

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

Stephen K. Burley, M.D., D.Phil.

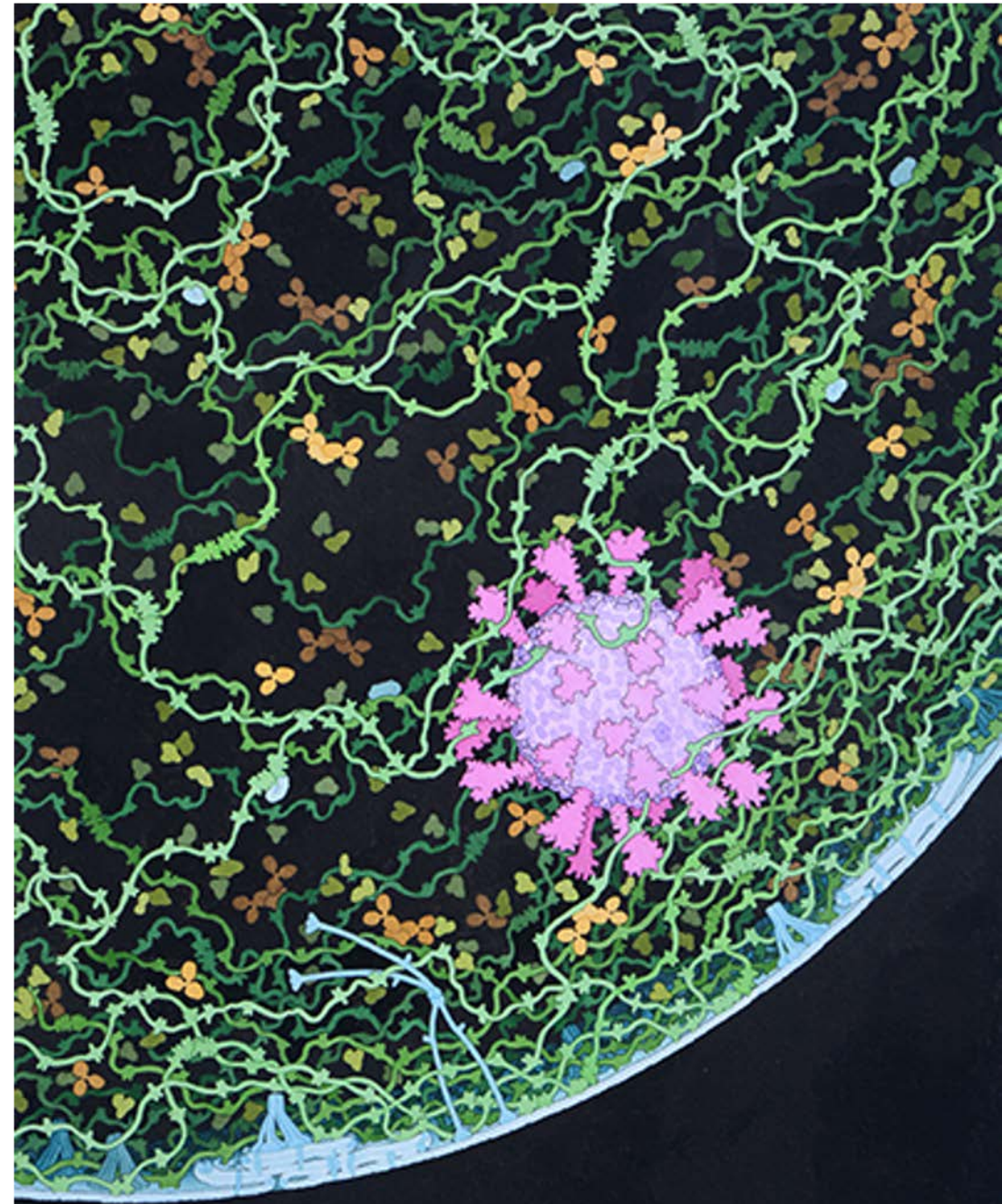
Director, RCSB Protein Data Bank, Rutgers University, NJ

Paul Craig, Ph.D.

Rochester Institute of Technology, NY

Shuchismita Dutta, Ph.D.

RCSB Protein Data Bank, Rutgers University, NJ

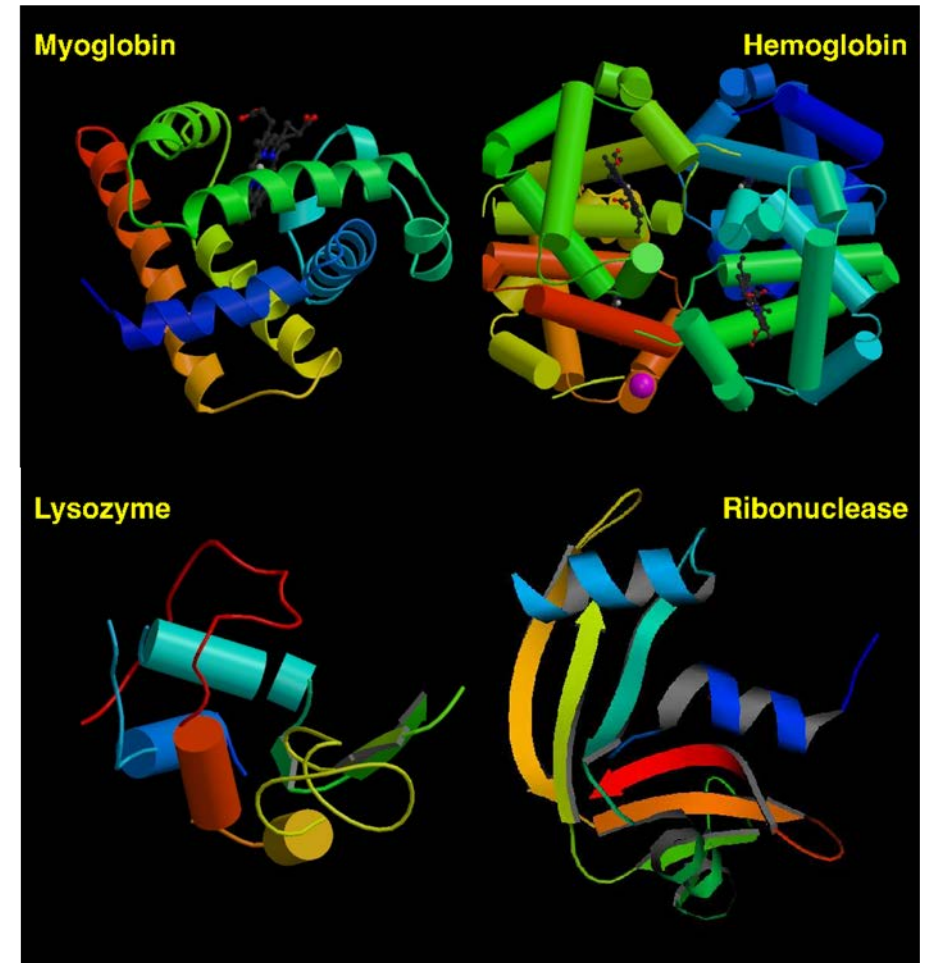


Today's Agenda

- Introduction to the Protein Data Bank and SARS-CoV-2
 - Stephen K. Burley, M.D., D.Phil. - Director, RCSB Protein Data Bank
- Exploring the SARS-CoV-2 Main Protease structure using RCSB.org
 - Paul Craig, Ph.D. - Rochester Institute of Technology
- Making connections using [RCSB.org](https://www.rcsb.org)
 - Shuchismita Dutta, Ph.D. - RCSB Protein Data Bank
- Discussions

