RCSB PDB
PROTEIN DATA BANK

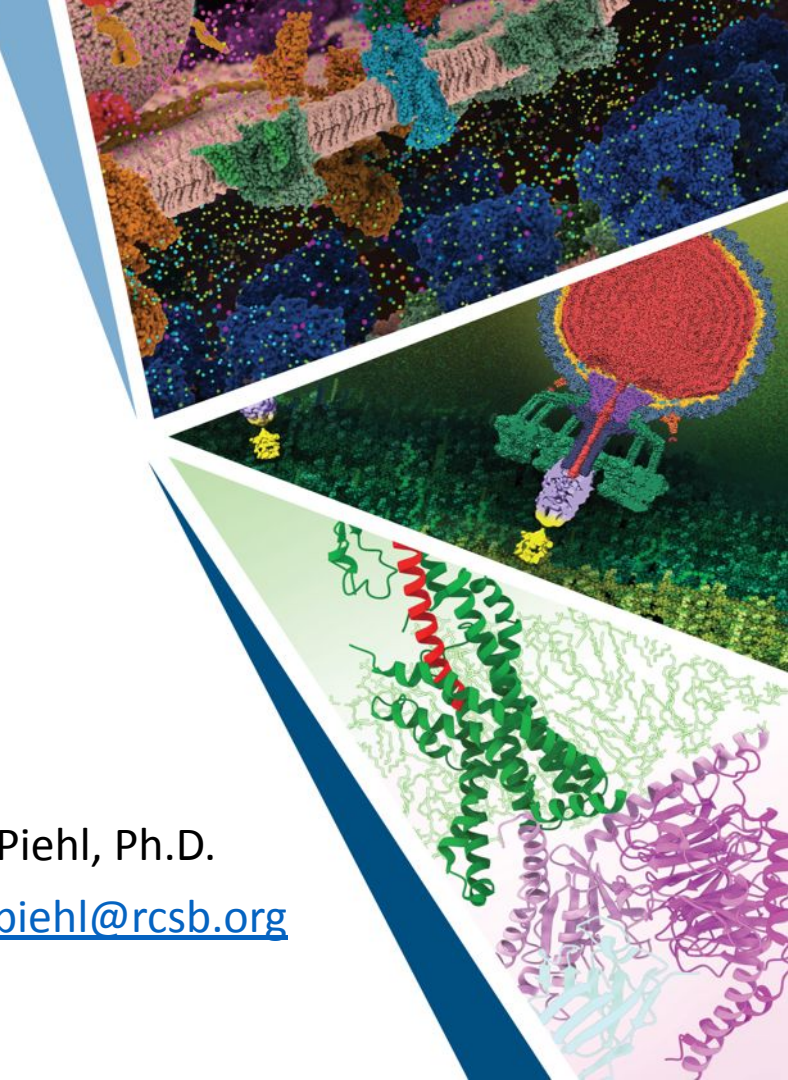
Webinar:

Streamlining Access to RCSB PDB APIs with Python

Dennis W. Piehl and Ivana Truong

RCSB PDB
PROTEIN DATA BANK

RCSB.org
info@rcsb.org



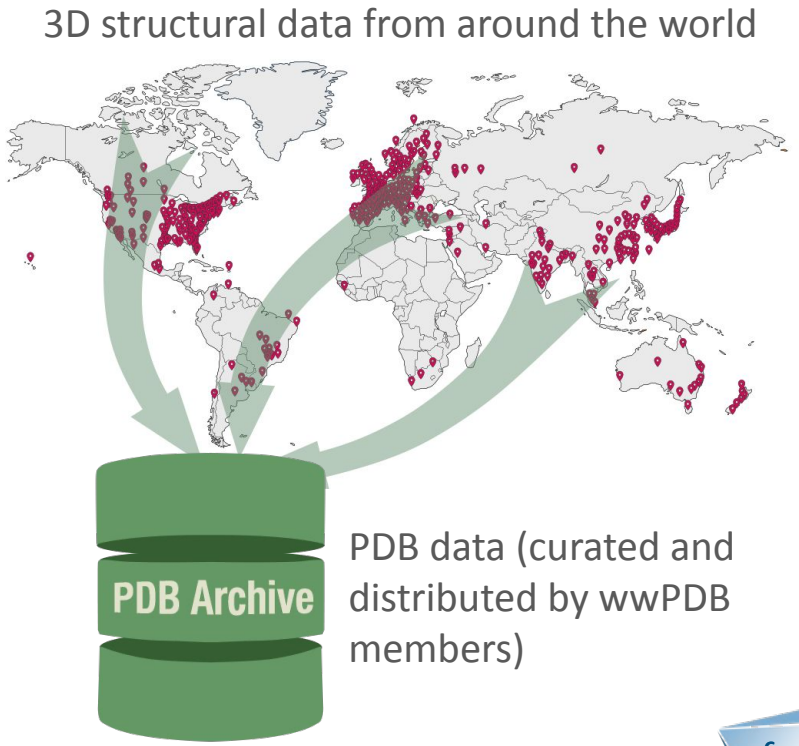
Introduction to RCSB.org Search and Data APIs

Dennis Piehl, Ph.D.
dennis.piehl@rcsb.org

March 24th, 2025

History of the Protein Data Bank (PDB)

- Established in 1971 as the first open-access digital data resource in biology, with just seven protein structures
- Now hosts >232,000 experimentally determined 3D structures of biomolecules
- The PDB Archive is jointly managed by the Worldwide PDB (wwPDB): RCSB PDB (US), PDBe (UK), PDBj (Japan), PDBc (China), BMRB (US/Japan), & EMDB (Europe)
- Committed to ensuring PDB data is “FAIR”: Findable, Accessible, Interoperable, & Reusable

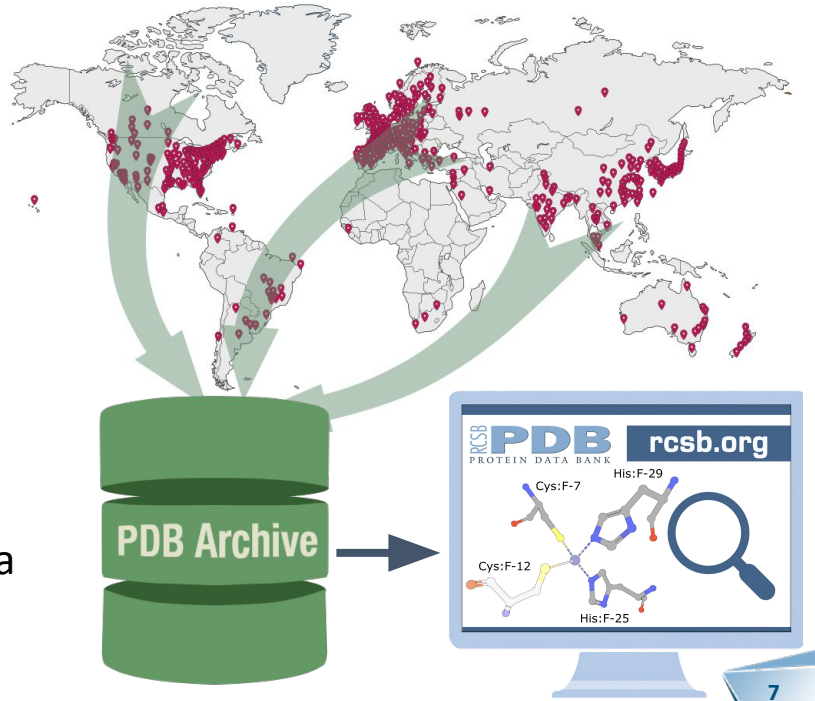


Protein Data Bank (1971) *Nature New Biology* **233**, 223.
Worldwide Protein Data Bank (2019) *Nucleic Acids Research* **47**, D520–D528.

