

# Searching the PDB for High-Quality Ligand-Bound Structures

Chenghua Shao, Ph.D.  
Scientific Software Developer, RCSB PDB  
Institute for Quantitative Biomedicine  
Rutgers, The State University of New Jersey  
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# Outline

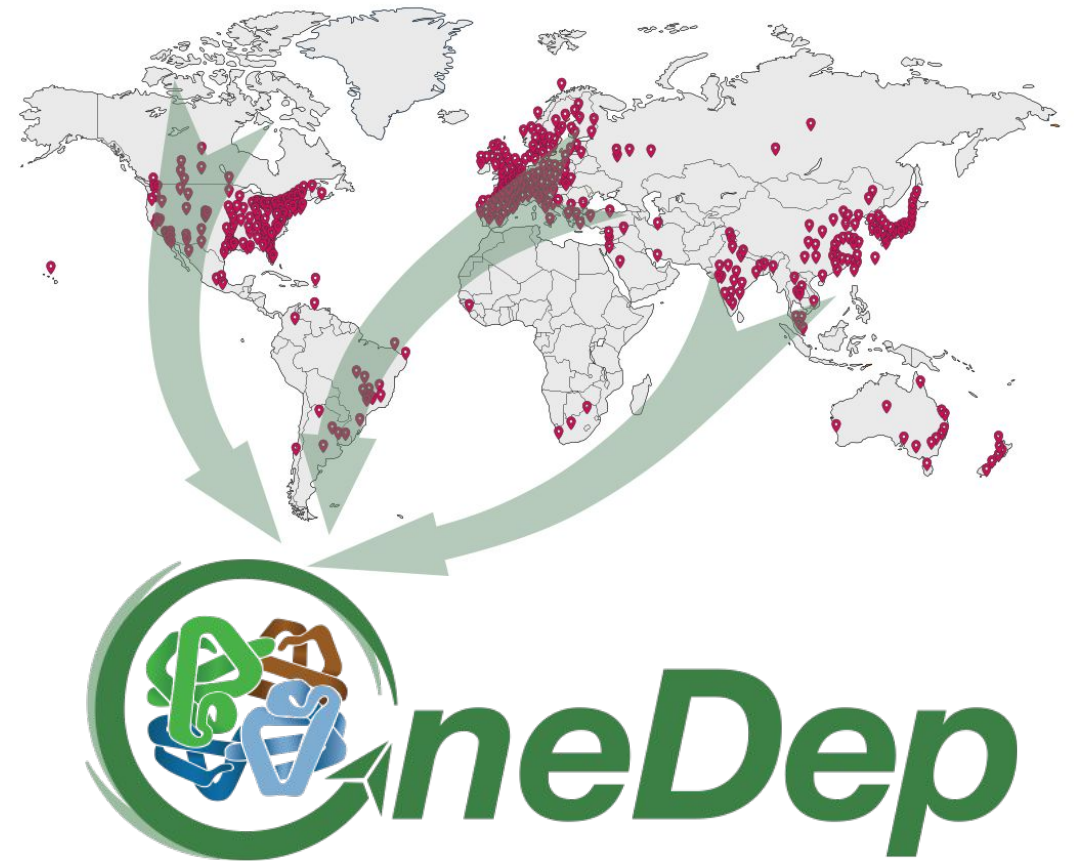
- Chemical Annotation: Ligand data in the wwPDB Chemical Component Dictionary (CCD)
- Quality Assessment: Ligand validation and quality metrics
- Quality Discernment: Ligand quality comparison in multiple structures
- Demonstration: Searching for ligands of better quality
  - Manually (RCSB.org)
  - Programmatically (RCSB PDB APIs)



# Ligand Data in the PDB

# Protein Data Bank (PDB) Archive

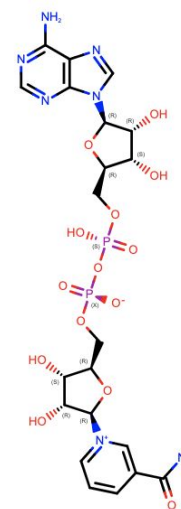
- 1st open access digital data resource in all of Biology established in 1971
- Single global archive for >240,000 protein and nucleic acid experimental structures
- Managed jointly by Worldwide PDB (wwPDB) regional partners
  - RCSB PDB (US)
  - Protein Data Bank in Europe (PDBe)
  - PDB Japan (PDBj)
  - Associate Member: PDB China (PDBc)
  - Plus EMDB and BMRB
- All PDB data are validated, deposited, and biocurated using wwPDB OneDep



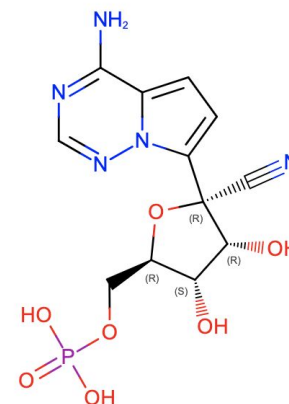
# Small Molecules in PDB

*Understanding interactions between proteins and small molecules (ligands) is key to understanding biological function*

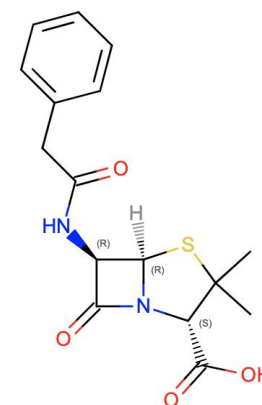
- >70% of PDB structures contain non-polymer small molecules as part of macromolecular complex structures
- All 47,000+ unique chemical components are described in the PDB Chemical Component Dictionary (CCD) with unique IDs
- Include drugs, enzyme cofactors, activators, inhibitors, substrates, intermediates, synthetic mimics, solvents, salts, ions, ...
- Each CCD entry is a chemically unique molecule, which may adopt different structural conformation in different structures



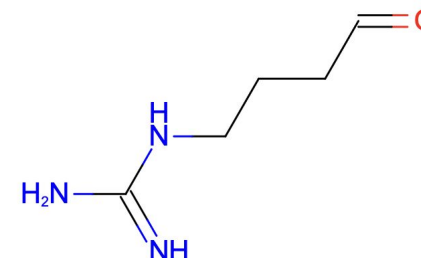
NAD in 1GPD (1975)  
CCD ID: NAD



Remdesivir in 7BV2 (2020)  
CCD ID: F86



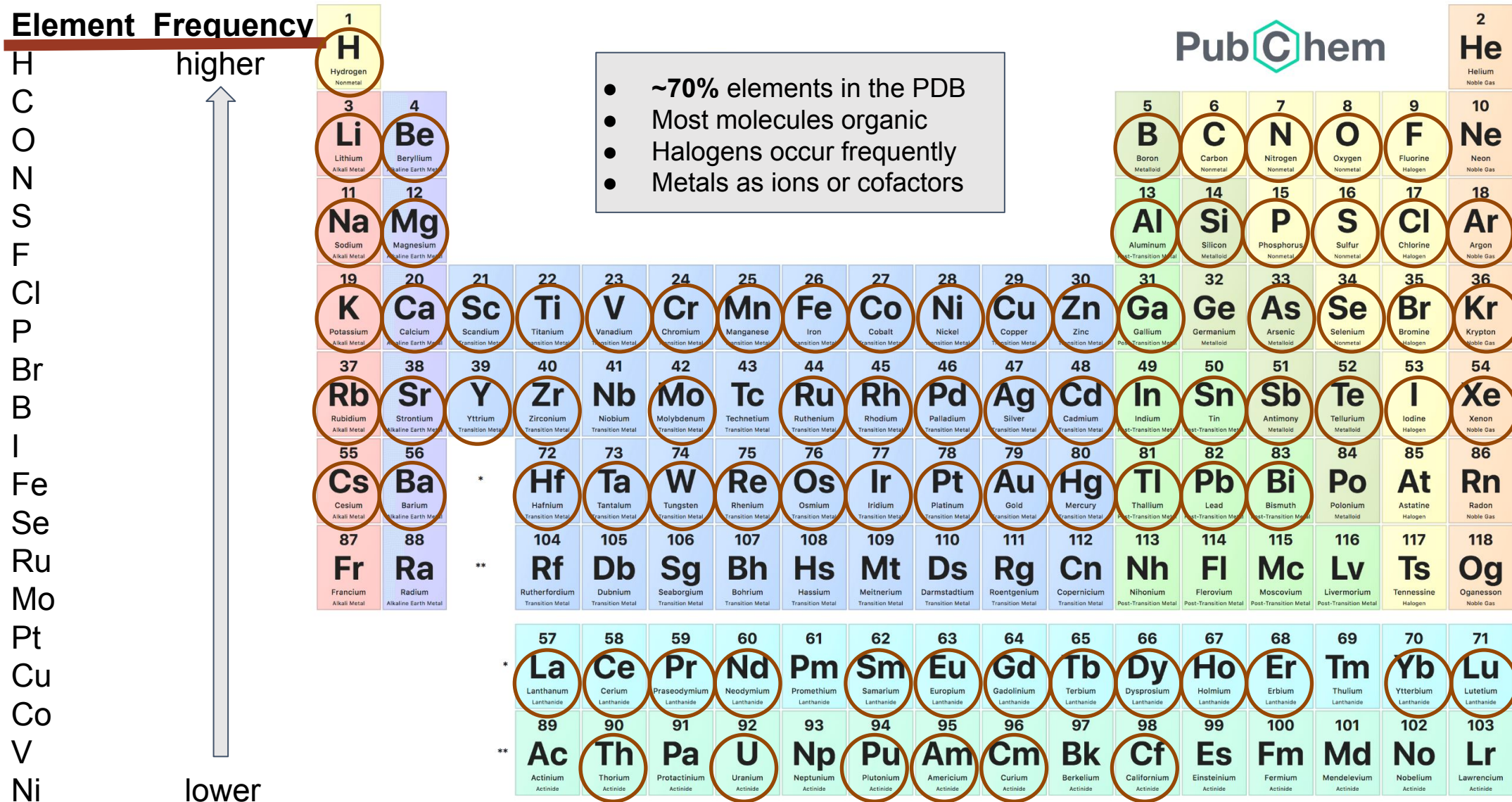
Penicillin G in 1FXV (2000)  
CCD ID: PNN



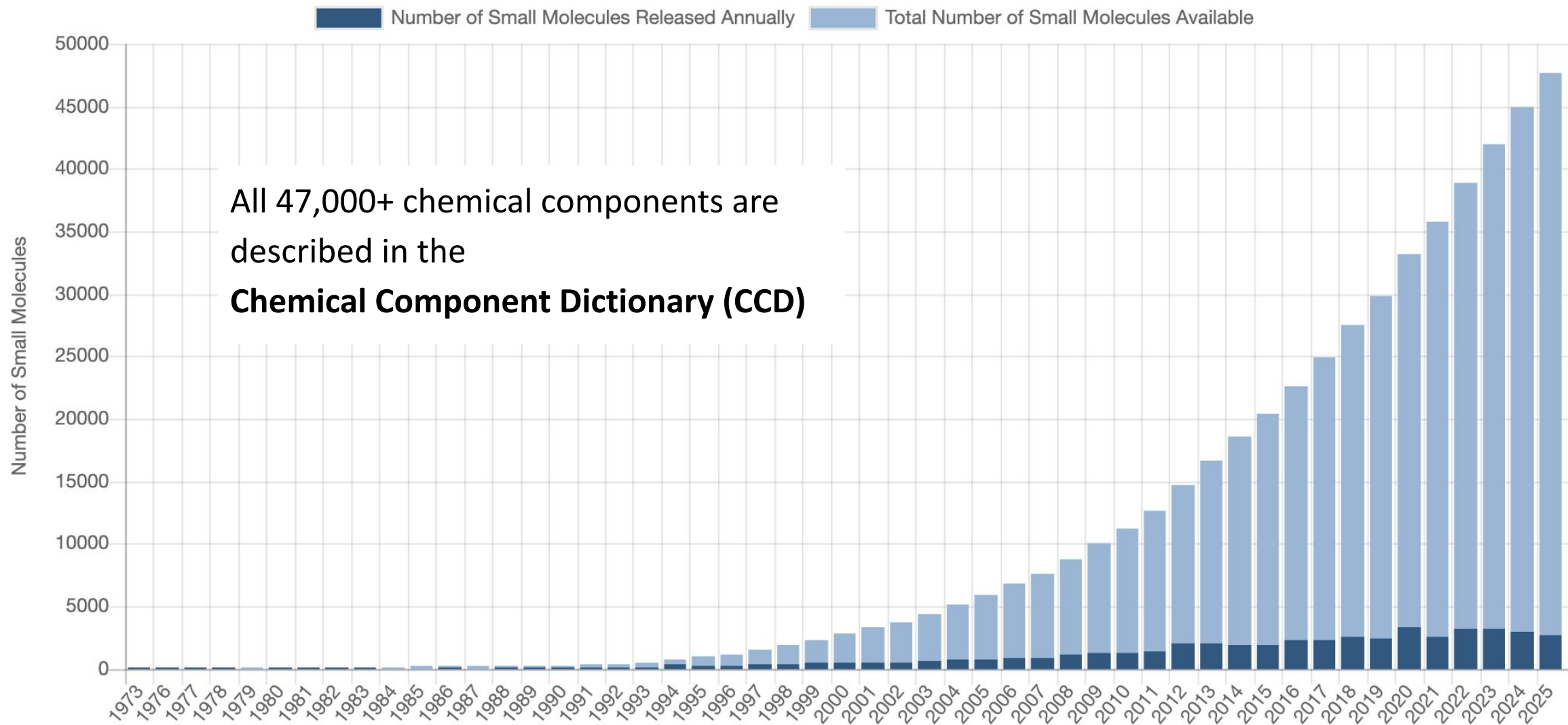
N-(4-oxobutyl)guanidine in  
9CPZ (2024)  
CCD ID: A1AZK

