Thursday November 6, 2025

1pm ET | 10am PT

Webinar:

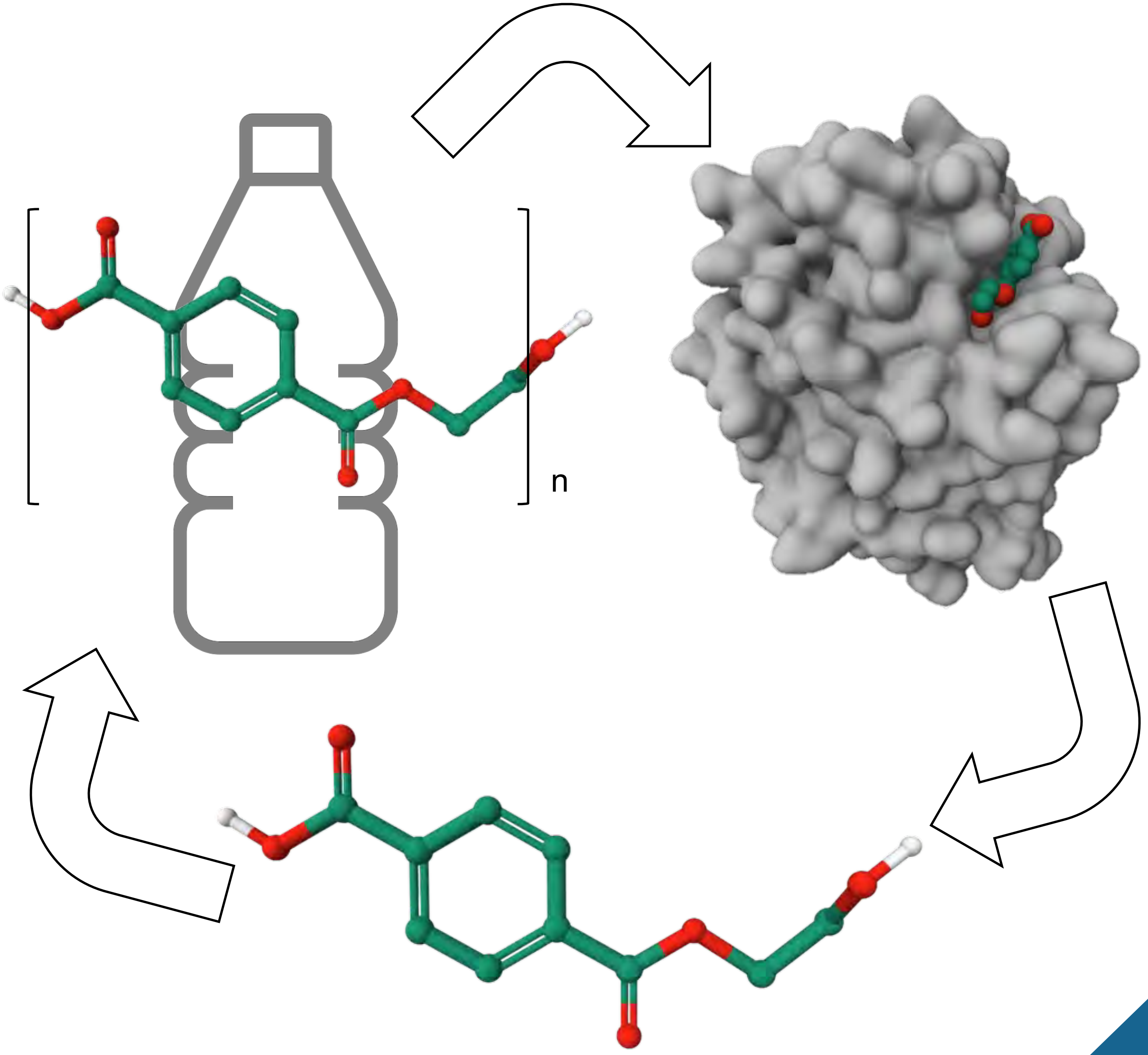
Exploring the workhorses of biotechnology:

Using RCSB.org to analyze plastic-degrading enzymes

Alison Biester

Outline

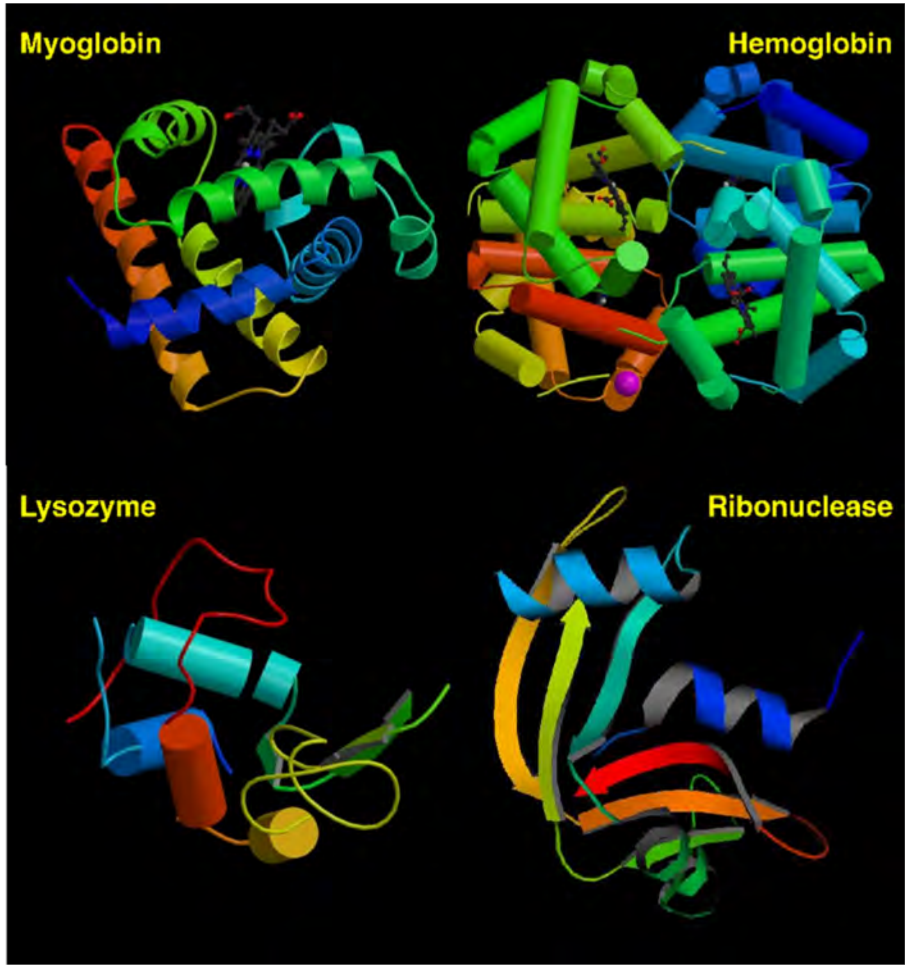
- Introduction to PDB
- Introduction to Plastic-Degrading Enzymes
- Using RCSB.org to Explore Plastic-Degrading Enzymes



Introduction to PDB

Protein Data Bank (Established 1971)

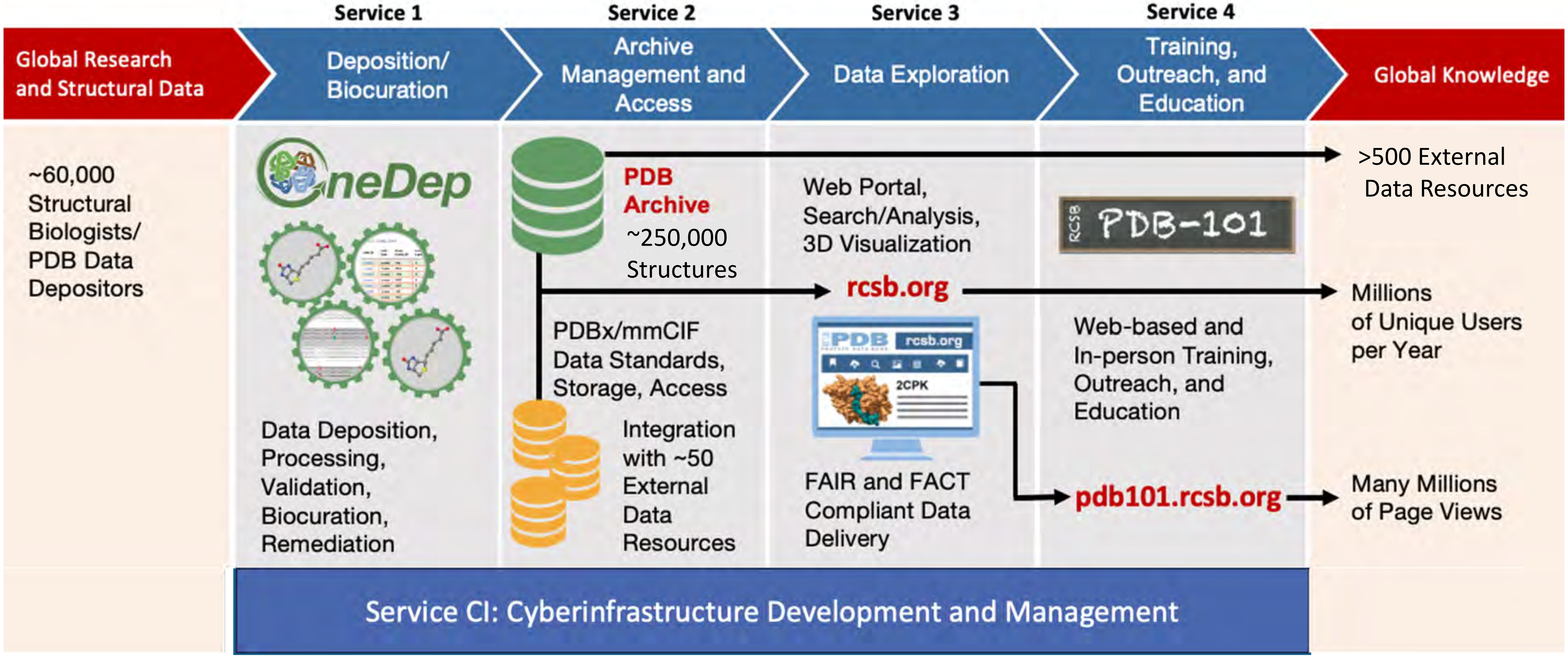
- PDB 1st online Open Access digital data resource in all of biology
- Founded 1971 with 7 protein structures
- Single global **archive** for protein and DNA/RNA experimental structures
- **Open Access >244,000 structures!**
- Adhere to FAIR Principles (Findability, Accessibility, Interoperability and Reusability)
- Members: RCSB PDB (US), PDBe (EMBL-EBI), PDBj (Japan), and PDBc (China); plus EMDB (3DEM) and BMRB (NMR)
- Accredited by Core Trust Seal and Global Biodata Coalition



