Engaging students in scientific literature review and structure visualization through the writing of molecular case studies

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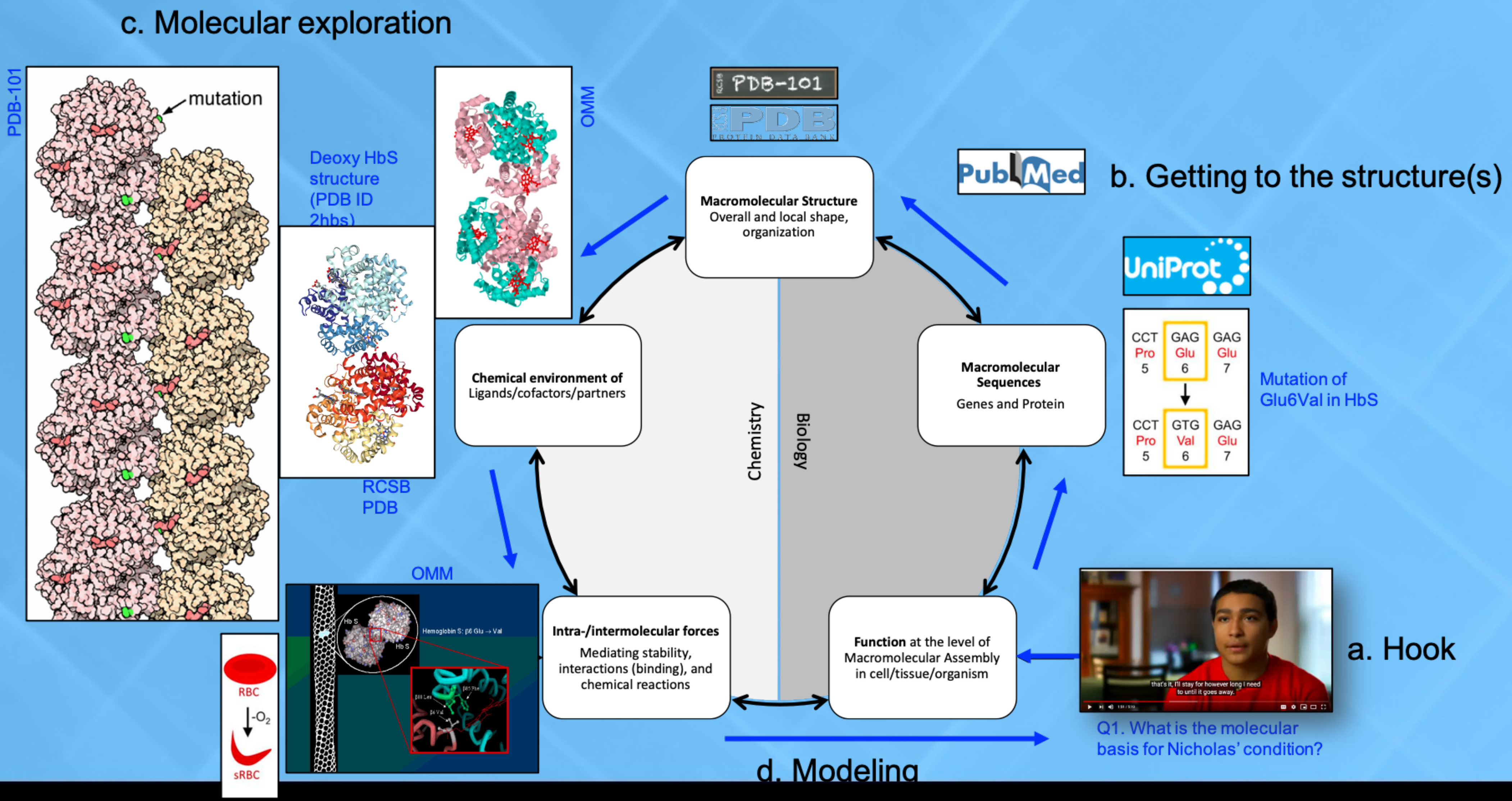
Partial summary of implementation logistics

Institution	Type of Institution	Class size	Notes
Stockton University	Public, mid-sized PUI	5 - 15	Students had previous experience with MCS; all biochemistry or biology majors
Rollins College	Private, small PUI	7-16	Students had previous experience with molecular visualization software and MCS; all seniors; all biochemistry majors
Boston University	Public, research focus	30	Assignment replaced the last two weeks of a laboratory module allocated for independent student projects. Students had used bioinformatics and molecular visualization tools throughout the semester; most of them were chemistry and BMB majors