# Chemical Element Coverage of PDB

In  
PDB



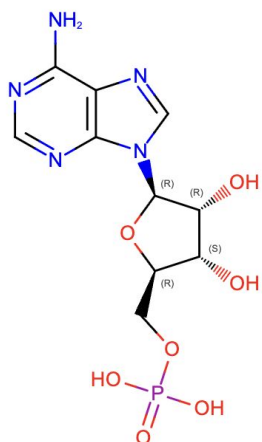
# Number of Ligands Grows Annually



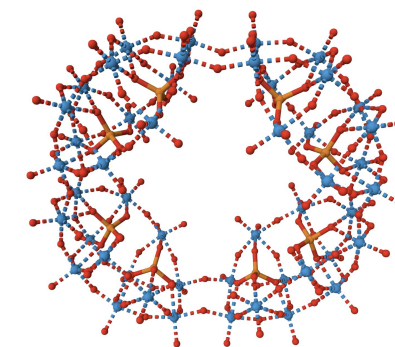
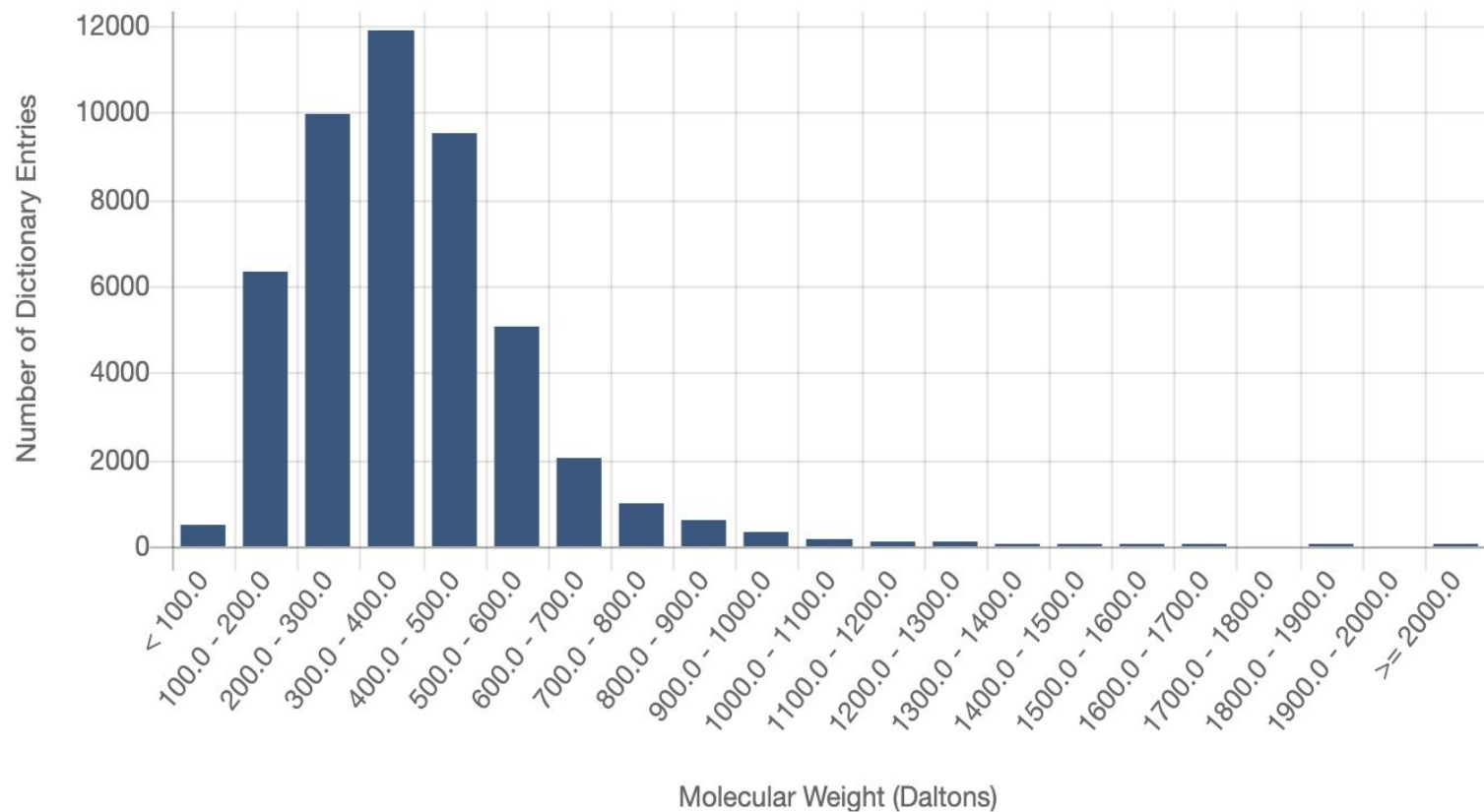
# Size Distribution of CCD Entries

$\text{Ca}^{+2}$

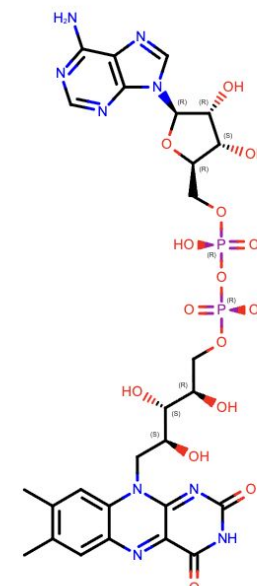
CA: Ca, 40 Da



AMP:C10 H14 N5 O7 P, 347 Da



IR0: O184 P8 W48, 12016 Da

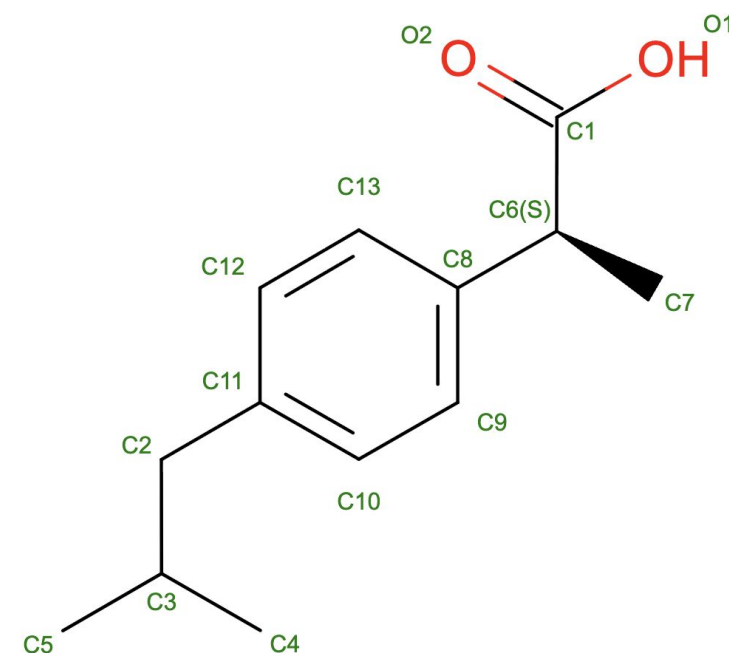


FAD:C27 H33 N9 O15 P2, 785 Da

# CCD Entries Contain Summary Information

```
data_IBP
#

_chem_comp.id          IBP
_chem_comp.name        IBUPROFEN
_chem_comp.type        NON-POLYMER
_chem_comp.pdbx_type   HETAIN
_chem_comp.formula     "C13 H18 O2"
_chem_comp.mon_nstd_parent_comp_id ?
_chem_comp.pdbx_synonyms "2-(4-ISOBUTYLPHENYL) PROPIONIC ACID"
_chem_comp.pdbx_formal_charge 0
_chem_comp.pdbx_initial_date 2000-04-10
_chem_comp.pdbx_modified_date 2020-06-17
_chem_comp.pdbx_ambiguous_flag N
_chem_comp.pdbx_release_status REL
_chem_comp.pdbx_replaced_by ?
_chem_comp.pdbx_replaces ?
_chem_comp.formula_weight 206.281
_chem_comp.one_letter_code ?
_chem_comp.three_letter_code IBP
_chem_comp.pdbx_model_coordinates_details ?
_chem_comp.pdbx_model_coordinates_missing_flag N
_chem_comp.pdbx_ideal_coordinates_details ?
_chem_comp.pdbx_ideal_coordinates_missing_flag N
_chem_comp.pdbx_model_coordinates_db_code 1EQG
...
```



Example shown is IBP: Ibuprofen

# CCD Entries Contain Coordinate Information

```

loop_
  chem_comp_atom.comp_id
  chem_comp_atom.atom_id
  chem_comp_atom.alt_atom_id
  chem_comp_atom.type_symbol
  _chem_comp_atom.charge
  chem_comp_atom.pdbx_align
  chem_comp_atom.pdbx_aromatic_flag
  chem_comp_atom.pdbx_leaving_atom_flag
  chem_comp_atom.pdbx_stereo_config
  chem_comp_atom.model_Cartn_x
  chem_comp_atom.model_Cartn_y
  chem_comp_atom.model_Cartn_z
  chem_comp_atom.pdbx_model_Cartn_x_ideal
  chem_comp_atom.pdbx_model_Cartn_y_ideal
  chem_comp_atom.pdbx_model_Cartn_z_ideal
  _chem_comp_atom.pdbx_component_atom_id
  _chem_comp_atom.pdbx_component_comp_id
  _chem_comp_atom.pdbx_ordinal
  
```

Atom Names

Element Types

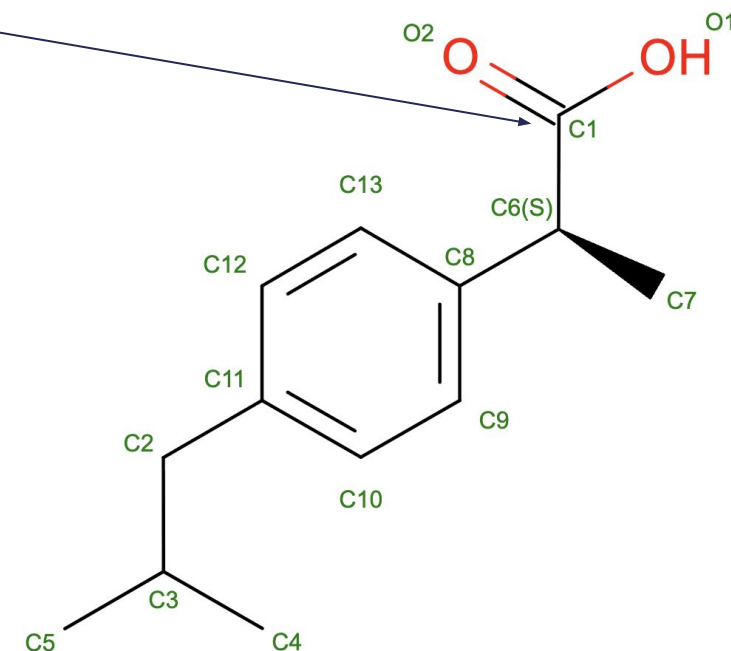
Aromaticity

R/S-Stereo Specificity

Model Coordinates

Ideal Coordinates by Corina  
(not validation target)

| IBP | C1  | C1  | C | 0 | 1 | N | N | N | 67.886 | 20.551 | 192.867 | -0.364 | -0.176 | -3.442 | C1  | IBP | 1  |
|-----|-----|-----|---|---|---|---|---|---|--------|--------|---------|--------|--------|--------|-----|-----|----|
| IBP | C2  | C2  | C | 0 | 1 | N | N | N | 68.473 | 23.285 | 186.859 | -0.931 | -0.349 | 2.970  | C2  | IBP | 2  |
| IBP | C3  | C3  | C | 0 | 1 | N | N | N | 68.608 | 24.781 | 187.174 | 0.010  | 0.473  | 3.851  | C3  | IBP | 3  |
| IBP | C4  | C4  | C | 0 | 1 | N | N | N | 68.059 | 25.613 | 186.018 | -0.455 | 0.394  | 5.307  | C4  | IBP | 4  |
| IBP | C5  | C5  | C | 0 | 1 | N | N | N | 70.054 | 25.158 | 187.423 | 1.430  | -0.083 | 3.739  | C5  | IBP | 5  |
| IBP | C6  | C6  | C | 0 | 1 | N | N | S | 67.852 | 19.721 | 191.594 | 0.825  | -0.050 | -2.526 | C6  | IBP | 6  |
| IBP | C7  | C7  | C | 0 | 1 | N | N | N | 66.601 | 18.848 | 191.541 | 1.515  | 1.293  | -2.768 | C7  | IBP | 7  |
| IBP | C8  | C8  | C | 0 | 1 | Y | N | N | 67.991 | 20.663 | 190.375 | 0.366  | -0.129 | -1.093 | C8  | IBP | 8  |
| IBP | C9  | C9  | C | 0 | 1 | Y | N | N | 69.229 | 20.777 | 189.706 | 0.844  | -1.130 | -0.268 | C9  | IBP | 9  |
| IBP | C10 | C10 | C | 0 | 1 | Y | N | N | 69.380 | 21.620 | 188.580 | 0.424  | -1.201 | 1.046  | C10 | IBP | 10 |
| IBP | C11 | C11 | C | 0 | 1 | Y | N | N | 68.296 | 22.385 | 188.074 | -0.473 | -0.271 | 1.536  | C11 | IBP | 11 |
| IBP | C12 | C12 | C | 0 | 1 | Y | N | N | 67.059 | 22.273 | 188.742 | -0.955 | 0.726  | 0.710  | C12 | IBP | 12 |
| IBP | C13 | C13 | C | 0 | 1 | Y | N | N | 66.907 | 21.429 | 189.870 | -0.531 | 0.800  | -0.603 | C13 | IBP | 13 |
| IBP | O1  | O1  | O | 0 | 1 | N | N | N | 69.056 | 20.622 | 193.431 | -0.194 | -0.134 | -4.773 | O1  | IBP | 14 |
| IBP | O2  | O2  | O | 0 | 1 | N | N | N | 66.901 | 21.095 | 193.346 | -1.471 | -0.316 | -2.979 | O2  | IBP | 15 |



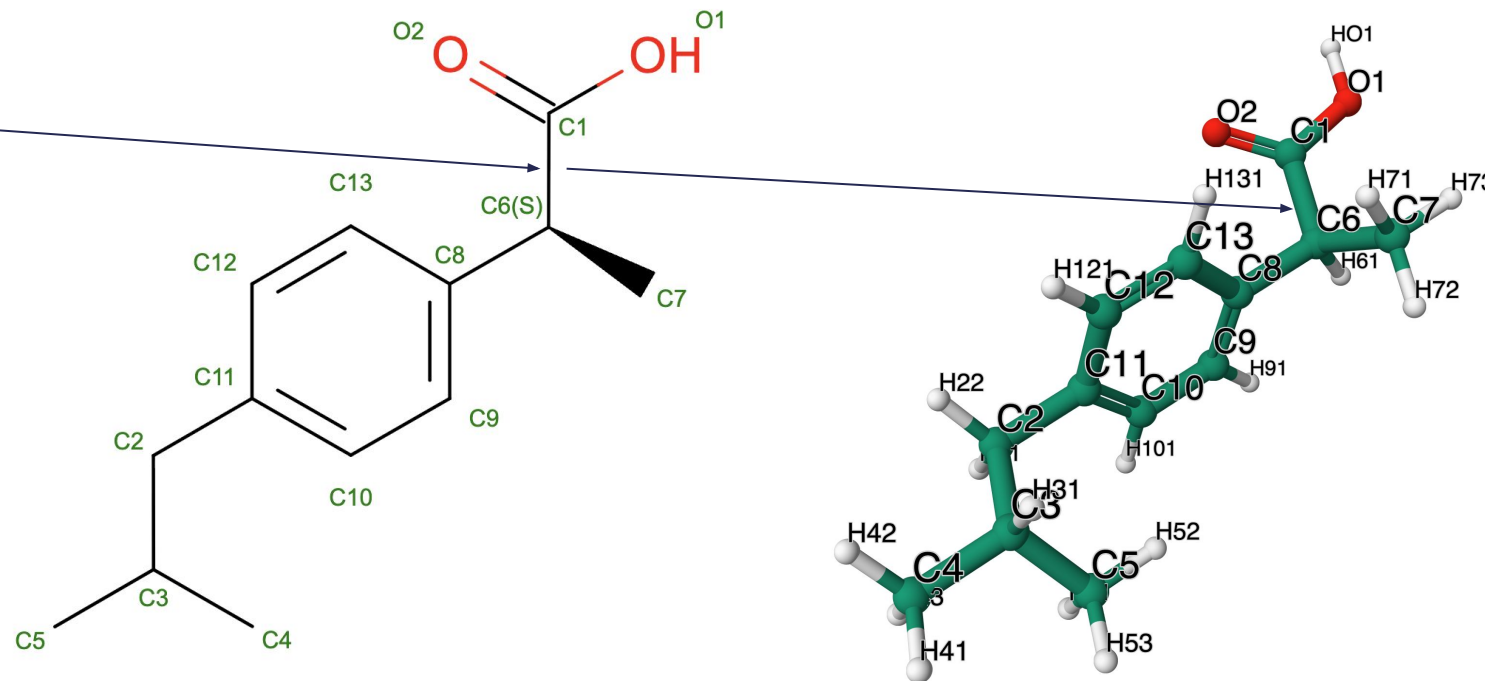
IBP: Ibuprofen

# CCD Entries Contain Explicit Bond Information

```
loop_  
_chem_comp_bond.comp_id  
_chem_comp_bond.atom_id_1  
_chem_comp_bond.atom_id_2  
_chem_comp_bond.value_order  
_chem_comp_bond.pdbx_aromatic_flag  
_chem_comp_bond.pdbx_stereo_config  
chem_comp_bond.pdbx_ordinal
```

|     |    |     |      |   |   |    |
|-----|----|-----|------|---|---|----|
| IBP | C1 | C6  | SING | N | N | 1  |
| IBP | C1 | O1  | SING | N | N | 2  |
| IBP | C1 | O2  | DOUB | N | N | 3  |
| IBP | C2 | C3  | SING | N | N | 4  |
| IBP | C2 | C11 | SING | N | N | 5  |
| IBP | C2 | H21 | SING | N | N | 6  |
| IBP | C2 | H22 | SING | N | N | 7  |
| IBP | C3 | C4  | SING | N | N | 8  |
| IBP | C3 | C5  | SING | N | N | 9  |
| IBP | C3 | H31 | SING | N | N | 10 |
| IBP | C4 | H41 | SING | N | N | 11 |
| IBP | C4 | H42 | SING | N | N | 12 |
| IBP | C4 | H43 | SING | N | N | 13 |
| IBP | C5 | H51 | SING | N | N | 14 |
| IBP | C5 | H52 | SING | N | N | 15 |
| IBP | C5 | H53 | SING | N | N | 16 |
| IBP | C6 | C7  | SING | N | N | 17 |
| IBP | C6 | C8  | SING | N | N | 18 |

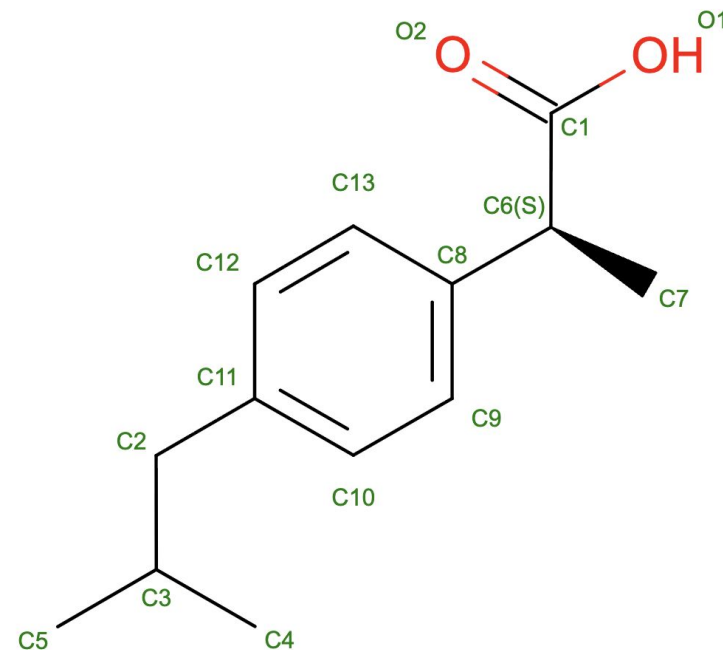
...