Protein Data Bank (Established 1971)

- PDB 1st online Open Access digital data resource in all of biology
- Founded 1971 with 7 protein structures
- Single global **archive** for protein and DNA/RNA experimental structures
- **Open Access to >222,000 structures!**
- wwPDB Partnership founded in 2003
- Members: RCSB PDB (US), PDBe (EMBL-EBI), PDBj (Japan), and PDBc (China); plus EMDB (3DEM) and BMRB (NMR)



Structures that Inspired Launch of the PDB

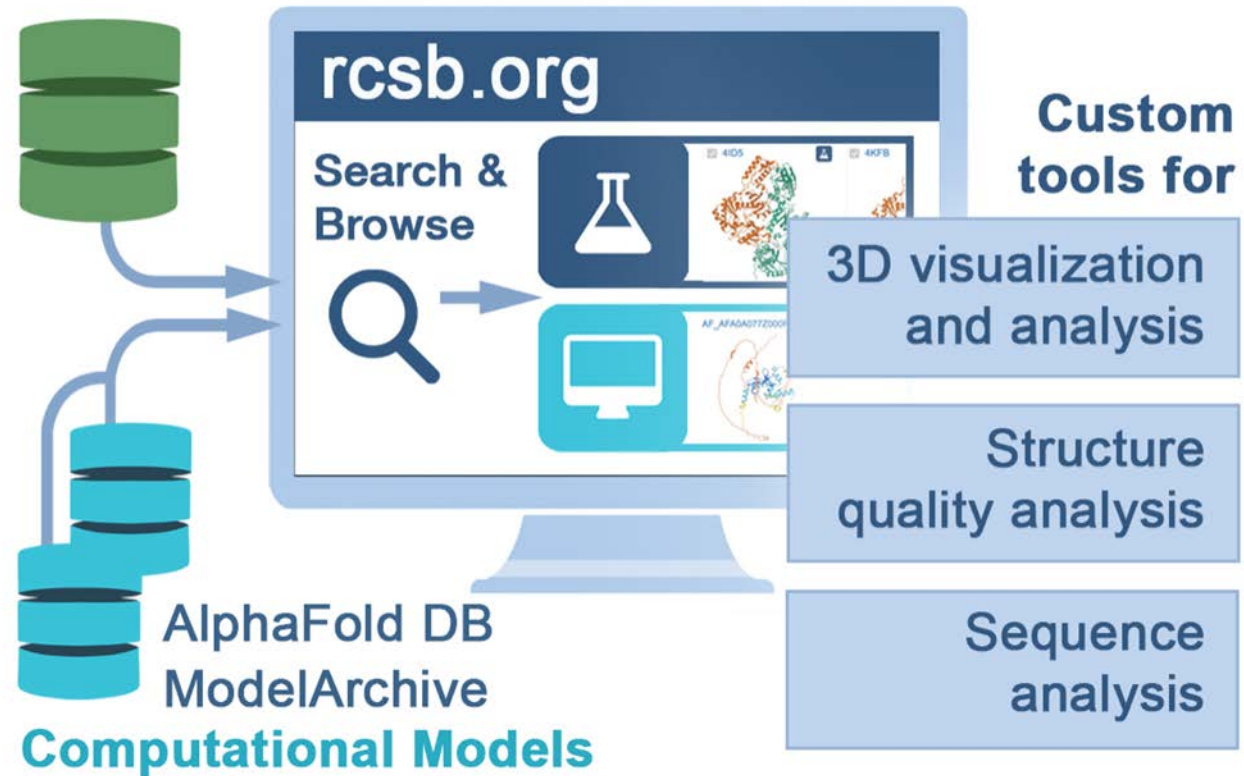
Protein Data Bank (1971) *Nature New Biology* 233, 223.

Worldwide Protein Data Bank (2019) *Nucleic Acids Research* 47, D520–D528.

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

- RCSB.org delivers
 - >222,000 PDB structures
 - >1 million Computed Structure Models (CSMs) from AlphaFold DB and the ModelArchive
- RCSB.org data exploration and visualization tools used by many millions of researchers, educators, and students worldwide
- Provenance/reliability of both data types are clearly identified

Experimental Models
Protein Data Bank



RCSB.org Opt In for Computed Structure Models

RCSB PDB

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COVID-19

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RCSB PDB

PROTEIN DATA BANK

222,036

Structures from the PDB

1,068,577

Computed Structure Models (CSM)

3D Structures ?

Enter search term(s), Entry ID(s), or sequence

Include CSM ? ☐

Q

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Help

PDB-101

PDB

EMDataResource

NAKB

wwPDB Foundation

PDB-Dev

f t y d in

Access Computed Structure Models (CSMs) of available model organisms

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Welcome

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RCSB Protein Data Bank (RCSB PDB) enables breakthroughs in science and education by providing access and tools for exploration, visualization, and analysis of:

Experimentally-determined 3D structures from the **Protein Data Bank (PDB)** archive

Computed Structure Models (CSM)

from AlphaFold DB and ModelArchive

These data can be explored in context of external annotations providing a structural view of biology.

Explore NEW Features

PDB

PROTEIN DATA BANK

NEW!

