Using a Molecular Case Study to integrate molecular structures into a Microbiology course

Saumya M. Sankaran
Sarah R. Alaei
University of Washington Tacoma

Shuchismita Dutta
Rutgers University

Introduction

- Molecular storytelling combines exploration of biomolecular structure and multidisciplinary functional information to build rich interdisciplinary learning opportunities in life science courses.
- We created a **molecular case study (MCS)** to help students connect and integrate important concepts in biochemistry and microbiology. The case study is focused on exploring the molecular mechanisms underlying antibiotic resistance. It examines the three-dimensional structures of penicillin binding protein (PBP) with and without the bound antibiotics and the functional consequences of mutations in the PBPs.
- This MCS aims to introduce students to various public scientific databases, molecular visualization tools available from the Protein Data Bank, and BLAST, in an exploratory, low-stakes, narrative-driven active learning opportunity.

Case Study Design

- **Guiding principles**: a topic that is current/relevant and illustrates a clear structure-function relationship underlying some phenotype of interest
- **Broad topic choice**: antibiotic resistance, a phenotype that can potentially result from small changes to protein structure
- We used the following case study design workflow:

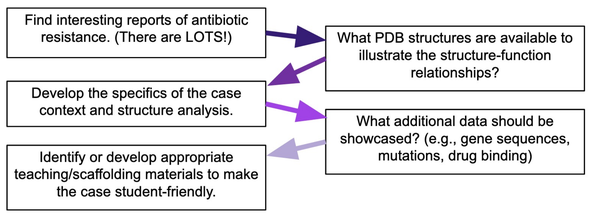


Figure 1: Molecular case study design workflow.

- **Choosing a specific example**: We first developed an MCS focused on methicillin-resistant *Staphylococcus aureus* (MRSA), then a second version examining cephalosporin-resistant *Neisseria gonorrhoeae*.
  - Round 1: In Autumn Quarter 2024, we implemented the MRSA version. The structure comparisons were not straightforward, and students seemed disengaged.
  - We revised the case with an example that had more direct structure comparisons (thus creating the second version) AND more scaffolding with discussions/interpretations in class throughout the activity.
  - Round 2: In Winter Quarter 2025, we implemented the drug-resistant *N. gonorrhoeae* version with better student engagement.

Why did we create this MCS?

GOAL: Create an interdisciplinary teaching module on a real-world relevant topic that connects a phenotype to its molecular structure-function basis.

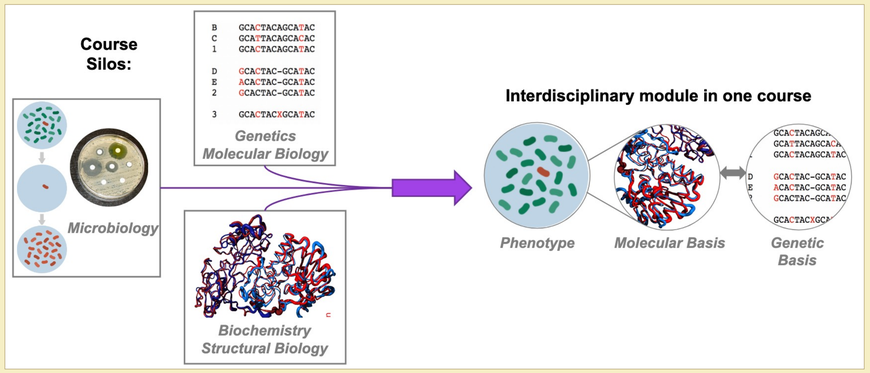


Figure 2: Creating an interdisciplinary case study

How did we use the MCS?

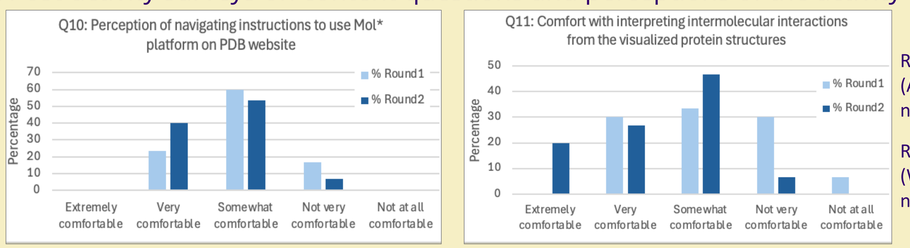
- We implemented it as a **1-week module** in an upper division Microbiology course
- Class time: **2 x 2-hr lecture periods** (+ preparatory readings)

Prep Work	Day 1	Day 2	Follow Up
Read about: • What are antibiotics? What do they target, and in what types of cells? • How does antibiotic resistance arise? Examine three mechanisms (efflux, alter target, modify drug). *Readings provided w/case.*	**Introduction to a real-world context** • Review basics of antibiotics • Review basics of protein structure **Part 1: The Structures** • Explore protein structures • Compare multiple structures *Develop familiarity with PDB and looking at structures.*	**Part 2: The Function** • Drug-protein interaction kinetics *Link structure to kinetics to understand the structure-function relationship.* **Part 3: Connecting Sequence, Structure, and Function** • Comparing gene sequences (BLAST) *Tie together mutations in genes, structural changes in proteins, and phenotypes.*	• Complete case packet (with written responses and screenshots). • On course assignment, answer questions relating structural changes to phenotypic consequence.

Figure 3: Steps in the implementation of the molecular case studies

How did students respond to the MCS?

- Pre-/Post-activity surveys on content questions and perceptions of the activity



Round 1 (Autumn 24) n=36.

Round 2 (Winter 25) n=15.

Figure 4: Comparing student perception between the two rounds of implementations.

- Perception of using case instructions to navigate Mol* (left) - similar levels of comfort in both rounds.
- Comfort interpreting intermolecular interactions in structures visualized (right) - improved in Round 2 cohort.

Lessons Learned

Student-centered design:

- Experience with implementing two versions of the MCS showed that students prefer a case where the **phenotype-to-molecular-basis connection is clear**.
- MCS design must ensure that the structural comparisons made to tell the molecular story are level-appropriate for students to grasp.
- The implementation should provide time to regroup/discuss understanding at key intervals during the activity to keep students engaged.

Faculty gains:

- This case type provides an opportunity for rich **interdisciplinary collaboration** between faculty from different disciplines to build a teaching module.
- Writing these case studies provides opportunities for **faculty development** in learning to use bioinformatics and molecular visualization tools.

Conclusions

- Molecular Case Studies can be incorporated into existing courses with minor adjustments to the course schedule.
- These case studies provide a change of pace and interdisciplinary connection as students are asked to tie phenotypes to their underlying molecular structure-function basis.

Future Work

We plan to continue implementing this MCS to:

- Gather Pre- and Post- survey data from implementation of the revised case (drug-resistant gonorrhea) over 2 more quarters of Microbiology course (AY24-25 & 25-26) to assess learning gains in microbiology & interdisciplinary thinking.
- Propose collaborations to implement molecular cases in other courses for more interdisciplinary case exposure.

Acknowledgements

- Molecular CaseNet (funded by NSF grant DBI 1827011; DBI 2018884) and BioQuest Faculty Mentoring Network

References

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Molecular CaseNet website:

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