IBP: Ibuprofen

# CCD Entries Contain Descriptors and Identifiers

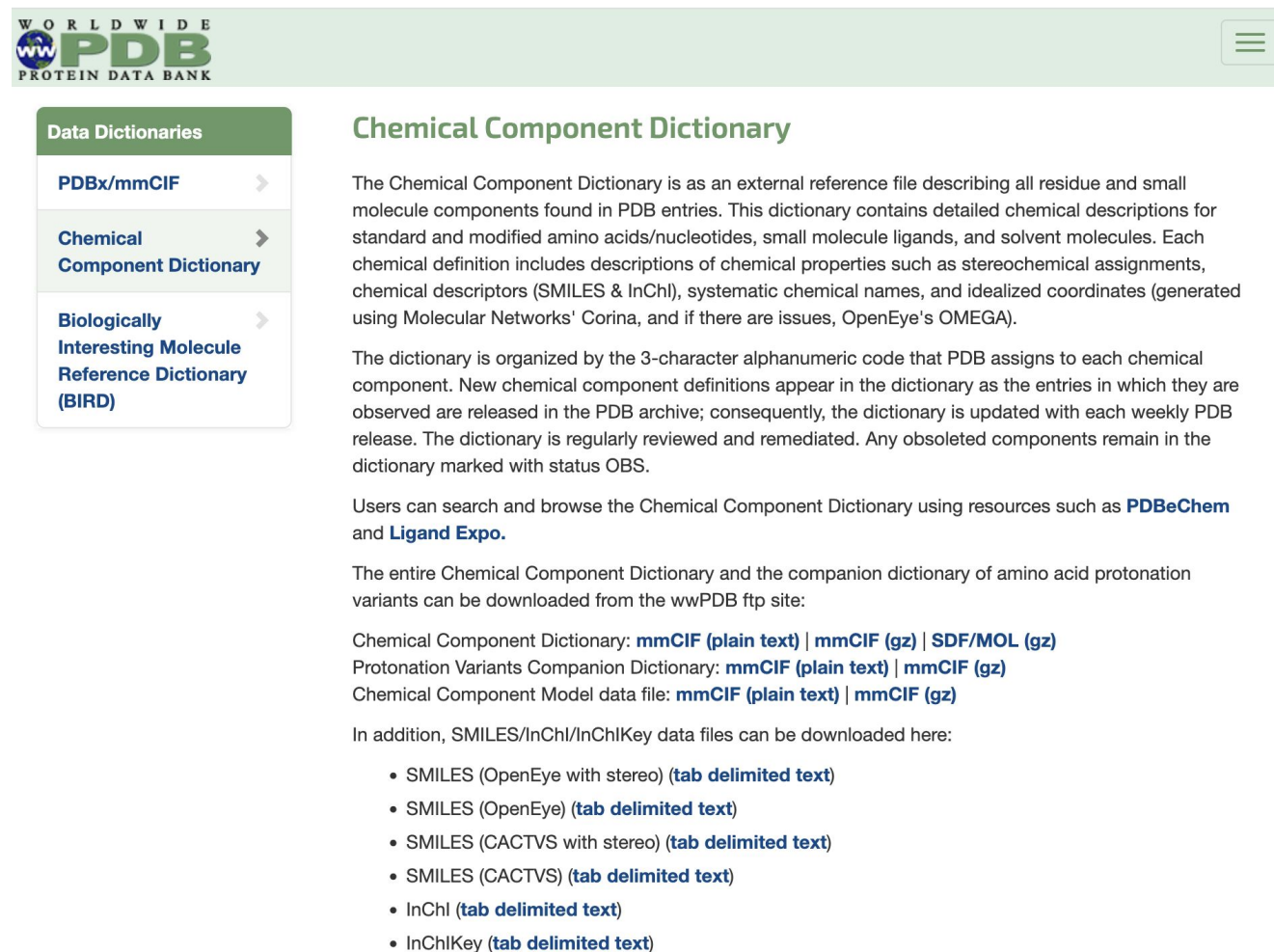
```
loop_
_pdbx_chem_comp_descriptor.comp_id
_pdbx_chem_comp_descriptor.type
_pdbx_chem_comp_descriptor.program
_pdbx_chem_comp_descriptor.program_version
_pdbx_chem_comp_descriptor.descriptor
IBP  SMILES          ACDLabs          10.04  "O=C(O)C(c1ccc(cc1)CC(C)C)C"
IBP  SMILES_CANONICAL CACTVS          3.341  "CC(C)Cc1ccc(cc1)[C@H](C)C(=O)O"
IBP  SMILES          CACTVS          3.341  "CC(C)Cc1ccc(cc1)[CH](C)C(=O)O"
IBP  SMILES_CANONICAL "OpenEye OEToolkits" 1.5.0  "CC(C)Cc1ccc(cc1)[C@H](C)C(=O)O"
IBP  SMILES          "OpenEye OEToolkits" 1.5.0  "CC(C)Cc1ccc(cc1)C(C)C(=O)O"
IBP  InChI           InChI           1.03   "InChI=1S/C13H18O2/c1-9(2)8-11-4-6-12(7-5-11)10(3)13(14)15/h4-7,9-10H,8H2,1-3H3,(H,14,15)/t10-/m0/s1"
IBP  InChIKey         InChI           1.03   HEFNNWSXXWATRW-JTQLQIEISA-N
#
loop_
_pdbx_chem_comp_identifier.comp_id
_pdbx_chem_comp_identifier.type
_pdbx_chem_comp_identifier.program
_pdbx_chem_comp_identifier.program_version
_pdbx_chem_comp_identifier.identifier
IBP  "SYSTEMATIC NAME" ACDLabs          10.04  "(2S)-2-[4-(2-methylpropyl)phenyl]propanoic acid"
IBP  "SYSTEMATIC NAME" "OpenEye OEToolkits" 1.5.0  "(2S)-2-[4-(2-methylpropyl)phenyl]propanoic acid"
#
```



IBP: Ibuprofen

# Downloading CCD Data

- Download Options
  - wwPDB
    - <https://www.wwpdb.org/data/ccd>
  - HTTPS file services
    - [https://files.rcsb.org/pub/pdb/refdata/chem\\_comp/](https://files.rcsb.org/pub/pdb/refdata/chem_comp/)
  - Batch download:
    - <https://www.rcsb.org/downloads/ligands>
- File Formats
  - mmCIF/SDF/Mol/Mol2 files
  - SMILES/InChI/InChIKey descriptors



The screenshot shows the wwPDB Protein Data Bank website. The header includes the logo and a navigation menu. The main content area is titled "Chemical Component Dictionary". It contains a paragraph describing the dictionary as an external reference file for residue and small molecule components. Below this, it explains the organization by 3-character alphanumeric codes and the update process. A section for search and browse resources lists "PDBeChem" and "Ligand Expo". Another section provides download links for the entire dictionary and companion dictionaries in various formats (mmCIF, SDF, MOL). A final section lists additional data files for download, including SMILES and InChI/InChIKey files in tab-delimited text format.

**WORLDWIDE PDB PROTEIN DATA BANK**

**Data Dictionaries**

- PDBx/mmCIF
- Chemical Component Dictionary
- Biologically Interesting Molecule Reference Dictionary (BIRD)

### Chemical Component Dictionary

The Chemical Component Dictionary is as an external reference file describing all residue and small molecule components found in PDB entries. This dictionary contains detailed chemical descriptions for standard and modified amino acids/nucleotides, small molecule ligands, and solvent molecules. Each chemical definition includes descriptions of chemical properties such as stereochemical assignments, chemical descriptors (SMILES & InChI), systematic chemical names, and idealized coordinates (generated using Molecular Networks' Corina, and if there are issues, OpenEye's OMEGA).

The dictionary is organized by the 3-character alphanumeric code that PDB assigns to each chemical component. New chemical component definitions appear in the dictionary as the entries in which they are observed are released in the PDB archive; consequently, the dictionary is updated with each weekly PDB release. The dictionary is regularly reviewed and remediated. Any obsoleted components remain in the dictionary marked with status OBS.

Users can search and browse the Chemical Component Dictionary using resources such as **PDBeChem** and **Ligand Expo**.

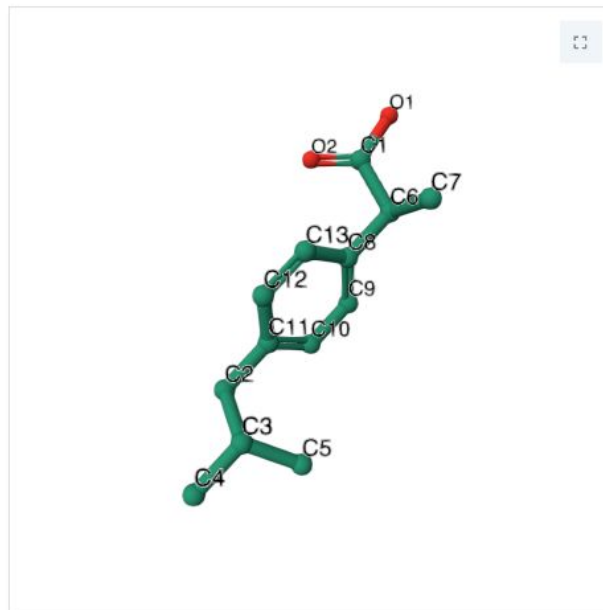
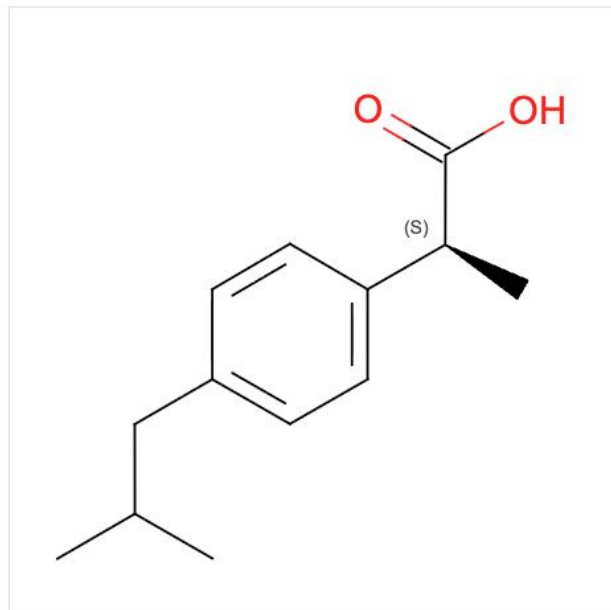
The entire Chemical Component Dictionary and the companion dictionary of amino acid protonation variants can be downloaded from the wwPDB ftp site:

Chemical Component Dictionary: **mmCIF (plain text)** | **mmCIF (gz)** | **SDF/MOL (gz)**  
Protonation Variants Companion Dictionary: **mmCIF (plain text)** | **mmCIF (gz)**  
Chemical Component Model data file: **mmCIF (plain text)** | **mmCIF (gz)**

In addition, SMILES/InChI/InChIKey data files can be downloaded here:

- SMILES (OpenEye with stereo) (**tab delimited text**)
- SMILES (OpenEye) (**tab delimited text**)
- SMILES (CACTVS with stereo) (**tab delimited text**)
- SMILES (CACTVS) (**tab delimited text**)
- InChI (**tab delimited text**)
- InChIKey (**tab delimited text**)

# Explore RCSB PDB Ligand Summary Pages



[Toggle Hydrogen](#) [Toggle Labels](#)

| Chemical Component Summary           |                                                 |
|--------------------------------------|-------------------------------------------------|
| Name                                 | IBUPROFEN                                       |
| Synonyms                             | 2-(4-ISOBUTYLPHENYL)PROPIONIC ACID              |
| Systematic Name (OpenEye OEToolkits) | (2S)-2-[4-(2-methylpropyl)phenyl]propanoic acid |
| Formula                              | C <sub>13</sub> H <sub>18</sub> O <sub>2</sub>  |
| Molecular Weight                     | 206.281                                         |
| Type                                 | NON-POLYMER                                     |

[Display Files](#) [Download Files](#) [Data API](#)

## IBP

### IBUPROFEN

Created: 2000-04-10

Last modified: 2020-06-05

#### Find Related PDB Entry

☒ 14 entries where IBP is found as a standalone ligand

[search](#)

#### Find related ligands:

[Help](#)

- ☐ Similar Ligands (Stereospecific)
- ☐ Similar Ligands (including Stereoisomers)
- ☐ Similar Ligands (Quick Screen)
- ☐ Similar Ligands (Substructure Stereospecific)
- ☐ Similar Ligands (Substructure including Stereoisomers)

[search](#)

#### Chemical Details

|                     |    |
|---------------------|----|
| Formal Charge       | 0  |
| Atom Count          | 33 |
| Chiral Atom Count   | 1  |
| Bond Count          | 33 |
| Aromatic Bond Count | 6  |

# Summary Pages Include External Data

## Drug Info: DrugBank

DrugBank data are sourced from datasets licensed under a [Creative Commons Attribution-NonCommercial 4.0 International](#)

|             |                                                                                                                                                                                                                                                                         |
|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| DrugBank ID | DB09213                                                                                                                                                                                                                                                                 |
| Name        | Dexibuprofen                                                                                                                                                                                                                                                            |
| Groups ?    | <ul style="list-style-type: none"><li>investigational</li><li>approved</li></ul>                                                                                                                                                                                        |
| Description | Dexibuprofen, S(+)-ibuprofen, is a non-steroidal anti-inflammatory more pharmacologically active and tolerable with a better safety profile in the gastric juices compared with the racemic ibuprofen and dexibuprofen.                                                 |
| Synonyms    | <ul style="list-style-type: none"><li>(2S)-2-(4-isobutylphenyl)propanoic acid</li><li>Dexibuprofen</li><li>(+)-(S)-p-isobutylhydratropic acid</li><li>(S)-<math>\alpha</math>-methyl-4-(2-methylpropyl)benzeneacetic acid</li><li>d-ibuprofen</li></ul> <div>more</div> |
| Indication  | For more information, refer to [ibuprofen].                                                                                                                                                                                                                             |
| Categories  | <ul style="list-style-type: none"><li>Acids, Carbocyclic</li><li>Agents causing hyperkalemia</li><li>Agents that produce hypertension</li><li>Anti-Inflammatory Agents</li><li>Anti-Inflammatory Agents, Non-Steroidal</li></ul> <div>more</div>                        |