PDB-101

PDB-101 Training Resources

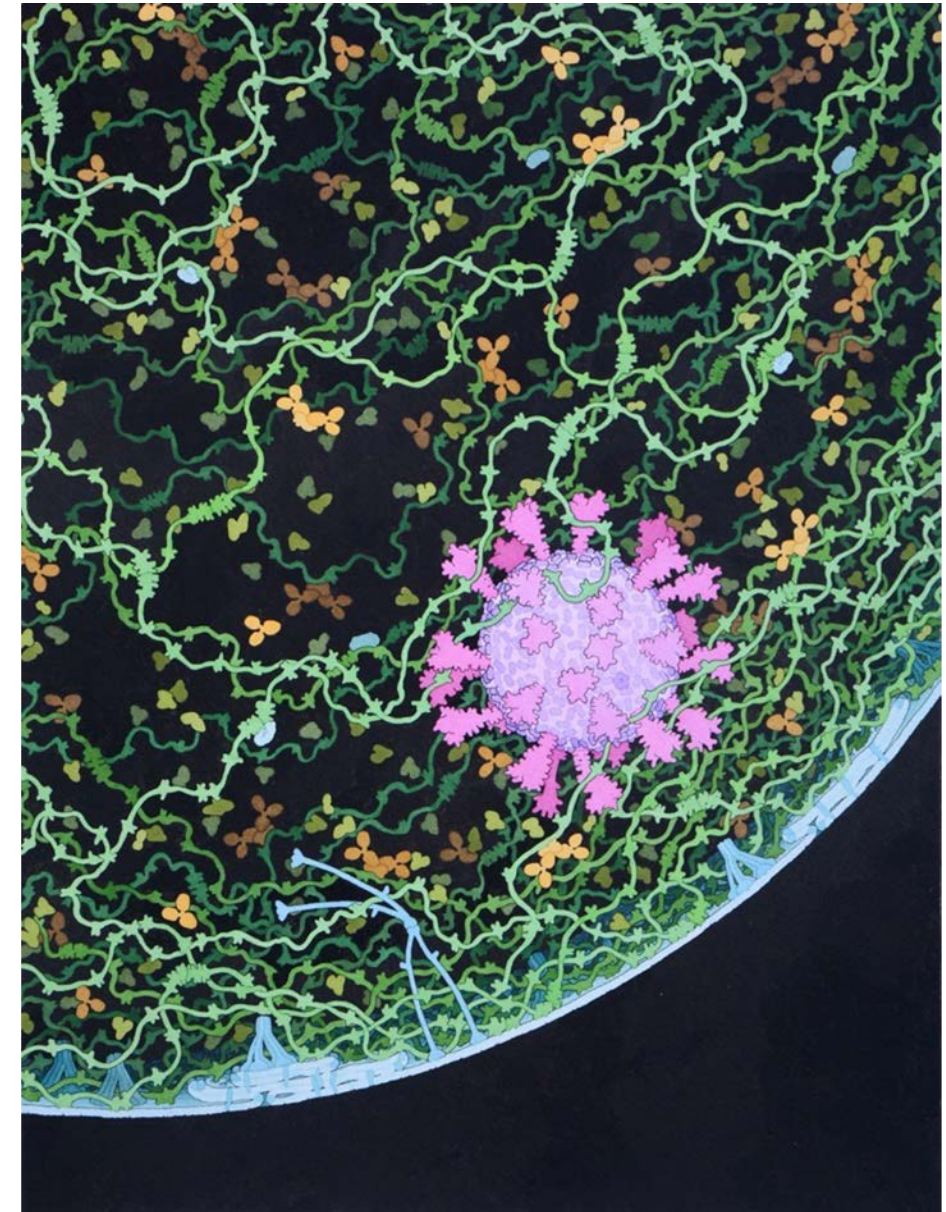
July Molecule of the Month



Ribosome Diversity

PDB Essential for Responding to Emerging Viruses

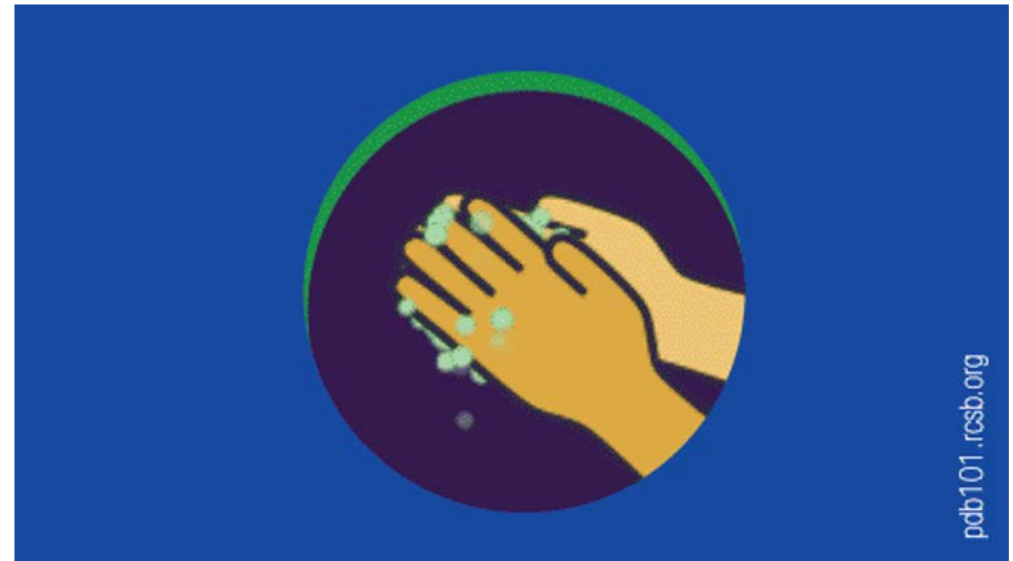
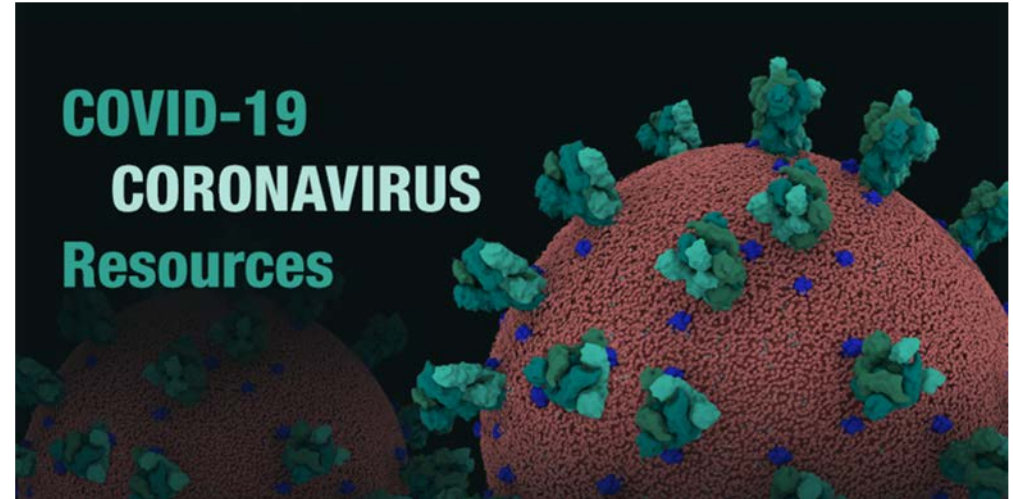
- SARS-CoV Epidemic 2002
>240 SARS-CoV structures in the PDB
- MERS-CoV Epidemic 2012
>170 MERS-CoV structures in the PDB
- COVID-19 Pandemic 2019
>4,300 SARS-CoV-2 structures in the PDB
- Effective mRNA vaccines designed and antiviral agents discovered/developed using PDB structures of SARS-CoV, MERS-CoV, and SARS-CoV-2 proteins