The RCSB PDB Web Portal (RCSB.org)

- **RCSB.org:** One-stop shop for 3D biostructure data, providing access to:
  - >232,000 experimental structures from the PDB archive
  - >1 million computed structure models (CSMs) from AlphaFold DB & Model Archive
- Tools for searching, visualizing, analyzing, & downloading data
- Integration of annotations from ~50 external data resources (e.g., UniProt, SCOPe, CATH, and more)
- Access to RCSB PDB data and tools is powered by a set of Application Programming Interfaces (APIs)

3D structural data from around the world



RCSB Protein Data Bank (2025) *Nucleic Acids Research* **53**, D564–D574.

RCSB.org is Powered by APIs

The *two main APIs* underlying RCSB.org are the **search API** and **data API**:

- **Search API:** *Powers all search capabilities*—returns a list of PDB IDs for a given query
- **Data API:** *Powers all data retrieval needs*—returns metadata for a given list of PDB IDs

https://www.rcsb.org/docs/programmatic-access/web-apis-overview

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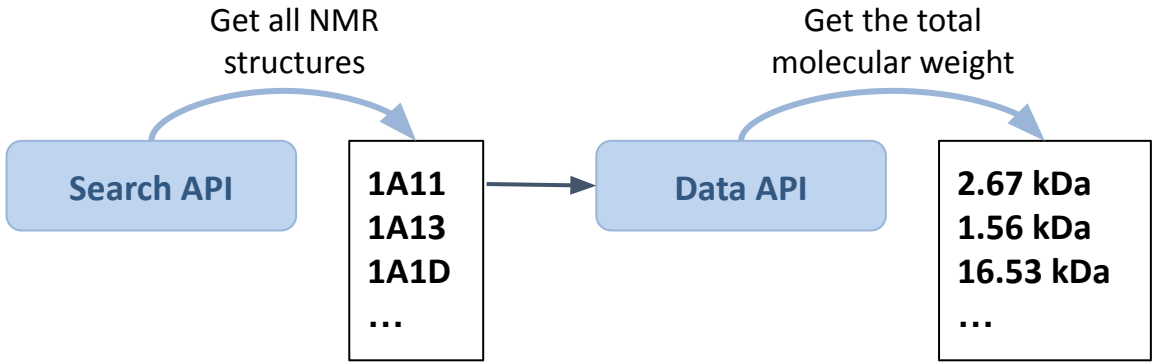

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Additional RCSB.org APIs:

- **Sequence Coordinate API:** Compiles alignments between structural & sequence databases and integrates protein positional features from multiple resources
- **Model Server API:** Delivers atomic coordinate data together with annotations in a compressed BinaryCIF encoding (BCIF)
- **Volume Server API:** Provides access to volumetric data (for X-ray and EM structures)
- **Alignment API:** Computes 3D structure alignments between structures

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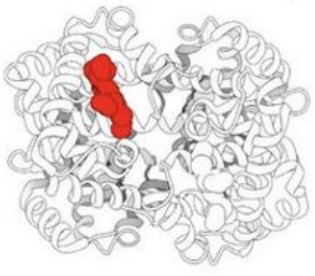
RCSB PDB: Data Organization

RCSB PDB data is organized based on macromolecular hierarchy, defined by schemas:

Object type:	**Entry** **4HHB**	**Entity** **1 (alpha subunit)**	**Entity instance** **C (chain C)**	**Assembly** **(quaternary structure)**	**Chemical component** **HEM (Heme molecule)**
					
Granularity:	Entire entry	Unique polymer sequence (or non-polymer)	Individual instance (or “chain”) of an entity	Groups of instances	Small molecules
Example data:	title, authors, citation	type (protein, DNA, RNA), sequence	binding sites, secondary structure	transformations required to generate the biological assembly	chemical descriptors (SMILES & InChI), chemical formula
Object ID format (`*rcsb_id*`):	4HHB (pdb_00004HHB)	4HHB_1	4HHB.C	4HHB-1	HEM

https://data.rcsb.org/index.html#data-organization
https://pdb101.rcsb.org/learn/guide-to-understanding-pdb-data/introduction-to-rcsb-pdb-apis