## Drug Targets

DrugBank data are sourced from datasets licensed under a [Creative Commons Attribution-NonCommercial 4.0 International](#)

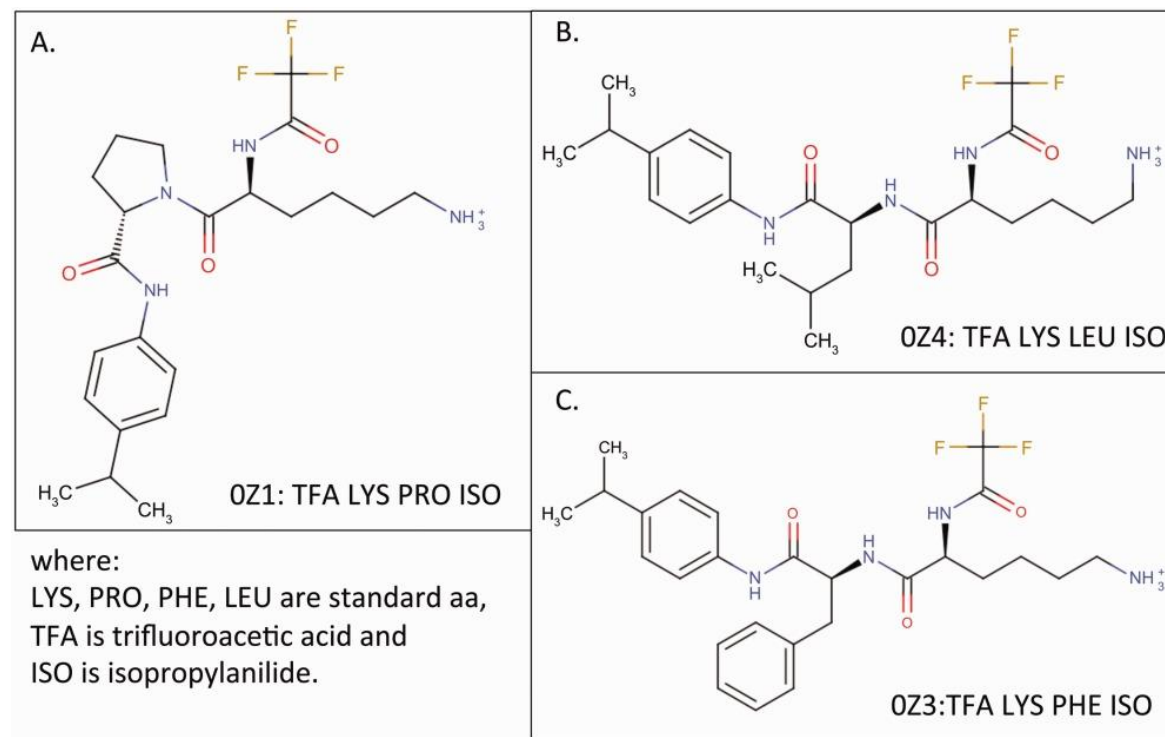
| Name                              | Target Sequence                                         |
|-----------------------------------|---------------------------------------------------------|
| Prostaglandin G/H synthase 2      | MLARALLLC AVLALSH TANPCCSHPCQNRGVCMSVGFDQYKCDCTRTGFY... |
| Prostaglandin G/H synthase 1      | MSRSLLLWFLFLLLL PPLPVLLADPGAPTPVNPCCYYPCQHQQGICVRFG...  |
| Apoptosis regulator Bcl-2         | MAHAGRTGYDNREIVMKYIHYKLSQRGYEWDA GDVGAAPPGAAPAGIFS...   |
| Thrombomodulin                    | MLGVVLV GALALAGLGFPAPAEPQPGGSQCVEHDCFALYPGPATFLNASQ...  |
| Tissue-type plasminogen activator | MDAMKRGLCCVLLLCGAVFVSPSQEI HARFRRGARSYQVICRDEKTQMIY...  |

## Related Resource References

| Resource Name | Reference                                                                                             |
|---------------|-------------------------------------------------------------------------------------------------------|
| Pharos        | CHEMBL175                                                                                             |
| PubChem       | 39912                                                                                                 |
| ChEMBL        | CHEMBL175                                                                                             |
| ChEBI         | CHEBI:43415                                                                                           |
| CCDC/CSD      | JEKNOC12, JEKNOC11, IBPRAC, SOGLAC, IBPRAC01, JEKNOC10, IBPRAC04, SODDIZ, JEKNOC, OWIGEH, I           |
| COD           | 2104678, 2209438, 2006278, 2300212, 2300213, 2300214, 2300215, 2300216, 2300217, 2300219, 2300218, 23 |

# Biologically Interesting Molecule Reference Dictionary (BIRD) for Short Oligomers

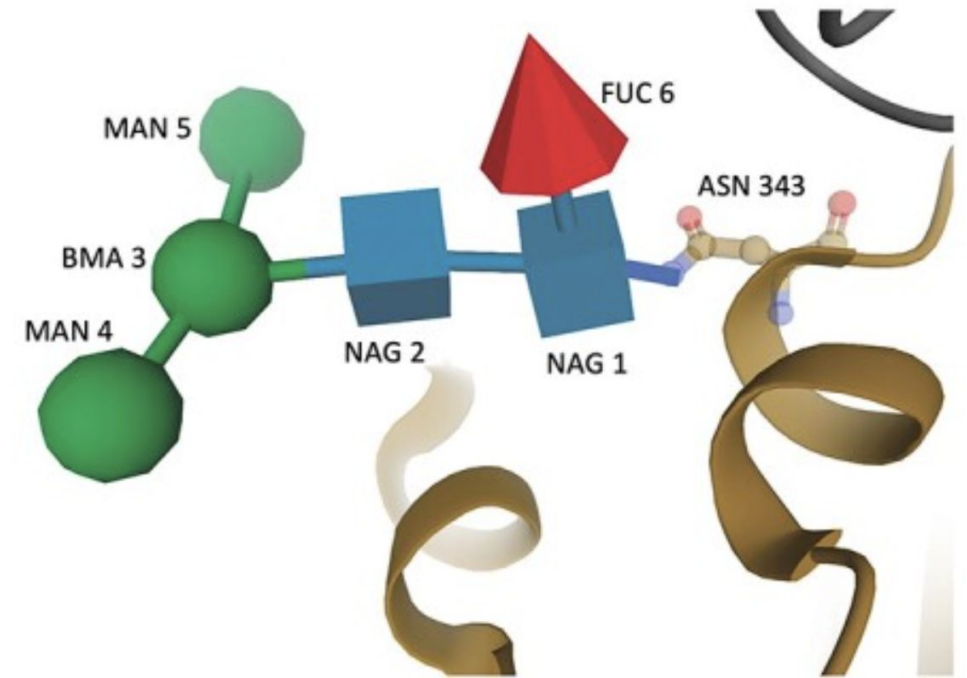
- Complementary chemical reference for peptide-like antibiotics, peptide-like inhibitors, and common oligosaccharides
- Every component/subcomponent defined in CCD
- Often contains chemical modification on the components and/or non-standard peptide linking
- Provides **dual representation** for polymeric sequence and single-molecule chemical description
- Used in OneDep to provide consistent representation in the PDB



BIRD examples: Trifluoroacetyl-dipeptide-anilide inhibitors of elastase

# Representing Oligosaccharides: Branched Entities

- ~10% PDB entries have saccharides
- Many have branched short oligomer with monosaccharide sequence, often covalently bound to proteins as glycans
- Oligosaccharides annotated as branched entities with each monosaccharide defined in CCD
- Provides linear descriptors commonly used by glycoscience community. Users can search PDB by descriptors and saccharide components.



SNFG depiction of the fucosylated *N*-glycan core on SARS-CoV-2 spike glycoprotein (PDB 6WPS) with linear descriptors of

**Glycam:**

DManpa1-3[DManpa1-6]DManpb1-4DGlcNac1-4[LFucpa1-6]DGlcNac1-  
**WURCS**=2.0/4,6,5/[a2122h-1b\_1-5\_2\*NCC/3=O][a1122h-1b\_1-5][a1122h-1a\_1-5][  
a1221m-1a\_1-5]/1-1-2-3-3-4/a4-b1\_a6-f1\_b4-c1\_c3-d1\_c6-e1

**LINUCS:**

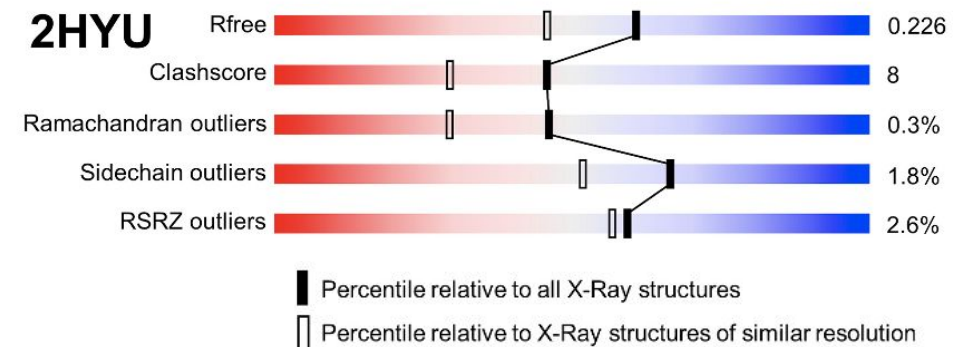
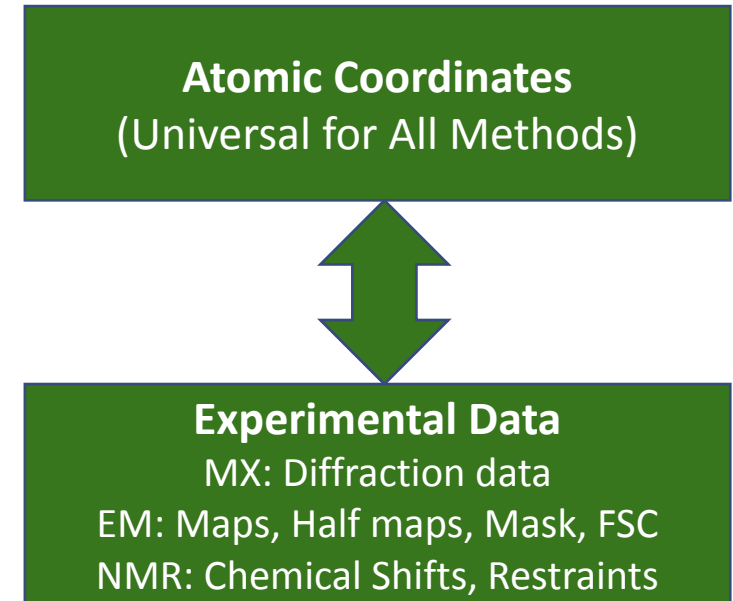
[ ]{[(4+1)][b-D-GlcNac]{[(4+1)][b-D-GlcNac]{[(4+1)][b-D-Manp]{[(3+1)][a-D-Manp]  
{ }[(6+1)][a-D-Manp]{ } } }{(6+1)][a-L-Fucp]{ } } }



# Ligand Validation at the PDB

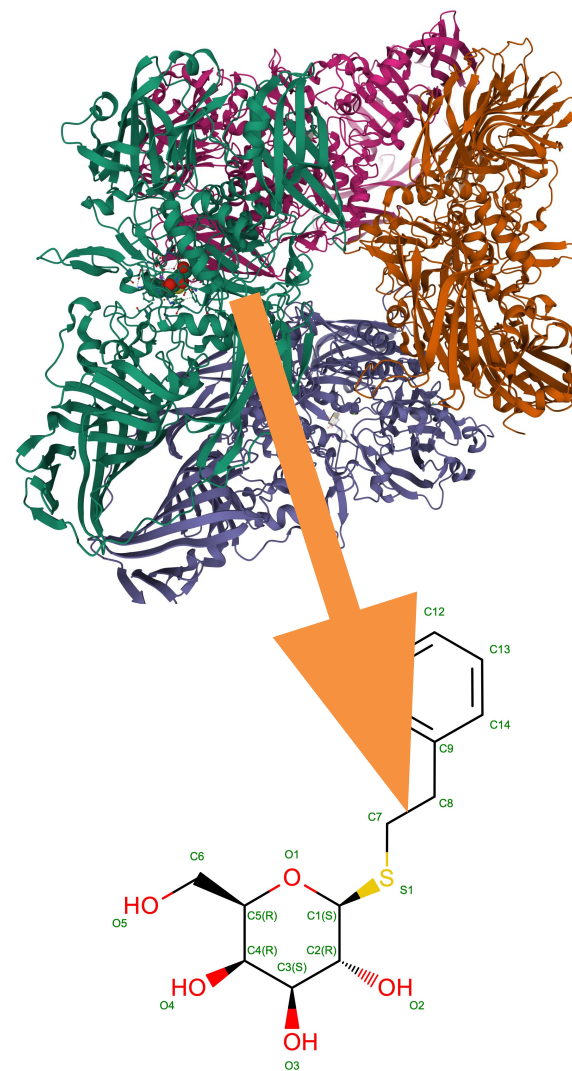
# wwPDB Validation Overview

- Measures
  - Geometry quality
  - Experimental data quality
  - Goodness-of-Fit
- Method-specific
  - Macromolecular crystallography (MX)
  - 3DEM
  - NMR
- Varies by components
  - Polymer
  - Ligand
  - Oligosaccharides
- Global --> local hierarchy
- Report provided in PDF/XML/mmCIF formats



# Ligand Validation Overview

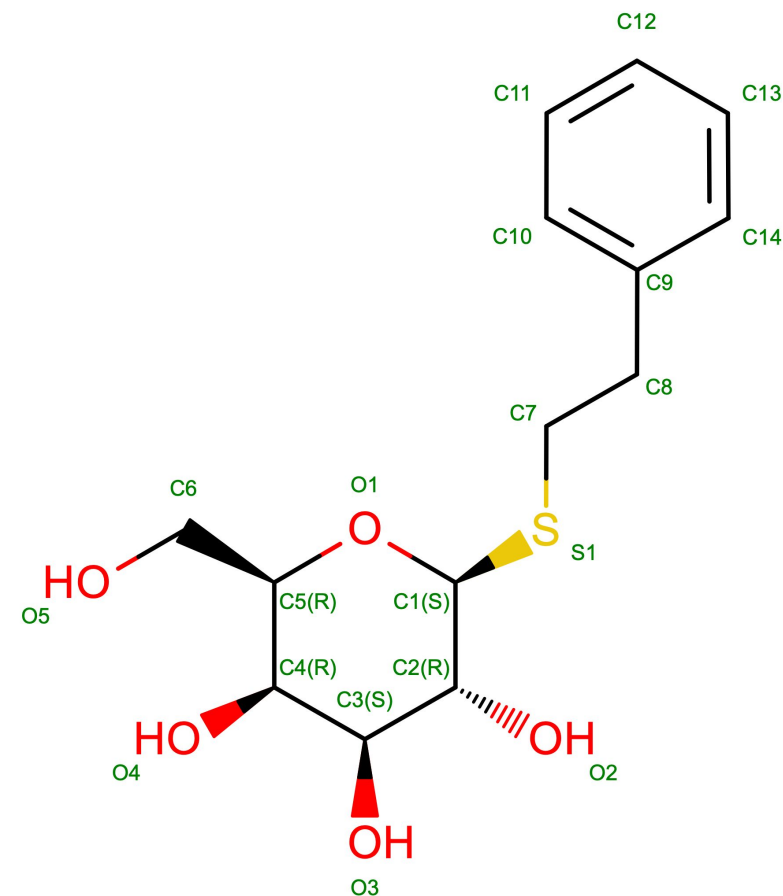
- Separate each instance of a ligand from the macromolecular complex
- Compare ligand model geometrical validation against Cambridge Structural Database (CSD) small molecule crystal structures using Mogul
- Review ligand model goodness-of-fit to experimental data
  - MX (Macromolecular Crystallography): Real Space R factor (RSR), Real Space CC (RSCC)
  - 3DEM: Atom inclusion, Q-score