Respiratory Droplet, 2020; David S. Goodsell

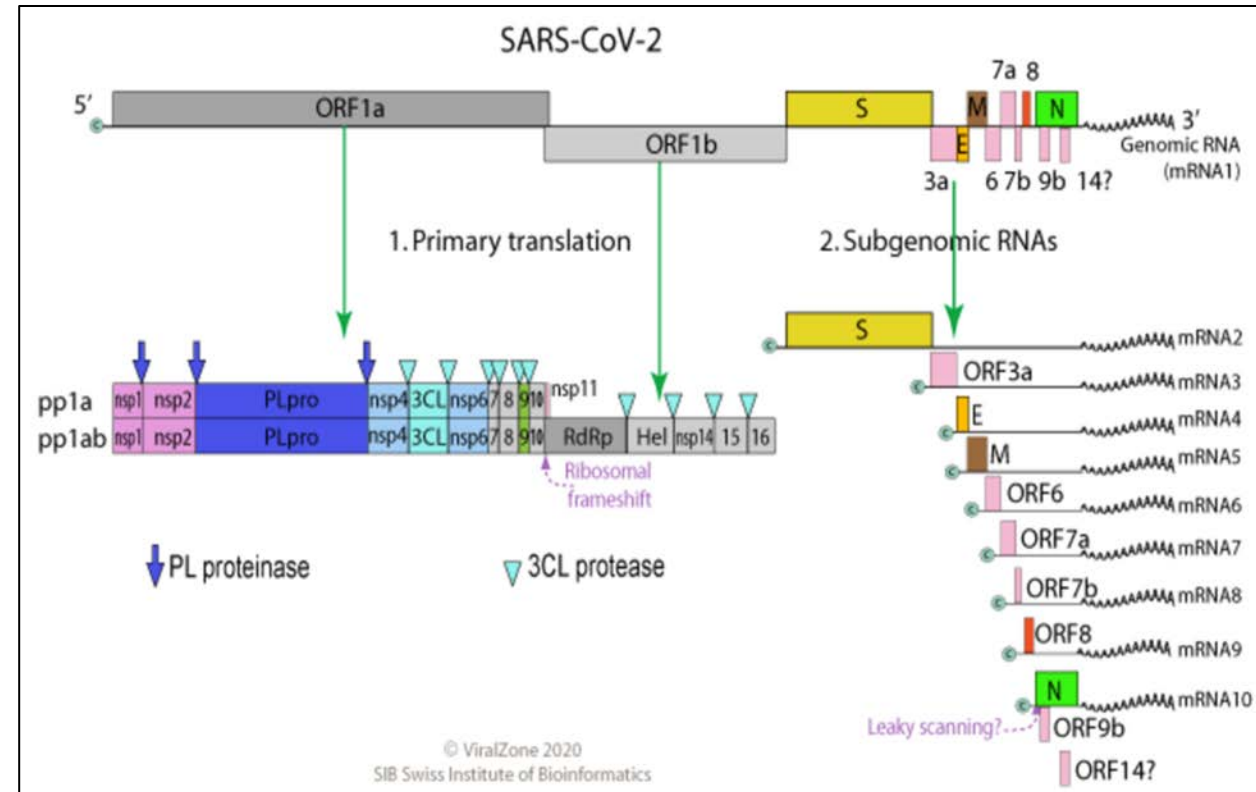
RCSB PDB Response to COVID-19

- Biocuration of COVID-19 structures prioritized, including post-release revisions (e.g., citation updates)
- PDB depositors strongly encouraged to release COVID-19 structures immediately
- Consistent taxonomy name/ID
 - Severe acute respiratory syndrome coronavirus 2; 2697049
- Consistent UniProt referencing
 - P0DTD1, P0DTC1, P0DTC2, P0DTC9
- Released structures and educational resources updated at <https://RCSB.org/covid19>



Coronavirus (SARS-CoV-2) Genome Organization

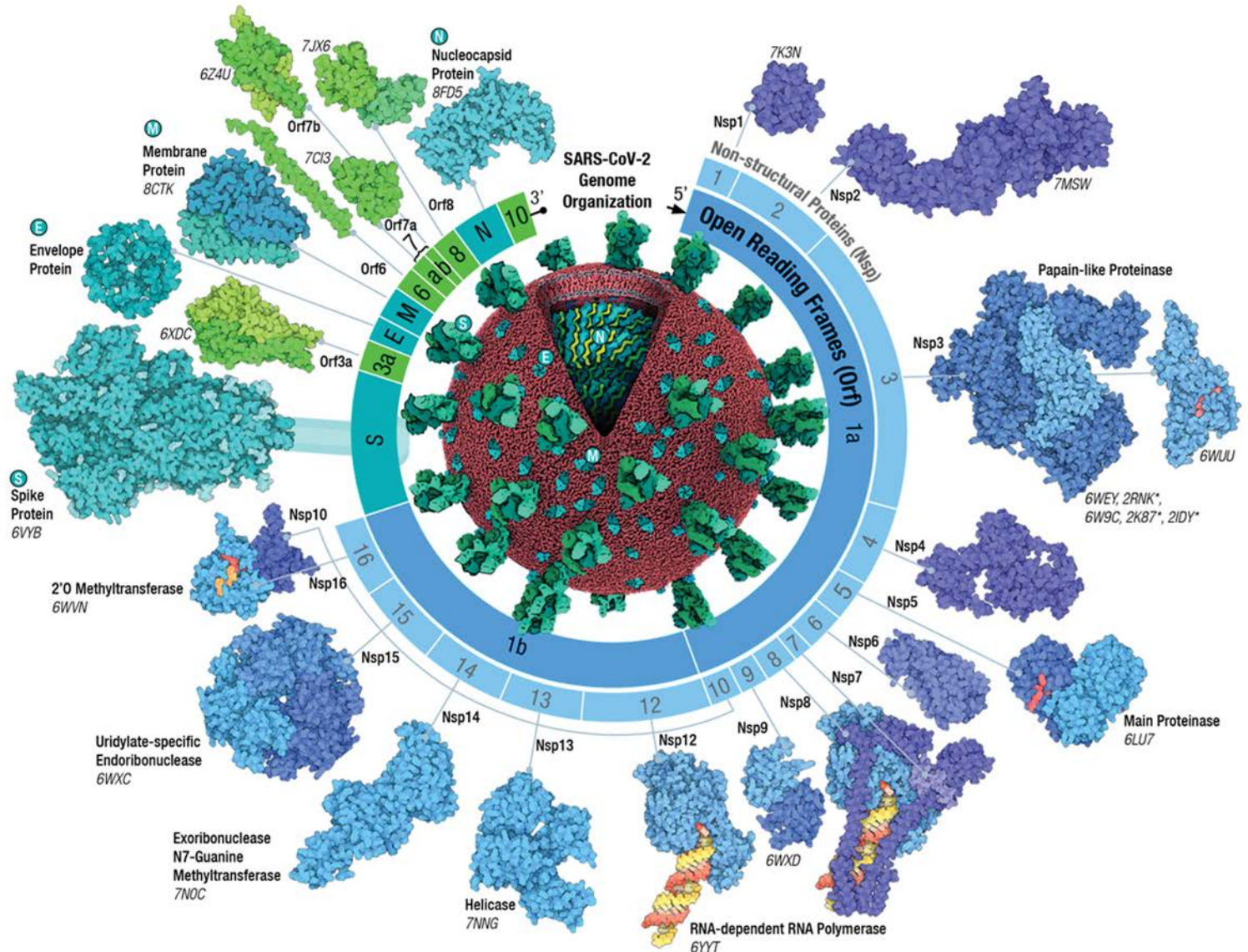
- Viral genome is a single-stranded, +ve-sense, 5'-capped, 3' polyadenylated messenger RNA
- Non-structural proteins expressed as polyproteins requiring enzymatic cleavage by
 1. Main Protease (Mpro) and
 2. Papain-Like Proteinase (PLpro)



