

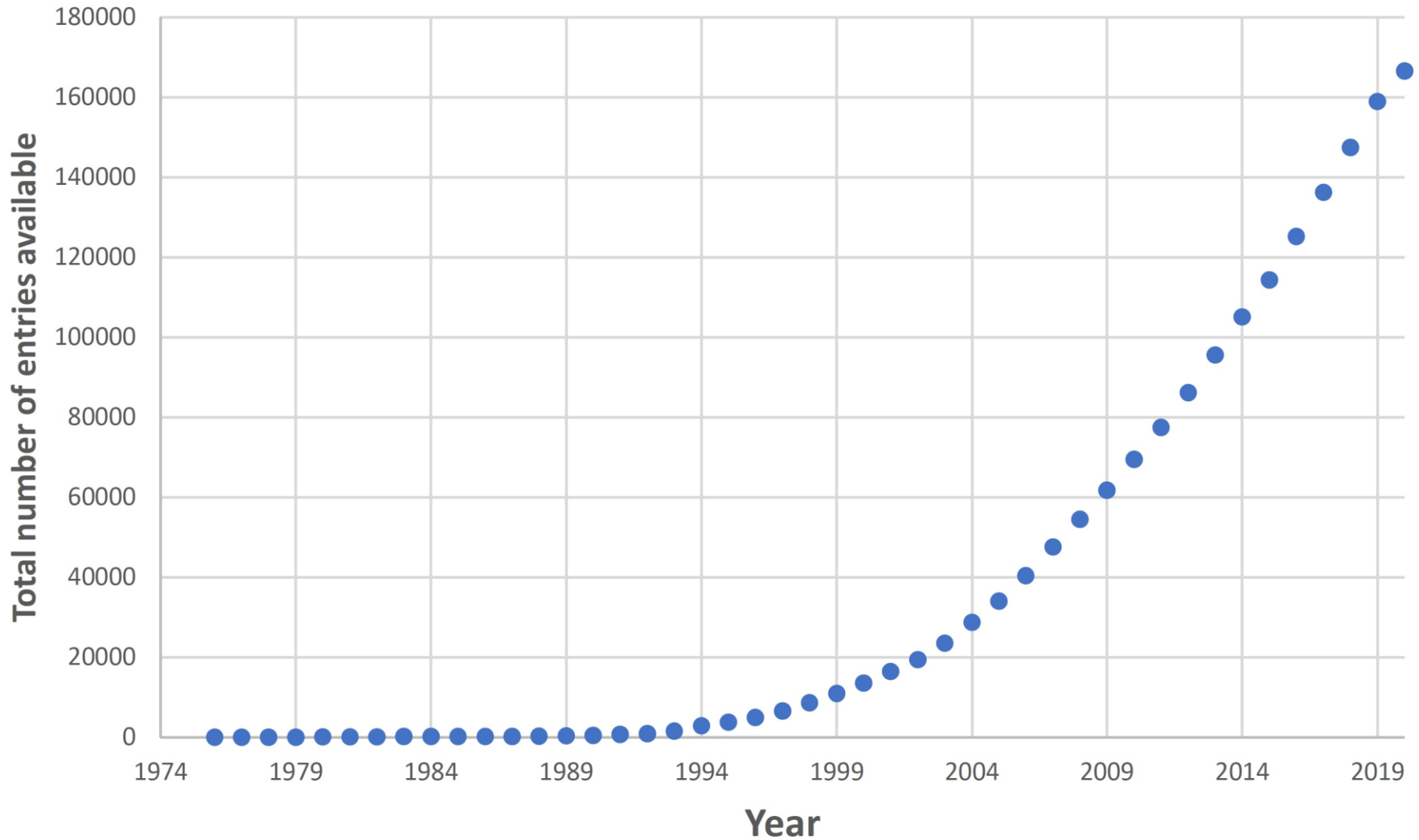
Secondary structure diagrams of proteins, protein families and ligands

Radka Svobodová

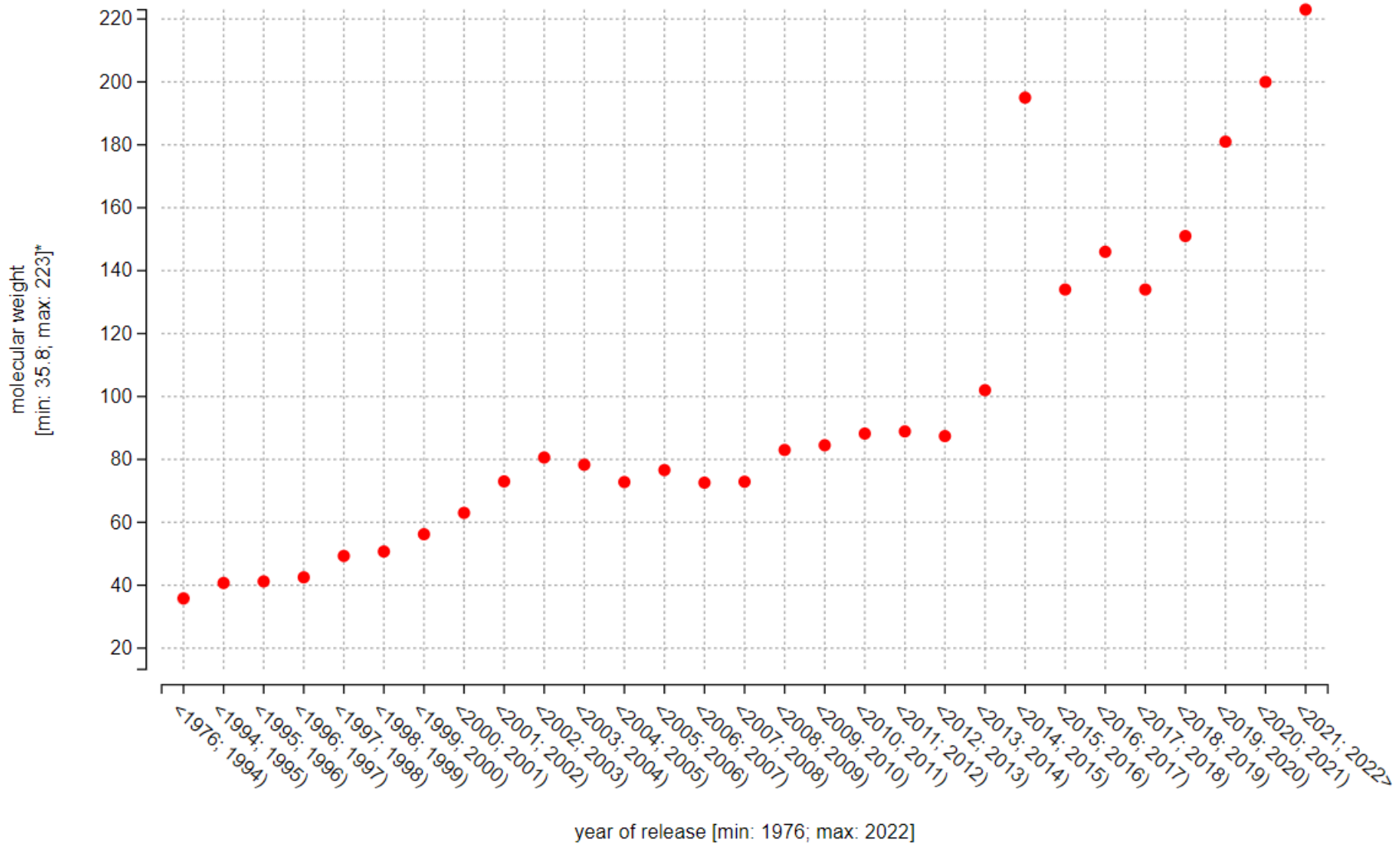
NCBR, CEITEC
MASARYK UNIVERSITY



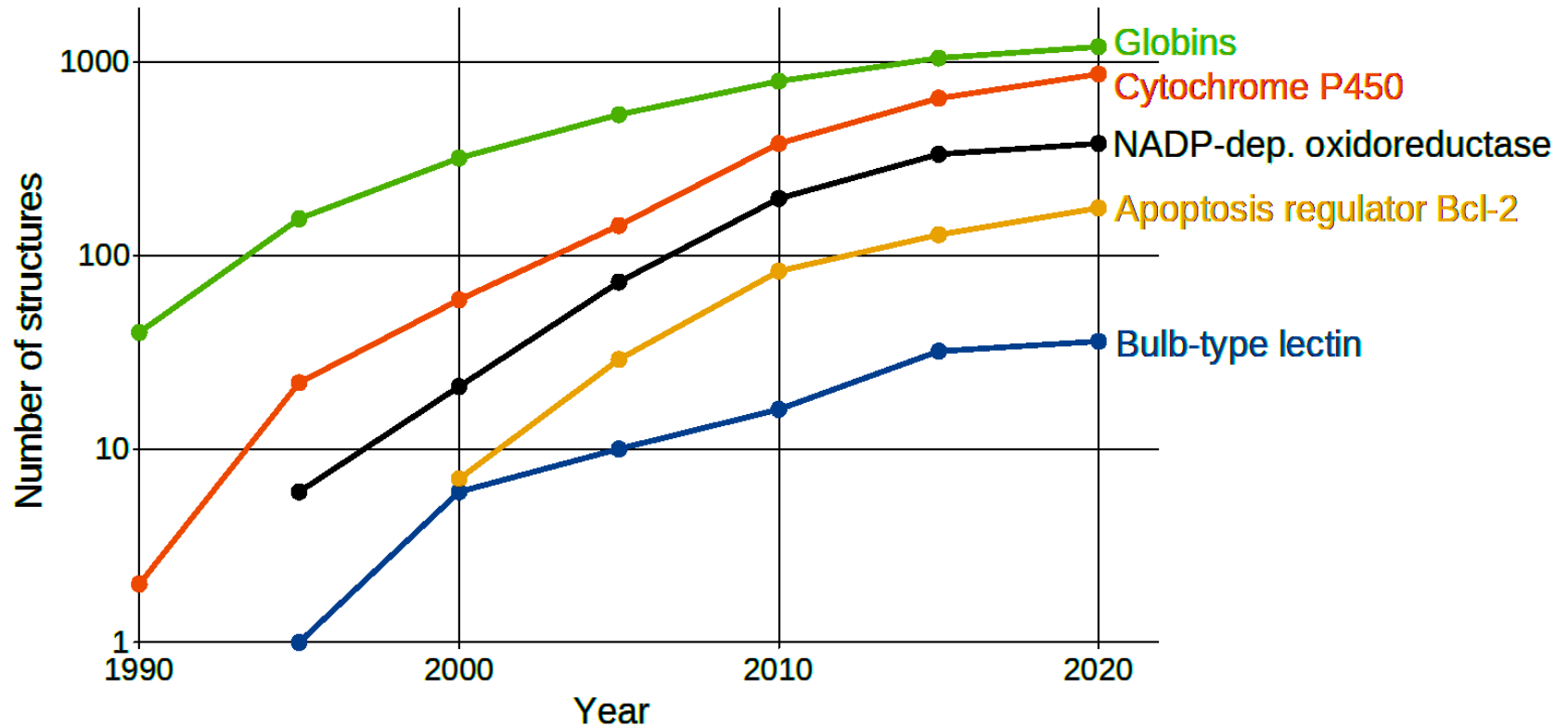
Current trends: Number of available structures grows