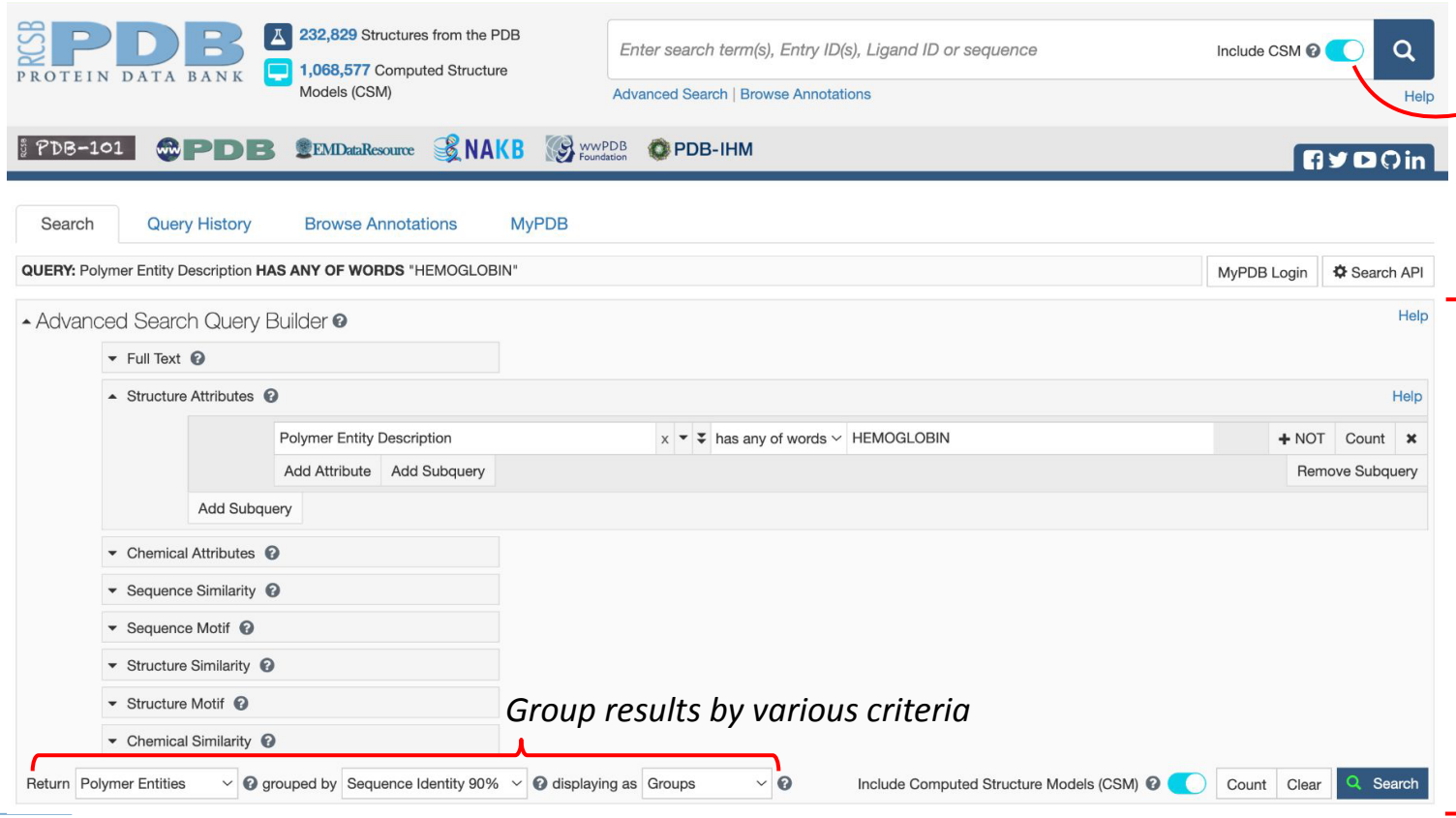
RCSB.org: Data Schema

RCSB PDB data is organized based on macromolecular hierarchy, as defined by schemas:

- Search API schema: https://search.rcsb.org/#search-attributes
  - Advanced Search attributes: rcsb.org/docs/search-and-browse/advanced-search/attribute-details
- Data API schema: https://data.rcsb.org/index.html#data-schema
  - Data API attributes: https://data.rcsb.org/data-attributes.html

Common attribute name (in Advanced Search)	Schema attribute (in APIs)
“Structure Title”	struct.title
“Polymer Entity Sequence Length”	entity_poly.rcsb_sample_sequence_length
“Scientific Name of Source Organism”	rcsb_entity_source_organism.ncbi_scientific_name

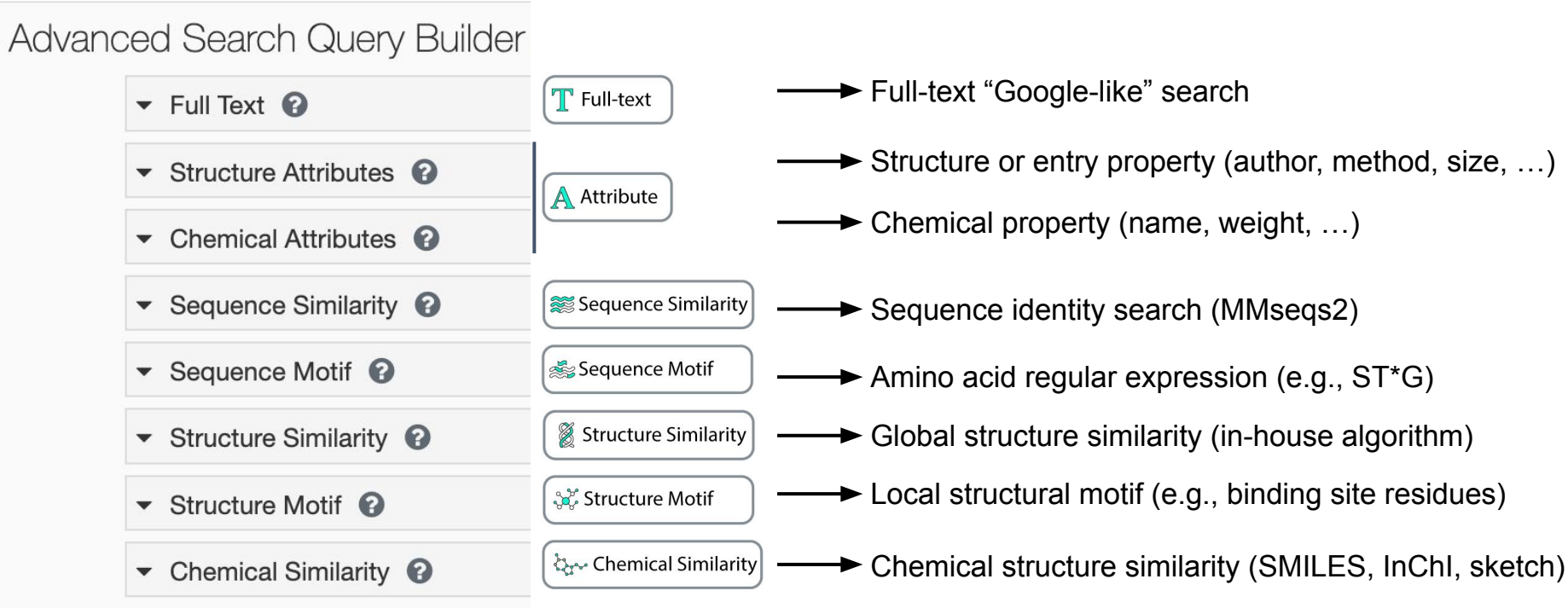
RCSB.org: Searching Data



Basic search (opt-in to include CSMs)