Structures that Inspired Launch of the PDB

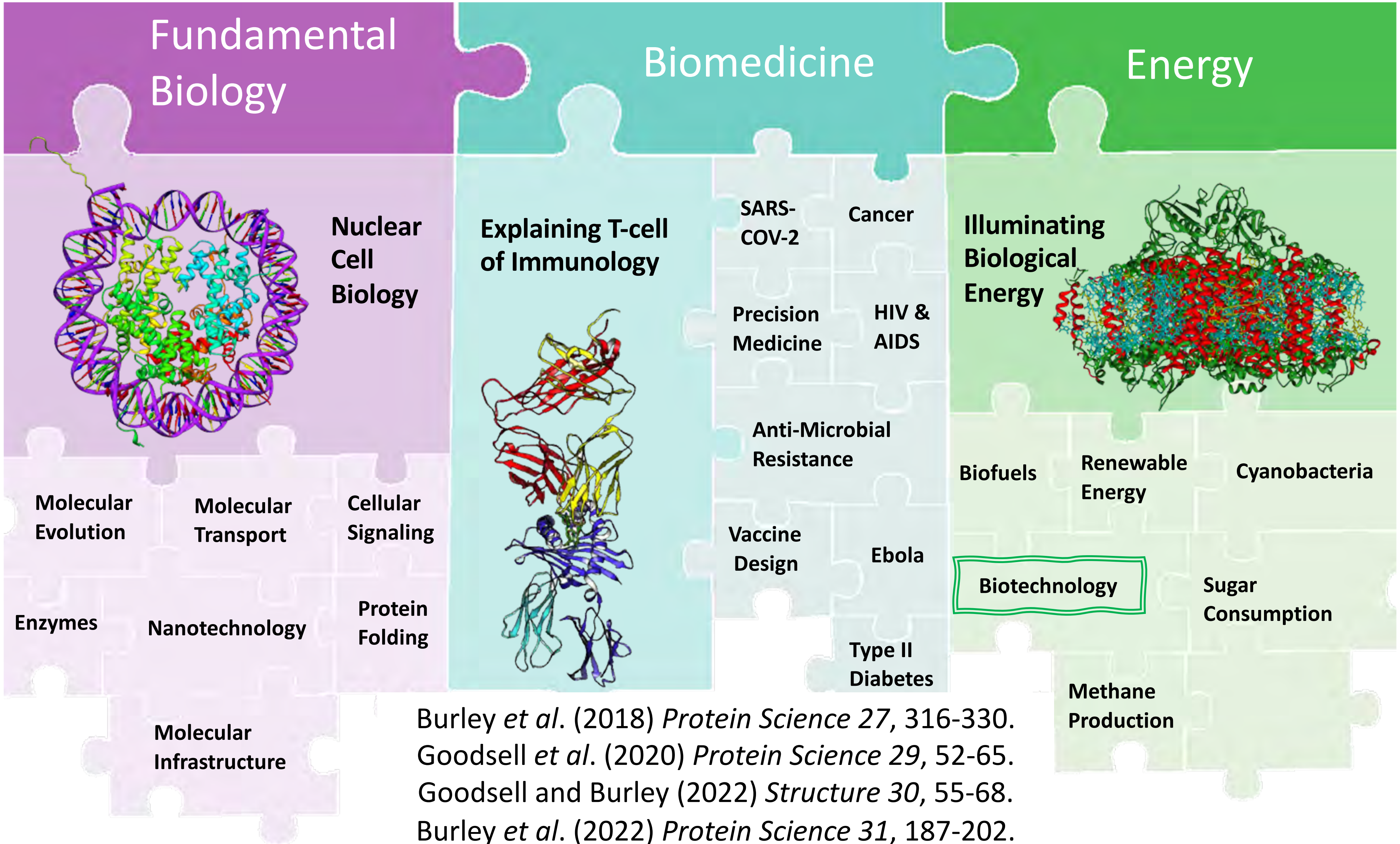
Protein Data Bank (1971) *Nature New Biology 233*, 223.
Worldwide Protein Data Bank (2019) *Nucleic Acids Research 47*, D520–D528.

RCSB Protein Data Bank (RCSB PDB) Services Convert Global Data into Global Knowledge



Burley *et al*. (2022) *Protein Science 31*, E4482.
Burley *et al*. (2023) *Nucleic Acids Research 51*, D488–D508.

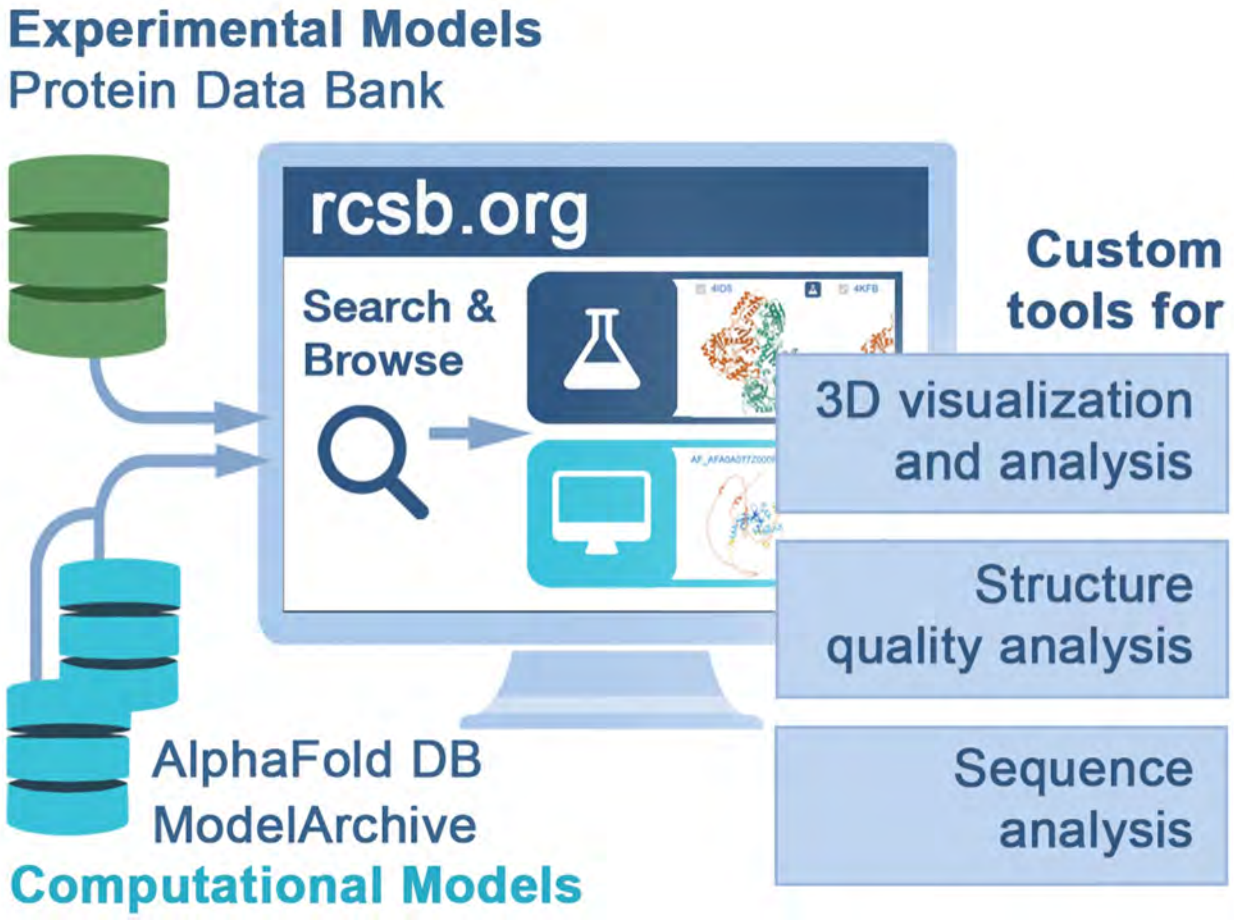
RCSB PDB Impact Across the Biosciences



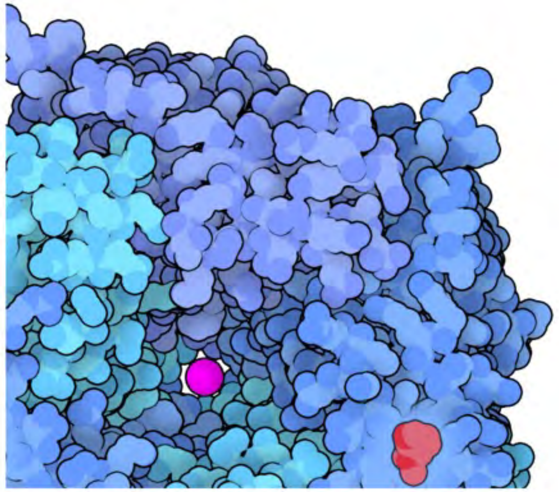
Burley *et al*. (2018) *Protein Science 27*, 316-330.
Goodsell *et al*. (2020) *Protein Science 29*, 52-65.
Goodsell and Burley (2022) *Structure 30*, 55-68.
Burley *et al*. (2022) *Protein Science 31*, 187-202.

RCSB.org Research-focused Web Portal: One-Stop-Shop for Public 3D Biostructure Data

- RCSB.org delivers
  - >244,000 PDB structures
  - >1 million Computed Structure Models (CSMs) from AlphaFold DB and the ModelArchive
- RCSB.org exploration and visualization tools used by many millions of researchers, educators, and students worldwide
- Provenance/reliability of both data types are clearly identified



Burley *et al*. (2023) *Nucleic Acids Research 51*, D488-D508.
Burley *et al*. (2025) *Nucleic Acids Research 53*, D564–D574.



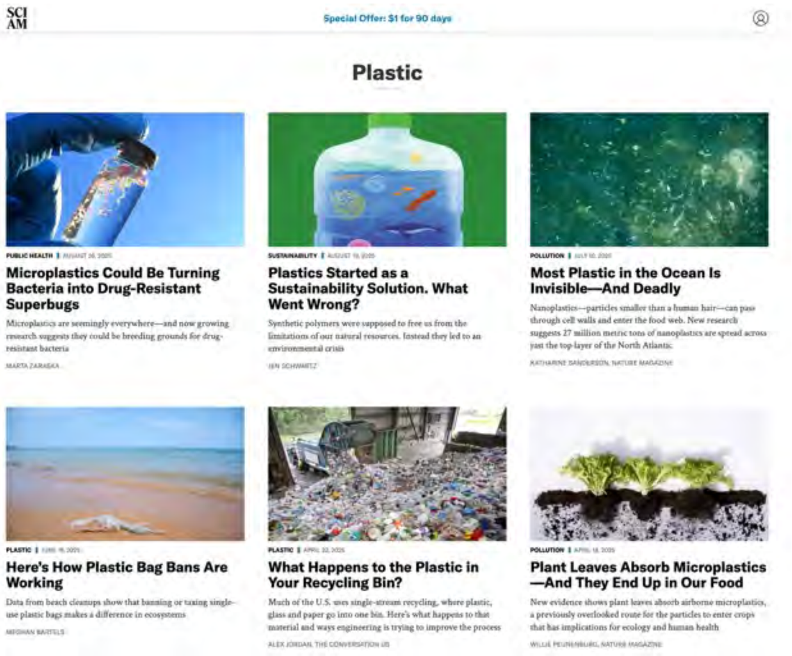
Introduction to Plastic-Degrading Enzymes

History of Plastics and Recycling

- First man-made plastic was created in 1856
- WWII led to expanded use of plastics for parachutes, aircraft windows, etc.
- Plastics replaced more expensive materials for packaging after WWII
- Plastic production reached 2 million tons/year by 1950
- First plastics observed in the ocean in the 1960s
- Municipalities began adopting recycling programs and mandates in the 1980s
- Production rate surpassed 400 million tons/year by 2020
- Only 9% of plastics are recycled in the 2020s due to high costs

Microplastics are Everywhere

- The term ‘microplastics’ was coined in 2004
- Microplastics have dimensions of 1 µm – 5 mm
- Nanoplastics have dimensions of 1 nm – 1 µm
- Humans are exposed to microplastics through inhalation/ingestion
- Microplastics consist of varied polymers with different properties



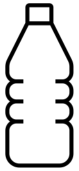
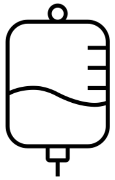
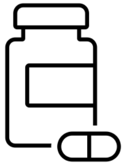

Lost at Sea: Where Is All the Plastic?