Current trends: Size of deposited structures also grows



Current trends: Protein families are getting bigger



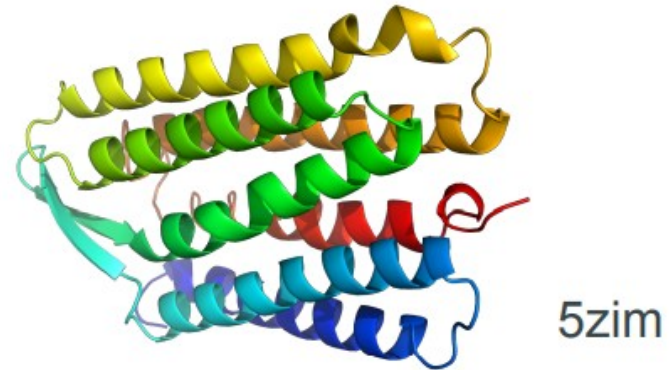
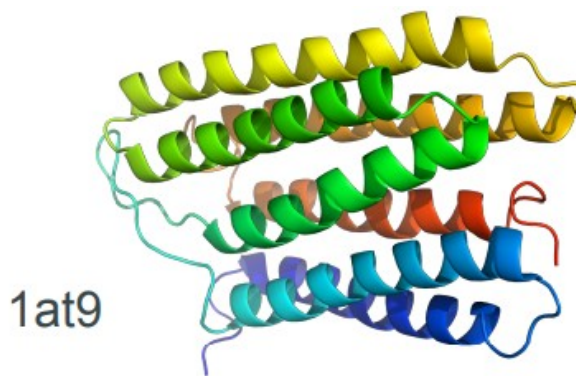
Analysis of individual structure



Analysis of a whole family

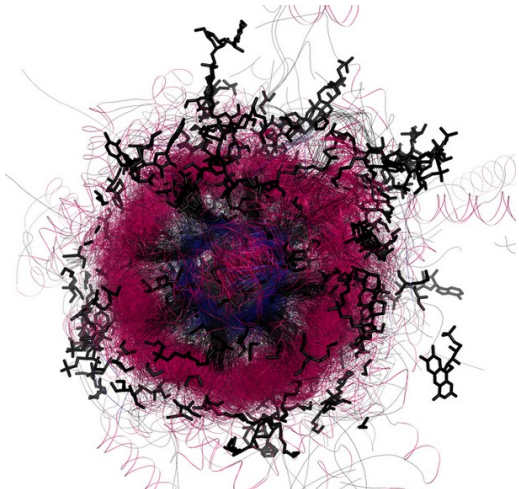
Protein family structures and their analysis

- Comparison of protein family members
 - Different species
 - Different substituents
 - Mutations
 - Active and inactive forms
- Firm (conserved) and flexible regions
- Binding of ligands



Protein family structures and their analysis

How to do it?



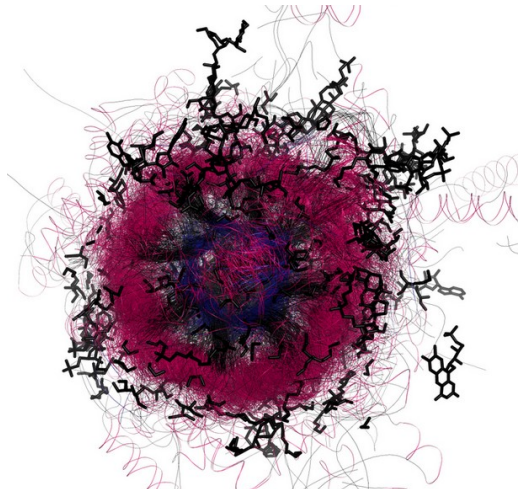
Aldolase class I
(protein family 3.20.20.70)



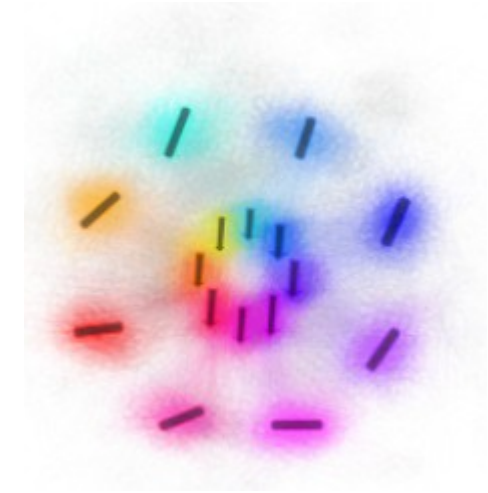
Cytochrome P450
(protein family 1.10.630.10)

Protein family structures and their analysis

How to do it?



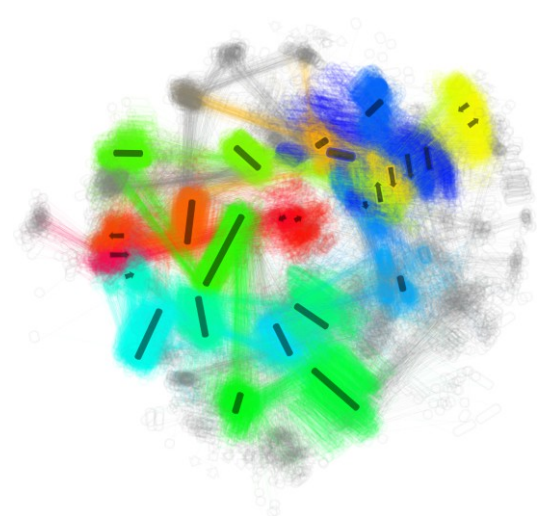
Aldolase class I
(protein family 3.20.20.70)



Insight into protein family:
Secondary structure
2D diagrams



Cytochrome P450
(protein family 1.10.630.10)



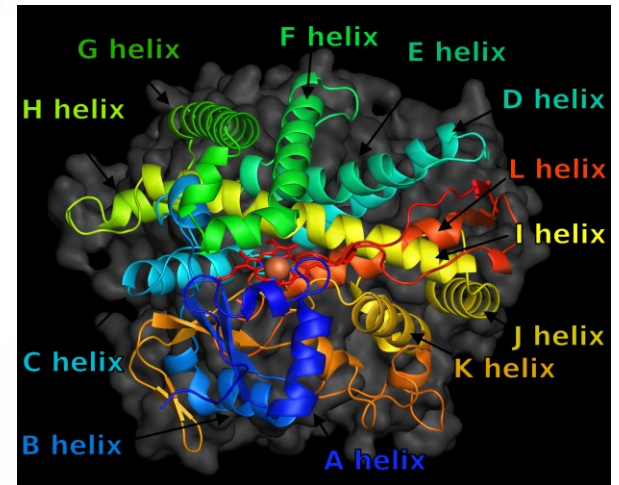
Protein family structures and their analysis

Secondary structure utilization – necessary steps

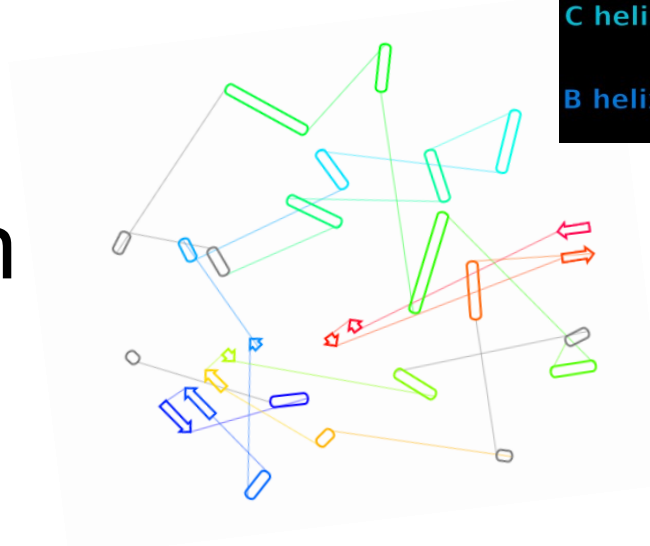
- Detection



- Annotation

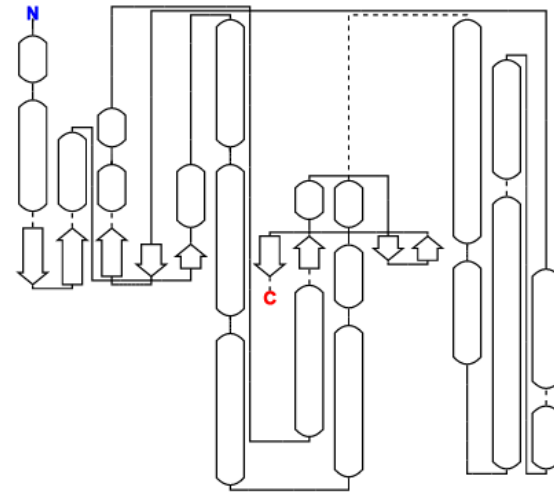
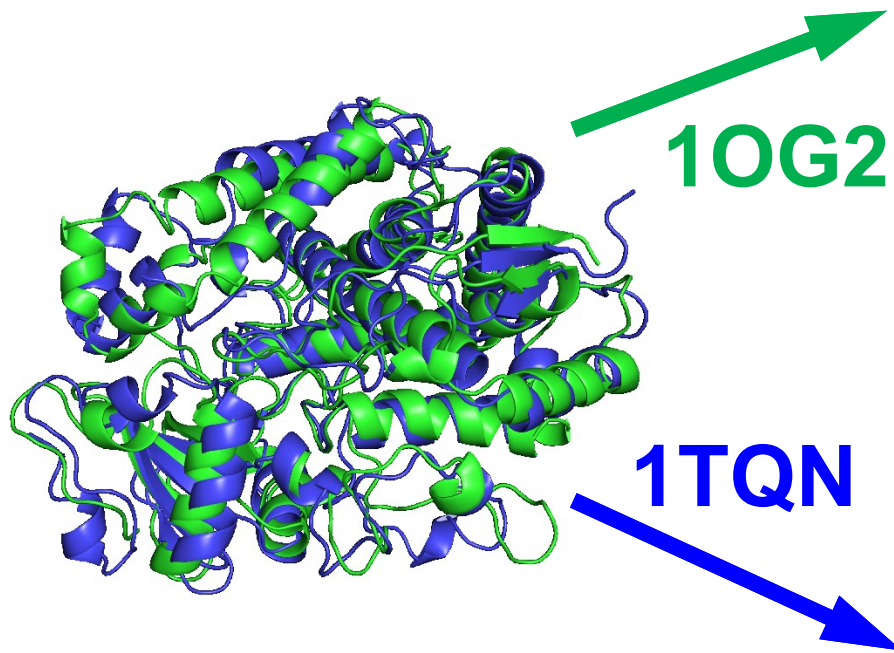