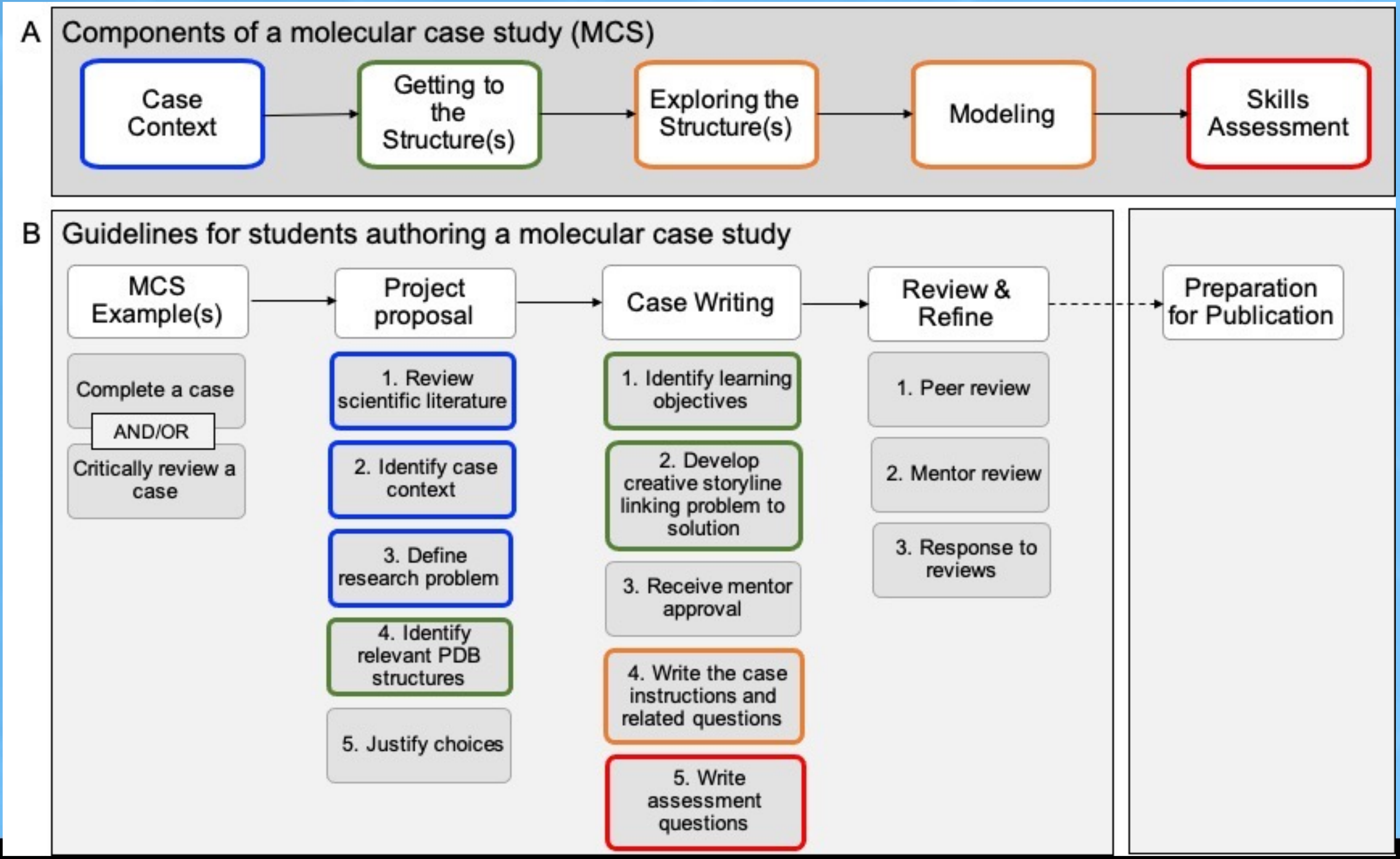
What is a molecular case study?