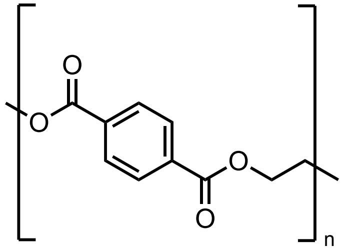
RICHARD C. THOMPSON, YLVA OLSEN, RICHARD P. MITCHELL, ANTHONY DAVIS, STEVEN J. ROWLAND, ANTHONY W. G. JOHN, DANIEL MCGONIGLE, AND ANDREA E. RUSSELL Authors Info & Affiliations

SCIENCE • 7 May 2004 • Vol 304, Issue 5672 • p. 838 • DOI: 10.1126/science.1094559

40,413 5,775

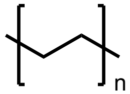
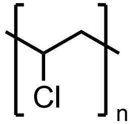
Common Plastic Uses and Structure

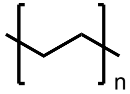
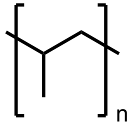
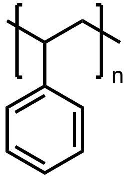
1	2	3	4	5	6
PET	HDPE	PVC	LDPE	PP	PS
polyethylene terephthalate	high-density polyethylene	polyvinyl chloride	low-density polyethylene	polypropylene	polystyrene
					
drink bottles, food jars	milk jugs, detergent bottles, toys, buckets	pipes, medical devices	cling wrap, sandwich bags, grocery bags	Tupperware, bottle caps, prescription bottles	takeout cups and containers, egg cartons



Hydrolyzable ester bond

→ Susceptible to degradation

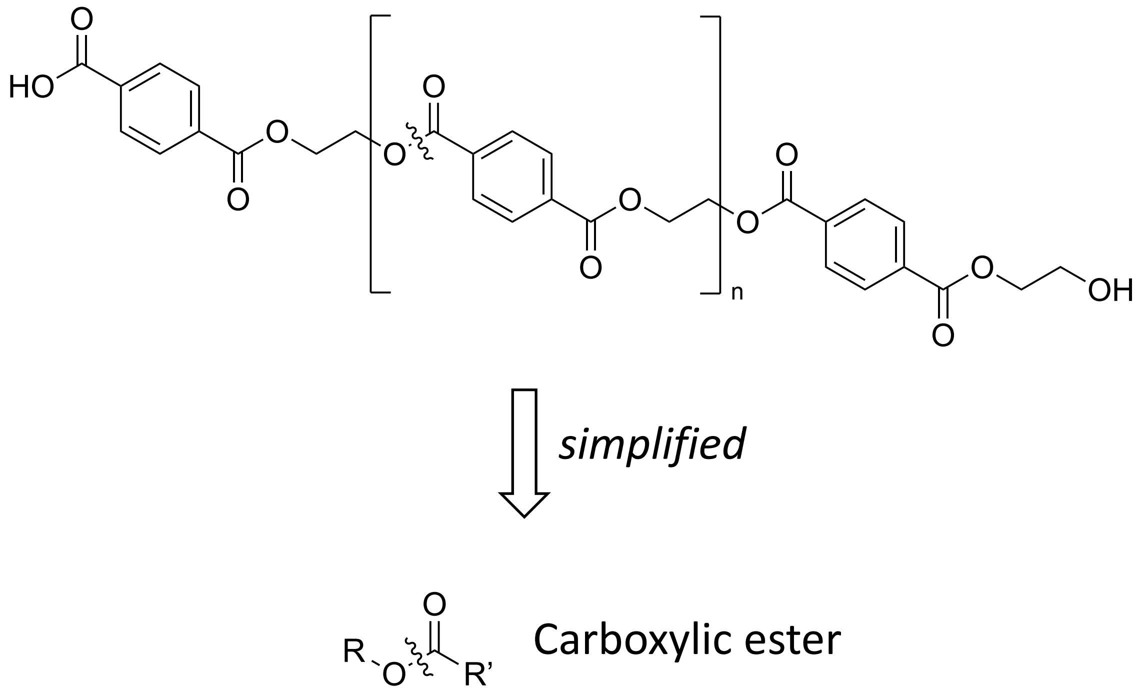



Stable carbon-carbon bonds

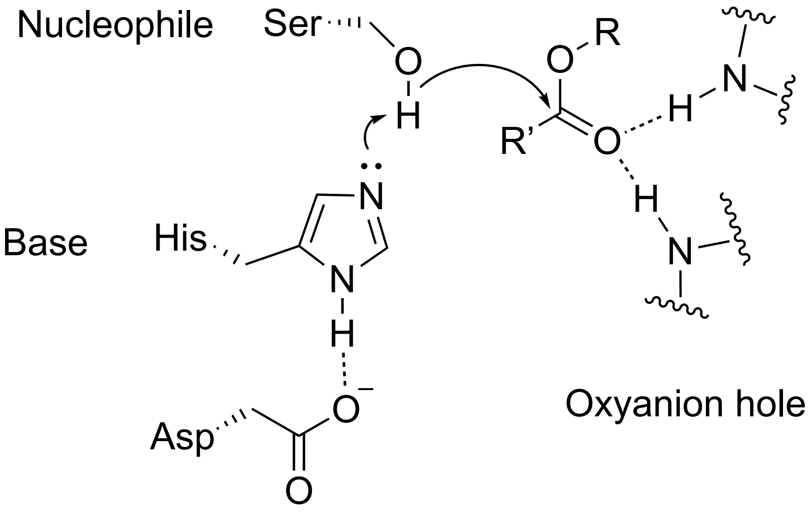
PET-Degrading Enzymes

PET hydrolases cleave PET ester bond



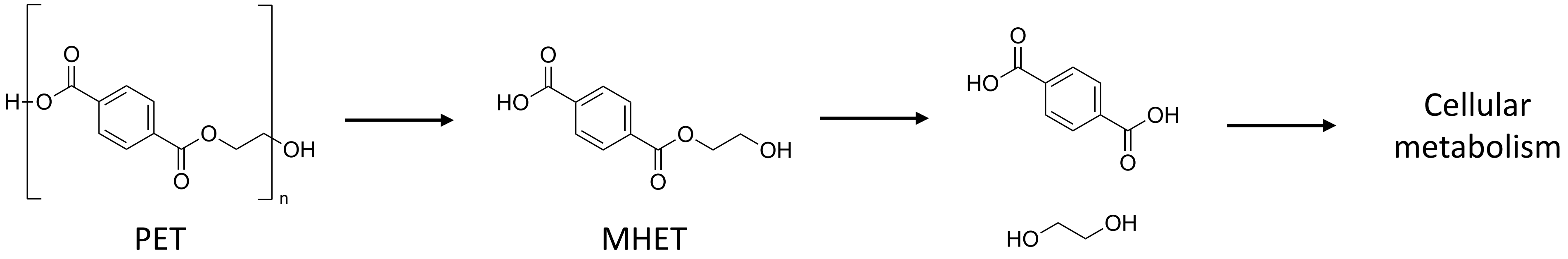
Carboxylic ester

- Carboxylic ester hydrolases are in enzyme class (EC) 3.1.1.-
- PET hydrolase belongs to the enzyme class (EC) 3.1.1.101
- PET-degrading enzymes use a Ser-His-Asp catalytic triad



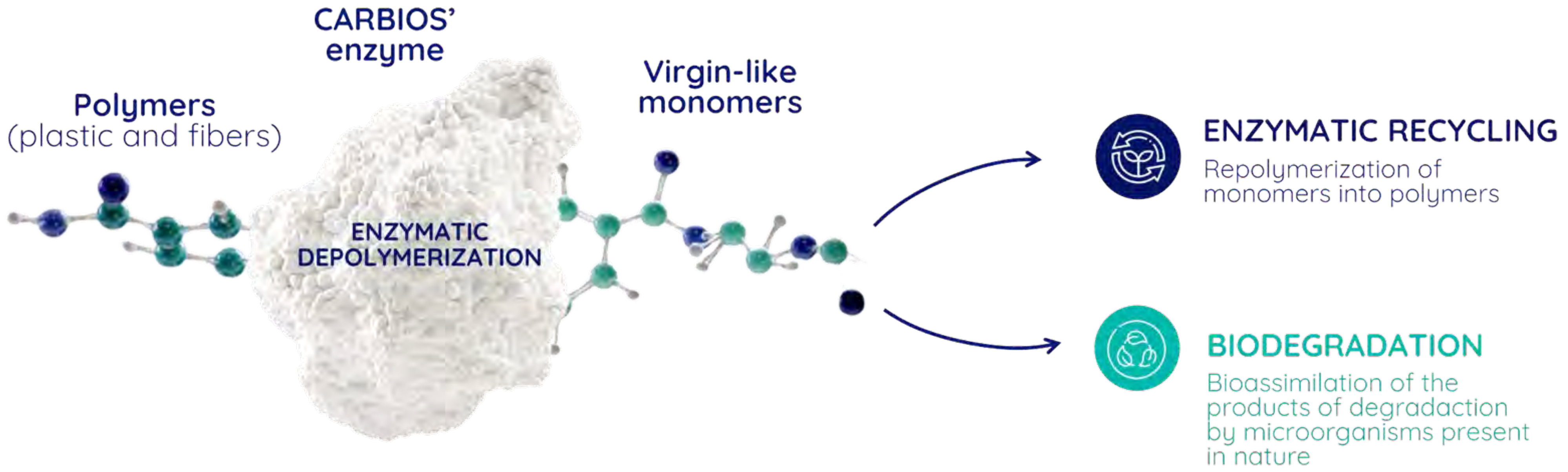
Bacteria Grow on PET

- *Piscinibacter sakaiensis* can use PET as a carbon and energy source
- In *Piscinibacter sakaiensis*, the PET monomers (mono(2-hydroxyethyl) terephthalic acid or MHET) are further broken down by MHETase allowing integration of carbon for cell growth
- *Ps*PETase is more active than other known PET-degrading enzymes (e.g. hydrolases, cutinases) on highly crystalline PET



Commercial Enzymatic Plastic Degradation

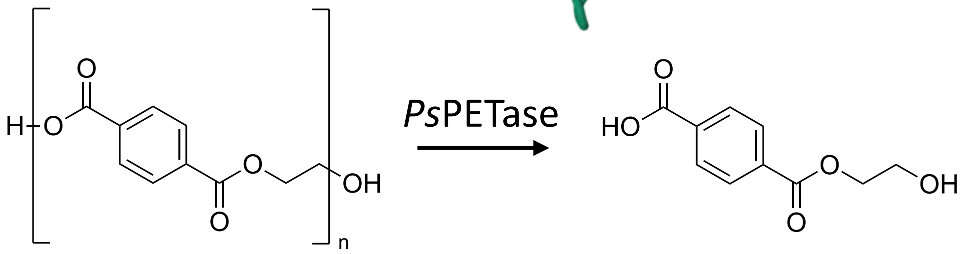
Biotechnology company plans to build a plant to process 50,000 tons of PET waste per year (out of >50 million tons, i.e. <0.1%)



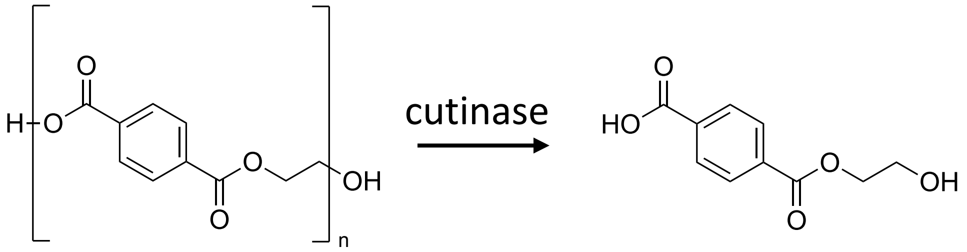
See more information: carbios.com/en/

Why is *Ps*PETase more active than other known PET-degrading enzymes on crystalline PET?

vs.