PTQ in PDB 6CVM

# Geometry Validation Using Mogul

- Knowledgebase of molecular geometry derived from CCDC's **Cambridge Structural Database**
- References are queried **per chemical feature** (e.g. bond length or angle), not per molecule
- Finding references is similar to a substructure search
  - Query substructure generated by extending outwards from the chemical feature by two bonds
- To avoid bias from very few references, set threshold of **15** references, and cap of 10000
- Validates bond length, bond angle, torsion angle, ring, and reports any outliers for each feature
- Calculates Z score for all bond lengths and angles and the average RMSZs for the ligand



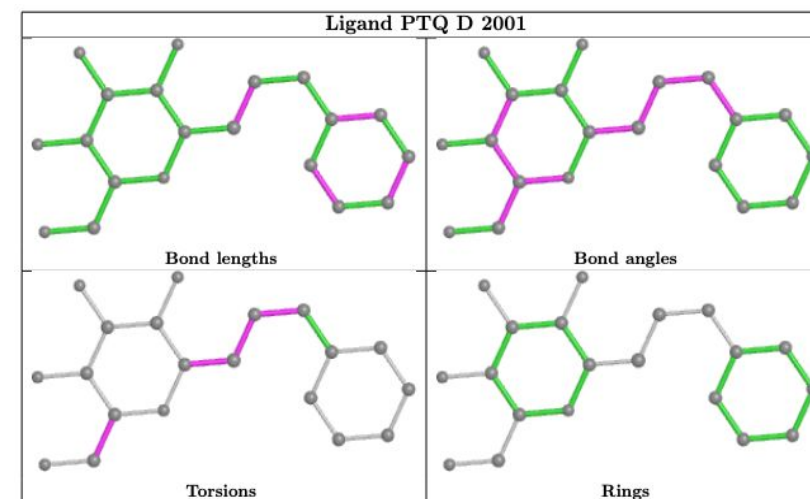
PTQ in PDB 6CVM

# OneDep Geometry Validation Results

- Mogul statistics
  - RMSZs for bond lengths and angles
  - Number of outliers for bond lengths and angles
- Individual outliers
  - Bond lengths
  - Bond angles
  - Torsion angles
  - Rings
- Graphical display
  - Green: good
  - Magenta: outlier
  - Gray: not validated

| Mol | Type | Chain | Res  | Link | Bond lengths |      |          | Bond angles |      |          |
|-----|------|-------|------|------|--------------|------|----------|-------------|------|----------|
|     |      |       |      |      | Counts       | RMSZ | # Z  > 2 | Counts      | RMSZ | # Z  > 2 |
| 2   | PTQ  | D     | 2001 | 4    | 21,21,21     | 2.40 | 4 (19%)  | 27,28,28    | 1.67 | 4 (14%)  |
| 2   | PTQ  | C     | 2001 | 4    | 21,21,21     | 2.39 | 4 (19%)  | 27,28,28    | 1.67 | 4 (14%)  |
| 2   | PTQ  | B     | 2001 | 4    | 21,21,21     | 2.39 | 4 (19%)  | 27,28,28    | 1.67 | 4 (14%)  |
| 2   | PTQ  | A     | 2001 | 4    | 21,21,21     | 2.38 | 4 (19%)  | 27,28,28    | 1.67 | 4 (14%)  |

| Mol | Chain | Res  | Type | Atoms   | Z    | Observed(Å) | Ideal(Å) |
|-----|-------|------|------|---------|------|-------------|----------|
| 2   | B     | 2001 | PTQ  | C13-C14 | 6.16 | 1.51        | 1.38     |
| 2   | C     | 2001 | PTQ  | C13-C14 | 6.16 | 1.51        | 1.38     |
| 2   | D     | 2001 | PTQ  | C13-C14 | 6.14 | 1.51        | 1.38     |
| 2   | D     | 2001 | PTQ  | C10-C9  | 5.65 | 1.51        | 1.38     |
| 2   | B     | 2001 | PTQ  | C10-C9  | 5.62 | 1.51        | 1.38     |

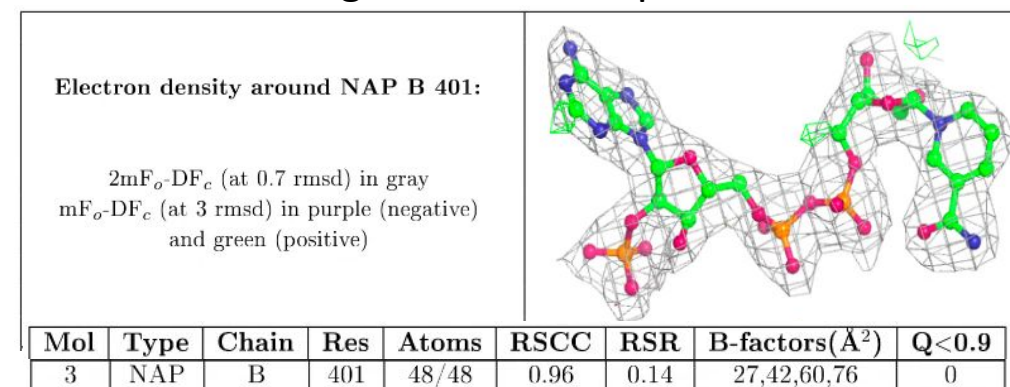


PTQ in PDB 6CVM

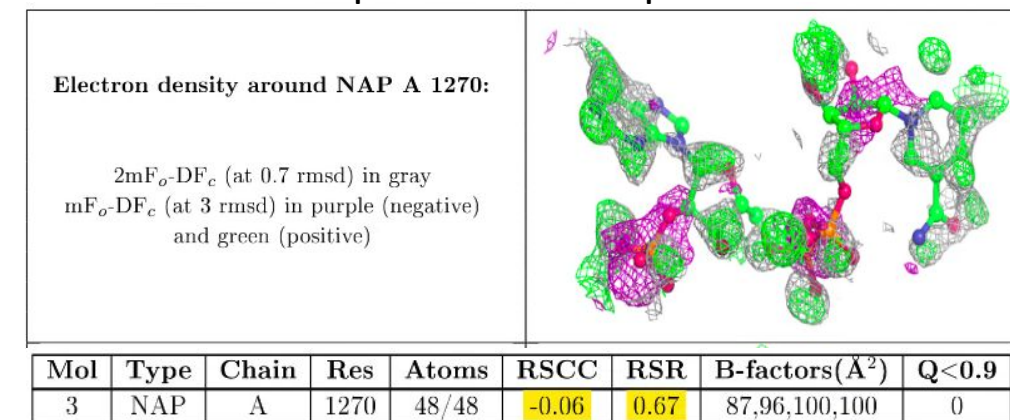
# Ligand Goodness-of-Fit for MX structures

- Atomic coordinates agreement with experimental MX data (Electron Density map)
  - Real Space R-factor (RSR) measures difference between (A) modeled ligand and (B) experimental electron density
  - Real Space Correlation Coefficient (RSCC) measures consistency between A and B
- Map-Model overlay on Ligand of Interest (LOI)
- Tabular report for validation metrics

PDB 5ZIX with good NADP Map-Model Fit

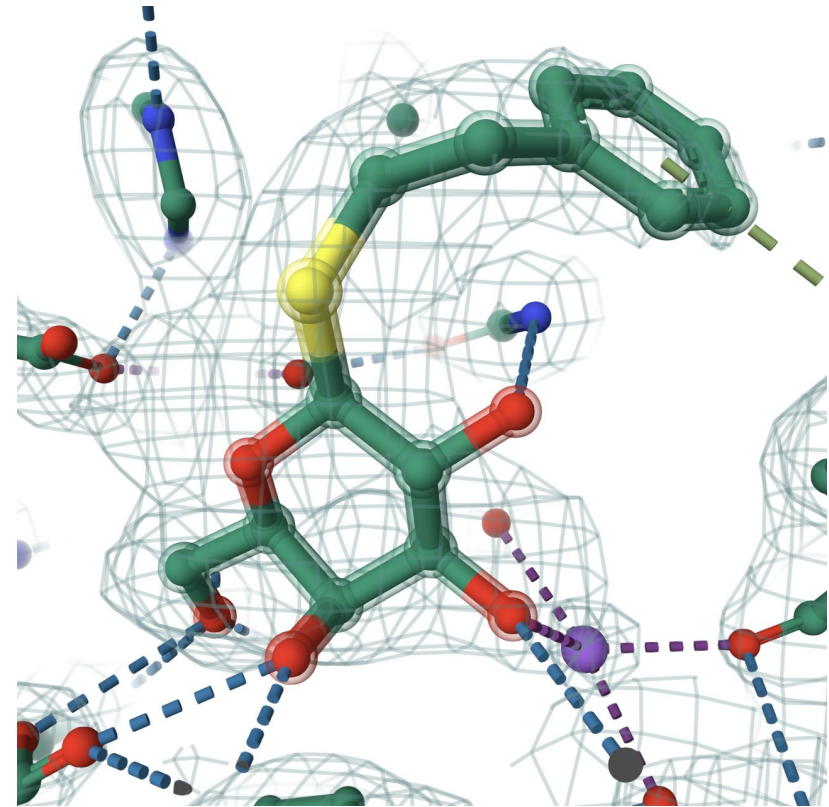


PDB 1ZK4 with poor NADP Map-Model Fit



# Ligand Goodness-of-Fit for 3DEM Structures

- 3DEM has recently become a major method for resolving ligands structures
  - In 2024, 5000+ 3DEM structures were deposited with bound ligands
    - Added 500+ new ligands to PDB
- wwPDB validation report calculates both atom inclusion and Q-score for each ligand
- Atom inclusion measures the fraction of atoms inside the map isosurface at author-selected contour level
- Q-score calculated for each residue on atom resolvability based on 3DEM map
  - Not subject to author-selected contour
  - Depends on resolution



PTQ in PDB 6CVM at 1.90 Å  
atom\_inclusion=0.7, Q-score=0.6

# Where to Find Ligand Validation Results

- wwPDB Validation PDF reports
  - Model quality -> Ligand geometry
  - (MX structures) Fit of model and data -> Ligand
- wwPDB Validation XML/mmCIF reports
  - per-residue geometry quality metrics
  - (MX structures) RSR and RSCC
  - (3DEM structures) atom inclusion and Q-score
- RCSB.org Structure Summary Pages
  - (MX structures) 1D and 2D ligand quality review
  - Mol\* 3D view by validation report

[https://files.rcsb.org/pub/pdb/validation\\_reports/na/5nak/5nak\\_validation.xml.gz](https://files.rcsb.org/pub/pdb/validation_reports/na/5nak/5nak_validation.xml.gz)

## PDB 5NAK X-ray structure with ligand FAD

```
<ModelledSubgroup num-H-reduce="31" rsc="0.986" rsr="0.056"
owab="15.730" avgoccu="1.000" NatomsEDS="53"
mogul_bonds_rms="0.54" mogul_rmsz_numbonds="53"
mogul_angles_rms="0.64" mogul_rmsz_numangles="68" model="1"
chain="A" resnum="501" said="C" ent="2" seq="." icode=" " resname="FAD"
altcode=" ">
```

```
<mog-angle-outlier atoms="C5A,C6A,N6A" numobs="41"
mean="120.35" stdev="1.52" mindiff="0.09" Zscore="2.34"
obsval="123.91"/>...
```

[https://files.rcsb.org/pub/pdb/validation\\_reports/cv/6cvm/6cvm\\_validation.xml.gz](https://files.rcsb.org/pub/pdb/validation_reports/cv/6cvm/6cvm_validation.xml.gz)

## PDB 6CVM 3DEM structure with ligand PTQ

```
<ModelledSubgroup residue_inclusion="0.7000" Q_score="0.601"
num-H-reduce="20" mogul_bonds_rms="2.38"
mogul_rmsz_numbonds="21" mogul_angles_rms="1.67"
mogul_rmsz_numangles="27" model="1" chain="A" resnum="2001" said="E"
ent="2" seq="." icode=" " resname="PTQ" altcode=" ">
```

```
<clash atom="O4" dist="2.26" clashmag="0.53" cid="38"/>
```

```
<mog-bond-outlier atoms="C7,S1" numobs="110" mean="1.81"
stdev="0.01" mindiff="0.00" Zscore="-2.72" obsval="1.78"/>...
```



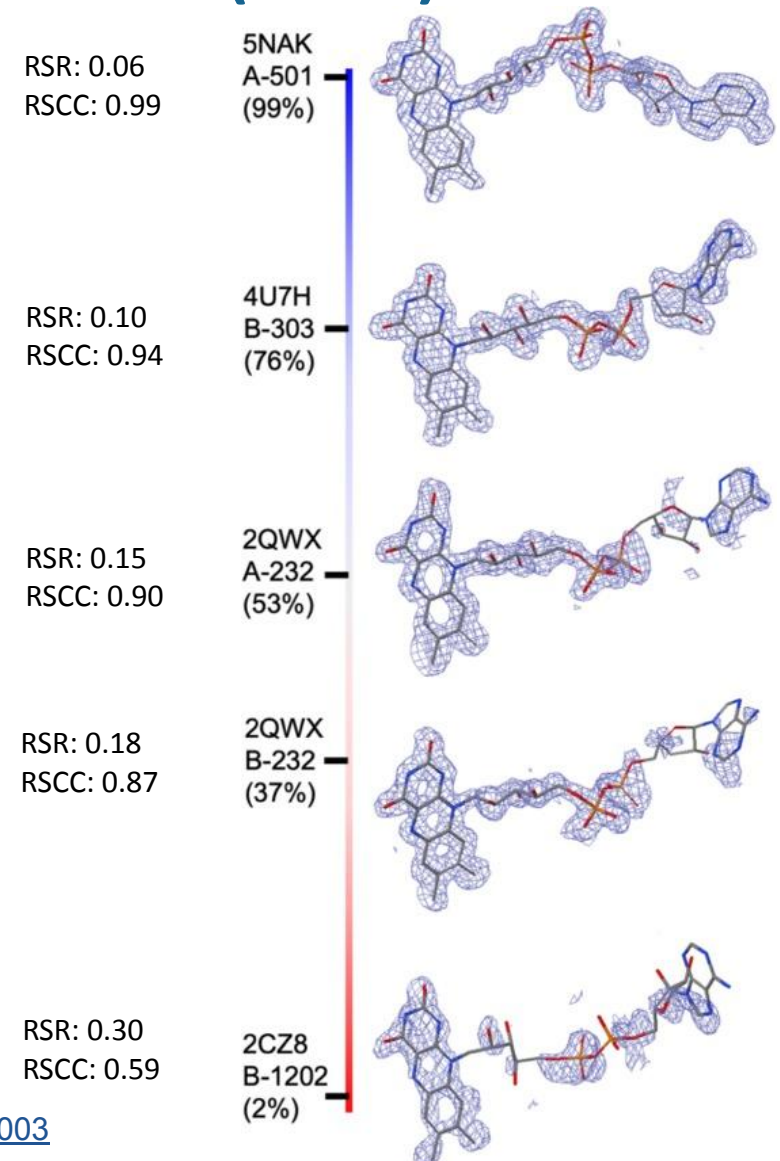
# Ligand Quality Comparison within the PDB

# Distribution of Primary Ligand Quality Metrics in MX Structures

|                  | Mean | Standard Deviation | Median | IQR  | Nature of Distribution                                                                 |
|------------------|------|--------------------|--------|------|----------------------------------------------------------------------------------------|
| RSR              | 0.18 | 0.09               | 0.16   | 0.10 | $0 \leq \text{RSR} \leq 1$ , Right-skewed, lower value indicating better quality       |
| RSCC             | 0.89 | 0.09               | 0.92   | 0.11 | $0 \leq \text{RSCC} \leq 1$ , Left-skewed, higher value indicating better quality      |
| RMSZ-bond-length | 1.12 | 1.03               | 0.81   | 1.06 | $0 \leq \text{RMSZ-bond-length}$ , Right-skewed, lower value indicating better quality |
| RMSZ-bond-angle  | 1.21 | 0.98               | 1.03   | 1.21 | $0 \leq \text{RMSZ-bond-angle}$ , Right-skewed, lower value indicating better quality  |
| clash-per-atom   | 0.07 | 0.15               | 0.01   | 0.08 | $0 \leq \text{clash-per-atom}$ , Right-skewed, lower value indicating better quality   |