Near Complete SARS-CoV-2 Parts List in 3D

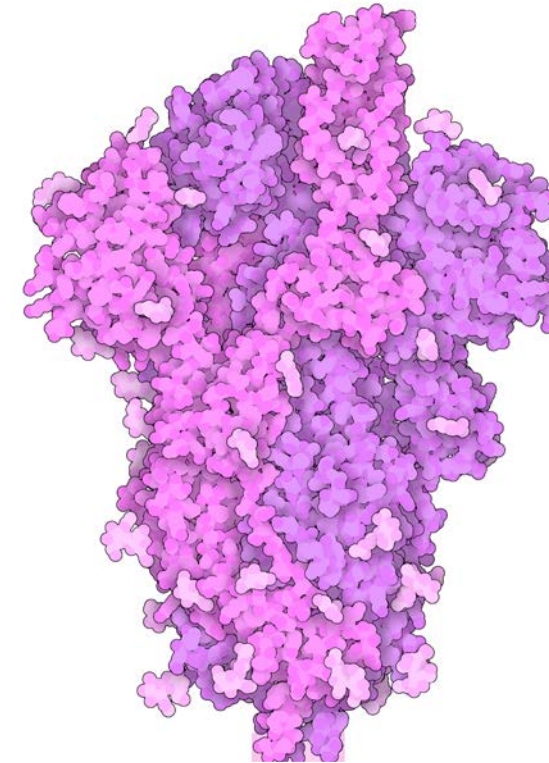


SARS-CoV-2 Fusion, 2020;
David S. Goodsell



Structure-Based Vaccine Design: Spike Protein

- Spike Protein
 - ~1,800 3DEM/Crystal structures
 - All Down and 1 Up/2 Down Trimers
 - Post-fusion Trimers
 - Complexes with ACE2, Fabs, etc.
- mRNA vaccine design relied on PDB structures of SARS-CoV and MERS-CoV spike proteins
- >5 billion vaccinated worldwide!
- Tens of millions of lives were saved!
- Hundreds of millions spared serious illness, hospitalization, etc!



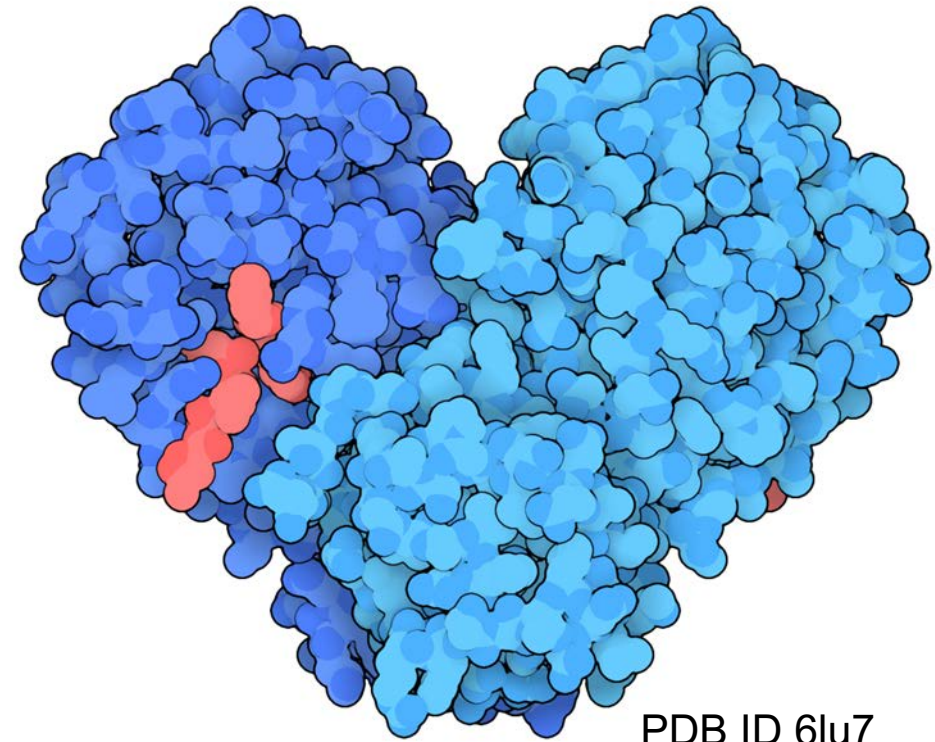
PDB ID 6vsb

Vaccine Discovery and Antibody Discovery Target

Wrapp *et al.* (2020) *Science* 367, 1260-1263.

Main Protease: Achilles Heel of SARS-CoV-2

- Nsp5/Main Protease (Mpro)
 - >1,450 Apo/Co-crystal structures
 - Target of Pfizer's nirmatrelvir (+ritonavir=Paxlovid)
- Paxlovid is approved for outpatient treatment of individuals infected with SARS-CoV-2