PET MHET



PET MHET

Using RCSB.org to Explore Plastic-Degrading Enzymes

Advanced Search

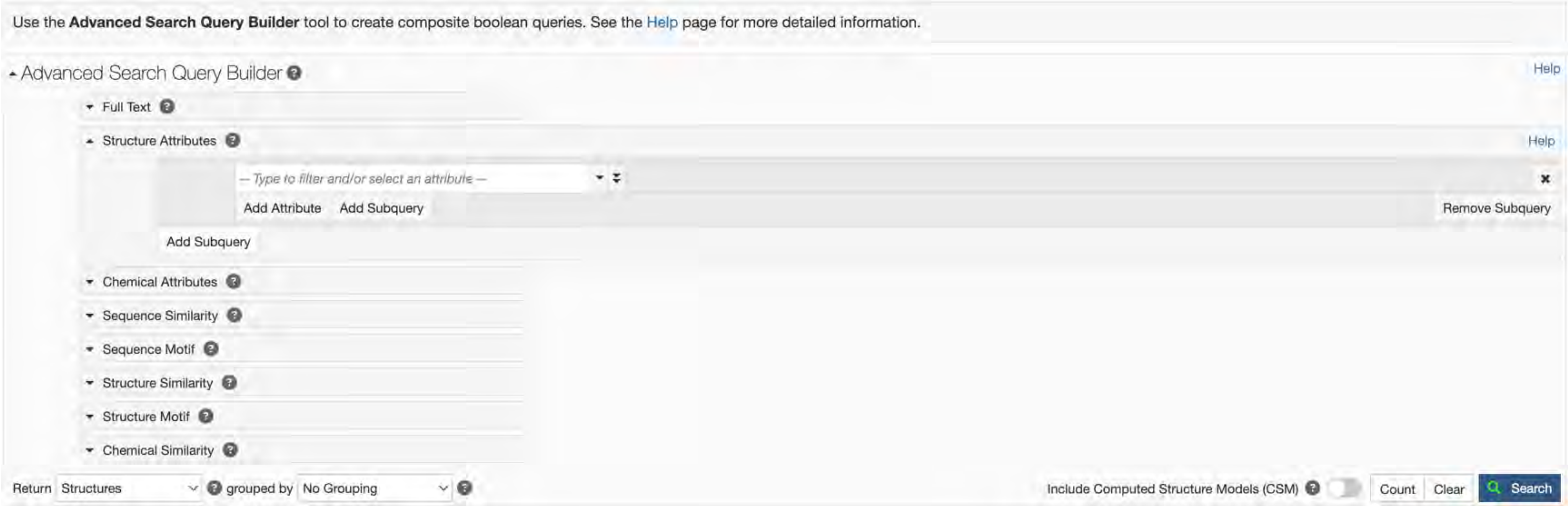
Sequence Annotations combined with Mol*

Pairwise Structure Alignment and Comparison

Harness the Power of RCSB.org Advanced Search

What search attributes can be used to identify PET-degrading enzymes?

https://www.rcsb.org/search/advanced



Casting the Net for PET-Degrading Enzymes

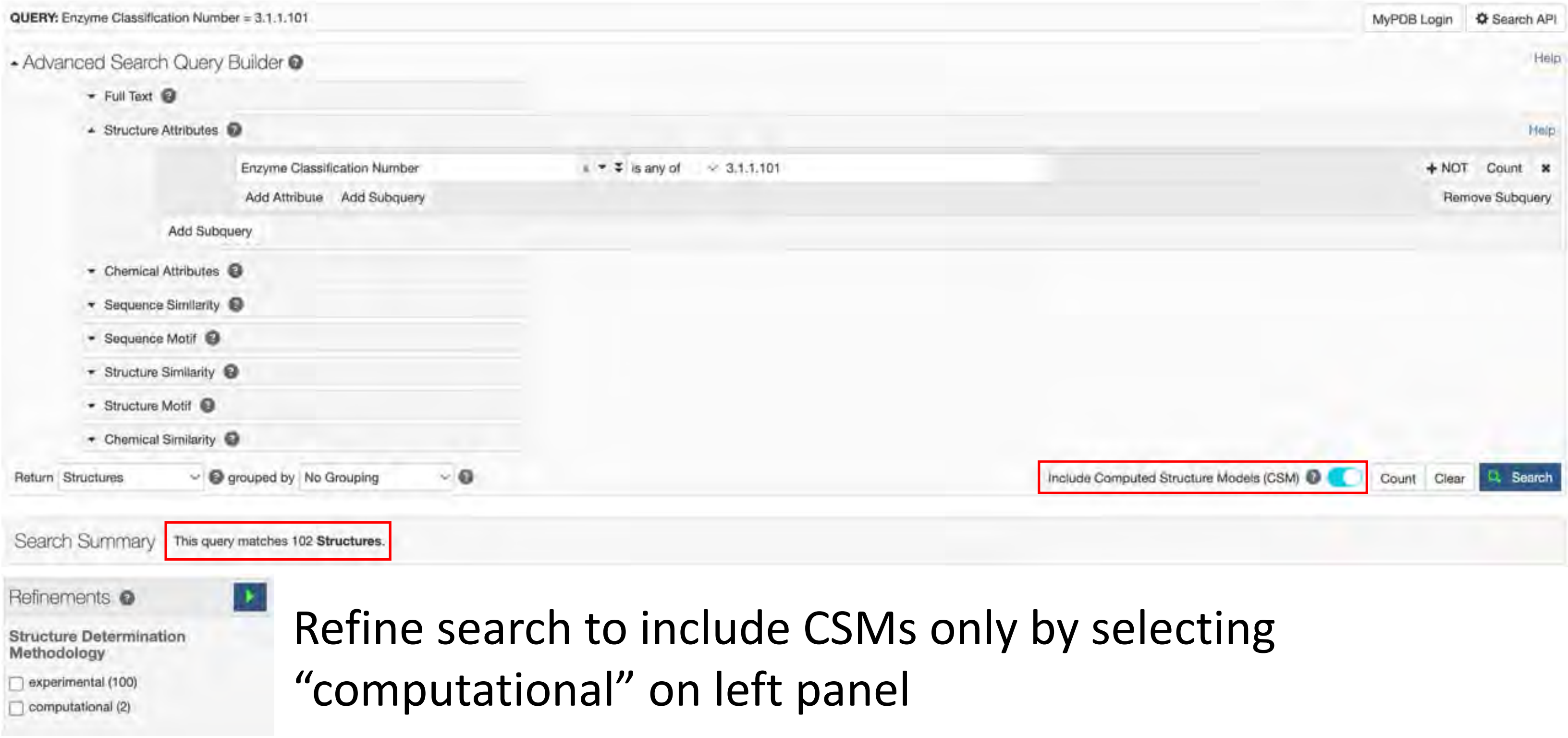
What search attributes can be used to identify PET-degrading enzymes?

Enzyme classification number(s): https://tinyurl.com/rcsb-search1

Search for PET-Degrading Enzyme CSMs

Toggle “Include Computed Structure Models (CSM)”

https://tinyurl.com/rcsb-searchCSM

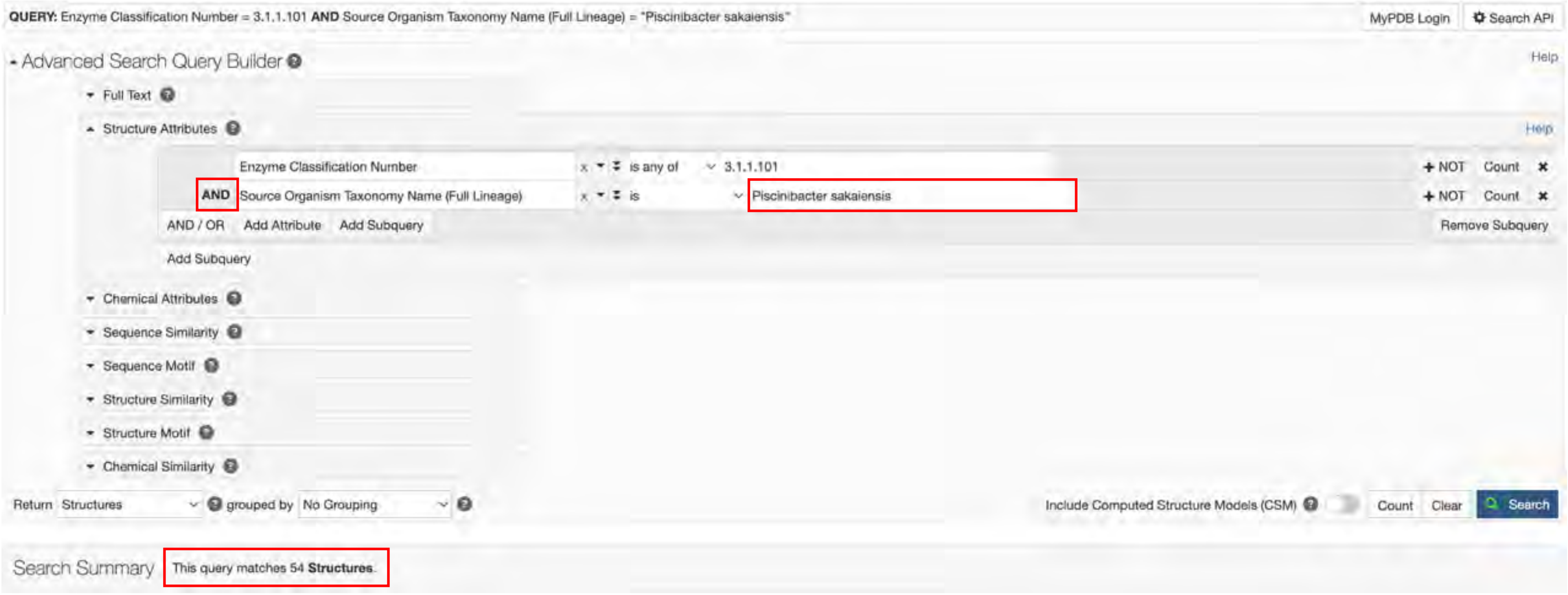


Refine search to include CSMs only by selecting “computational” on left panel

Narrowing the Search – Source Organism

How can we focus our search to address our question(s)?