- Visualization

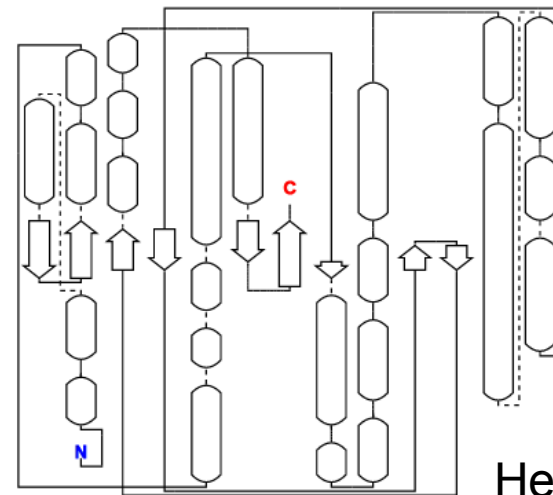


Visualization of secondary structure in 2D: Solved in past? Not for protein families!

ISSUE 1: Similar proteins have
different 2D diagrams



RMSD: 2.295 Å



Hera, PDBe

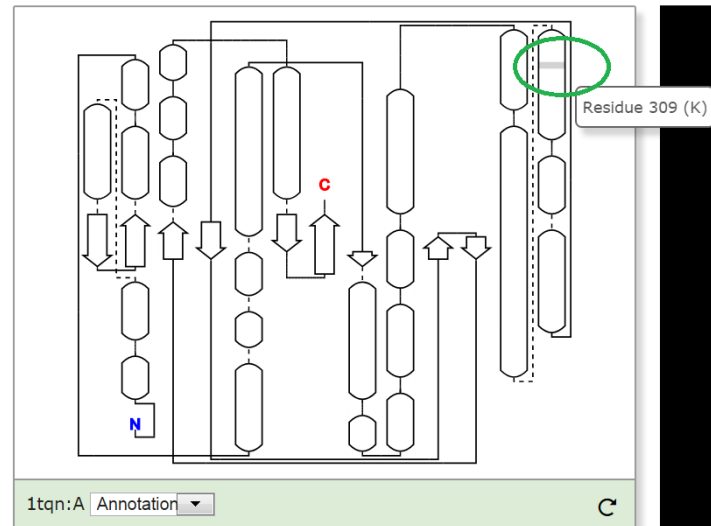
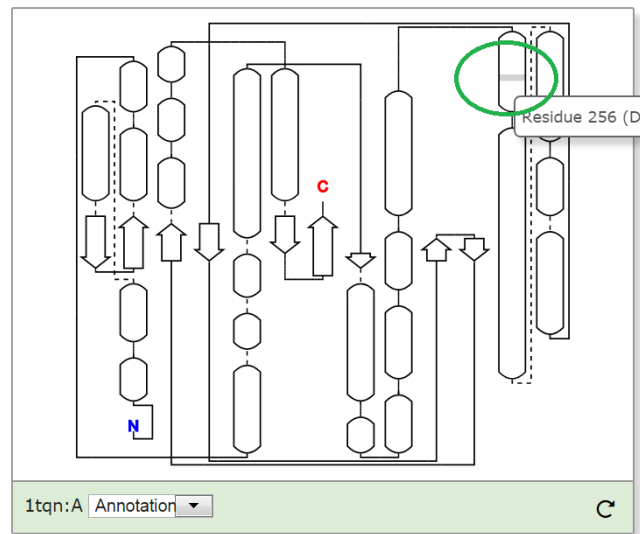
Visualization of secondary structure in 2D: Solved in past? Not for protein families!

ISSUE 2:

Secondary structure elements close in 2D diagrams are far in reality

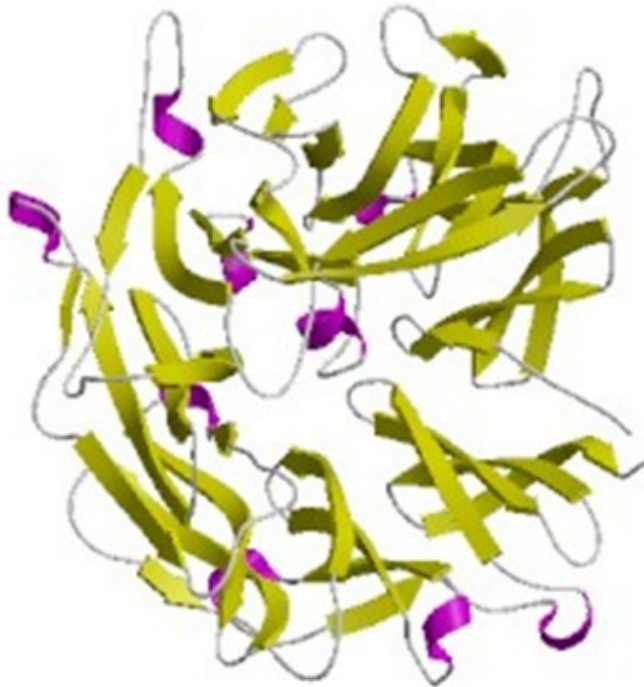
1TQN

Hera,
PDBe

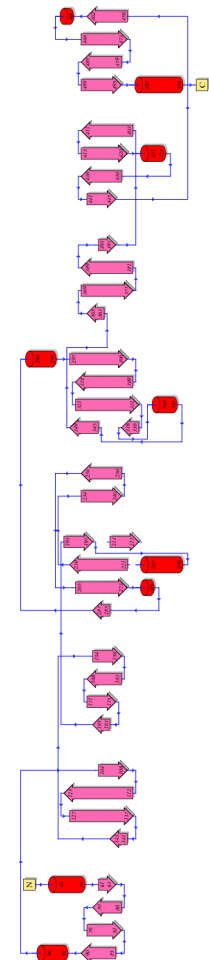


Visualization of secondary structure in 2D: Solved in past?

ISSUE 3: 2D diagrams does not reflect
a shape of a protein



1ORW



HERA

Protein family based 2D diagrams

How to get them?

Input:



Step 1: Detection & annotation

- Find secondary structure elements (SSE)
- Annotate them

Step 2: Statistics

- Average length of SSE
- Average occurrence of SSE

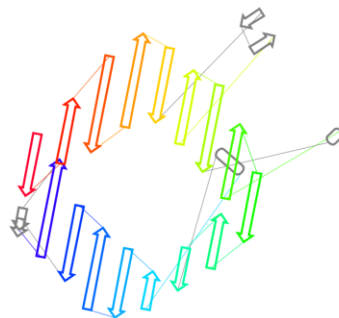
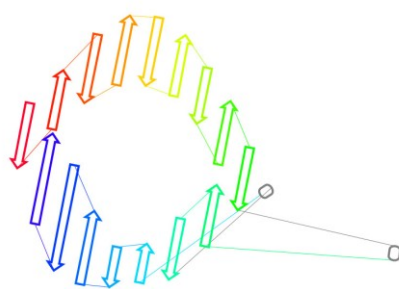
Protein family based 2D diagrams

How to get them?

Step 3: Construct the 2D diagram

- Group all β -strands into sheets
- Divide the **helices and sheets into primary** (common for most of the domains) **and secondary** (the remaining ones).
- **Place all primary** helices and sheets into the 2D diagram.
- **Adjust the angles** of the primary helices and sheets.
- **Add all secondary** helices and sheets into the 2D diagram.
- **Adjust the angles** of the secondary helices and sheets.

Step 4: Draw the 2D diagrams



Protein family 2D diagrams

2DProts database

<https://2dprots.ncbr.muni.cz>

2DProts

Custom entry

User manual

Description of methods

e.g., 1r9nA01, 1r9n, 2.140.10.