Examples of cases submitted by students

Protein	Diseases	Main molecular explorations and bioinformatics tools/resources used
lysosomal hydrolase	Sanfilippo's syndrome	•*Genetic testing* •*KEGG database to explore metabolic pathways* •*Chemical mechanism from literature*
cytochrome P450	vitamin D deficiency	•*Analyzing data from literature* •*Sequence alignment*
MPro protease from SARS-CoV2	COVID	•*BLAST searches to identify proteins with similar sequences* •*Analyzing data from literature*
lactate dehydrogenase	cancer, malaria, infertility, heart disease	•*Analyzing literature and/or student-generated data* •*Sequence alignment* •*Drugbank*
VegF	cancer, Milroy disease, corodial neurovascularization	•*Analyzing data from literature* •*Sequence alignment*

Getting students involved in the writing



Example of student work – vitamin D deficiency

Table 1. Biochemical and Radiographic Characteristics of Five Subjects With *CYP2R1* Mutations

Subject	Subject II-1 (Family 1) Philip				Subject II-2 (Family 1)			Subject I-1 (Family 1)	Subject II-1 (Family 2) Kevin		Subject I-2 (Family 2)	
Age, y	**12.5**	**13**	**13.5**	**20**	**11**	**11.5**	**18**	**49**	**5**	**5.5**	**24**	
Characteristic	**Before**	**After calcium[a]**	**After vitamin D_3[b]**		**Before**	**After calcium[a]**			**Before**	**After calcium**		**Reference Ranges**
Calcium, mg/dL	5.9	5.7		6.7	6.1	6.3	7.8	9.6	9.6	9.9	9.2	8.5–10.6
Phosphorus. mg/dL	2.6	3.4		4.0	3.9	4.3	5.5	3.2	2.0	4.6	3	2.5–5.4; 5–14 y 2.5–4.5 adults
Albumin, g/dL	3.7	3.9			3.7	3.4			4.4	3.9	4.3	3.5–5.0
Alkaline phosphatase, U/L	4866	5029		551	2391	2131	413	109	714	275	172	162–587; 5–14 y 45–115 adults
25(OH)D, ng/mL	8.0	2.2		1.5	4.1	3.7	3.1	4.9	16.4	25.9	18.7	>20
1,25$(OH)_2$D. pg/mL	18	22			17	26			180	241		22–67
PTH, pg/mL	123	382		339	208	199	182	60	107	42	85	11–67
Radiographic score	10	8	0.5		9	1			5	1		0

To convert values for calcium to millimoles per L, multiply by 0.25. To convert values for phosphorus to millimoles per L, multiply by 0.32. To convert values for 25(OH)D to nanomoles per L, multiply by 2.50. To convert values for 1,25$(OH)_2$D to picomoles per L, multiply by 2.40. To convert the values for PTH to picomoles per L, multiply by 0.11.

[a] Calcium was given as ground fish including bones 10 g twice daily, providing approximately 952 mg of elemental calcium daily for 6 mo.

[b] Vitamin D_3 600 000 IU (15 mg) was given im twice at 3-month intervals.

Figure 3: Patient data for children in two families that have been diagnosed with rickets. Note: since vitamin D_2 and D_3 both go through 25 and then 1 hydroxylation to become active vitamin D, when the table lists 25(OH)D and 1,25(OH)D it is referring to hydroxylated vitamin D_2 or D_3, not the biologically active form of vitamin D.[6]

1. Based on the data presented above, explain how the levels of calcium, phosphorus, 25(OH)D and 1,25(OH)D are consistent with a vitamin D deficiency diagnosis. *Reference ranges are in the yellow box on the right of Figure 3.*

Yes, the vitamin D deficiency is evident from the decreased levels of 25(OH)D and 1,25$(OH)_2$D. As a result of being deficient in vitamin D precursors and not being able to make sufficient vitamin D they are low in calcium because vitamin D promotes the absorption of calcium and phosphorus.

5. Is L99 involved in any secondary structure? If so, can you predict its role within this secondary structure? How might the mutations to P99 disrupt this secondary structure?

Yes, L99 is part of an alpha-helix. Therefore, it is likely involved in some structurally important hydrophobic interactions since it is a leucine residue. Mutation of L99 to P99 is expected to have a negative effect on protein folding, since proline disrupts the α-helix due to its unique structure and causing a kink in the helix.

6. Is L99 in close proximity to any relevant small molecules in the structure? What might this imply about functional consequences of a mutation to this residue? Capture an image showing the positioning of L99 relative to any nearby small molecules.

L99 is involved in an α-helix secondary structure. It is probably involved in some important hydrophobic interactions within the protein.

7. Upload an image of the protein showing the relevant non-covalent interactions for L99. What does this tell about the function of L99 within the protein?

L99 is mostly involved in hydrophobic interactions, so its main role is likely to participate in stabilizing interactions that could help drive protein folding. .