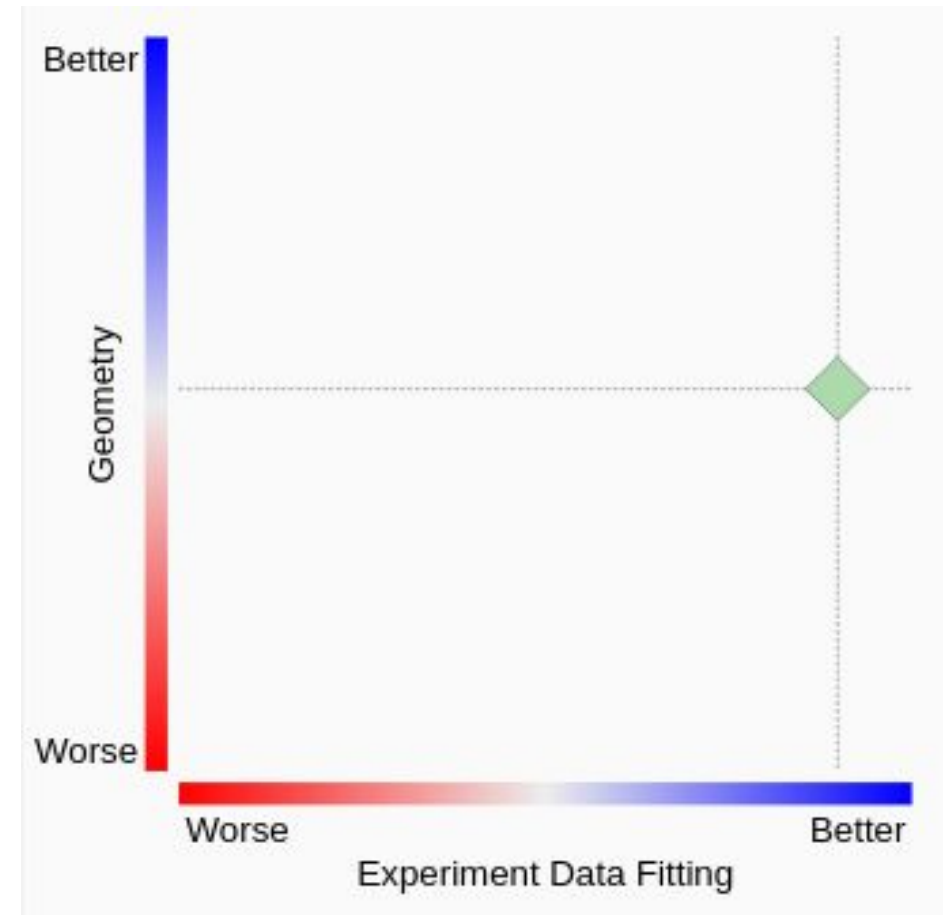
# Comparing Ligand Goodness-of-fit (MX)

- Examples of FAD (Flavin-Adenine Dinucleotide) at different levels of local electron density support at 1.5 Å
- Principal Component Analysis (PCA) of ligand goodness-of-fit metrics RSR and RSCC
  - 1st principal component (PC1-fit) as a combined metric of the fitting quality
  - Percentile ranking of PC1-fit as a fitting score (0%-100%) to measure the relative quality on goodness-of-fit in 1D slider



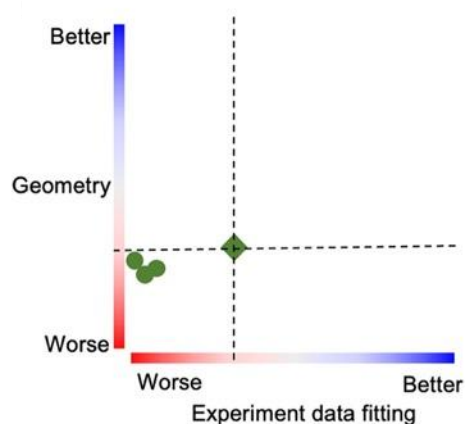
# 2D Ligand Quality Graphs at RCSB.org

- Similar to the fitting score, a combined geometry score was calculated for ligands in PDB MX structures
- RCSB.org ligand quality page displays a 2D graph with the fitting score slider as X-axis, and geometry score slider as Y-axis. Blue for better quality and red for worse.
- A ligand instance's placement (green diamond) illustrates both fitting and geometry quality

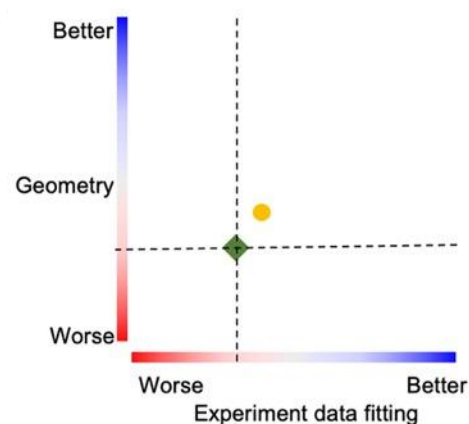


[Ligand JUJ in PDB 7FUR](#) at  
RCSB.org

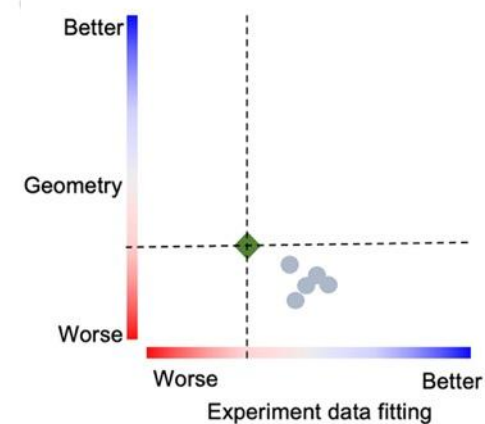
# Compare Ligands in PDB MX Structures



All Instances in 6WJC



Best fitted Instance in 6WJC vs. best fitted PDB Instances with the same molecular target



Best fitted Instance in 6WJC vs. best fitted PDB Instances

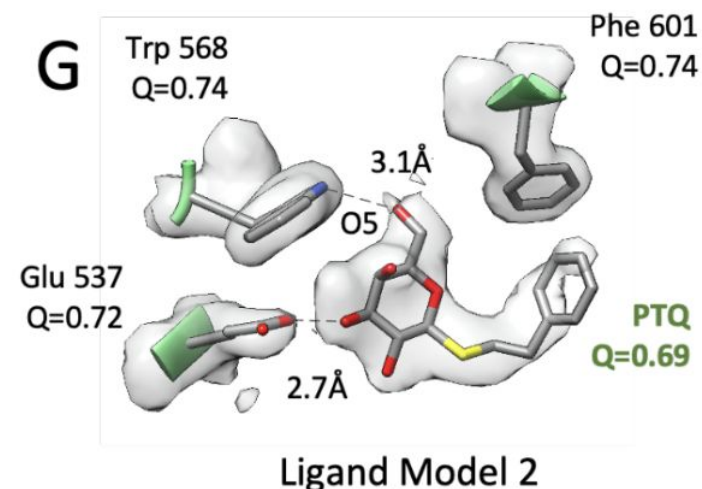
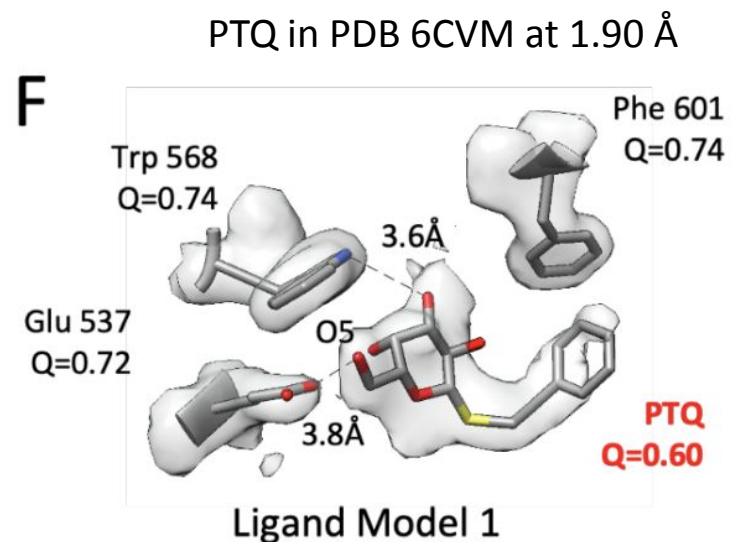
Interactive  
between  
graph and  
table

| Identifier      | Composite ranking of goodness-of-fit | Composite ranking of geometry | Real space R factor | Real space correlation coefficient | RMSZ-bond-length | RMSZ-bond-angle | Outliers of bond length | Outliers of bond angle | Atomic clashes | Stereo-chemical errors | Model completeness | Average occupancy |
|-----------------|--------------------------------------|-------------------------------|---------------------|------------------------------------|------------------|-----------------|-------------------------|------------------------|----------------|------------------------|--------------------|-------------------|
| 6WJC_Y01_A_502  | 31.4%                                | 35.7%                         | 0.227               | 0.892                              | 1.31             | 1.34            | 5                       | 8                      | 0              | 0                      | 100%               | 1                 |
| 6WJC_Y01_A_503  | 3.5%                                 | 31.5%                         | 0.518               | 0.871                              | 1.28             | 1.58            | 4                       | 12                     | 0              | 0                      | 100%               | 1                 |
| 6WJC_Y01_A_504  | 2.3%                                 | 31.0%                         | 0.422               | 0.714                              | 1.27             | 1.62            | 4                       | 9                      | 3              | 0                      | 100%               | 1                 |
| 6WJC_Y01_A_505  | 0.4%                                 | 33.5%                         | 0.727               | 0.761                              | 1.32             | 1.44            | 4                       | 10                     | 3              | 0                      | 100%               | 1                 |
| 5CXV_Y01_A_502  | 37.1%                                | 43.2%                         | 0.207               | 0.899                              | 1.02             | 1.24            | 1                       | 5                      | 0              | 0                      | 100%               | 1                 |
| 2Y00_Y01_B_401  | 51.2%                                | 25.7%                         | 0.195               | 0.946                              | 1.24             | 1.94            | 3                       | 13                     | 1              | 0                      | 100%               | 1                 |
| 2Y01_Y01_A_401  | 50.3%                                | 27.7%                         | 0.208               | 0.956                              | 1.23             | 1.84            | 3                       | 15                     | 1              | 0                      | 100%               | 1                 |
| 2Y03_Y01_B_401  | 49.3%                                | 25.3%                         | 0.213               | 0.957                              | 1.21             | 1.99            | 3                       | 13                     | 2              | 0                      | 100%               | 1                 |
| 3ZPR_Y01_A_401  | 48.5%                                | 17.8%                         | 0.215               | 0.956                              | 1.24             | 2.46            | 3                       | 13                     | 1              | 0                      | 100%               | 1                 |
| 4XNV_Y01_A_1103 | 47.4%                                | 28.7%                         | 0.175               | 0.911                              | 1.9              | 1.15            | 9                       | 3                      | 0              | 0                      | 100%               | 1                 |

# Q-score Comparison for 3DEM Structures

- PDB 6cvm ligand pose improved during recent 3DEM ligand-modeling challenges
- 
- Model 2 improvements include
  - improved Q-score
  - better fitting to the density
  - more favorable interaction with nearby residues

Lawson *et al.* Nat Methods. 2024 21(7):1340-1348. doi: [10.1038/s41592-024-02321-7](https://doi.org/10.1038/s41592-024-02321-7)  
Pintilie *et al.* Acta Cryst D. 2025 81:410-422. doi: [10.1107/S2059798325005923](https://doi.org/10.1107/S2059798325005923)



# Q-score as a Measure of Goodness-of-fit

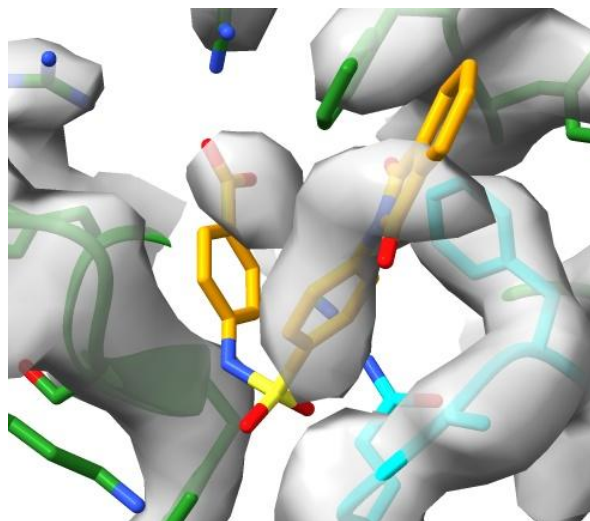
PDB ID: 6GZV/EMD-0103

CCD ID FHK

4.0 Å

Q Struct: 0.454

Q Ligand: 0.2



vs.

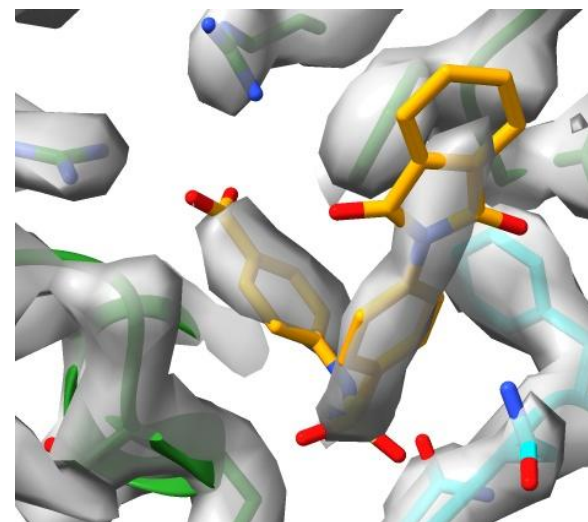
PDB ID: 6ZCL/EMD-11166

Reprocessed and  
remodeled

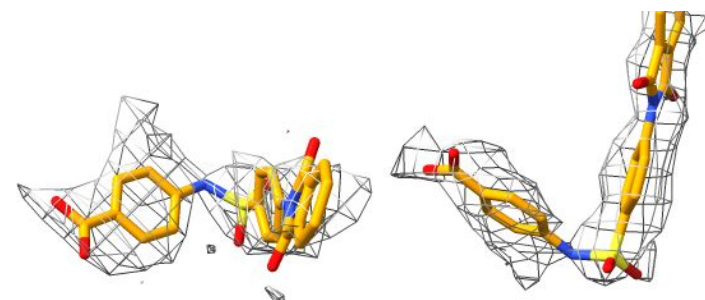
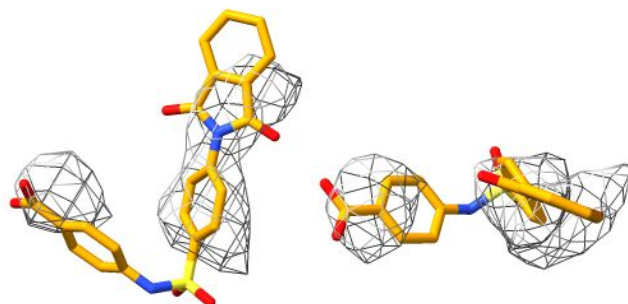
2.8 Å