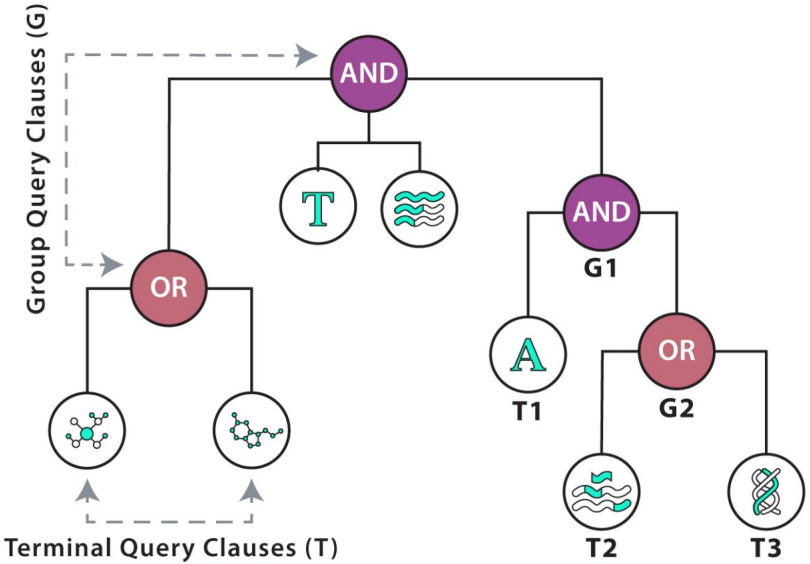
Advanced search

RCSB.org: Searching Data

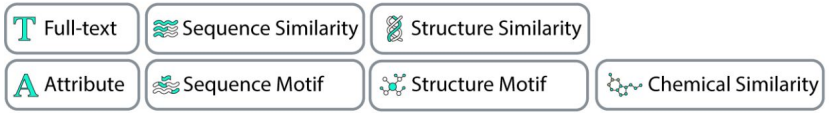


RCSB.org: Search API

Search API allows for nested grouping of any search service type (attribute, sequence, …):



Search service types:



Terminal Query Clauses (T): individual search criteria, e.g. match a particular value in a particular field or run a sequence search

Group Query Clauses (G): wrap other terminal or group queries and are used to combine multiple queries in a logical fashion (AND, OR)

https://search.rcsb.org/#query-language

Piehl, D.; Vallat, B.; Truong, I., et al. (2025), *JMB*. https://doi.org/10.1016/j.jmb.2025.168970
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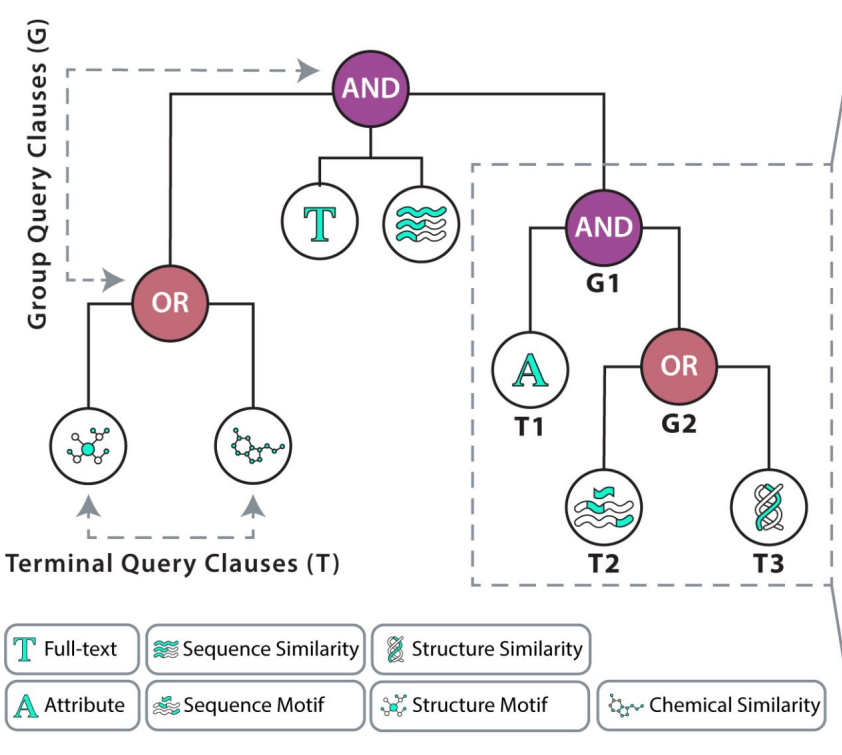
RCSB.org: Search API

Search API provides a full DSL (Domain Specific Language) based on JSON to define queries:




```
{
  "query": {
    "type": "group",                                   G1
    "logical_operator": "and",
    "nodes": [
      {
        "type": "terminal",                            T1
        "service": "text",
        "parameters": {
          "attribute": "rcsb_accession_info.initial_release_date",
          "operator": "greater",
          "negation": false,
          "value": "2019-08-20"
        }
      },
      {
        "type": "group",                               G2
        "logical_operator": "or",
        "nodes": [
          {
            "type": "terminal",                        T2
            "service": "seqmotif",
            "parameters": {
              "value": "C-x(2,4)-C-x(3)-[LIVMFYWC]-x(8)-H-x(3,5)-H.",
              "pattern_type": "prosite",
              "sequence_type": "protein"
            }
          },
          {
            "type": "terminal",                        T3
            "service": "structure",
            "parameters": {
              "operator": "strict_shape_match",
              "target_search_space": "assembly",
              "value": {
                "entry_id": "1CLL",
                "assembly_id": "1"
              }
            }
          }
        ]
      }
    ]
  },
  "return_type": "entry"
}
```

Terminal Query Clauses (T): individual search criteria, e.g. match a particular value in a particular field or run a sequence search

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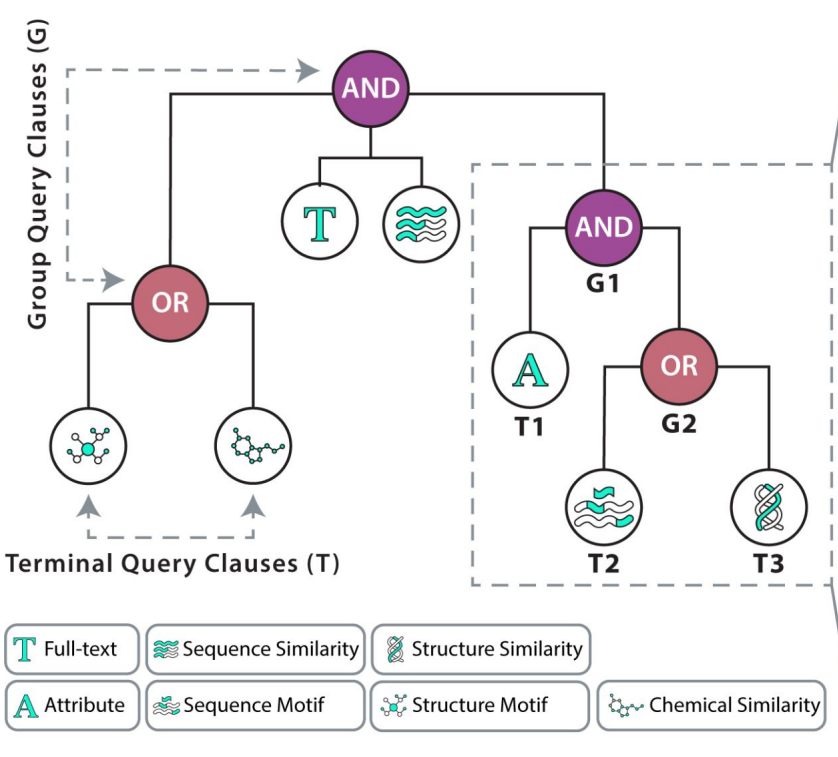


```
{
  "query": {
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    "logical_operator": "and",
    "nodes": [
      {
        "type": "terminal",                            T1
        "service": "text",
        "parameters": {
          "attribute": "rcsb_accession_info.initial_release_date",
          "operator": "greater",
          "negation": false,
          "value": "2019-08-20"
        }
      },
      {
        "type": "group",                               G2
        "logical_operator": "or",
        "nodes": [
          {
            "type": "terminal",                        T2
            "service": "seqmotif",
            "parameters": {
              "value": "C-x(2,4)-C-x(3)-[LIVMFYWC]-x(8)-H-x(3,5)-H.",
              "pattern_type": "prosite",
              "sequence_type": "protein"
            }
          },
          {
            "type": "terminal",                        T3
            "service": "structure",
            "parameters": {
              "operator": "strict_shape_match",
              "target_search_space": "assembly",
              "value": {
                "entry_id": "1CLL",
                "assembly_id": "1"
              }
            }
          }
        ]
      }
    ]
  },
  "return_type": "entry"
}
```

```
{
  "query_id": "d2125b839b404b429e5f7daf3d9edab2",
  "result_type": "entry",
  "total_count": 280,
  "result_set": [
    "6J0D",
    "6KI6",
    "6LI0",
    "6LI2",
    "6LQM",
    "6LSR",
    "6LSS",
    "6LTH",
    "6LTJ",
    "6LU8",
    "6M62",
    "6NQ3",
    "6PV0",
    "6PV1",
    "6PV2",
    "6PV3",
    "6SKG",
    "6U9Q",
    "6UCO",
    "6UCP",
    "6UML",
    "6V8U",
    "6VIX"
```