Search 2DProts

2DProts

Database of 2D diagrams of domain secondary structures

Examples

Click headings below to expand:



Porin (protein family 2.40.160.10)

Protein family 2D diagrams

2DProts database

2DProts

Custom entry

User manual

Description of methods

e.g., 1r9nA01, 1r9n, 2.140.10.3

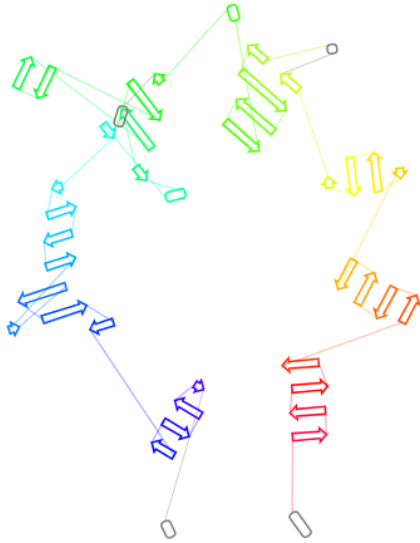
Search 2DProts

Domain 1j2eA01

2D domain diagram

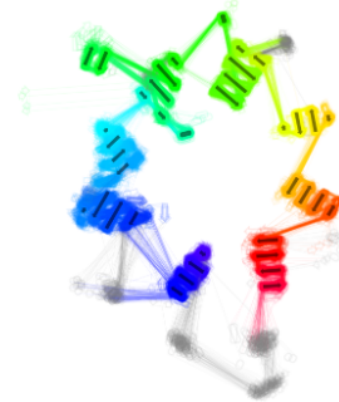
No ligands

With ligands



« no prev. | [1j2eB01](#) »

Member of
family:
[2.140.10.30](#)



Part of protein:
[1j2e](#)

Protein family 2D diagrams

2DProts database

Family 2.140.10.30

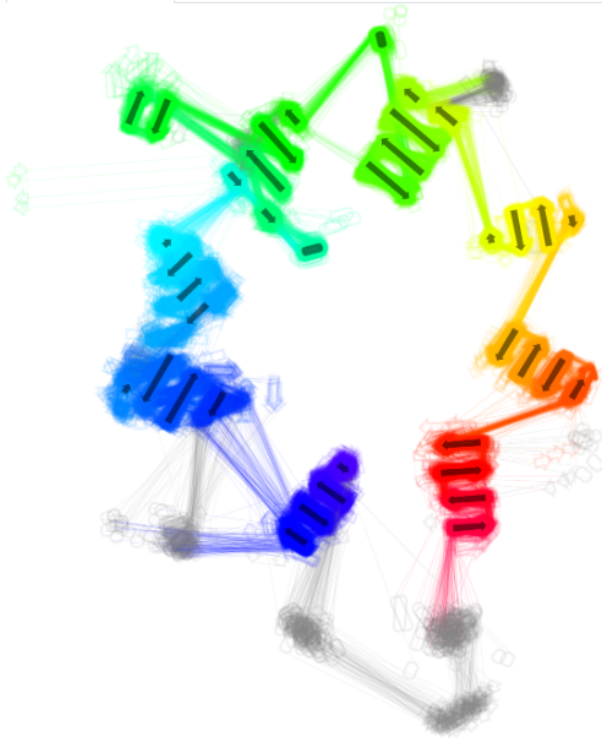
2D multi diagram

No ligands

With ligands

No ligands, opaque

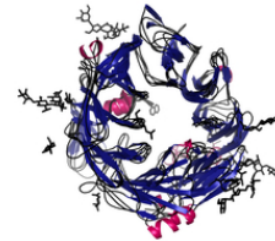
No ligands, opaque, no averages



Multi image for 2.140.10.30 ([svg source](#))

[« 2.140.10.20](#) | [2.150.10.10 »](#)

3D model ([CATH](#))

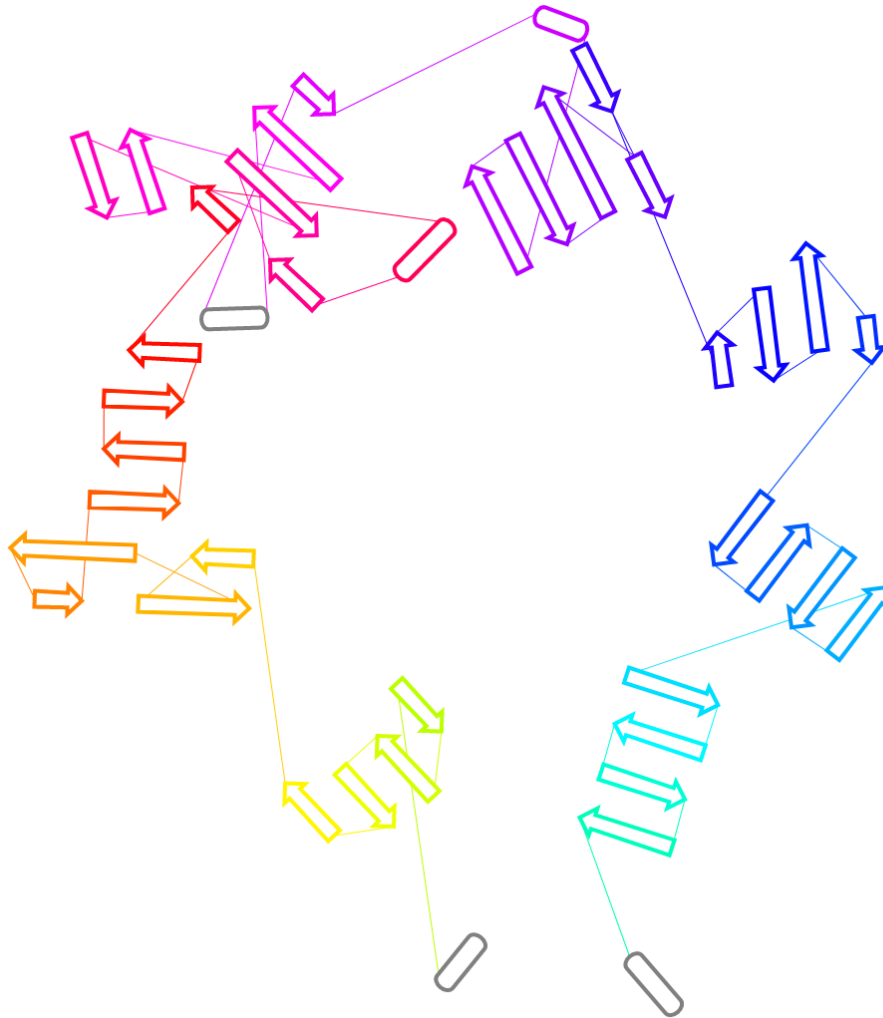


Domains (325)

- [1j2eA01](#)
- [1j2eB01](#)
- [1n1mA02](#)
- [1n1mB01](#)
- [1nu6A01](#)
- [1nu6B01](#)
- [1nu8A01](#)
- [1nu8B01](#)
- [1orvA01](#)

2DProts outputs

2D diagram of a protein domain



2DProts outputs:

Multiple 2D diagram of protein domains in a family



With opacity



No opacity

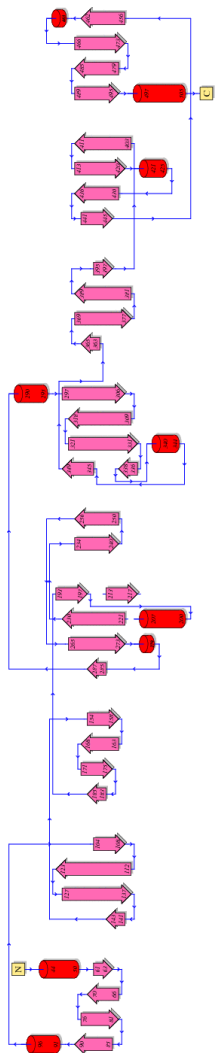
Superfamily: Dipeptidylpeptidase IV (2.140.10.30)

PROTEIN

PROTEIN FAMILY

Current solution

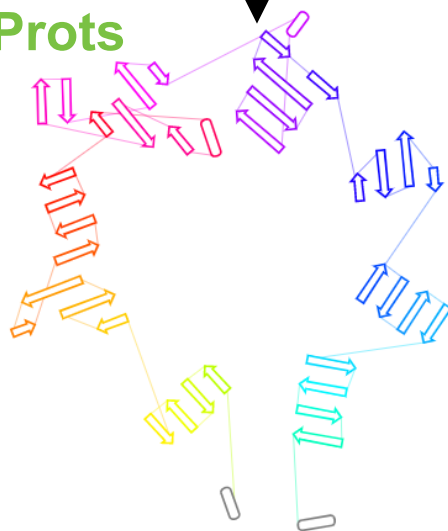
HERA



CATH



2DProts



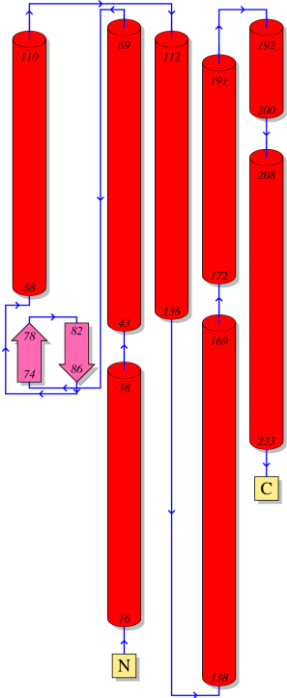
Superfamily: Rhodopsin 7-helix transmembrane proteins

PROTEIN (1.20.1070.10)

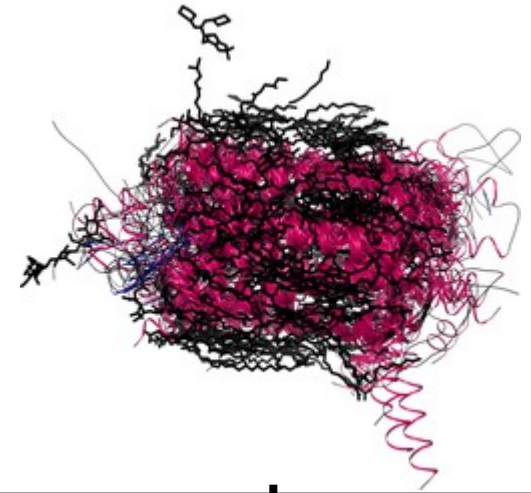
PROTEIN FAMILY

Current solution

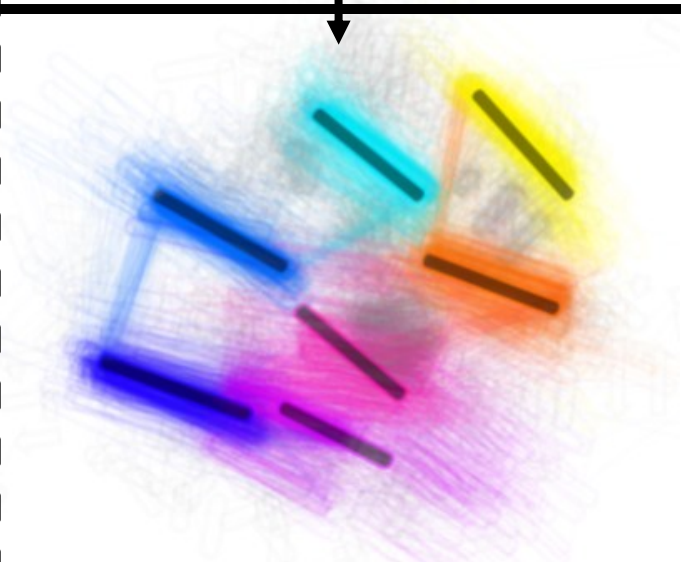
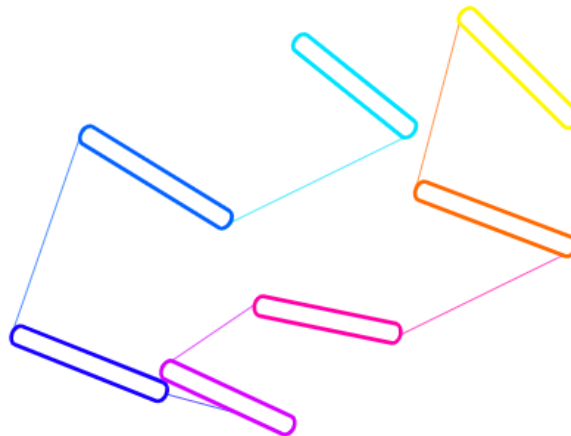
HERA