Q Struct: 0.62

Q Ligand: 0.52



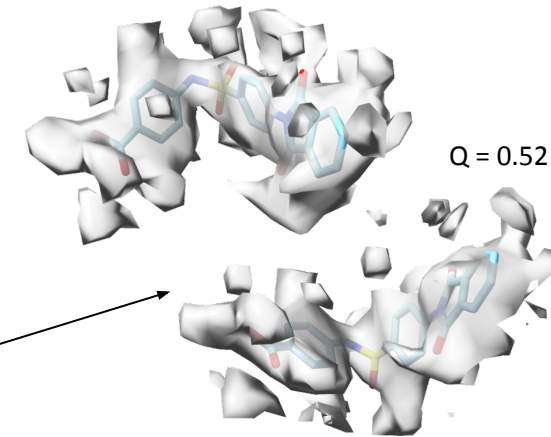
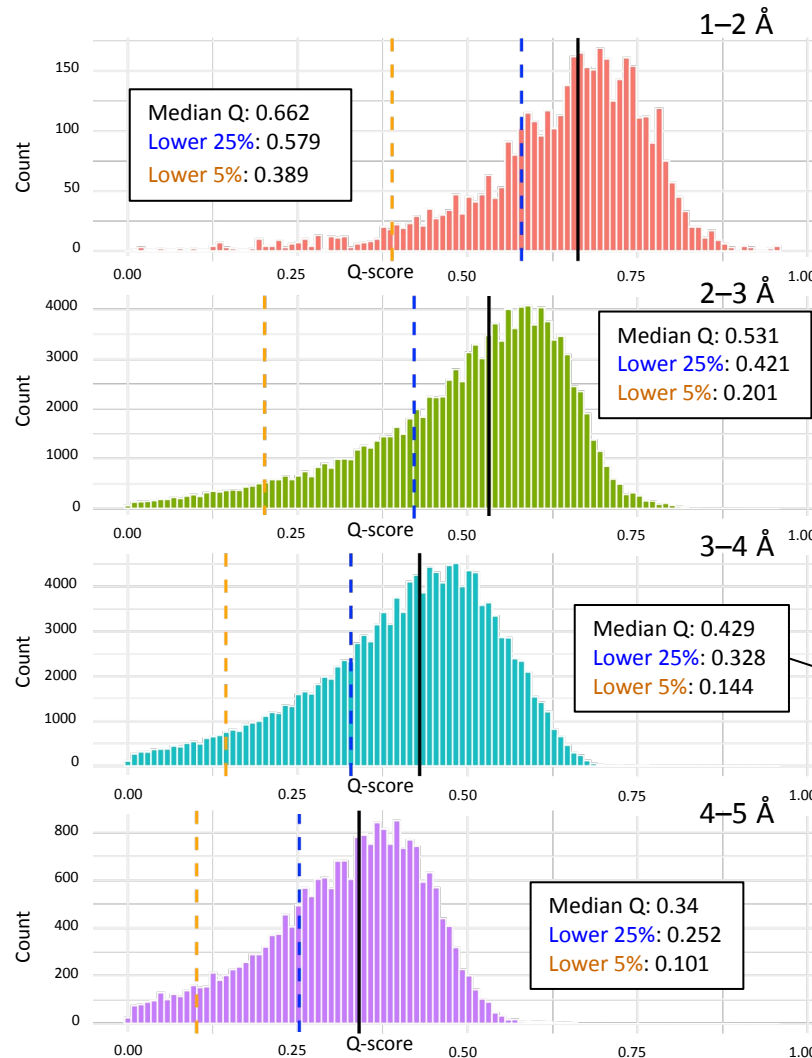
Fit 1



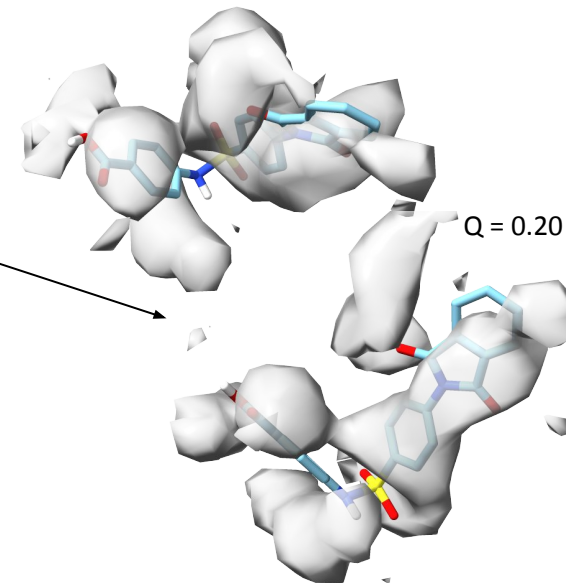
Fit 2

# Q-scores Distribution by Resolution

Ligand Q-score Distribution Across Resolution Bins



FHK in  
PDB 6ZCL



FHK in  
PDB 6GZV

# Summary: Ligand Structure Quality Metrics

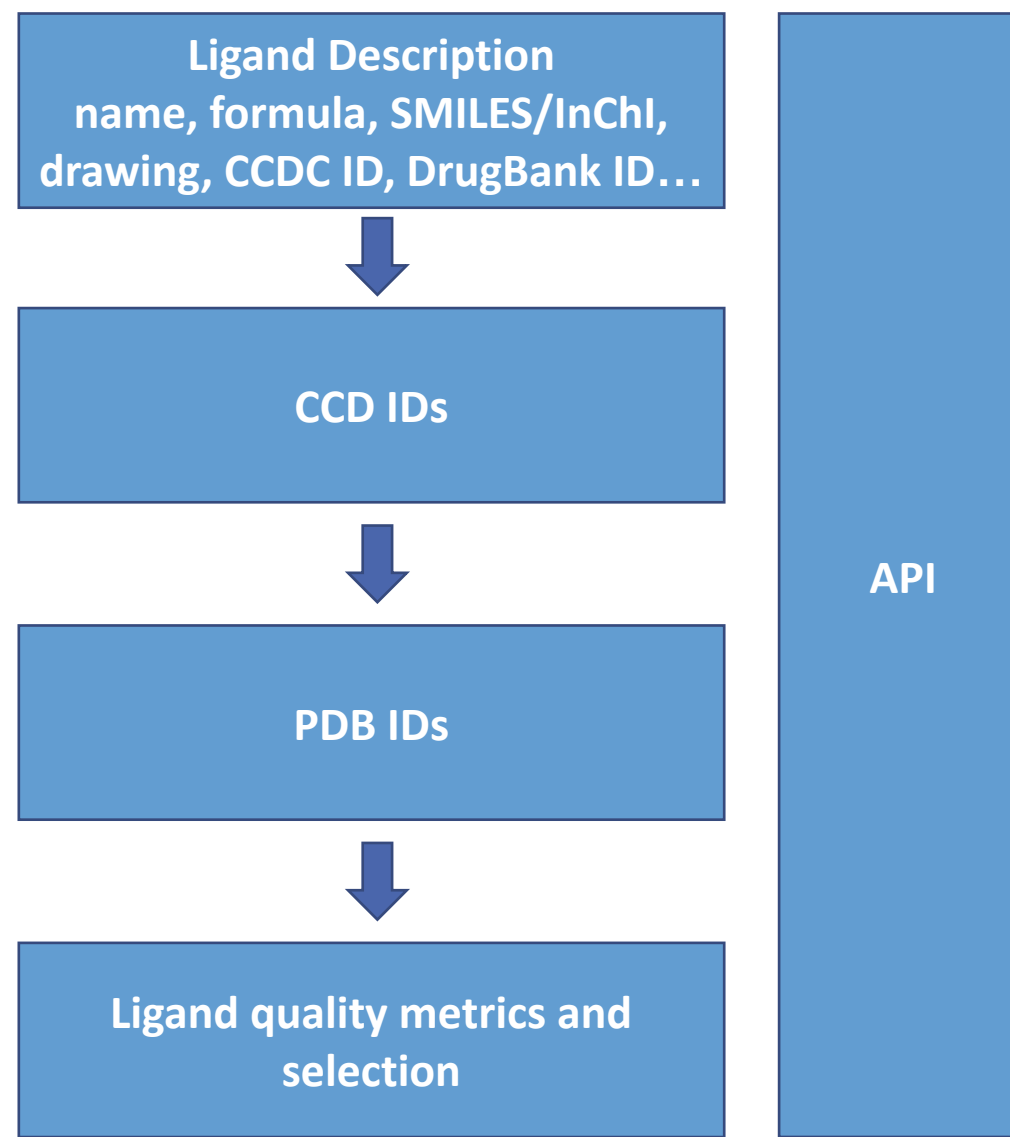
| Metric                 | Category        | Experimental Method |             | Better Quality | Best Value Currently in PDB |
|------------------------|-----------------|---------------------|-------------|----------------|-----------------------------|
|                        |                 | <b>MX</b>           | <b>3DEM</b> |                |                             |
| ranking_model_geometry | Geometry        | x                   | x           | larger         | ~1.0                        |
| mogul_bonds_RMSZ       | Geometry        | x                   | x           | smaller        | ~0                          |
| mogul_bond_outliers    | Geometry        | x                   | x           | smaller        | 0                           |
| mogul_angles_RMSZ      | Geometry        | x                   | x           | smaller        | ~0                          |
| mogul_angle_outliers   | Geometry        | x                   | x           | smaller        | 0                           |
| intermolecular_clashes | Geometry        | x                   | x           | smaller        | 0                           |
| stereo_outliers        | Geometry        | x                   | x           | smaller        | 0                           |
| Resolution             | Goodness-of-fit | x                   | x           | smaller        | 0.48                        |
| completeness           | Goodness-of-fit | x                   | x           | larger         | 1.0                         |
| ranking_model_fit      | Goodness-of-fit | x                   |             | larger         | ~1.0                        |
| average_occupancy      | Goodness-of-fit | x                   |             | larger         | 1.0                         |
| RSR                    | Goodness-of-fit | x                   |             | smaller        | ~0                          |
| RSCC                   | Goodness-of-fit | x                   |             | larger         | ~1.0                        |
| Q-score                | Goodness-of-fit |                     | x           | larger         | ~1.0                        |
| Atom inclusion         | Goodness-of-fit |                     | x           | larger         | ~1.0                        |



# Search PDB for Ligand Structures of Better Quality

# Search Ligand Structures using RCSB PDB Tools

- Ligand search
  - Chemical attribute search
  - Chemical similarity search
  - Chemical sketch tool
- PDB entry search
  - Advanced search
  - Ligand summary page
- Quality assessment
  - Review validation reports
  - Interactive 2D ligand quality graph for MX
- Combined search through API
  - Search API
  - Data API
  - Model Server API



# Demonstration

## Scenario #1

Manual Investigation at [RCSB.org](https://www.rcsb.org)

- Use Chemical Attribute search to find ligand CCD ID
- Use Ligand Summary page to find PDB IDs with the ligand
- Review validation reports
- Use 2D ligand quality graph to find best examples

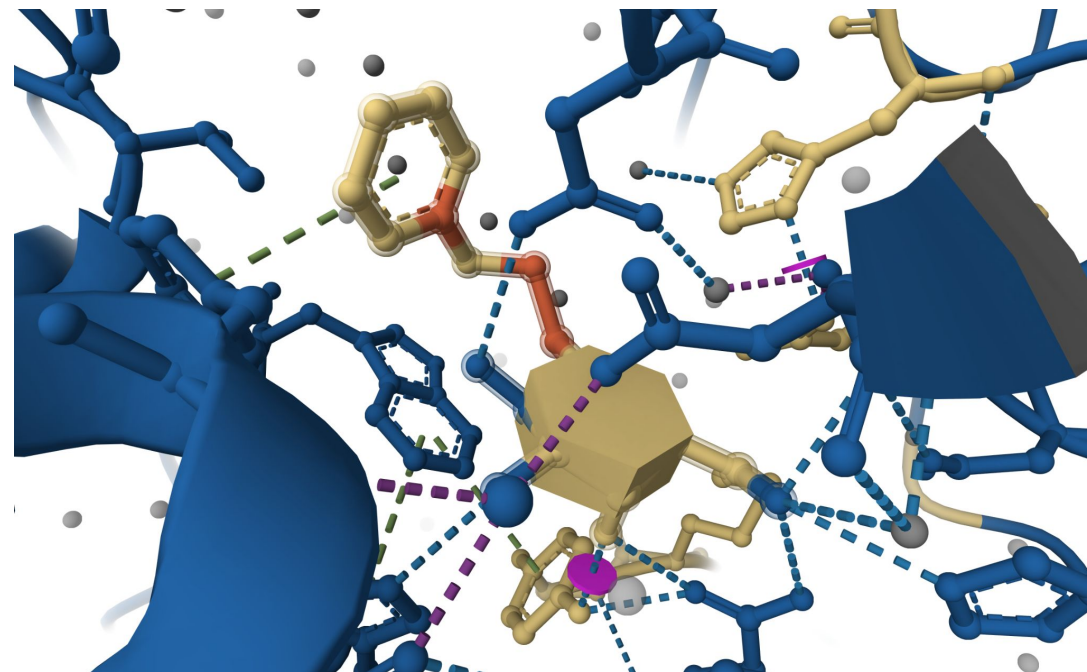
## Scenario #2

Programmatic Investigation through RCSB PDB APIs

- Use search API to find CCD ID and PDB IDs
- Use data API to retrieve ligand quality metrics
- Use API results to find the best examples

# RCSB.org Tools for Ligand Quality Assessment

- Validation reports for detailed review
  - PDF report for reading
  - CIF/XML report for programmatic parsing
- Structure Summary Page
  - Resolution
  - Overall quality slider
  - Ligand quality slider (MX only)
- Mol\* 3D visualization
  - Model-map overlay
  - View by validation report
- Ligand quality page (MX only)
  - 2D ligand quality graph
  - Interactive 3D model-map overlay on ligands
  - Comparison among structures with the same ligand



Validation view of Mol\* 3D viewer, focused on ligand PTQ in PDB 6CVM

Color code: blue: no issue; yellow: 1 issue; orange: 2 issues; purple disk: atomic clash

# PDB Chemical Data Resources

- CCD
  - <https://wwpdb.org/data/ccd>
  - <https://files.wwpdb.org/pub/pdb/data/monomers/components.cif>
- BIRD
  - <https://www.wwpdb.org/data/bird>
  - <https://files.wwpdb.org/pub/pdb/data/bird/prd/prd-all.cif.gz>
- Individual data files (PDBx/mmCIF, PDBML, SDF/MOL)
  - <https://files.wwpdb.org/pub/pdb/refdata/>
  - wwPDB partners websites ([rcsb.org](https://rcsb.org), [pdbe.org](https://pdbe.org), [pdbj.org](https://pdbj.org))

## [RCSB.org](https://rcsb.org)

| Type                        | Format | Example URL                                                                                                                                                                                           |
|-----------------------------|--------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| BIRD atom representation    | CIF    | <a href="https://files.rcsb.org/birds/download/PRDCC_000001.cif">https://files.rcsb.org/birds/download/PRDCC_000001.cif</a>                                                                           |
| BIRD definition             | CIF    | <a href="https://files.rcsb.org/birds/download/PRD_000001.cif">https://files.rcsb.org/birds/download/PRD_000001.cif</a>                                                                               |
| Definition                  | CIF    | <a href="https://files.rcsb.org/ligands/download/HEM.cif">https://files.rcsb.org/ligands/download/HEM.cif</a>                                                                                         |
| Ideal coordinates           | SDF    | <a href="https://files.rcsb.org/ligands/download/HEM_ideal.sdf">https://files.rcsb.org/ligands/download/HEM_ideal.sdf</a>                                                                             |
| Chemical Component Instance | SDF    | <a href="https://models.rcsb.org/v1/4hhb/ligand?auth_asym_id=A&amp;auth_seq_id=142&amp;encoding=sdf">https://models.rcsb.org/v1/4hhb/ligand?auth_asym_id=A&amp;auth_seq_id=142&amp;encoding=sdf</a>   |
| Chemical Component Instance | MOL    | <a href="https://models.rcsb.org/v1/4hhb/ligand?auth_asym_id=A&amp;auth_seq_id=142&amp;encoding=mol">https://models.rcsb.org/v1/4hhb/ligand?auth_asym_id=A&amp;auth_seq_id=142&amp;encoding=mol</a>   |
| Chemical Component Instance | MOL 2  | <a href="https://models.rcsb.org/v1/4hhb/ligand?auth_asym_id=A&amp;auth_seq_id=142&amp;encoding=mol2">https://models.rcsb.org/v1/4hhb/ligand?auth_asym_id=A&amp;auth_seq_id=142&amp;encoding=mol2</a> |

# PDB Validation Resources

- PDF/CIF/XML validation reports  
[https://files.wwpdb.org/pub/pdb/validation\\_reports/](https://files.wwpdb.org/pub/pdb/validation_reports/)
- Direct access at wwPDB partner websites ([rcsb.org](https://rcsb.org), [pdbe.org](https://pdbe.org), [pdbj.org](https://pdbj.org))
- Validation documents and user guides  
<https://www.wwpdb.org/validation/>

Display Files ▾ Download Files ▾ Data API

2HYV

pdb\_00002hyv

Human Annexin A2 with heparin hexasaccharide bound

PDB DOI: <https://doi.org/10.2210/pdb2HYV/pdb>

Classification: METAL BINDING PROTEIN

Organism(s): Homo sapiens

Expression System: Escherichia coli BL21(DE3)

Mutation(s): No

Deposited: 2006-08-07 Released: 2006-09-05

Deposition Author(s): Shao, C., Head, J.F., Seaton, B.A.