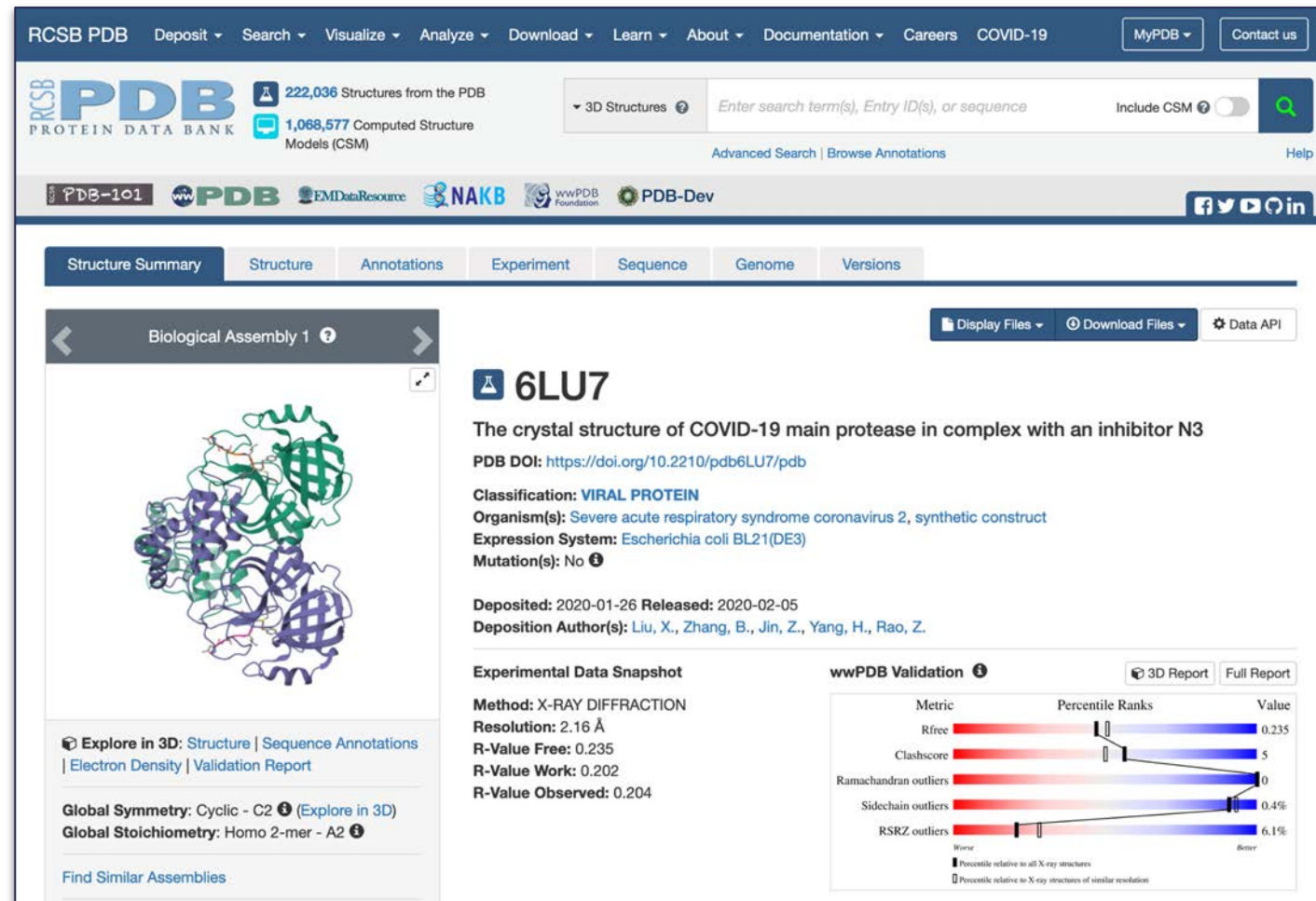


Drug Discovery Target
Symmetric Homodimer; Two Active Sites

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The Structure of COVID-19 Main Protease



<https://www.rcsb.org/structure/6lu7>

To follow along in this section, go to [Exploring the SARS-CoV-2 Main Protease](#)

SSP: Experiment, Validation, and Literature

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

6LU7


The crystal structure of COVID-19 main protease in complex with an inhibitor N3

PDB DOI: <https://doi.org/10.2210/pdb6LU7/pdb>

Classification: **VIRAL PROTEIN**

Organism(s): Severe acute respiratory syndrome coronavirus 2, synthetic construct

Expression System: Escherichia coli BL21(DE3)

Mutation(s): No 

Deposited: 2020-01-26 Released: 2020-02-05

Deposition Author(s): [Liu, X.](#), [Zhang, B.](#), [Jin, Z.](#), [Yang, H.](#), [Rao, Z.](#)

Experimental Data Snapshot

Method: X-RAY DIFFRACTION

Resolution: 2.16 Å

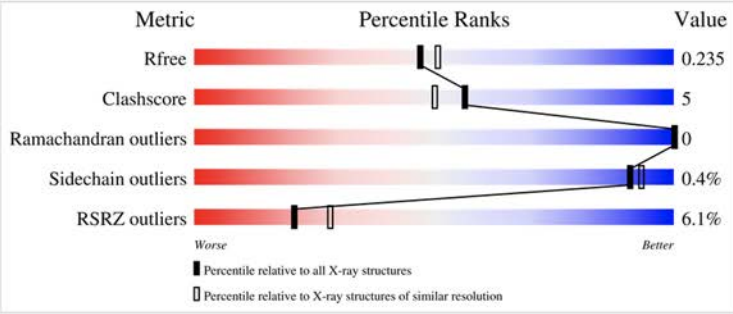
R-Value Free: 0.235

R-Value Work: 0.202


R-Value Observed: 0.204


wwPDB Validation


[3D Report](#) [Full Report](#)



Metric	Percentile Ranks	Value
Rfree		0.235
Clashscore		5
Ramachandran outliers		0
Sidechain outliers		0.4%
RSRZ outliers		6.1%

Worse  Better

 Percentile relative to all X-ray structures

 Percentile relative to X-ray structures of similar resolution

Literature [Download Primary Citation](#)

Structure of Mpro from SARS-CoV-2 and discovery of its inhibitors.

[Jin, Z.](#), [Du, X.](#), [Xu, Y.](#), [Deng, Y.](#), [Liu, M.](#), [Zhao, Y.](#), [Zhang, B.](#), [Li, X.](#), [Zhang, L.](#), [Peng, C.](#), [Duan, Y.](#), [Yu, J.](#), [Wang, L.](#), [Yang, K.](#), [Liu, F.](#), [Jiang, R.](#), [Yang, X.](#), [You, T.](#), [Liu, X.](#), [Yang, X.](#), [Bai, F.](#), [Liu, H.](#), [Liu, X.](#), [Guddat, L.W.](#), [Xu, W.](#), [Xiao, G.](#), [Qin, C.](#), [Shi, Z.](#), [Jiang, H.](#), [Rao, Z.](#), [Yang, H.](#)

(2020) Nature **582**: 289-293

PubMed: [32272481](#) [Search on PubMed](#) [Search on PubMed Central](#)

DOI: <https://doi.org/10.1038/s41586-020-2223-y>

Primary Citation of Related Structures:
[6LU7](#), [7BQY](#)

PubMed Abstract:

A new coronavirus, known as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), is the aetiological agent responsible for the 2019-2020 viral pneumonia outbreak of coronavirus disease 2019 (COVID-19) ¹⁻⁴. Currently, there are no targeted therapeutic agents for the treatment of this disease, and effective treatment...

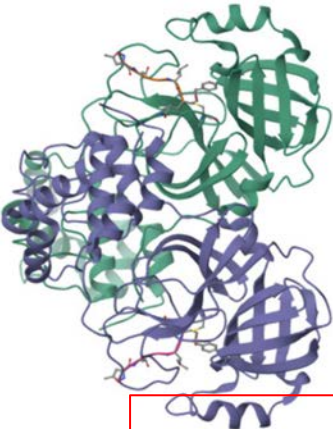
[View More](#)

Organizational Affiliation:

Shanghai Institute for Advanced Immunochemical Studies and School of Life Science and Technology, ShanghaiTech University, Shanghai, China.

SSP and Structure: Visualize and Explore

Biological Assembly 1 ?



Explore in 3D: **Structure** | [Sequence Annotations](#) | [Electron Density](#) | [Validation Report](#)

Global Symmetry: Cyclic - C2 ⓘ ([Explore in 3D](#))
Global Stoichiometry: Homo 2-mer - A2 ⓘ

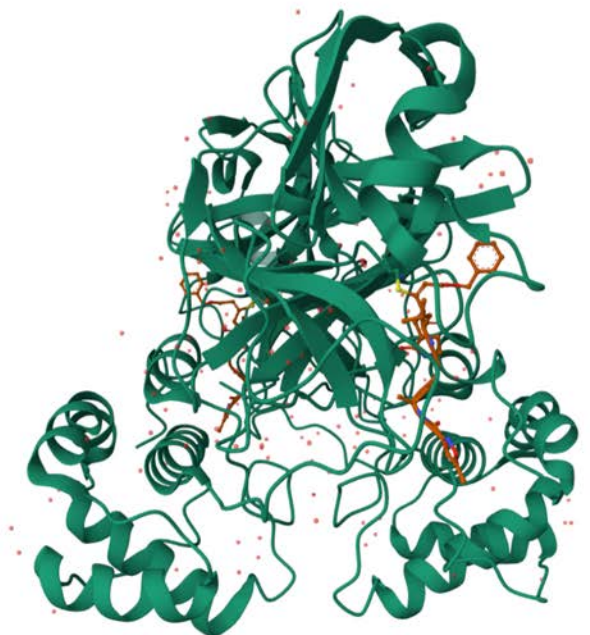
[Find Similar Assemblies](#)

Biological assembly 1 assigned by authors and generated by PISA (software)