Piehl, D.; Vallat, B.; Truong, I., et al. (2025), *JMB*. https://doi.org/10.1016/j.jmb.2025.168970
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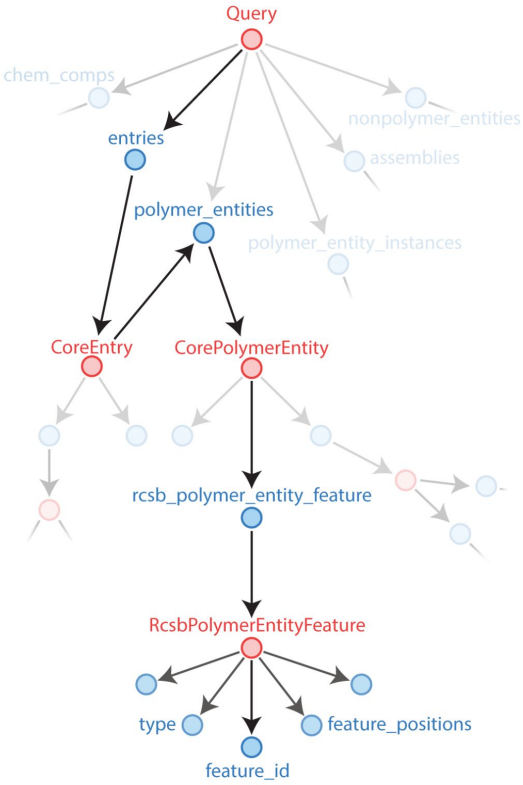
RCSB.org: Data API

Data API supports the use of GraphQL to form queries for fetching data:

- Data are organized by hierarchical level
- You can also query specifically for other hierarchy levels *(e.g., starting at entities vs. entries)*

```
{
  entries(entry_ids: ["1HXW", "1N49", "1RL8"]) {
    rcsb_id
    polymer_entities {
      rcsb_polymer_entity_feature {
        type
        feature_id
        name
        description
        provenance_source
        assignment_version
        reference_scheme
        feature_positions {
          values
          value
          end_seq_id
          beg_seq_id
          beg_comp_id
        }
        additional_properties {
          name
          values
        }
      }
    }
  }
}
```



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    rcsb_id
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        feature_positions {
          values
          value
          end_seq_id
          beg_seq_id
          beg_comp_id
        }
        additional_properties {
          name
          values
        }
      }
    }
  }
}
```