8. Now that we have more clearly understand the role of L99 within the protein, explain the consequences of Philip's L99P mutation. Be sure to include an explanation on how this change in primary structure impacts higher order protein structure and how the position of this residue within the protein may impact its ability to function/contribute to rickets. *Note: if you are using Pymol, it has a mutagenesis feature, so feel free to include an image in the explanation.*

Example of student work -interferons

Questions based on KEGG pathway

Q1: What is the purpose of this pathway?

Q2: What is the rate determining step? What would be considered an allosteric regulator?

Q3: Hypothesize how disruption in the JAK family of tyrosine kinase can disrupt homeostatic processes? (Hint: think about allosteric regulation)

Questions based on PDB

Q2: using prior knowledge of amino acid properties, hypothesize how this mutation has affected the overall JAK2 structure and interactions.

Q3: using icn3D, explore this mutation in more detail. Provide a screenshot of the mutation and with what residue it interacts.

Q5: provide a labeled screenshot below with the ATP-site ligand

Student perceptions of learning

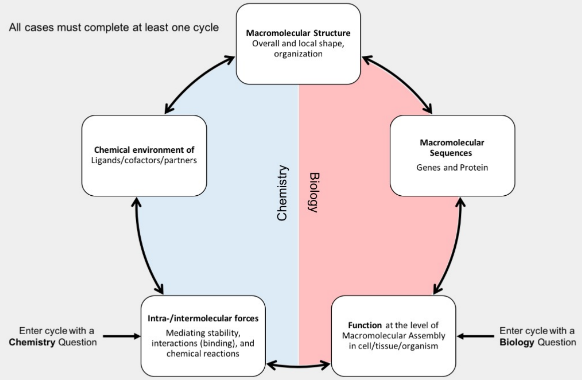
Statement	Completely Agree/Agree	Neither agree or disagree	Disagree/ Completely Disagree
Helped me integrate biochemical concepts I studied in the course with their practical applications	29	1	0
Made me more comfortable with accessing and using databases and bioinformatics tools	28	2	0
Increased my understanding of the interactions between macromolecules and the importance of such interactions to functional specificity	26	3	1
Helped me identify, locate, and use the primary literature	26	3	1
Helped me connect concepts and ideas encountered in one or more different courses	25	5	0
Improved my confidence in my understanding of the biochemistry course material	23	7	0
Made me more comfortable working with complex ideas	22	6	2
Improved my written communication skills in explaining scientific concepts and data	21	9	0
Increased my enthusiasm for the biochemical field	19	8	3

Resources available at Molecular CaseNet

Biological Macromolecules

- Biomolecular Building Blocks: Atoms, Bonds, and Conformations
- Amino Acids: Types and Properties
- *Types of Chemical Interactions in Biology*
  - Noncovalent Interactions: Overviews
    - Electrostatic force (Part 1) (v) and
    - Partial charges and inter-molecular forces comparisons (Part 2) (v)
  - What are ...
    - Disulfide bonds
    - Hydrogen bonds (v)
    - Ionic bonds/Salt Bridges
    - Pi interactions
    - Halogen bonds (v)
    - Hydrophobic interactions
  - Chemical Bonds in a Macromolecular Structure (example gamma Chymotrypsin) (v)
- What is a Protein? (w+v)

Molecular Case Studies



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The Molecular Case Study Cycle

Exploring Protein Data Bank

- Methods for Determining Atomic Structures (w)
- Understanding PDB data (w)
- Entry, Entity, Assembly, and Instance (v)
- What is in the PDB File? (v)
- Exploring a PDB entry (w, see related pages)
- Navigating the Structure Summary Page (v)
- Coordinate files in PDB and PDBx/mmCIF Format (w)
- Missing coordinates (w)
- Biological assemblies (w)
- Molecular Visualization Conventions:

Molecular Visualization Tools

- Mol*
  - Intro Guide (v); Exploring Overall Shape and Local Environments (v); Documentation (w); Cheat Sheet (d)
- Chimera
  - Basics (v); Menus (v); Selecting atoms, residues and chains (v); Structure analysis (v); Structure Comparisons (v); Cheat Sheet (d)
- iCn3D
  - Tutorials – Part 1 (windows, menus, representations) (v) and Part 2 (interactions,

Bioinformatics: Data, Tools, and Resources

- Sequence, Structure, and Function
- Resources and Tools of Interest
  - Resources/Tools commonly used in molecular case studies
  - Detailed lists (w)
  - Protein Sequences: UniProt (r)
    - How to use UNP (v playlist); The PDB-UniProt Connection (v)