Biological Assembly Evidence: gel filtration

Sequence of 6LU7 | The cr... Chain 1: 3C-like pro... A ASM_1

1 11 21 31 41 51 61 71 81 91 101 111
SGFRKMAFP SGKVEGCMVQVTCGTTTLNGLWLDVVYCPRHVICTSEDMLNPNYEDLLIRKSNHNFVQAGNVQLRVIGHSMQNCVLKLVDTANPKTPKYKFVRIQPGQTFSV
121 131 141 151 161 171 181 191 201 211 221
LACYNGSPSGVYQCAMPNFTIKGSFLNGSCGSGVGFNIIDYDCVSFCYMHMELPTGVHAGTDLEGNFYGPFDVDRQTAQAAGTDTTITVNVLAWLAAVINGDRWFLNRETTTLN
231 241 251 261 271 281 291 301
DFNLVAMKYNYEPLTQDHVDILGPLSAQTGIAVLDMCASLKELLQNGMNGRTILGSALLEDEFTPFDDVVRQCSGVTFQ



Structure

6LU7 | The crystal structure of COV...

Type	Assembly
Asm Id	1: Author And Softwar...

Dynamic Bonds × Off

Nothing Focused

Measurements

Structure Motif Search

Components 6LU7

Preset	+ Add	⌵	⌵
Polymer	Cartoon	⌵	⌵
Ligand	Ball & Stick	⌵	⌵
Water	Ball & Stick	⌵	⌵

Unit Cell C 1 2 1

Density

Quality Assessment

Assembly Symmetry

Export Models

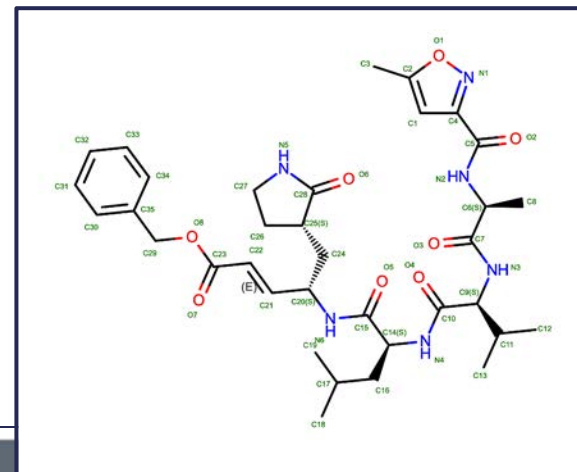
Export Animation

Export Geometry

15

Structure: Interactions

[2D diagram](#)



Biologically Interesting Molecules (External Reference) **1 Unique**

Entity ID: 2

ID	Chains ⓘ	Name	Type/Class	2D Diagram	3D Interactions
PRD_002214 Query on PRD_002214	B [auth C]	N-[(5-METHYLISOXAZOL-3-YL)CARBONYL]ALANYL-L-VALYL-N-1-~-(1R,2Z)-4-(BENZYLOXY)-4-OXO-1-[(3R)-2-OXOPYRROLIDIN-3-YL]METHYL]BUT-2-ENYL)-L-LEUCINAMIDE	Peptide-like / Inhibit or		<div>Interactions ▾</div> <div>Interactions & Density ▾</div>

PRD_002214

N-[(5-METHYLISOXAZOL-3-YL)CARBONYL]ALANYL-L-VALYL-N-1-~-(1R,2Z)-4-(BENZYLOXY)-4-OXO-1-[(3R)-2-OXOPYRROLIDIN-3-YL]METHYL]BUT-2-ENYL)-L-LEUCINAMIDE

PRD_002214 is described in the Biologically Interesting Molecule Reference Dictionary (BIRD).

The representative PDB ID is 5EUK.

Find entries where PRD_002214 is present

Chemical Component Summary

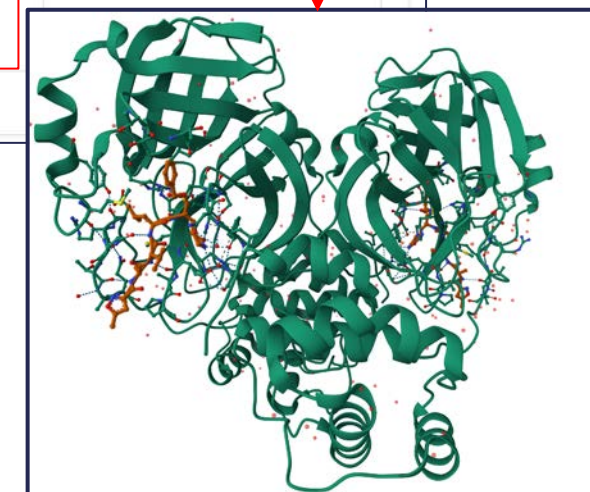
Name	N-[(5-METHYLISOXAZOL-3-YL)CARBONYL]ALANYL-L-VALYL-N-1-~-(1R,2Z)-4-(BENZYLOXY)-4-OXO-1-[(3R)-2-OXOPYRROLIDIN-3-YL]METHYL]BUT-2-ENYL)-L-LEUCINAMIDE
Identifiers	[phenylmethyl] (4-[(S)]-4-[(2-[(S)]-4-methyl-2-[(S)]-3-methyl-2-[(2-[(S)]-2-[(5-methyl-1,2-oxazol-3-ylcarbonyl)amino]propanoyl)amino]butanoyl)amino]pentan-5-ylamino]-5-[(3-[(S)]-2-oxo-1,4-dihydropyridin-3-yl)pent-2-en-2-yl]amino
Formula	C ₅₂ H ₆₂ N ₆ O ₉

Chemical Details

Formal Charge	0
Atom Count	97
Chiral Atom Count	5
Bond Count	99
Aromatic Bond Count	11

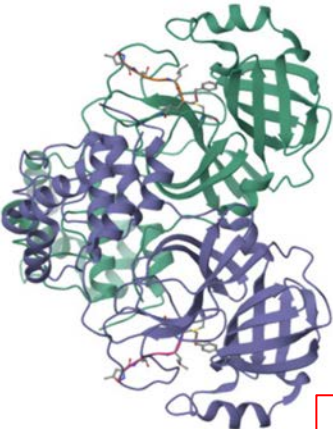
[Biologically Interesting Reference Dictionary Summary Page](#)

[Ligand Interaction](#)



SSP: Symmetry, Similar Assemblies and more

Biological Assembly 1 ?