Validation Full PDF

Validation (XML - gz)

Validation (CIF - gz)

Validation 2fo-fc coefficients (CIF - gz)

Validation fo-fc coefficients (CIF - gz)

Experimental Data Snapshot

Method: X-RAY DIFFRACTION

Resolution: 1.42 Å

R-Value Free: 0.223 (Depositor), 0.210 (DCC)

R-Value Work: 0.212 (Depositor), 0.200 (DCC)

Starting Model: experimental

[View more details](#)

wwPDB Validation

3D Report Full Report

| Metric                | Percentile Ranks | Value |
|-----------------------|------------------|-------|
| Rfree                 |                  | 0.209 |
| Clashscore            |                  | 6     |
| Ramachandran outliers |                  | 0.3%  |
| Sidechain outliers    |                  | 1.8%  |
| RSRZ outliers         |                  | 4.2%  |

Worse Better

■ Percentile relative to all X-ray structures

▨ Percentile relative to X-ray structures of similar resolution

*Click on the validation slider to access the validation PDF or select one of the download options shown inset*

# RCSB PDB API Resources

- API overview  
<https://www.rcsb.org/docs/programmatic-access/web-apis-overview>
- Search API <https://search.rcsb.org/#search-api>
- Data API <https://data.rcsb.org/#data-api>
  - Data API attributes <https://data.rcsb.org/data-attributes.html>
- Past training courses on APIs:
  - Streamlining Access to RCSB PDB APIs with Python  
<https://pdb101.rcsb.org/train/training-events/apis-python>
  - Leveraging RCSB PDB APIs for Bioinformatics Analyses and Machine Learning  
<https://pdb101.rcsb.org/train/training-events/api>
  - The demo scripts used for this webinar and RCSB API:  
<https://github.com/rcsb/rcsb-training-resources> under  
/training-events/2025/ligand-structure-quality

# Register for Upcoming Events

**Register for**  
**Thursday September 25, 2025**  
1pm ET | 10am PT

Virtual Office Hour  
***PDB Policies for  
Deposition and  
Biocuration***



Sutapa Ghosh  
Irina Persikova



Recordings posted at [PDB-101.rcsb.org](https://pdb-101.rcsb.org)

**Register for**  
**Thursday October 30, 2025**  
1pm ET | 10am PT

Virtual Office Hour:  
***Structure  
Summary  
Pages***



Rachel Kramer Green

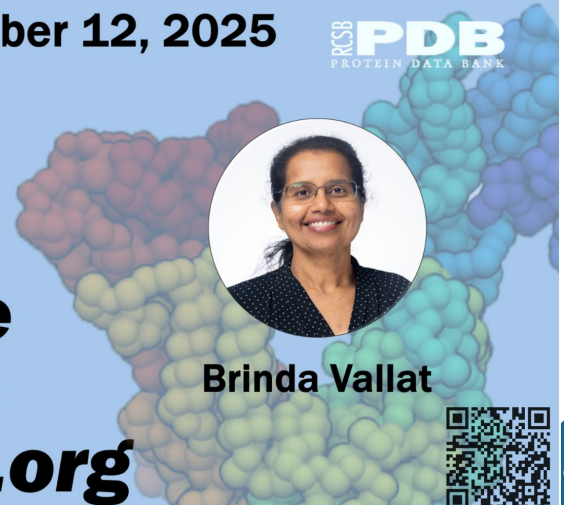


**Register for**  
**Wednesday November 12, 2025**  
2pm ET | 11am PT

Webinar:  
***Exploring  
Integrative  
Structures  
with RCSB.org***



Brinda Vallat



# Notice: Ligand Expo To Be Retired in 2025



Users should transition to RCSB PDB and wwPDB services as soon as possible

# 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.

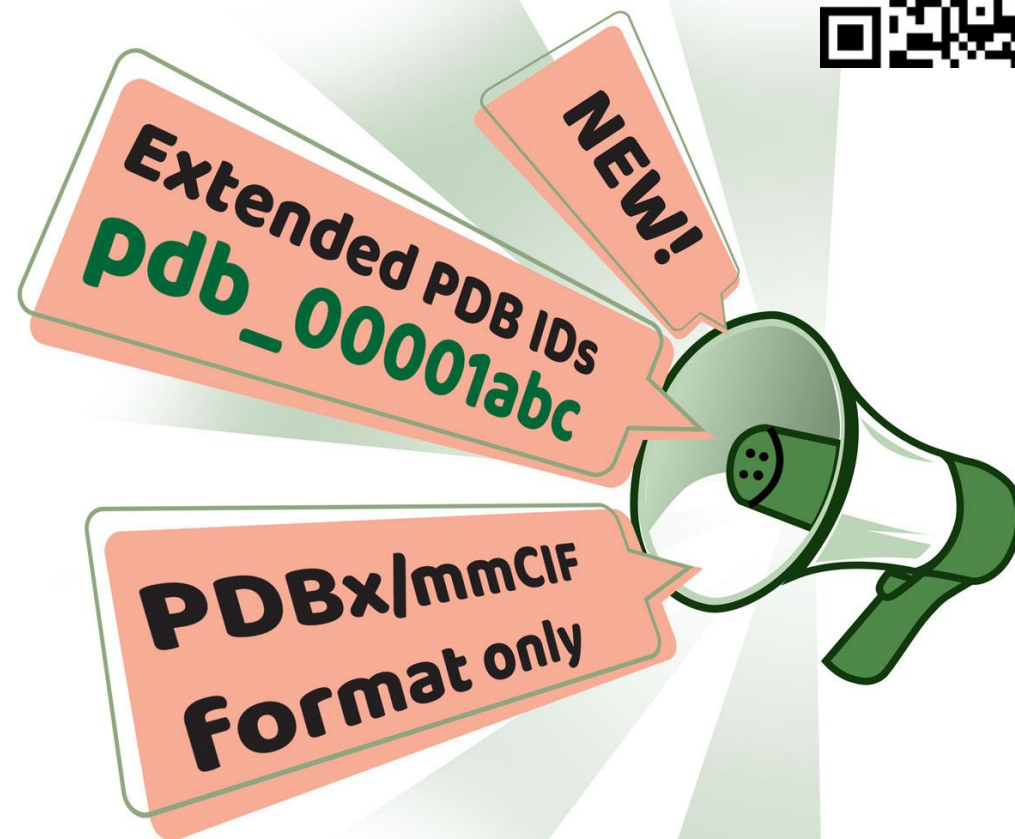
## **Extended PDB ID Format**

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



[www.pdb.org/  
documentation/new-format-for-pdb-ids](http://www.pdb.org/documentation/new-format-for-pdb-ids)

# Exit Survey and Certificates of Completion

Please take the exit survey  
at [go.rutgers.edu/m91nio4r](https://go.rutgers.edu/m91nio4r)



This survey will be closed on  
Monday September 15, 2025.

Want to receive a certificate of  
completion?  
You **MUST** complete the exit  
survey.

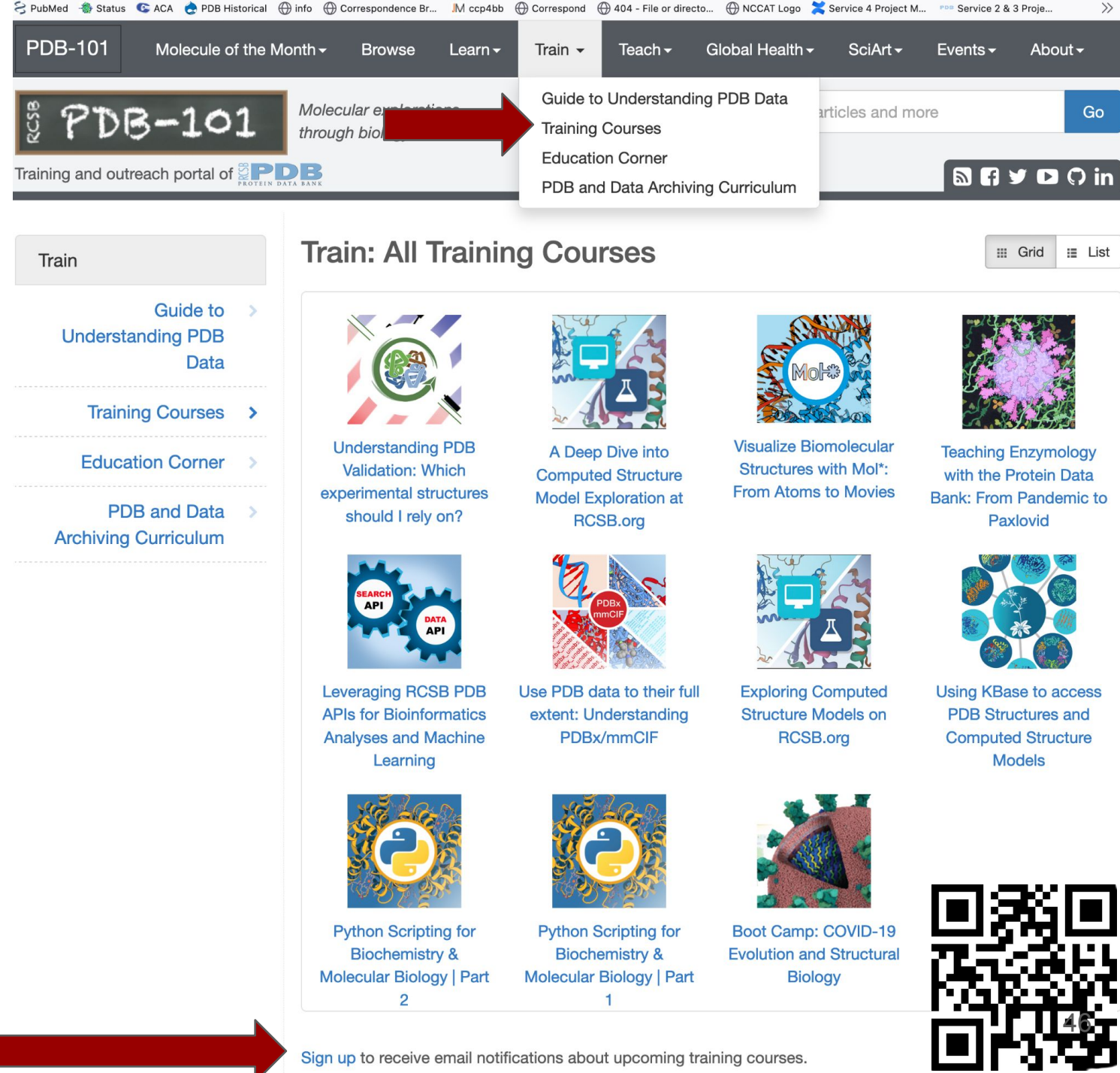
Please allow 4-6 weeks to  
receive the certificate.

# Course Materials

Course recordings and presentations will be published at [PDB-101.rcsb.org](https://PDB-101.rcsb.org) later this semester.

They will not be emailed separately.

Sign up to receive emails about upcoming training events



The screenshot displays the PDB-101 website, which is the training and outreach portal of the RCSB Protein Data Bank. The top navigation bar includes links for PDB-101, Molecule of the Month, Browse, Learn, Train, Teach, Global Health, SciArt, Events, and About. A red arrow points to the 'Train' dropdown menu, which lists: Guide to Understanding PDB Data, Training Courses, Education Corner, and PDB and Data Archiving Curriculum. Below the navigation bar, a sidebar on the left titled 'Train' contains links to the same four categories. The main content area, titled 'Train: All Training Courses', features a grid of course cards. Each card includes a representative image, a title, and a brief description. The courses shown are: 'Understanding PDB Validation: Which experimental structures should I rely on?', 'A Deep Dive into Computed Structure Model Exploration at RCSB.org', 'Visualize Biomolecular Structures with Mol\*', 'Teaching Enzymology with the Protein Data Bank: From Pandemic to Paxlovid', 'Leveraging RCSB PDB APIs for Bioinformatics Analyses and Machine Learning', 'Use PDB data to their full extent: Understanding PDBx/mmCIF', 'Exploring Computed Structure Models on RCSB.org', 'Using KBase to access PDB Structures and Computed Structure Models', 'Python Scripting for Biochemistry & Molecular Biology | Part 2', 'Python Scripting for Biochemistry & Molecular Biology | Part 1', and 'Boot Camp: COVID-19 Evolution and Structural Biology'. At the bottom of the page, a red arrow points to a sign-up link: 'Sign up to receive email notifications about upcoming training courses.' A QR code is located in the bottom right corner.

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

RCSB PDB-101 Molecular exploration through bioinformatics Training and outreach portal of RCSB PDB PROTEIN DATA BANK

Guide to Understanding PDB Data  
Training Courses  
Education Corner  
PDB and Data Archiving Curriculum

Train

Guide to Understanding PDB Data  
Training Courses  
Education Corner  
PDB and Data Archiving Curriculum

Train: All Training Courses

Grid List

Understanding PDB Validation: Which experimental structures should I rely on?

A Deep Dive into Computed Structure Model Exploration at RCSB.org

Visualize Biomolecular Structures with Mol\*: From Atoms to Movies

Teaching Enzymology with the Protein Data Bank: From Pandemic to Paxlovid

Leveraging RCSB PDB APIs for Bioinformatics Analyses and Machine Learning

Use PDB data to their full extent: Understanding PDBx/mmCIF

Exploring Computed Structure Models on RCSB.org

Using KBase to access PDB Structures and Computed Structure Models

Python Scripting for Biochemistry & Molecular Biology | Part 2

Python Scripting for Biochemistry & Molecular Biology | Part 1

Boot Camp: COVID-19 Evolution and Structural Biology

Sign up to receive email notifications about upcoming training courses.



[RCSB.ORG](https://rcsb.org) • [info@rcsb.org](mailto:info@rcsb.org)

## Core Operations Funding

US National Science Foundation (DBI-2321666),  
National Institute of General Medical Sciences,  
National Institute of Allergy and Infectious Disease, and  
National Cancer Institute (NIH R01GM157729), and the  
US Department of Energy (DE-SC0019749)

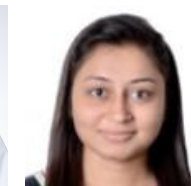
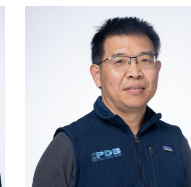
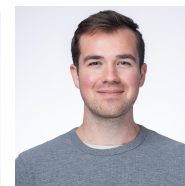
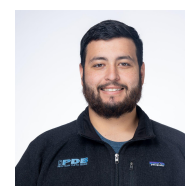
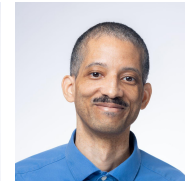
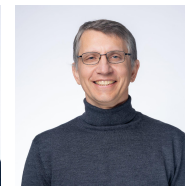
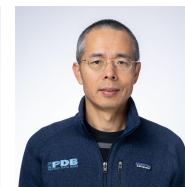
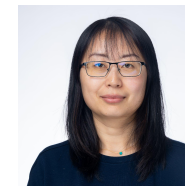
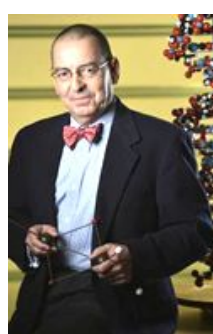
## Management



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Member of the  
Worldwide Protein Data Bank  
([wwPDB](https://wwpdb.org); [wwpdb.org](https://wwpdb.org))



# Questions?

The demo scripts used for this webinar and RCSB API:  
<https://github.com/rcsb/rcsb-training-resources>  
under /training-events/2025/ligand-structure-quality