```
{
  "data": {
    "entries": [
      {
        "rcsb_id": "1HXW",
        "polymer_entities": [
          {
            "rcsb_polymer_entity_feature": [
              {
                "name": "Retroviral aspartyl protease (RVP)",
                "description": null,
                "reference_scheme": null,
                "additional_properties": null,
                "feature_positions": [
                  {
                    "value": null,
                    "values": null,
                    "end_seq_id": 98,
                    "beg_seq_id": 5,
                    "beg_comp_id": null
                  }
                ],
                "feature_id": "PF00077",
                "assignment_version": "34.0",
                "provenance_source": "Pfam",
                "type": "Pfam"
              },
              {
                "name": "Hydropathy values",
                "description": null,
                "reference_scheme": null,
                "additional_properties": null,
                "feature_positions": [
                  {
                    "value": null,
                    "values": [
                      -0.89,
                      -0.29,
                      0.57,
                      -0.01,
                      0.57,
                      -0.29,
                      0.31,
                      0.66,
                      1.11,
                      0.9,
```


Piehl, D.; Vallat, B.; Truong, I., et al. (2025), *JMB*. https://doi.org/10.1016/j.jmb.2025.168970
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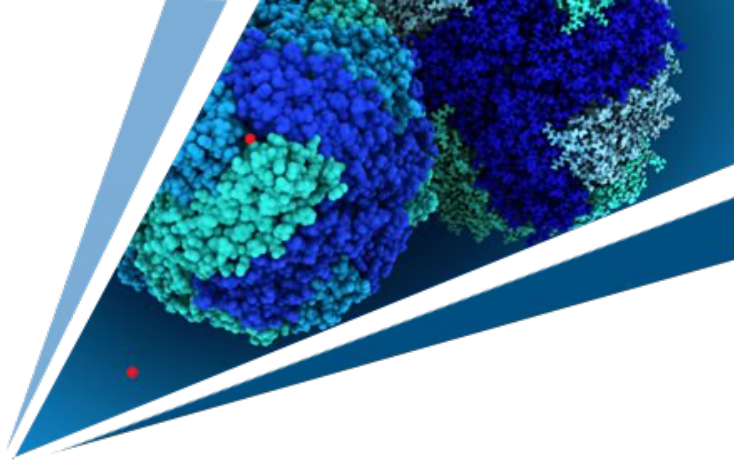
Accessing APIs on RCSB.org

Quick tour of Search and Data APIs on RCSB.org

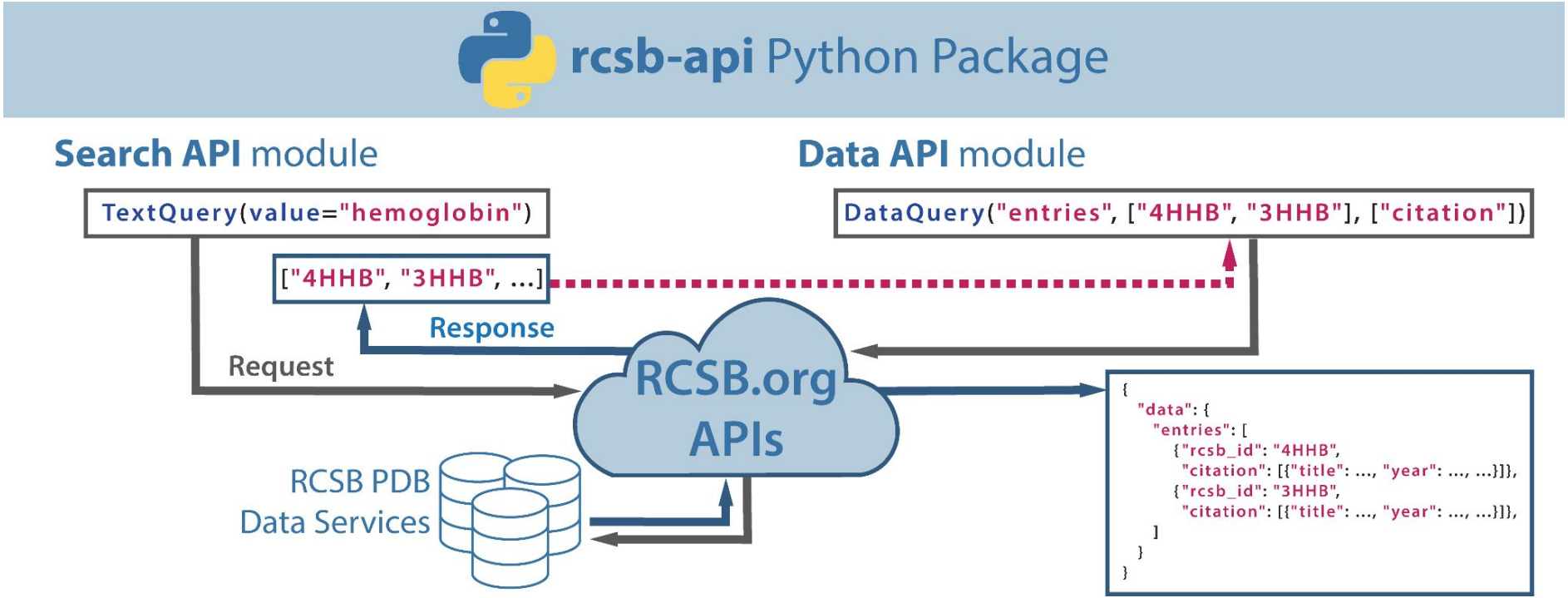
Pre-constructed query (hemoglobin, human): https://go.rutgers.edu/f8phhb3z



rcsb-api: Python package for accessing RCSB.org APIs

rcsb-api: Access RCSB.org APIs with Python

rcsb-api: Python package that provides access to RCSB.org APIs (rcsbapi.readthedocs.io)



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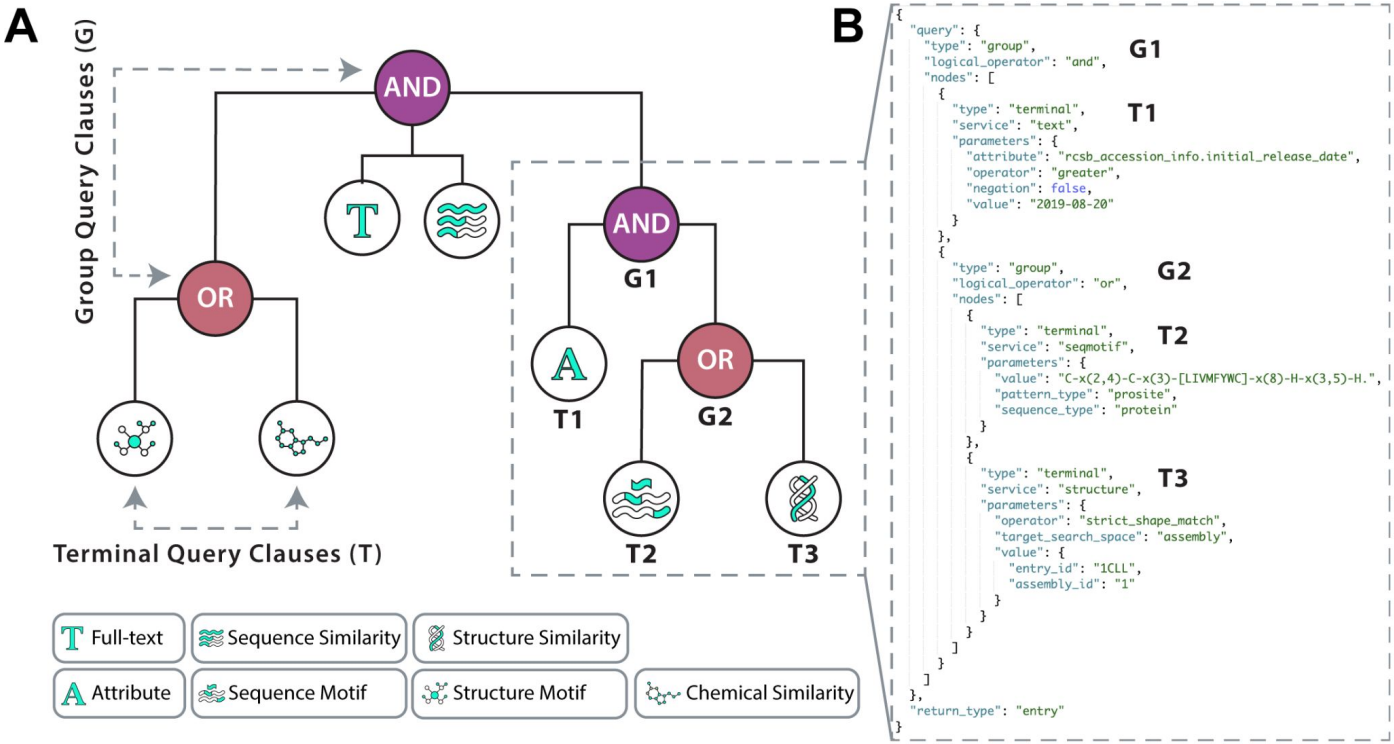
rcsb-api: Access RCSB.org APIs with Python

rcsb-api: Python package that provides access to RCSB.org APIs (rcsbapi.readthedocs.io)

- **Search API module:** Enables fetching of structure IDs
  - Simplistic query construction using intuitive Boolean operator syntax
  - Supports all search types (full-text, attribute, sequence & structure similarity, etc.)
  - Allows users to upload custom structure files for structure similarity searches
  - Inclusion of computed structure models (CSMs)
  - Supports grouping of results (e.g., by sequence identity) and faceted queries
- **Data API module:** Enables data retrieval for a given list of structure IDs
  - Automatic resolution of partial and nested field paths
  - Offers easy mechanism for fetching data for all structures
- Both modules provide helper functions for exploring schemas

Piehl, D.; Vallat, B.; Truong, I., et al. (2025), *JMB*. https://doi.org/10.1016/j.jmb.2025.168970

rcsb-api: Search API module