CATH



2DProts



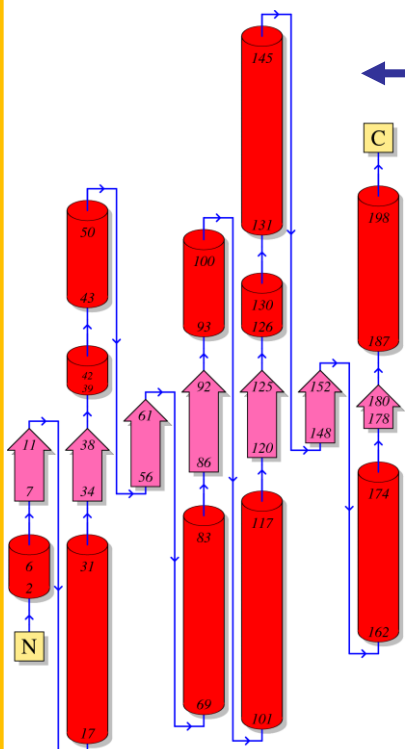
Superfamily: Aldolase class I (3.20.20.70)

PROTEIN

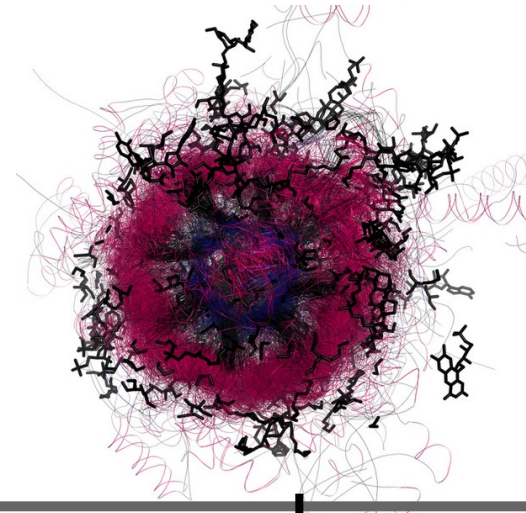
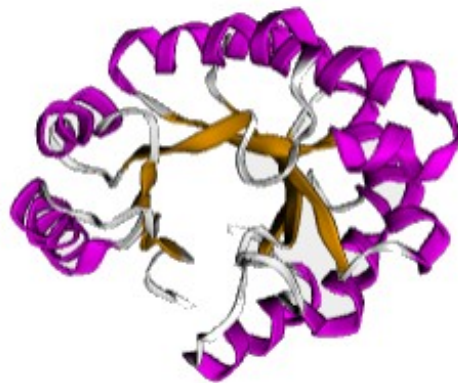
PROTEIN FAMILY

Current solution

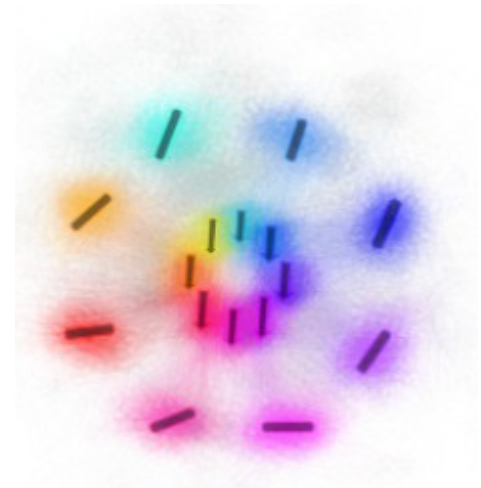
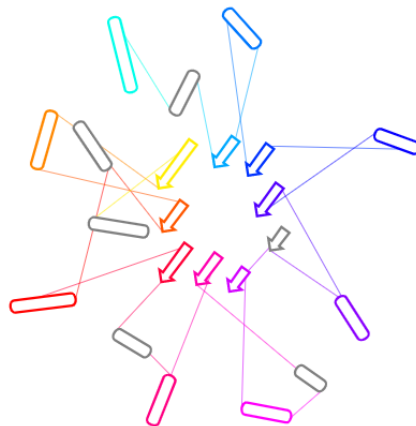
HERA



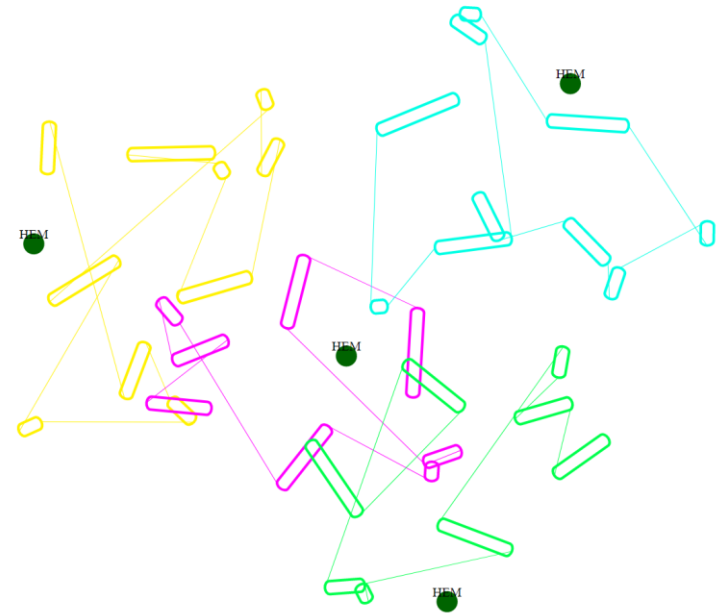
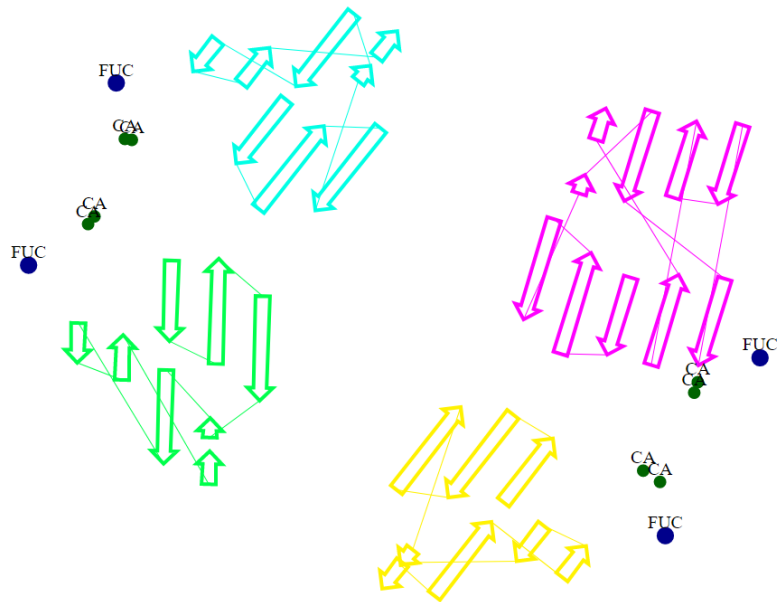
CATH