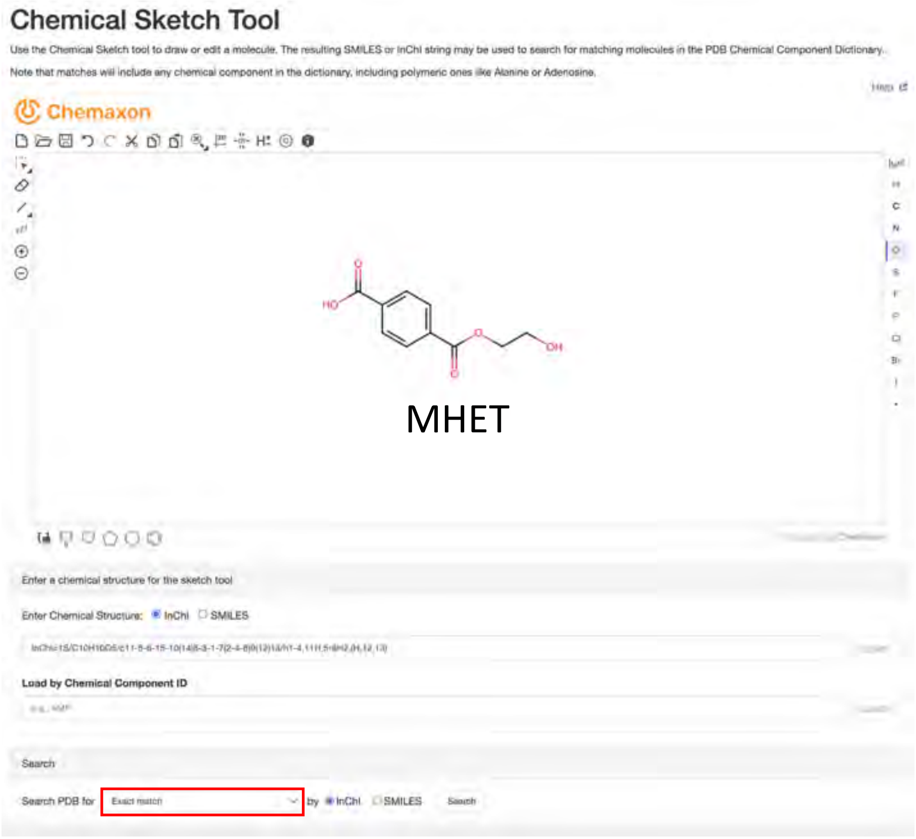
Source Organism Taxonomy Name (Full Lineage): https://tinyurl.com/rcsb-search2

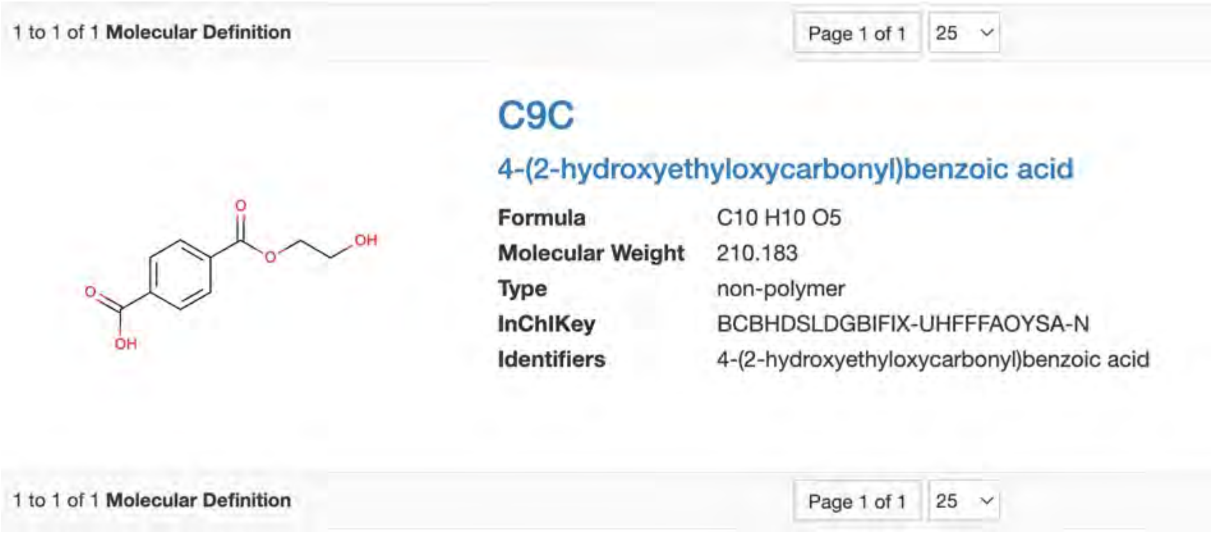


Narrowing the Search – Chemical Similarity

How can we focus our search to address our question(s)?

Chemical Similarity: https://tinyurl.com/rcsb-search3



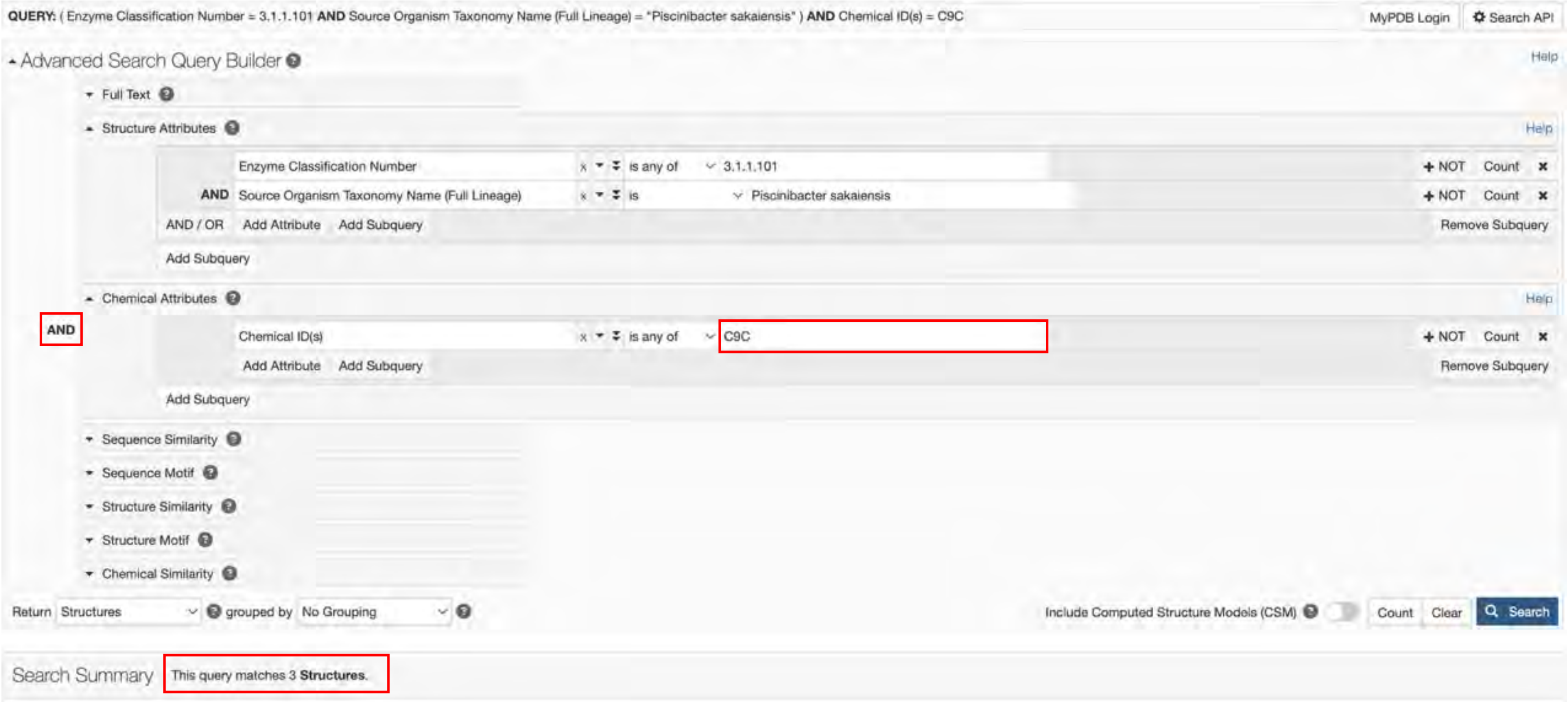


Chemical ID (C9C) can be used to narrow search further

Narrowing the Search – Chemical ID

How can we focus our search to address our question(s)?

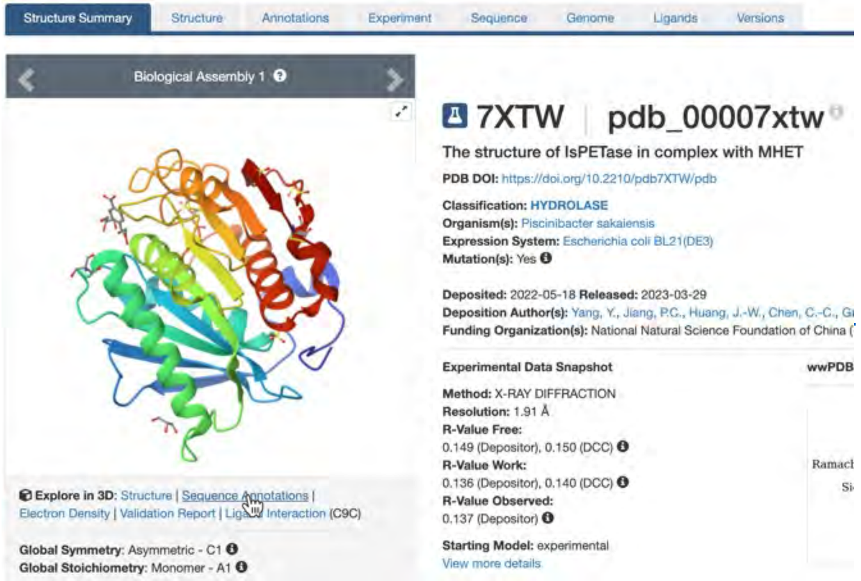
Chemical ID(s): https://tinyurl.com/rcsb-search4



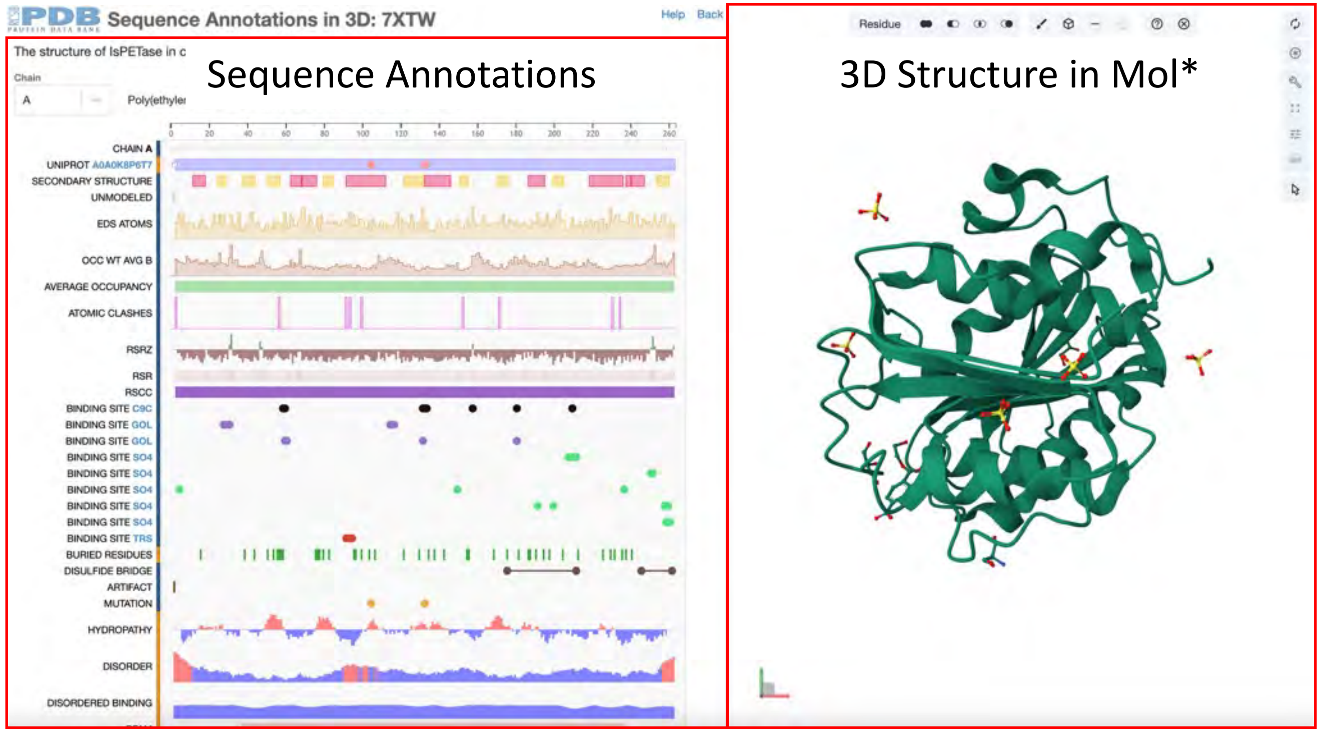
Explore Sequence-Structure Relationships Using the Sequence Annotations Viewer and Mol*