```
{
  "query": {
    "type": "group",
    "logical_operator": "and",
    "nodes": [
      {
        "type": "terminal",
        "service": "text",
        "parameters": {
          "attribute": "rcsb_accession_info.initial_release_date",
          "operator": "greater",
          "negation": false,
          "value": "2019-08-20"
        }
      },
      {
        "type": "group",
        "logical_operator": "or",
        "nodes": [
          {
            "type": "terminal",
            "service": "seqmotif",
            "parameters": {
              "value": "C-x(2,4)-C-x(3)-[LIVMFYWC]-x(8)-H-x(3,5)-H.",
              "pattern_type": "prosite",
              "sequence_type": "protein"
            }
          },
          {
            "type": "terminal",
            "service": "structure",
            "parameters": {
              "operator": "strict_shape_match",
              "target_search_space": "assembly",
              "value": {
                "entry_id": "1CLL",
                "assembly_id": "1"
              }
            }
          }
        ]
      }
    ]
  },
  "return_type": "entry"
}
```

C

```
from rcsbapi.search import AttributeQuery, SeqMotifQuery, StructSimilarityQuery
t1 = AttributeQuery("rcsb_accession_info.initial_release_date", "greater", "2019-08-20")
t2 = SeqMotifQuery("C-x(2,4)-C-x(3)-[LIVMFYWC]-x(8)-H-x(3,5)-H.", pattern_type="prosite", sequence_type="protein")
t3 = StructSimilarityQuery(entry_id="1CLL", assembly_id="1", operator="strict_shape_match")
query = t1 & (t2 | t3)
results = list(query())
```

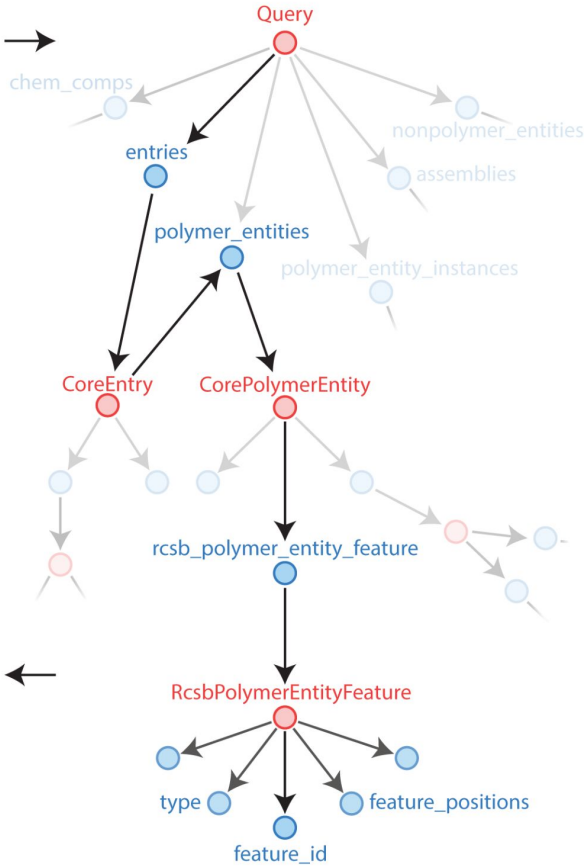
Piehl, D.; Vallat, B.; Truong, I., et al. (2025), *JMB*. DOI: 10.1016/j.jmb.2025.168970

rcsb-api: Data API module

A

```python
from rcsbapi.data import DataSchema, DataQuery
query = DataQuery(
  input_type="entries",
  input_ids=["1HXW", "1N49", "1RL8"],
  return_data_list=["rcsb_polymer_entity_feature"]
)
results = query.exec()
```

B



C

```
{
  entries(entry_ids: ["1HXW", "1N49", "1RL8"]) {
    rcsb_id
    polymer_entities {
      rcsb_polymer_entity_feature {
        type
        feature_id
        name
        description
        provenance_source
        assignment_version
        reference_scheme
        feature_positions {
          values
          value
          end_seq_id
          beg_seq_id
          beg_comp_id
        }
        additional_properties {
          name
          values
        }
      }
    }
  }
}
```

Piehl, D.; Vallat, B.; Truong, I., et al. (2025), *JMB*. DOI: 10.1016/j.jmb.2025.168970

rcsb-api: Search and Data API pipeline

A Search for all structures containing ritonavir

```
from rcsbapi.search import search_attributes as attrs
q1 = attrs.rcsb_chem_comp_annotation.annotation_lineage.id == "J05AE03"
q2 = attrs.rcsb_chem_comp_annotation.type == "ATC"
search_query = q1 & q2
search_results = list(search_query())
```

```
["1HXW", "1N49", "1RL8", "1SH9", "2B60", ...]
```

B Get instance-level features for all structures

```
from rcsbapi.data import DataQuery
data_query = DataQuery(
    input_type="entries",
    input_ids=["1HXW", "1N49", "1RL8", "1SH9", "2B60", ...],
    return_data_list=["rcsb_polymer_instance_feature"]
)
data_results = data_query.exec()
```

C Extract ligand-residue interactions