2DProts



2DProts: 2D diagrams for proteins

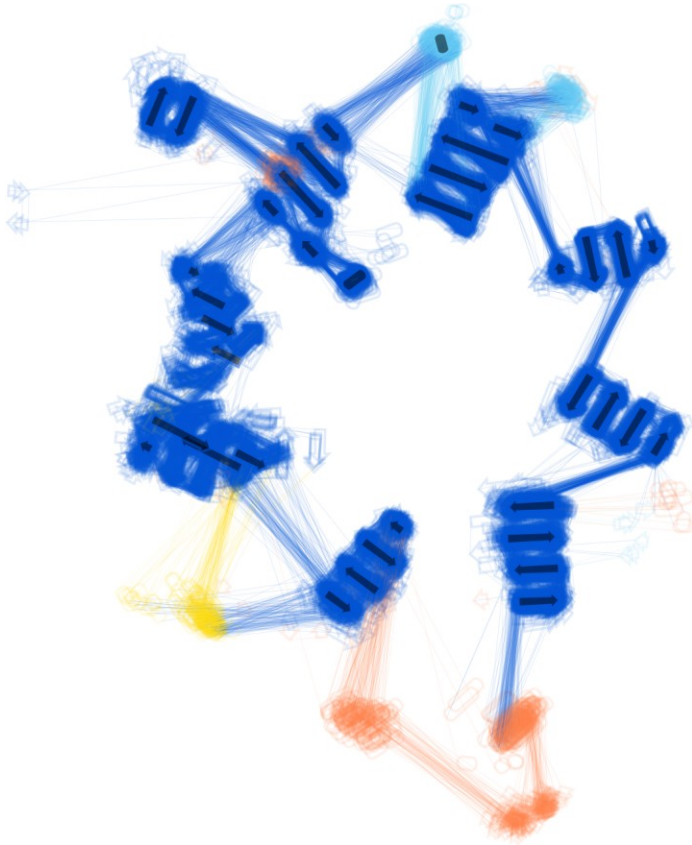


**Pseudomonas
aeruginosa lectin II
PDB ID 1gzt**

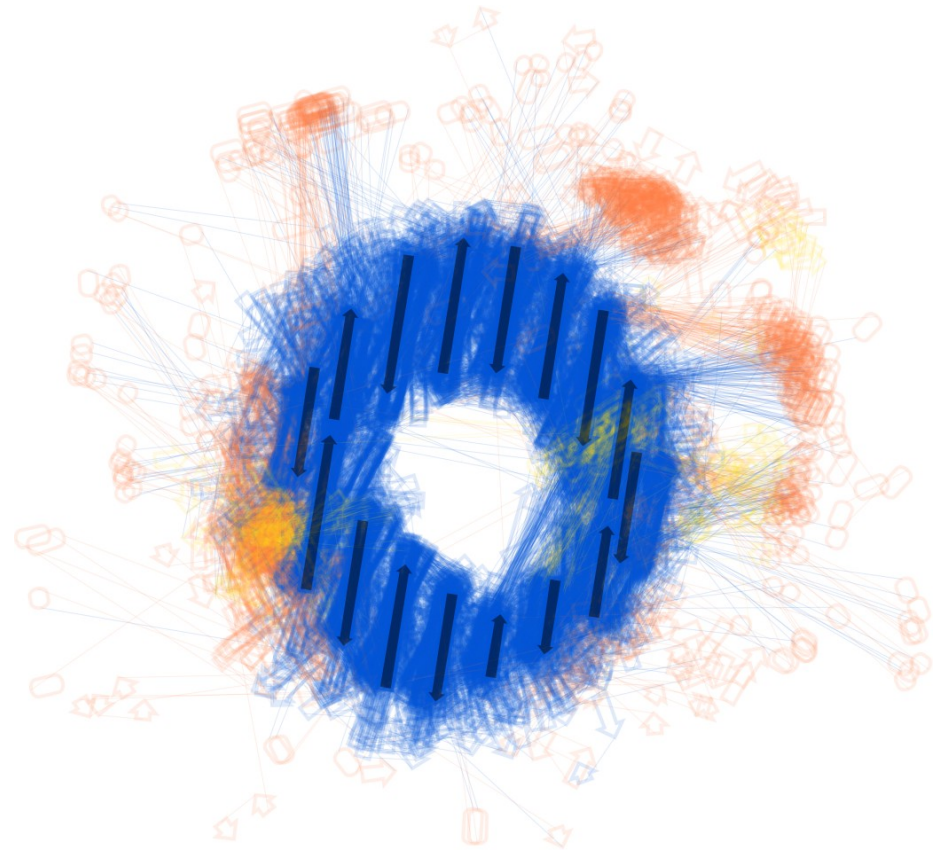
**Hemoglobine
PDB ID 1v4w**

2DProts: Coloring by structure properties

Example: Occurrence of secondary structures

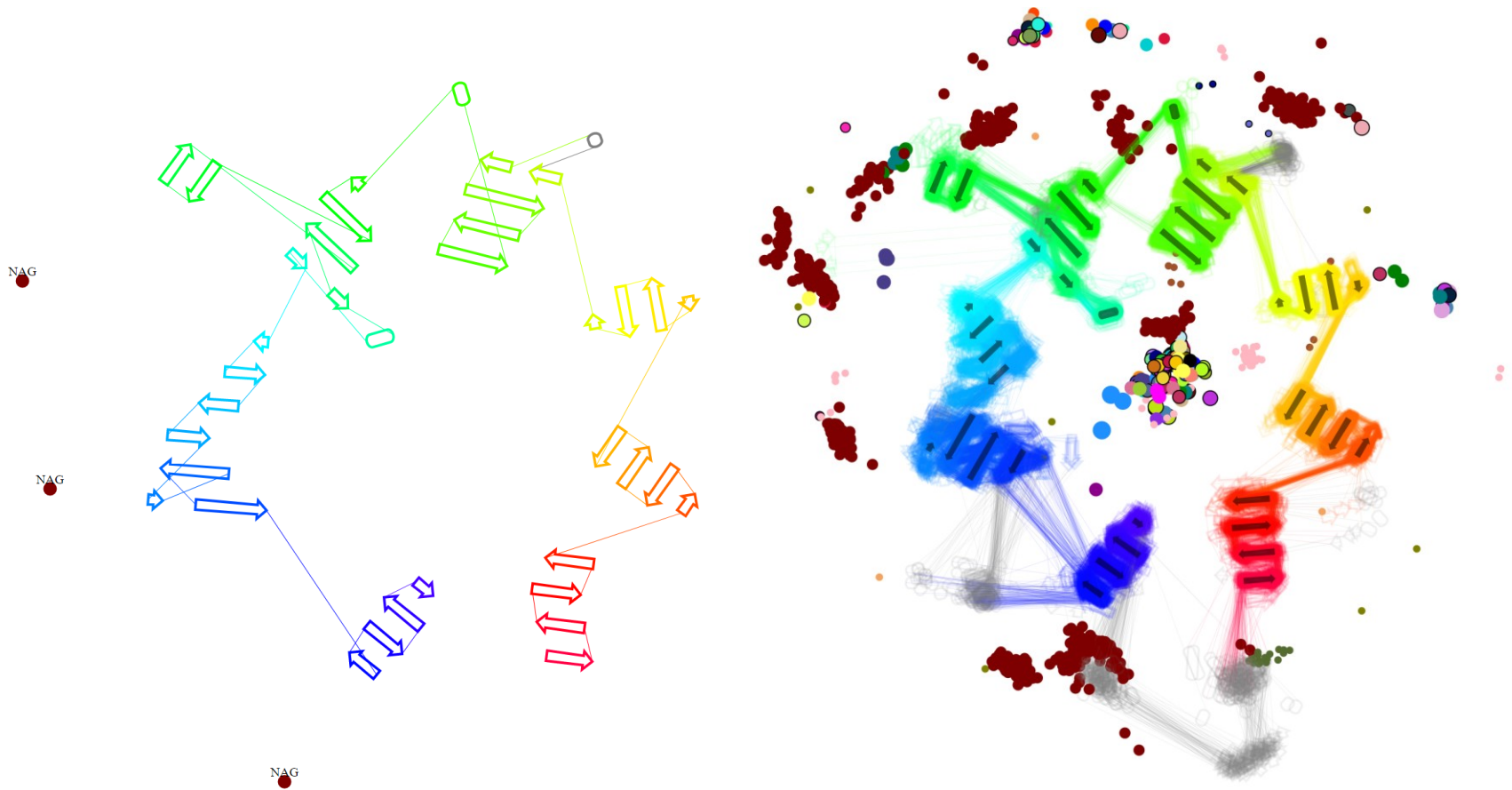


**Cytochrome reductase,
Family 2.140.10.30**



**Porin
Family 2.40.160.10**

2DProts: Integration of ligands

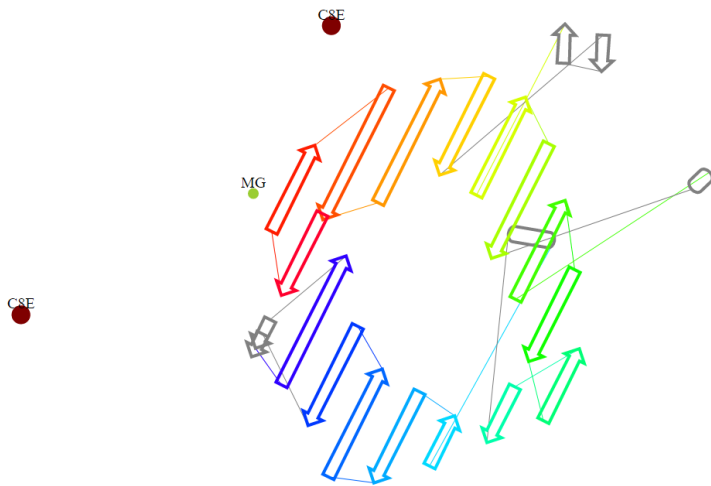


**PDB ID 2bgn,
domain A00**

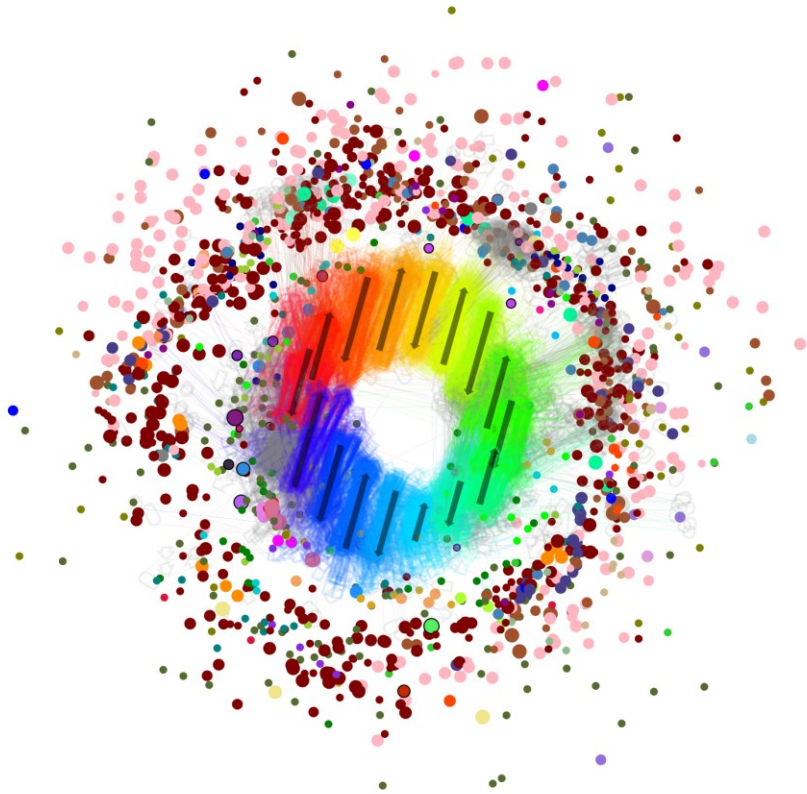
Cytochrome reductase, family 2.140.10.30

- | | | | | | | | |
|-------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| ●...NAG (742 pcs) | ●...SY1 (8 pcs) | ●...T22 (4 pcs) | ●...RUF (4 pcs) | ●...P2Y (4 pcs) | ●...0WG (4 pcs) | ●...10T (4 pcs) | ●...B2Q (2 pcs) |
| ●...SO4 (56 pcs) | ●...SC3 (8 pcs) | ●...6RL (4 pcs) | ●...B2Y (4 pcs) | ●...8O3 (4 pcs) | ●...0QG (4 pcs) | ●...008 (4 pcs) | ●...P54 (2 pcs) |
| ●...NA (20 pcs) | ●...6Z8 (8 pcs) | ●...8OL (4 pcs) | ●...7AC (4 pcs) | ●...BPR (4 pcs) | ●...AES (4 pcs) | ●...01T (4 pcs) | ●...677 (2 pcs) |
| ●...HG (10 pcs) | ●...XIH (5 pcs) | ●...8VU (4 pcs) | ●...LF7 (4 pcs) | ●...007 (4 pcs) | ●...13Z (4 pcs) | ●...LUI (4 pcs) | ●...277 (2 pcs) |
| ●...EDO (9 pcs) | ●...715 (4 pcs) | ●...RUM (4 pcs) | ●...PHI (4 pcs) | ●...PEG (4 pcs) | ●...9K4 (4 pcs) | ●...75L (2 pcs) | ●...D3C (2 pcs) |

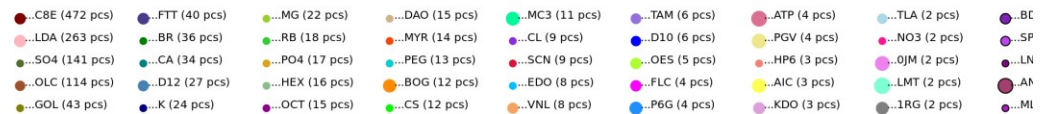
2DProts: Integration of ligands



OMPF Porin
PDB ID 2zfg,
domain A00



Porin, Family 2.40.160.10



2DProts integration to CATH

The screenshot shows the CATH Superfamily 1.10.60.10 page. The browser address bar shows the URL www.cathdb.info/version/latest/superfamily/1.10.60.10/superposition. The page title is "CATH Superfamily 1.10.60.10" with a description "Iron dependent repressor, metal binding and dimerisation domain". A "View in Gene3D" button is present. The navigation menu includes "Home", "Search", "Browse", "Download", "About", and "Support". A search bar is labeled "Search CATH by keywords or ID".