Structure Summary → Sequence Annotation combined with Mol*

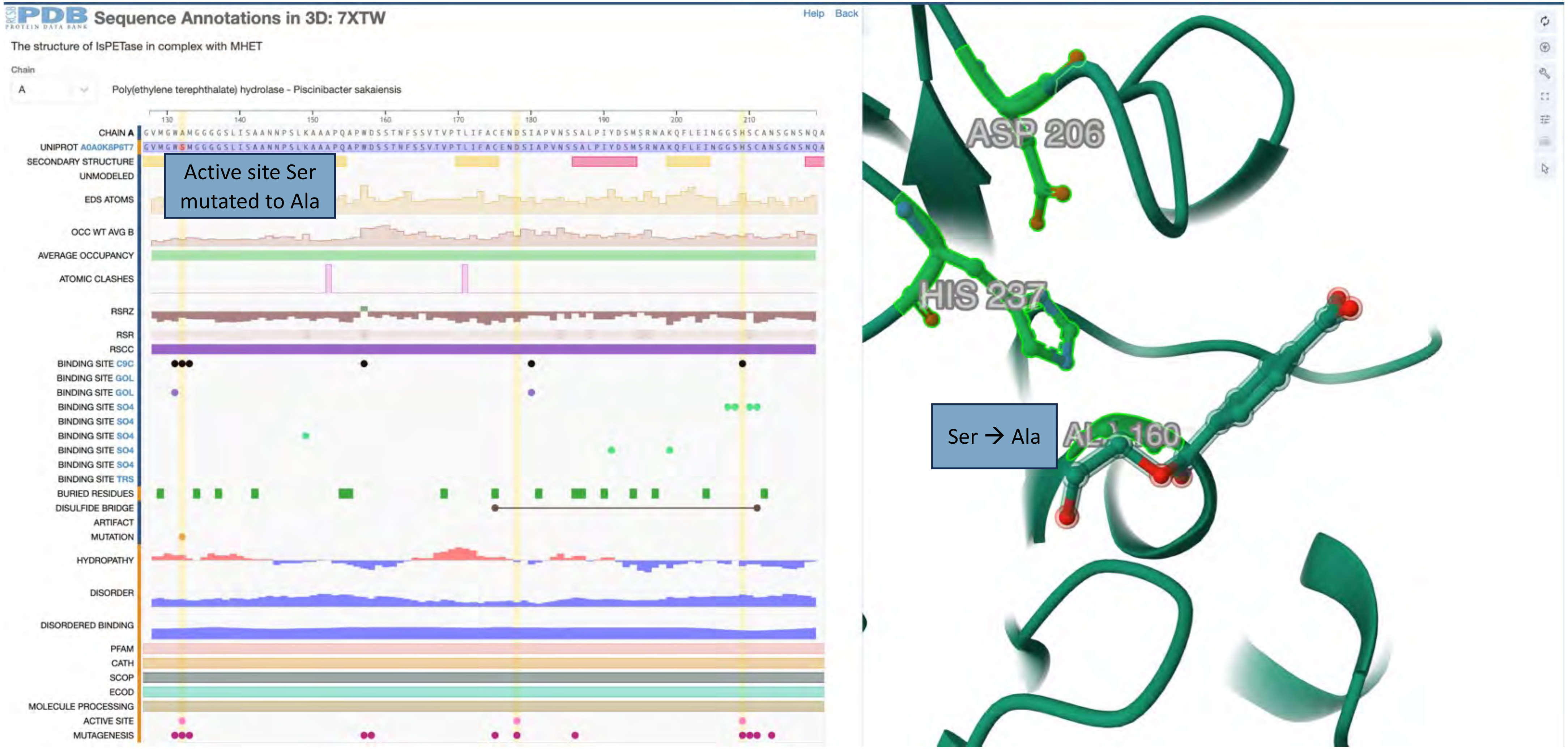
https://www.rcsb.org/structure/7XTW → https://www.rcsb.org/3d-sequence/7XTW?assemblyId=1



→

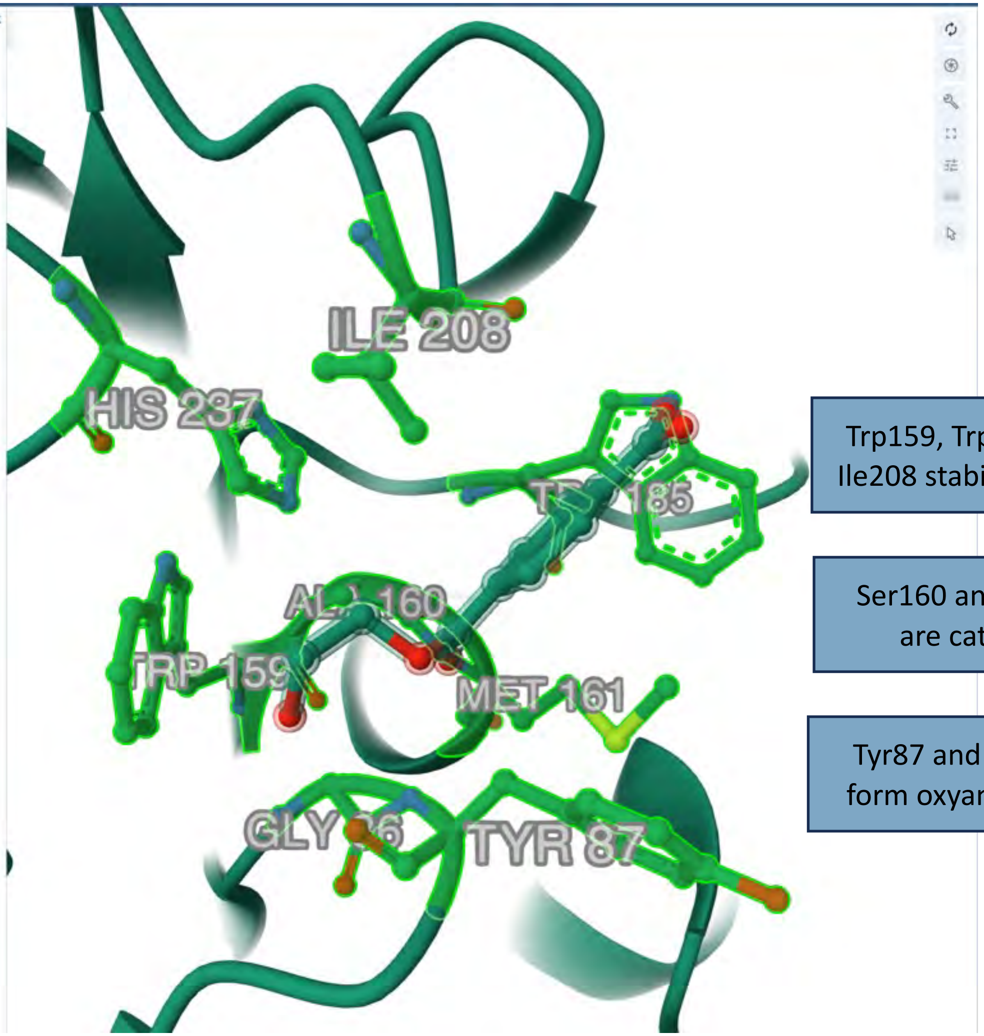


MHET-Bound State Captured via Active Site Mutation



PDB ID pdb_00007xtw, https://tinyurl.com/3d-seq-7xtw

Sequence Annotation Shows MHET Binding Site Residues



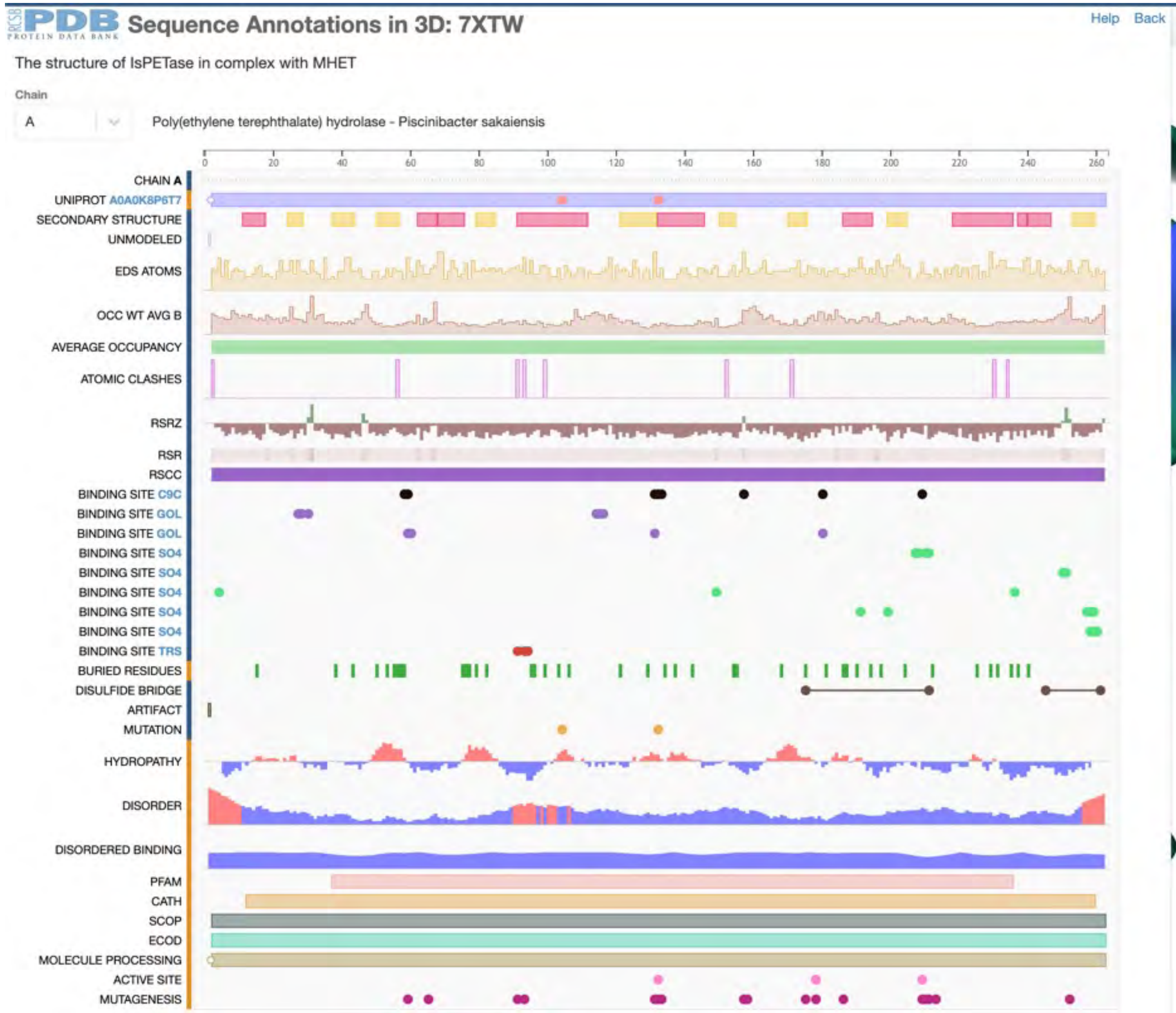
Trp159, Trp185, and Ile208 stabilize ligand