```
{
 "data": {
   "entries": [
     {
      "rcsb_id": "1HXW",
      "polymer_entities": [
        {
         "polymer_entity_instances": [
           {
            "rcsb_polymer_instance_feature": [
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                 ...
```

Piehl, D.; Vallat, B.; Truong, I., et al. (2025), *JMB*. DOI: 10.1016/j.jmb.2025.168970

RCSB PDB
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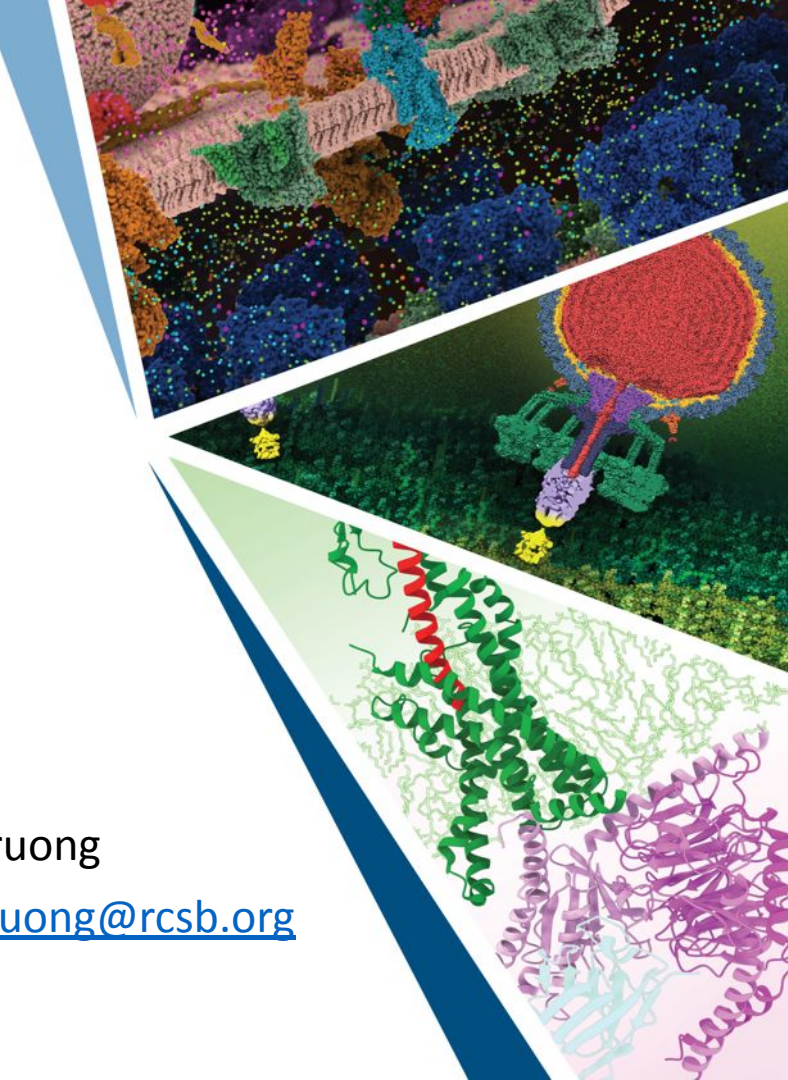
RCSB.org
info@rcsb.org



Guided demonstration of *rcsb-api* Python package

Ivana Truong
ivana.truong@rcsb.org

March 24th, 2025

Live demo

https://github.com/rcsb/rcsb-training-resources/tree/master/training-events/2025/python-rcsb-api

Short URL: https://go.rutgers.edu/o1cr0dwm

Open notebook on GitHub, then click "*Open in Colab*" badge at top of page (to open in Google Colab)

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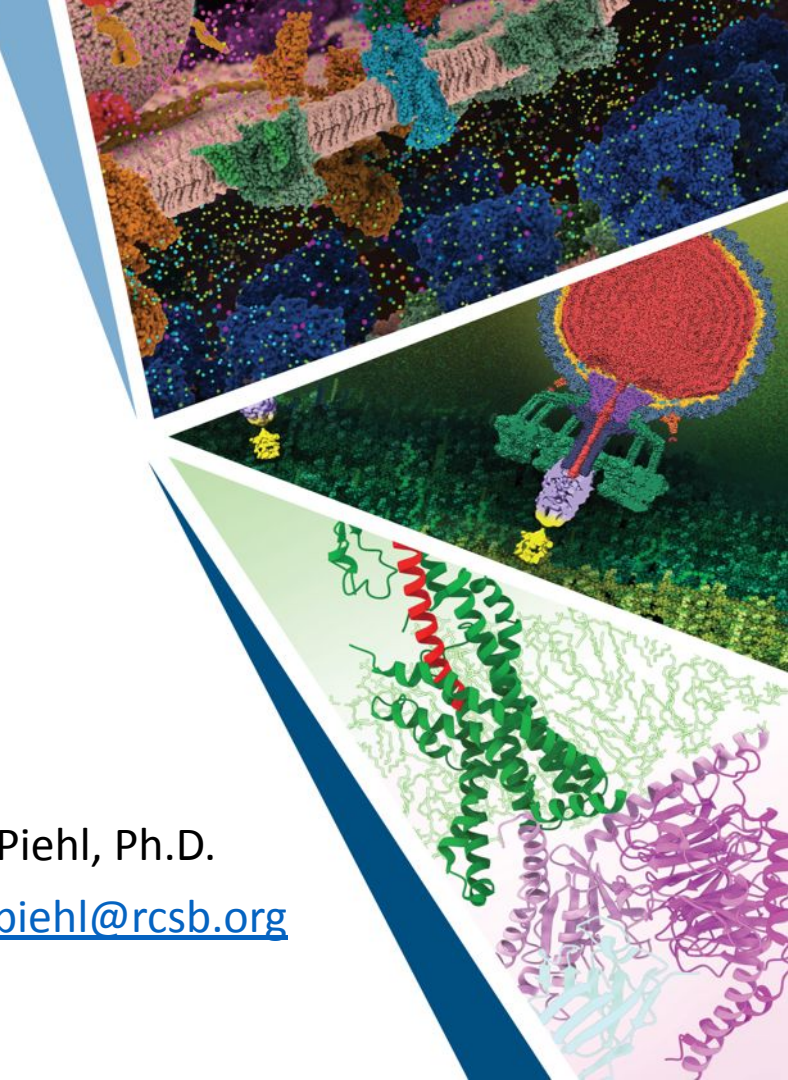

Summary, Resources & Links, and Announcements

Dennis Piehl, Ph.D.
dennis.piehl@rcsb.org

March 24th, 2025

Summary and Future directions

Summary:

- The ***rcsb-api*** Python package enables facilitated access to RCSB.org search and data APIs, increasing the FAIRness of PDB data
- All source code is open source and available on GitHub (https://github.com/rcsb/py-rcsb-api)
- Demonstrated usage and applications of the package via Python notebooks

Future directions:

- Add support for additional RCSB.org APIs (e.g., sequence coordinate API)
- Add support for 3D coordinate file downloading (e.g., model server API)

Resources and Links

- ***rcsb-api*** Python package: https://rcsbapi.readthedocs.io
  - GitHub: https://github.com/rcsb/py-rcsb-api
- Webinar notebooks: https://github.com/rcsb/rcsb-training-resources/tree/master/training-events/2025/python-rcsb-api
- RCSB.org APIs: https://rcsb.org/docs/programmatic-access/web-apis-overview
- Webinar recordings will be published at: https://pdb101.rcsb.org/train/training-events
  - Previous API webinar: https://pdb101.rcsb.org/train/training-events/api

Schema references:

- Search API schema: https://search.rcsb.org/#search-attributes
  - Advanced Search attributes: rcsb.org/docs/search-and-browse/advanced-search/attribute-details
- Data API schema: https://data.rcsb.org/index.html#data-schema
  - Data API attributes: https://data.rcsb.org/data-attributes.html

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