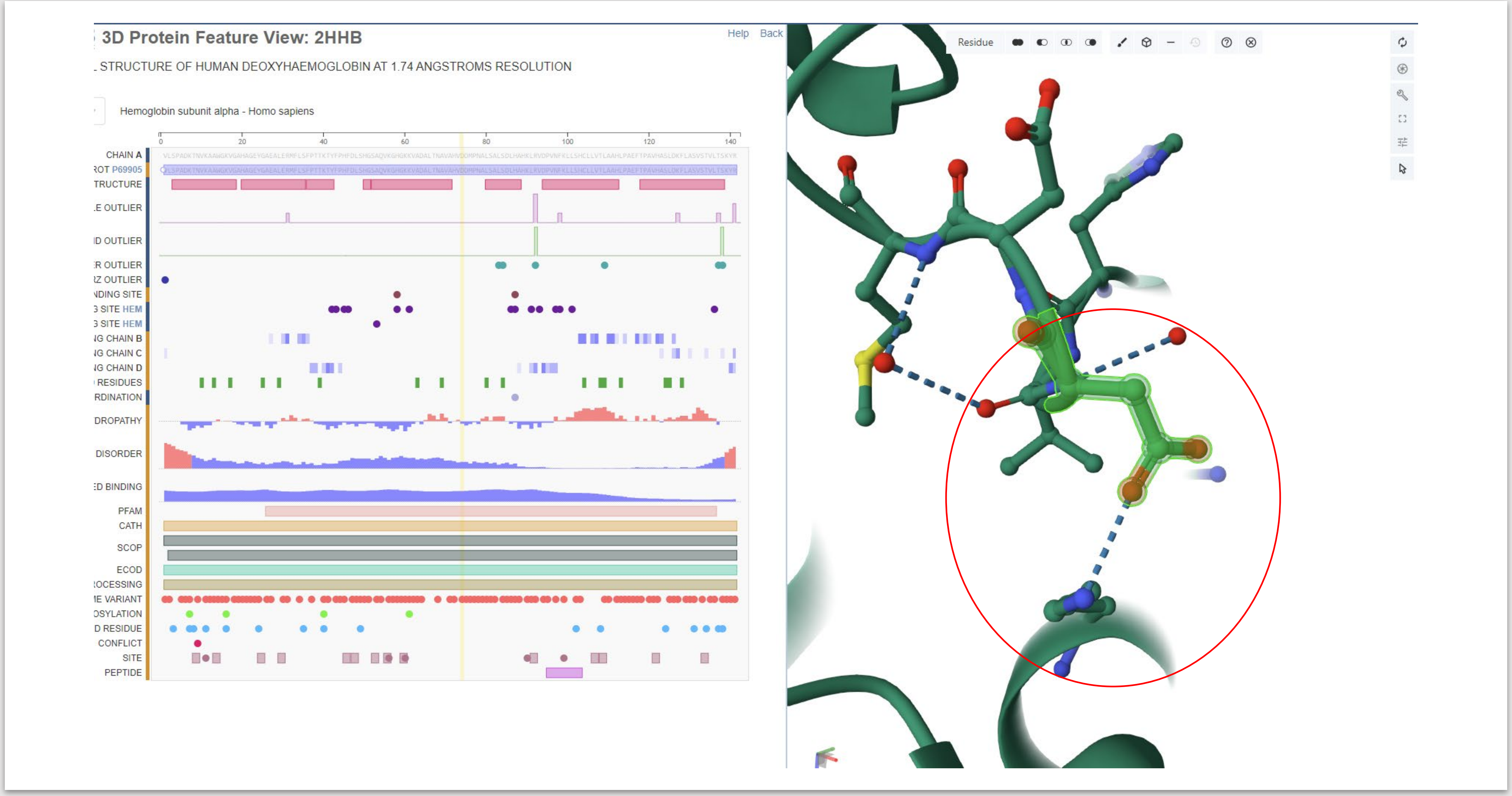
a. Identify the **amino acid #7** in Chain A (Hemoglobin alpha) - what is it?

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....



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
0
20
40
60
80
100
120
140
CHAIN A
P69905
PFAM
CATH
SCOP
ECOD
CONFLICT
SITE
PEPTIDE
DISORDER
Residue

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

olecular CaseNet

ecular Case Studies

olecular 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.

ow 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 s (PDB) and a variety of open access data resources
- Connect with a community of educators developing an participation in Professional Development

Student Benefits:

- Introduction to authentic data resources
- Opportunities to experience the scientific method (inclu author molecular case studies for submission to Molecular
- Engaging and real-world examples of concepts and skills le 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.