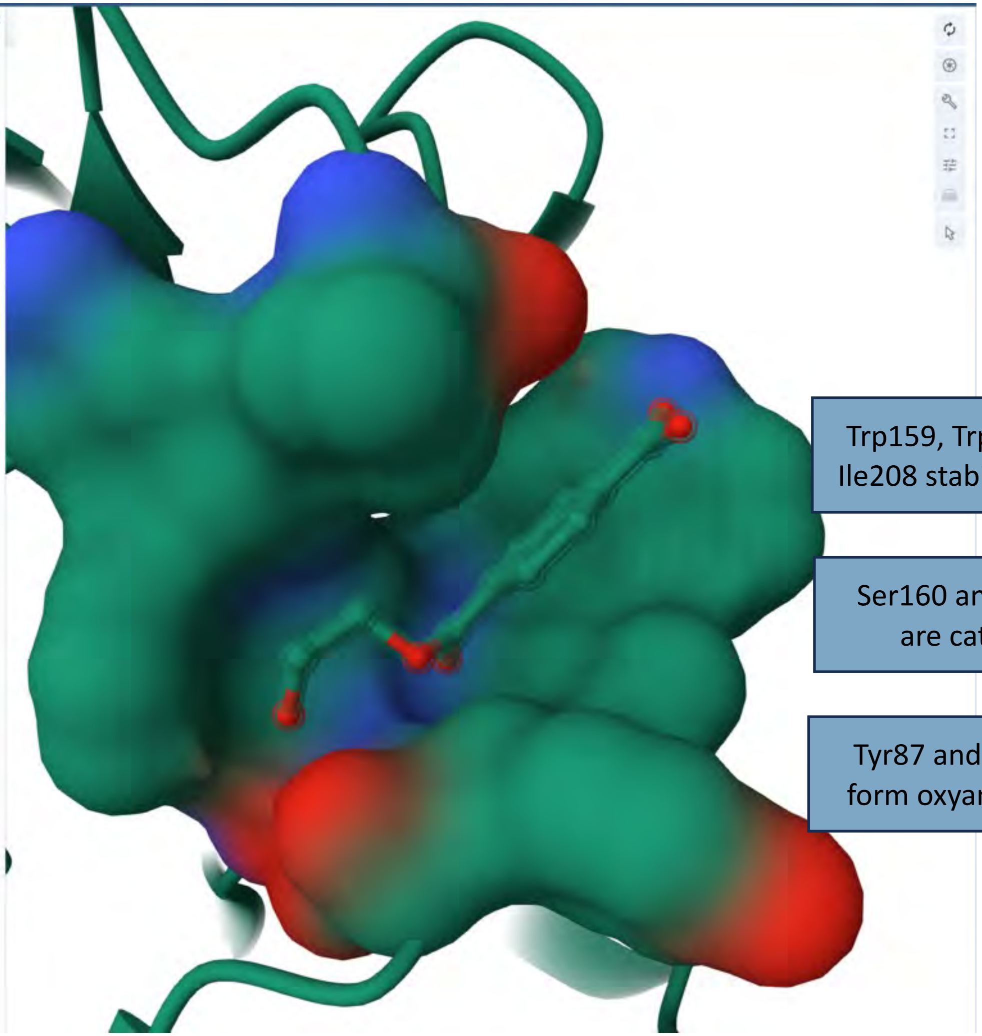
Ser160 and His237 are catalytic

Tyr87 and Met161 form oxyanion hole

PDB ID pdb_00007xtw, https://tinyurl.com/3d-seq-7xtw

Sequence Annotation Shows MHET Binding Site Residues





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Ser160 and His237 are catalytic

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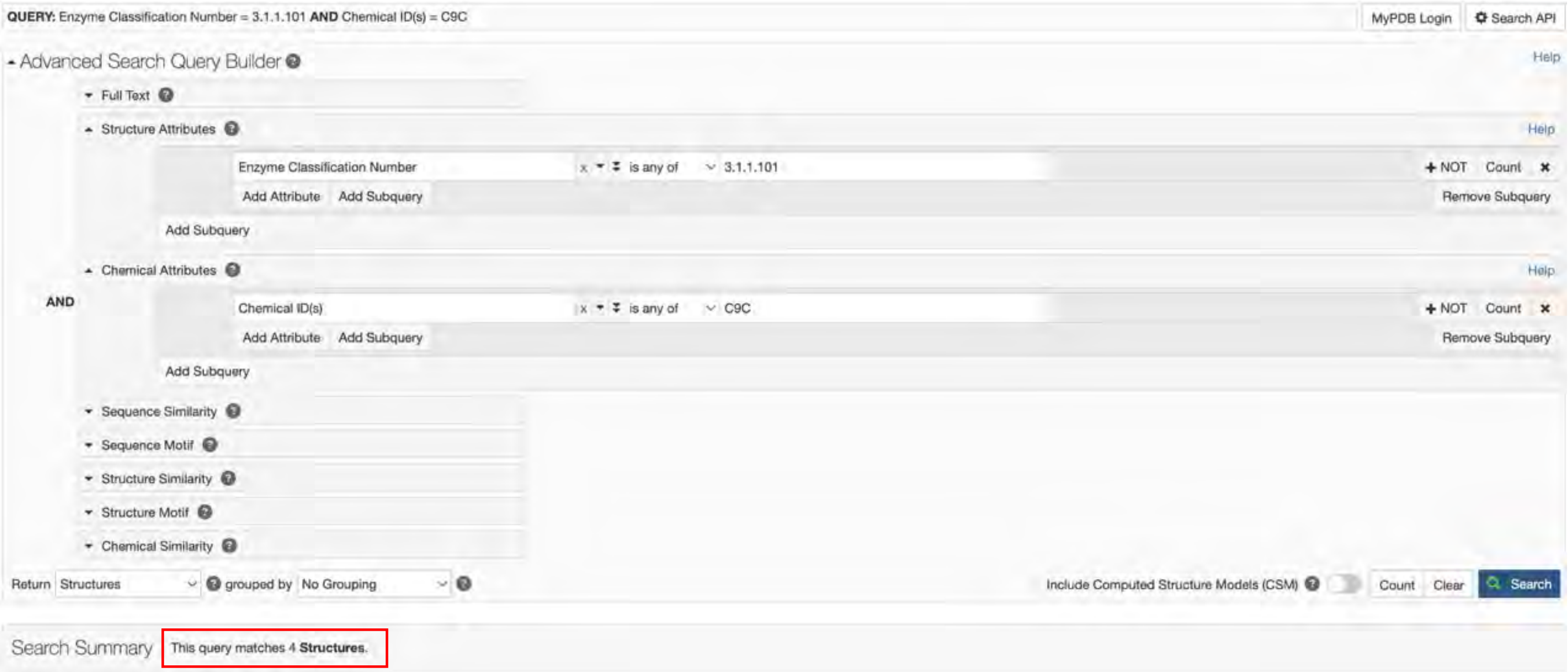
PDB ID pdb_00007xtw, https://tinyurl.com/3d-seq-7xtw

Comparison of MHET Binding Modes

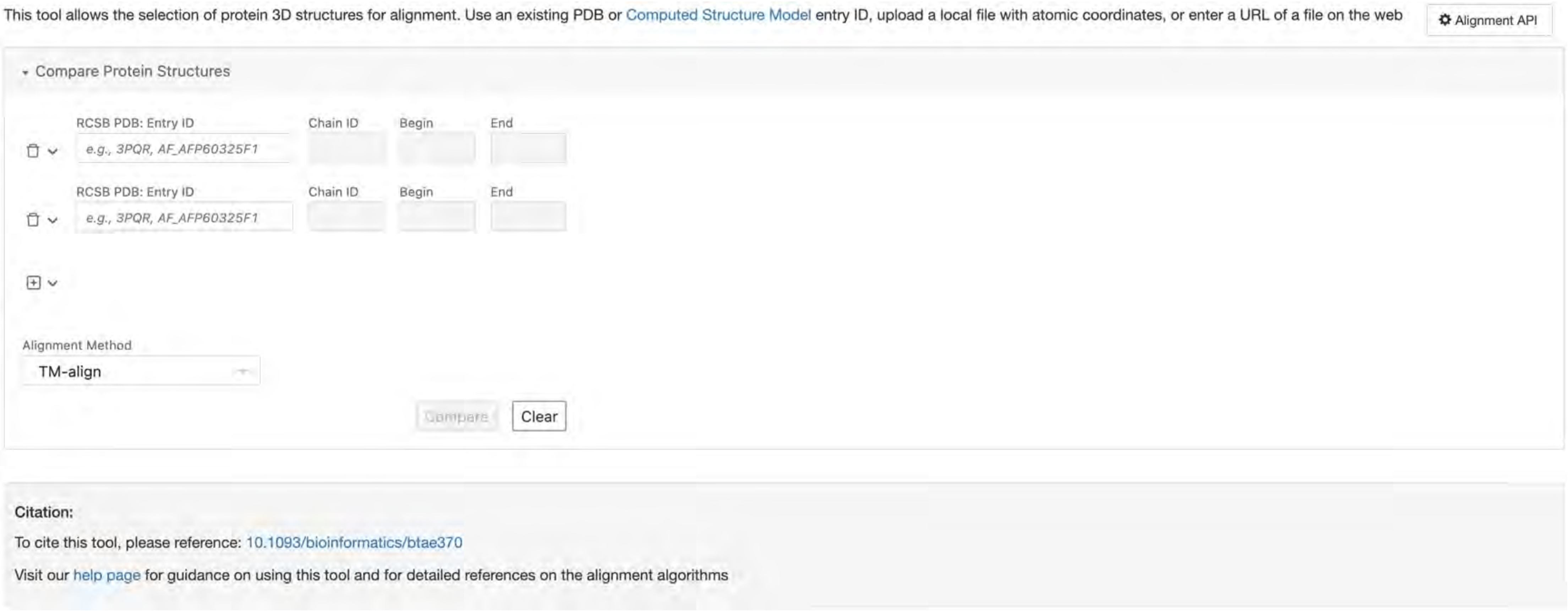
Broaden search outside of *Piscinibacter sakaiensis*

https://tinyurl.com/rcsb-search5



Gain Scientific Insights from Pairwise Structure Alignment

https://www.rcsb.org/alignment



Pairwise Structure Alignment Reveals Amino Acid Substitutions Repositioning Ligand

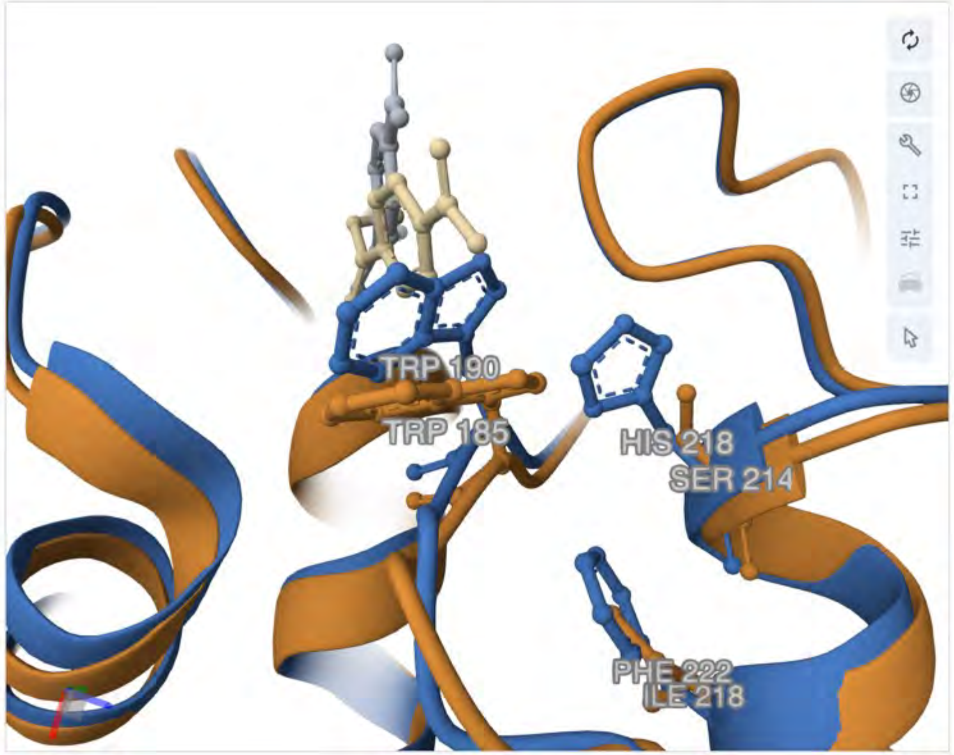
Entry	Chain	RMSD	TM-score	Identity	Aligned Residues	Sequence Length	Modeled Residues
7XTW	A	-	-	-	-	262	261
7VVE	A	1.39	0.92	48%	250	260	258