On the left sidebar, under "SUPERFAMILY LINKS", the "Superfamily Superposition" link is highlighted in blue. Other links include "Summary", "Classification / Domains", "Functional Families", and "Structural Neighbourhood".

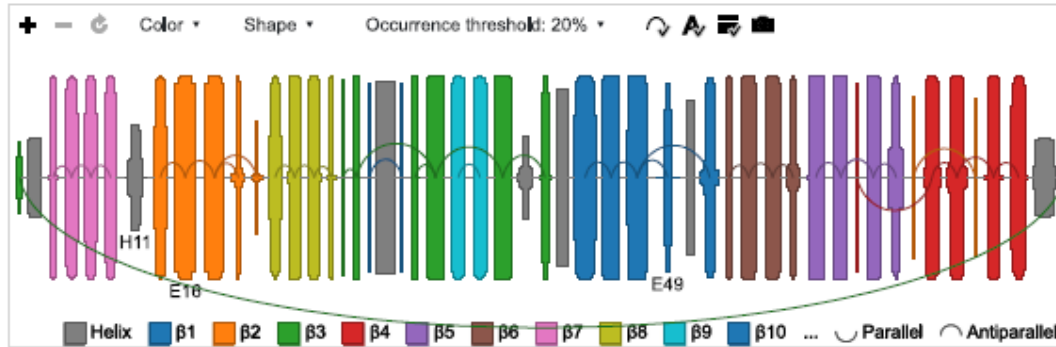
Under "Functional Families", there is an "Overview of the Structural Clusters (SC) and Functional Families within this CATH Superfamily. Clusters with a representative structure are represented by a filled circle." A diagram shows a red filled circle labeled "SC:1" connected to four functional families: "Diphtheria t Transcriptio", "Transcriptio", "Iron (Metal)", and "Manganese".

The main content area features a "SUPERFAMILY LINKS" section with icons for "SS", "Alignbow", and "2DProts". The "2DProts" icon is highlighted. Below this is a "Superfamily Superposition" section with a "Visit 2DProts (1.10.60.10)" button. The central image is a 3D superposition of protein structures, with a blue arrow pointing to a specific domain. A text box at the bottom explains: "These superposition figures provide an indication of the relative distance and position of secondary structure elements of structural domains within CATH superfamilies. Image are generated by the 2DProts database".

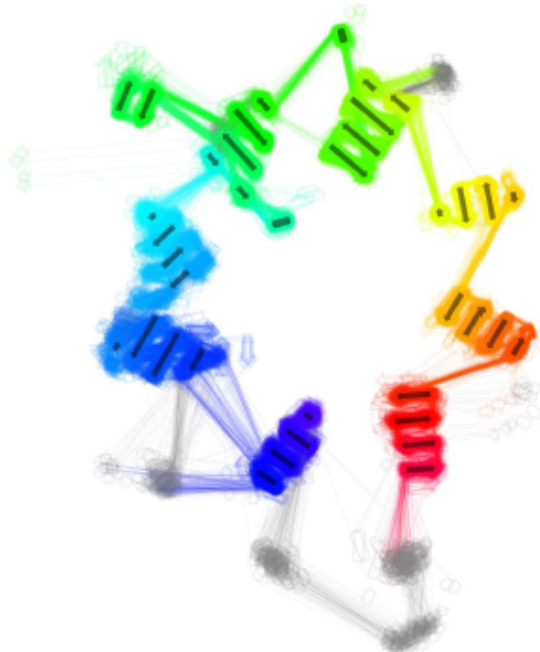
2DProts integration into OverProt

<https://overprot.ncbr.muni.cz>

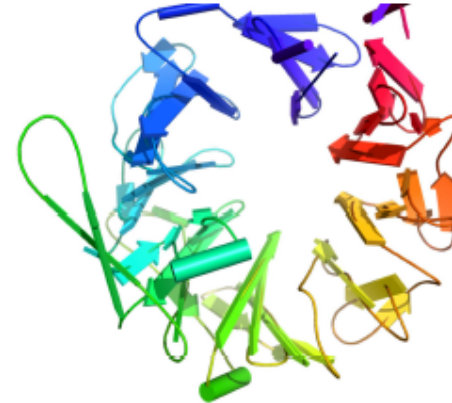
Family: 2.140.10.30 *Dipeptidylpeptidase IV, N-terminal domain*



2D view (2DProts)



3D view (MAPSCI + OverProt)



2DProts integration into OverProt

<https://overprot.ncbr.muni.cz>

Integrated Viewer

Current family (CATH): 2.160.10.30
Current domain: 3ogzA02

Protein family (CATH): 2.160.10.30
Protein domain: 3ogzA02

Submit

+ - ↺ Color ▾ Shape ▾ Beta-connectivity ▾ Occurrence threshold: 25% ▾ 📷

E2 H3 H4 H5 E7 E9 E10 E12 E13 H14 E15

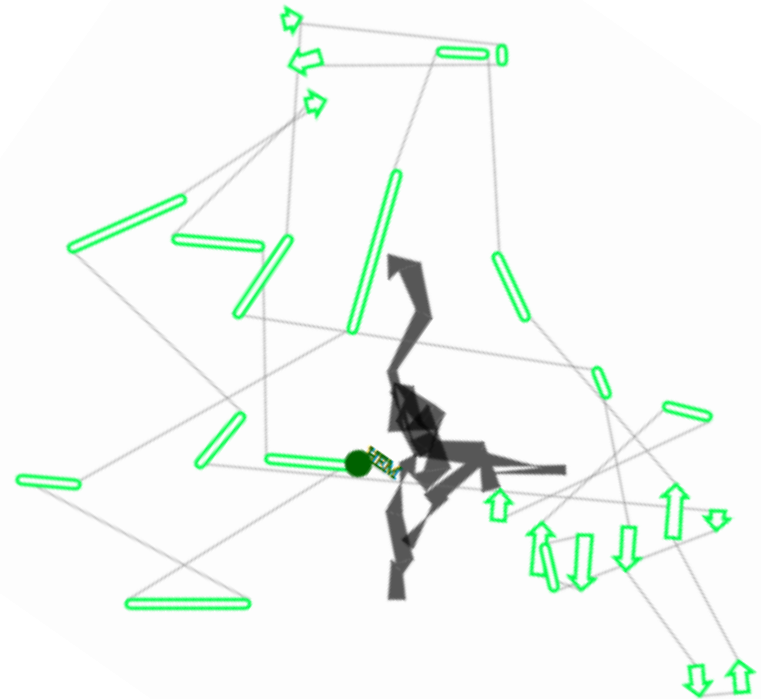
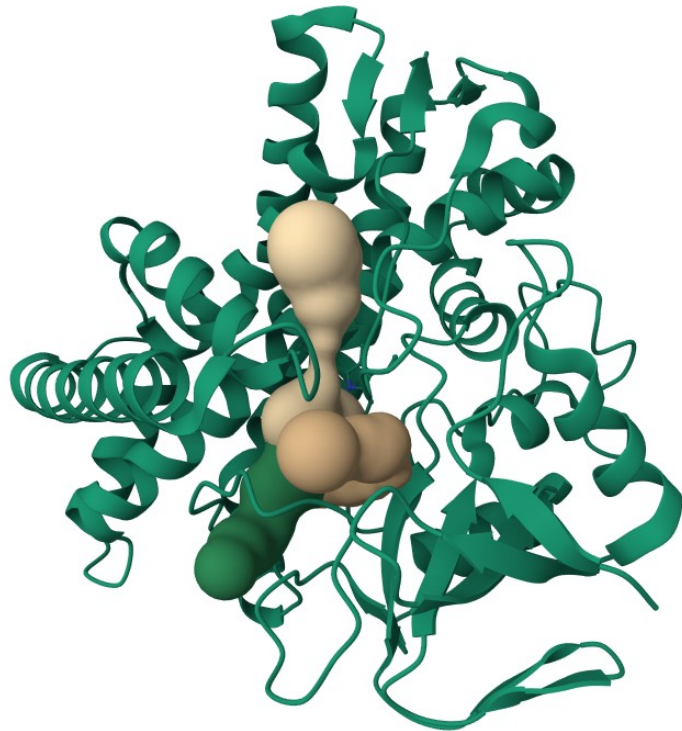
3ogz | Entity 1 | Chain A