Sequence Alignment in 3D

Export Copy Link

Substitutions (His → Ser and Phe → Ile) provide active site flexibility, thereby increasing enzyme activity

Read more here:
[Chen *et al.* (2021) *Nat Catal 4*, 425-430]



[Structure alignment] of PDB IDs: [pdb_00007xtw] and [pdb_00007vve], https://tinyurl.com/pairwise-7xtw-7vve

Conclusions

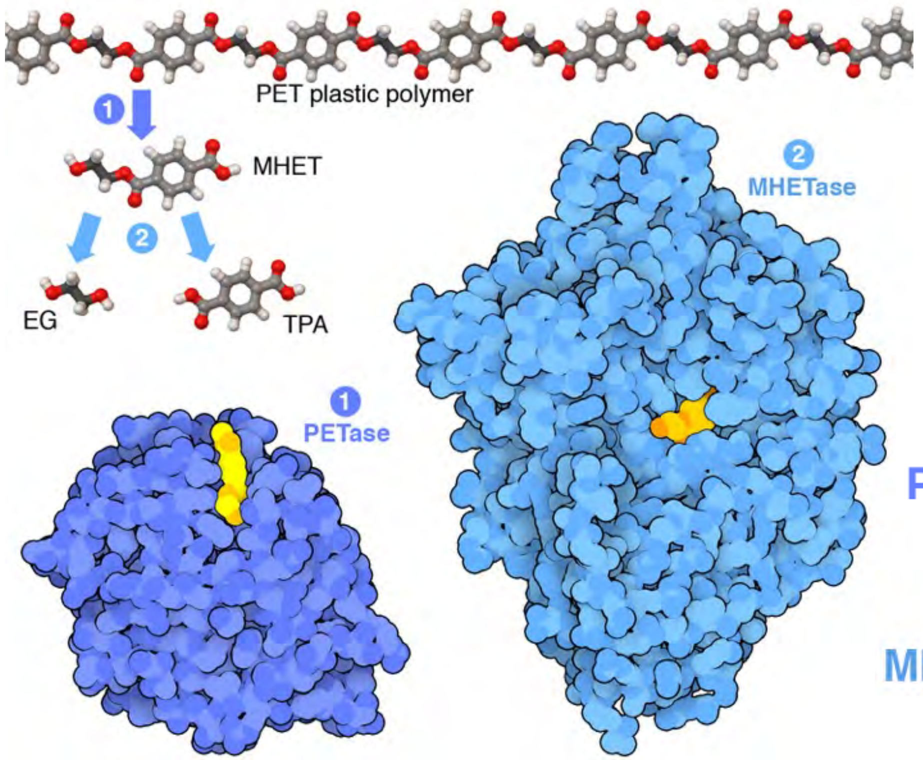
Conclusions

- 3D structures archived in the PDB are freely available to help guide biotechnology research
- Advanced Search provided an entry point for RCSB.org to find structures based on desired search attributes with Boolean logic
- Sequence Annotation highlighted key residues for PET substrate binding
- The Pairwise Structure Alignment highlighted His → Ser and Phe → Ile substitutions in *Ps*PETase that afford active site flexibility and increase activity

Reference Materials on PET-Degrading Enzymes

Molecule of the Month: Plastic-eating Enzymes

https://pdb101.rcsb.org/motm/277



Entries highlighted in this webinar:
Primary citation for entry pdb_00007xtw:
Yang *et al.* (2023) *Nat Commun 14*, 1645
Primary citation for entry pdb_00007vve:
Zeng et al. (2022) ACS Catal 12(5), 3033-3040

1 PETase — Primary citation for entry pdb_00005xh3:
Han *et al.* (2017) *Nat Commun 8*, 2106

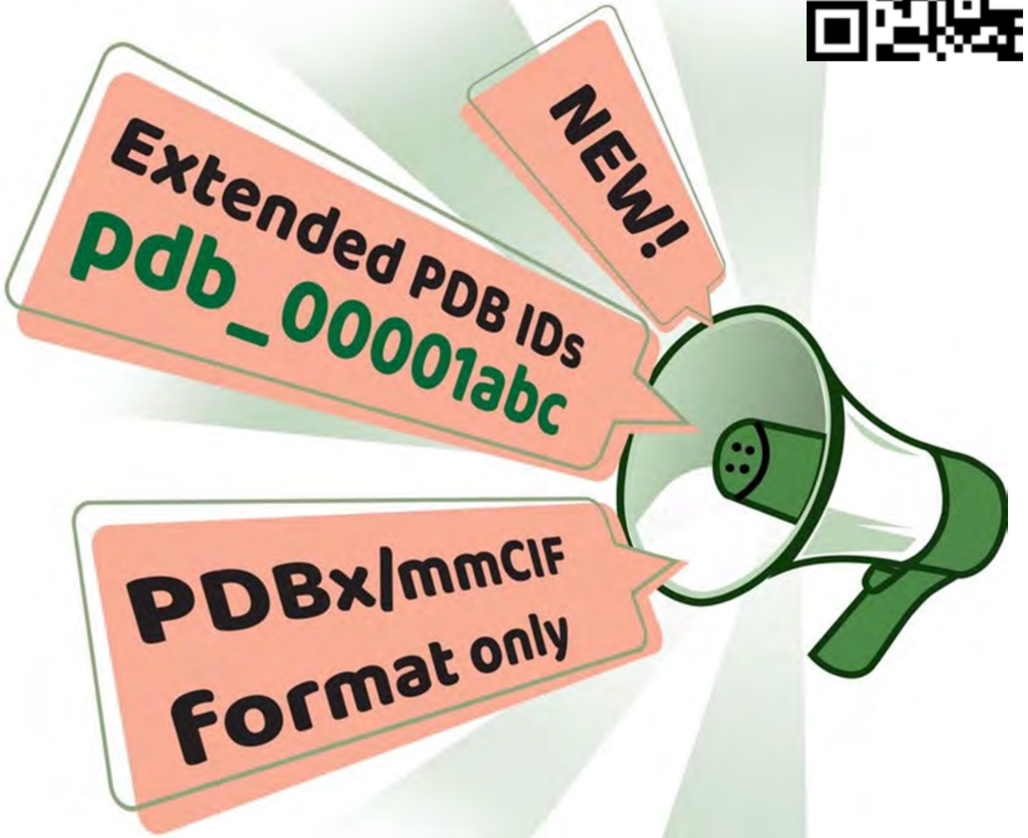
2 MHETase — Primary citation for entry pdb_00006qga:
Palm *et al.* (2019) *Nat Commun 10*, 1717

Transition to Extended PDB IDs and PDBx/mmCIF File Format

By 2028
4-character PDB IDs (*e.g.* **1abc**) will be fully allocated.
After that, all new entries will be assigned only extended PDB IDs.

Extended PDB ID Format
8 alphanumeric characters with prefix *pdb_*
e.g. **pdb_00001abc**

Entries with extended PDB IDs will be available only in PDBx/mmCIF format.
All PDB users, including software developers, and journal editors must transition to this format.
Start using extended IDs and PDBx/mmCIF data files today



WORLDWIDE PDB PROTEIN DATA BANK

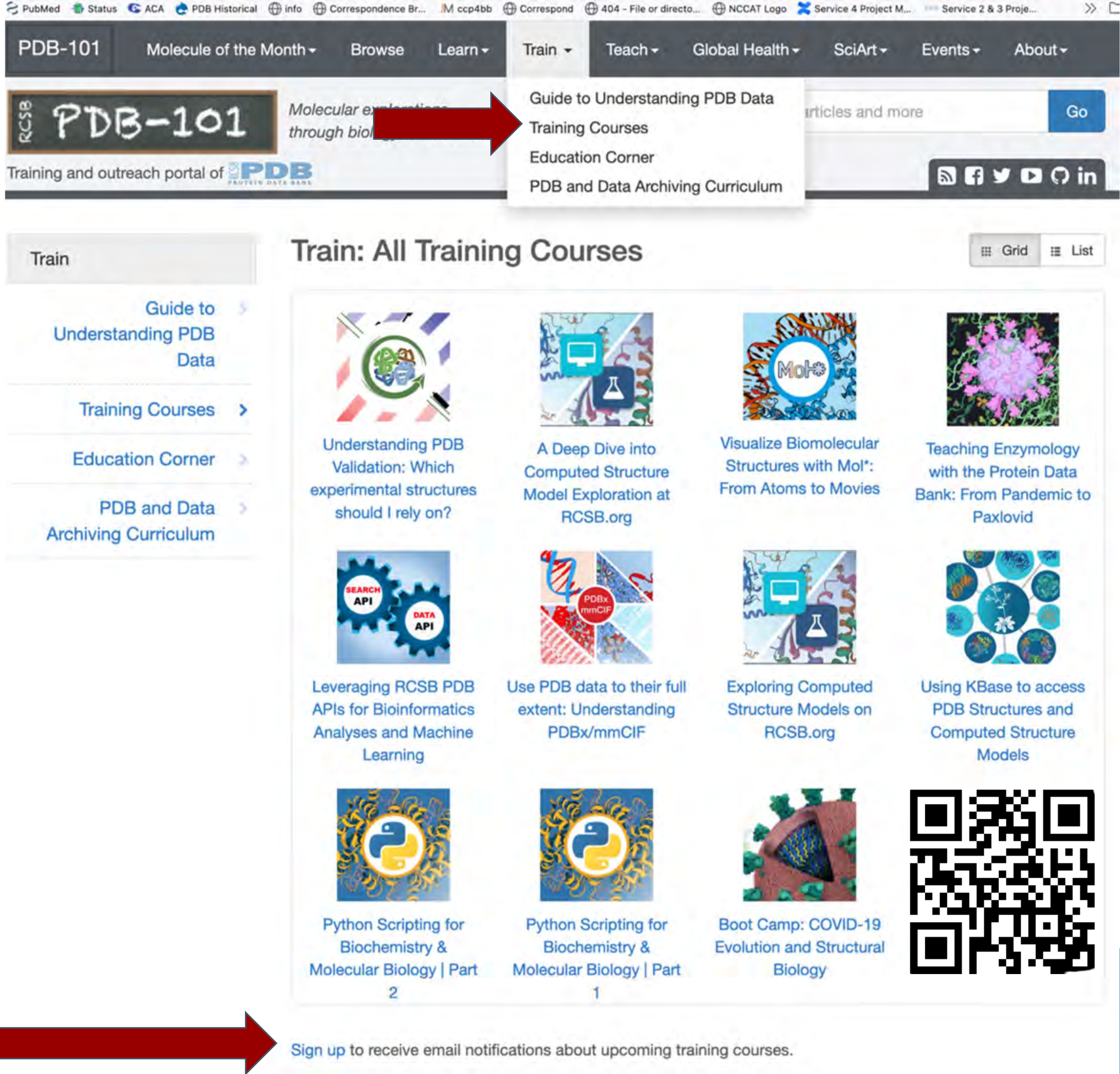
wwpdb.org/documentation/new-format-for-pdb-ids

Course Materials

Course recordings and presentations may be published at PDB-101.rcsb.org later this year.

They will not be emailed separately.

Sign up to receive emails about upcoming training events



RCSB PDB
PROTEIN DATA BANK

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