Annotation ▾

UDP-sugar pyrophosphorylase
3OGZ | Model 1 | Instance_1_555 | A | VAL 575

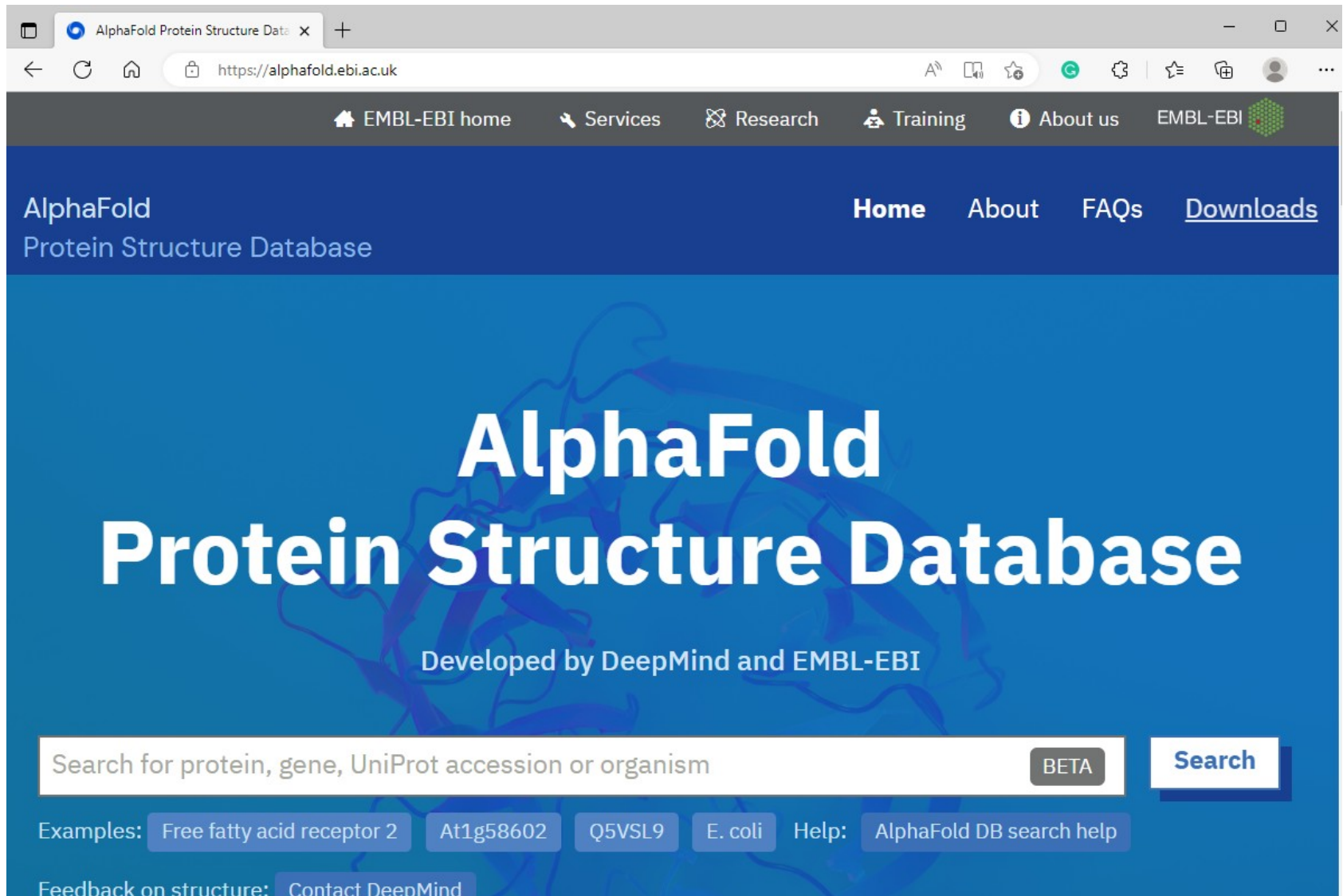
2DProts integration into MOLEonline

<https://moleonline.biodata.ceitec.cz/>



4mm0 P450-like monooxygenase

2DProts: Integration of AlphaFoldDB



AlphaFold Protein Structure Database

Home About FAQs Downloads

AlphaFold Protein Structure Database

Developed by DeepMind and EMBL-EBI

Search for protein, gene, UniProt accession or organism BETA Search

Examples: Free fatty acid receptor 2 At1g58602 Q5VSL9 E. coli Help: AlphaFold DB search help

Feedback on structure: Contact DeepMind

2DProts: Integration of AlphaFoldDB

AlphaFold Protein Structure Database

Home About FAQs Downloads

AlphaFold DB provides open access to over 200 million protein structure predictions to accelerate scientific research.

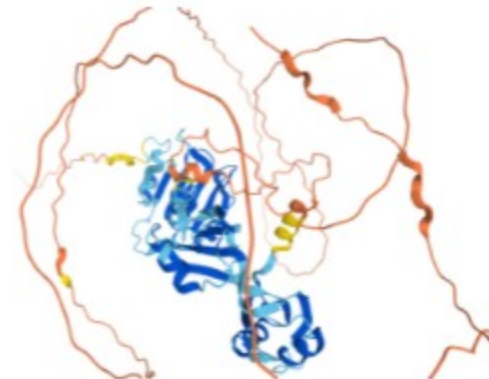
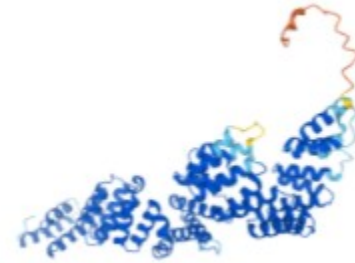
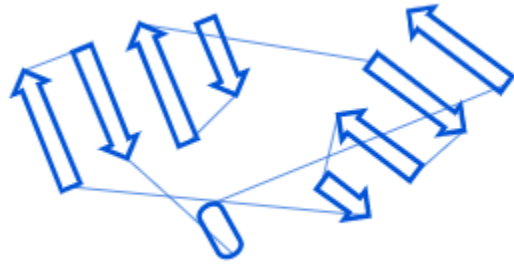
Developed by DeepMind and EMBL-EBI

Search for protein, gene, UniProt accession or organism BETA Search

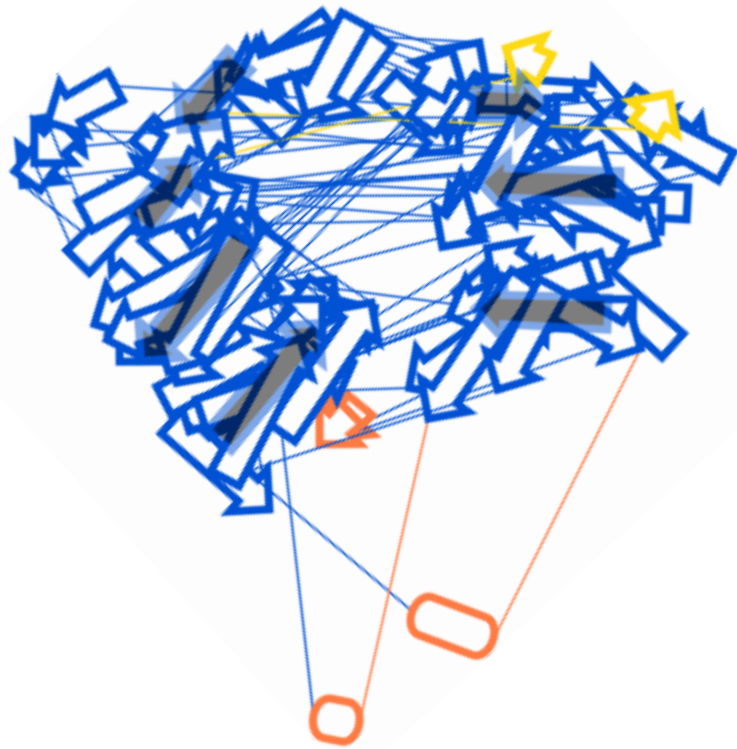
Examples: Free fatty acid receptor 2 At1g58602 Q5VSL9 E. coli Help: AlphaFold DB search help

Feedback on structure: Contact DeepMind

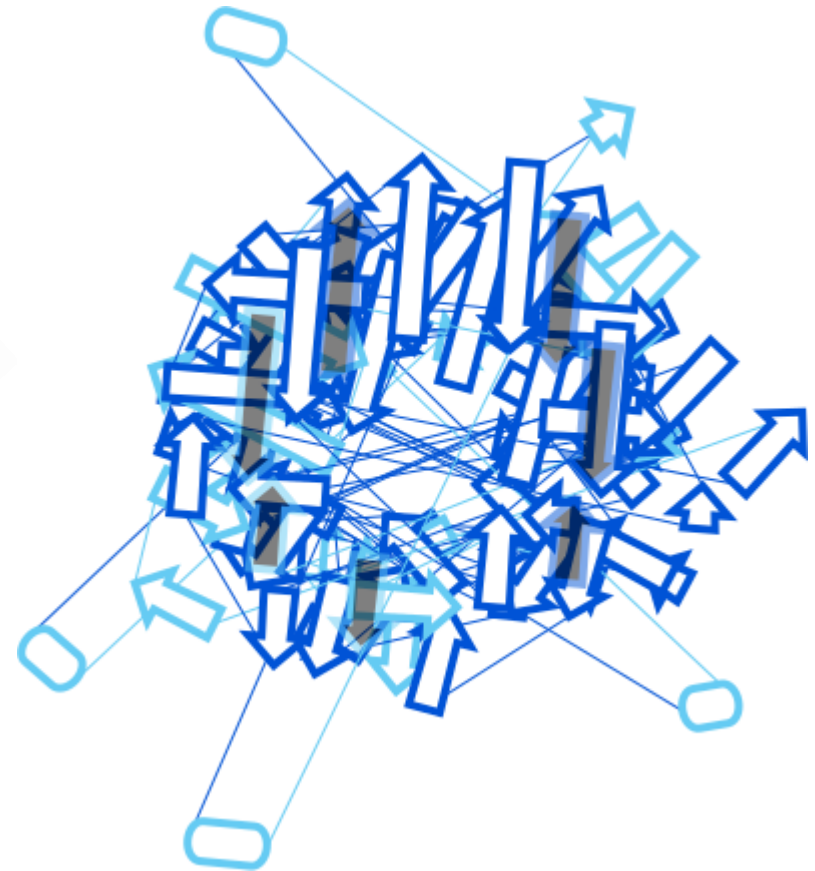
2DProts: Integration of AlphaFoldDB



2DProts: Integration of AlphaFoldDB



**Structures
from PDB**



**Structures from
AlphaFoldDB**

**E. coli PapC protein, C-terminal domain
Family 2.60.40.2070**

Publications

Sillitoe I, ..., Berka K, Hutařová Vařeková I, Svobodová R., et al. (2021). *CATH: increased structural coverage of functional space*. **Nucleic Acids Research**, 49(D1), D266-D273.

Hutařová Vařeková, I., Hutař, J., Midlik, A., Horský, V., Hladká, E., Svobodová, R., & Berka, K. (2021). *2DProts: database of family-wide protein secondary structure diagrams*. **Bioinformatics**, 37(23), 4599-4601.

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