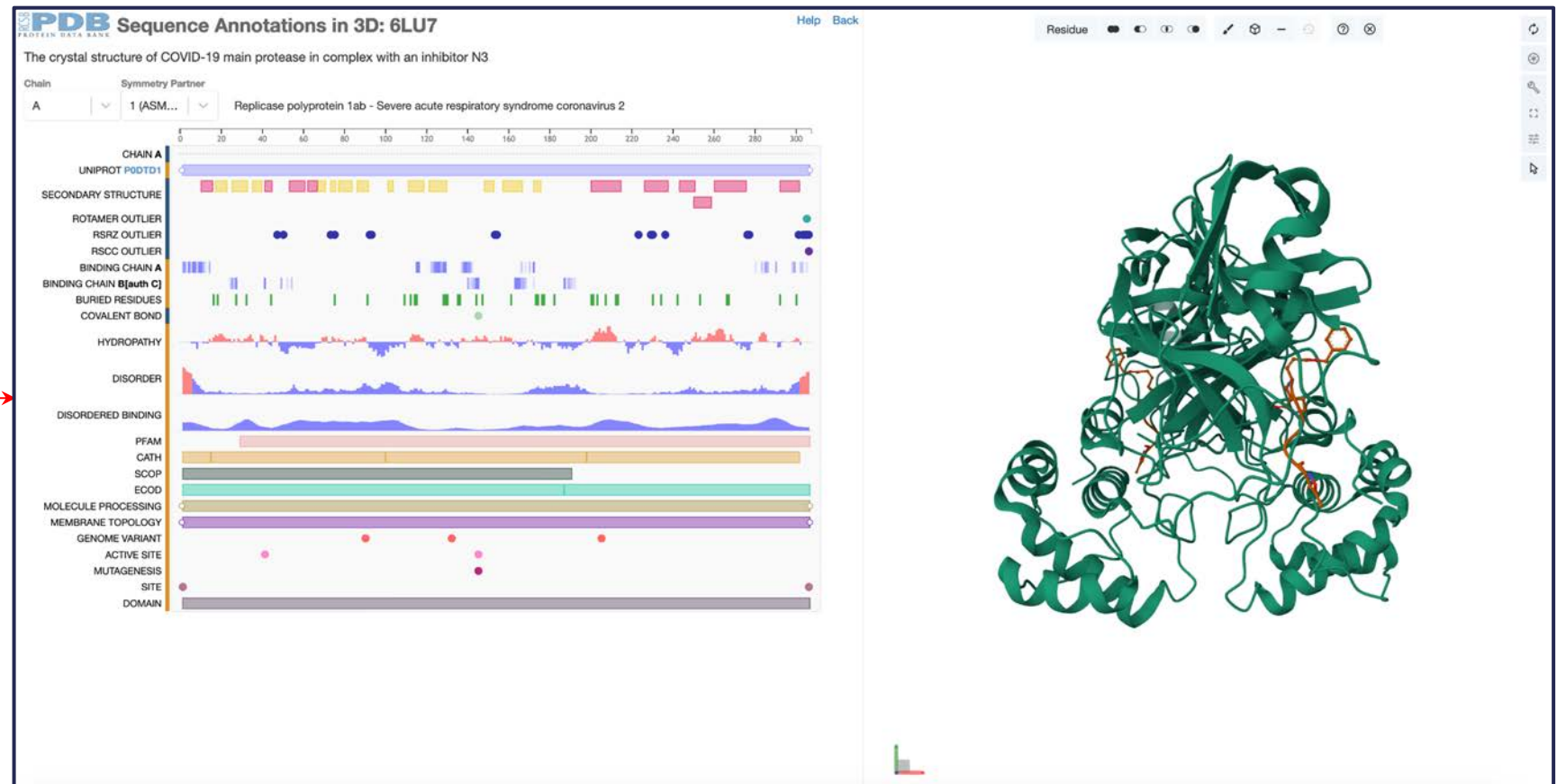
Explore in 3D: [Structure](#) | [Sequence Annotations](#)
| [Electron Density](#) | [Validation Report](#)

Global Symmetry: Cyclic - C2 ⓘ ([Explore in 3D](#))
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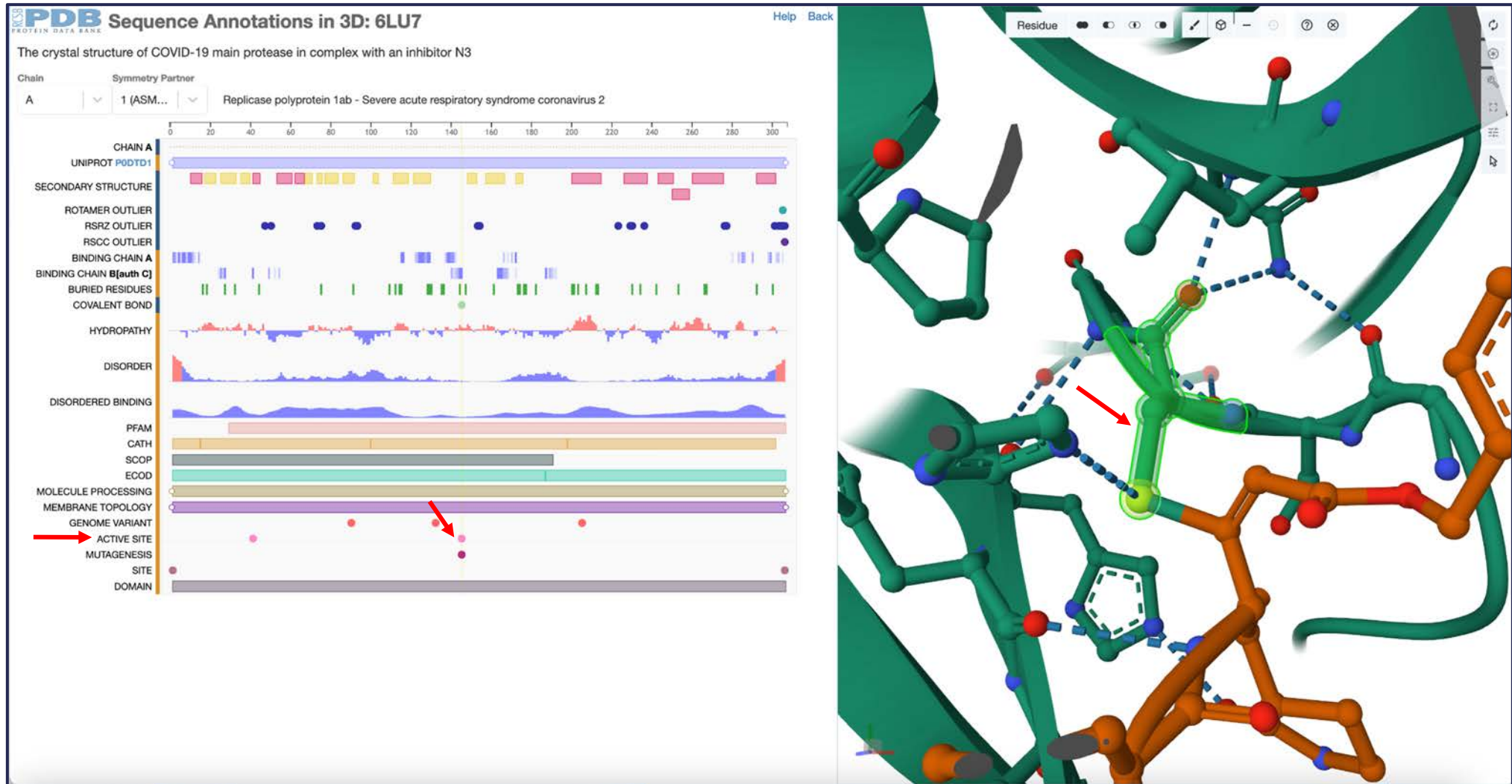
[Find Similar Assemblies](#)

Biological assembly 1 assigned by authors and generated by PISA (software)

Biological Assembly Evidence: gel filtration

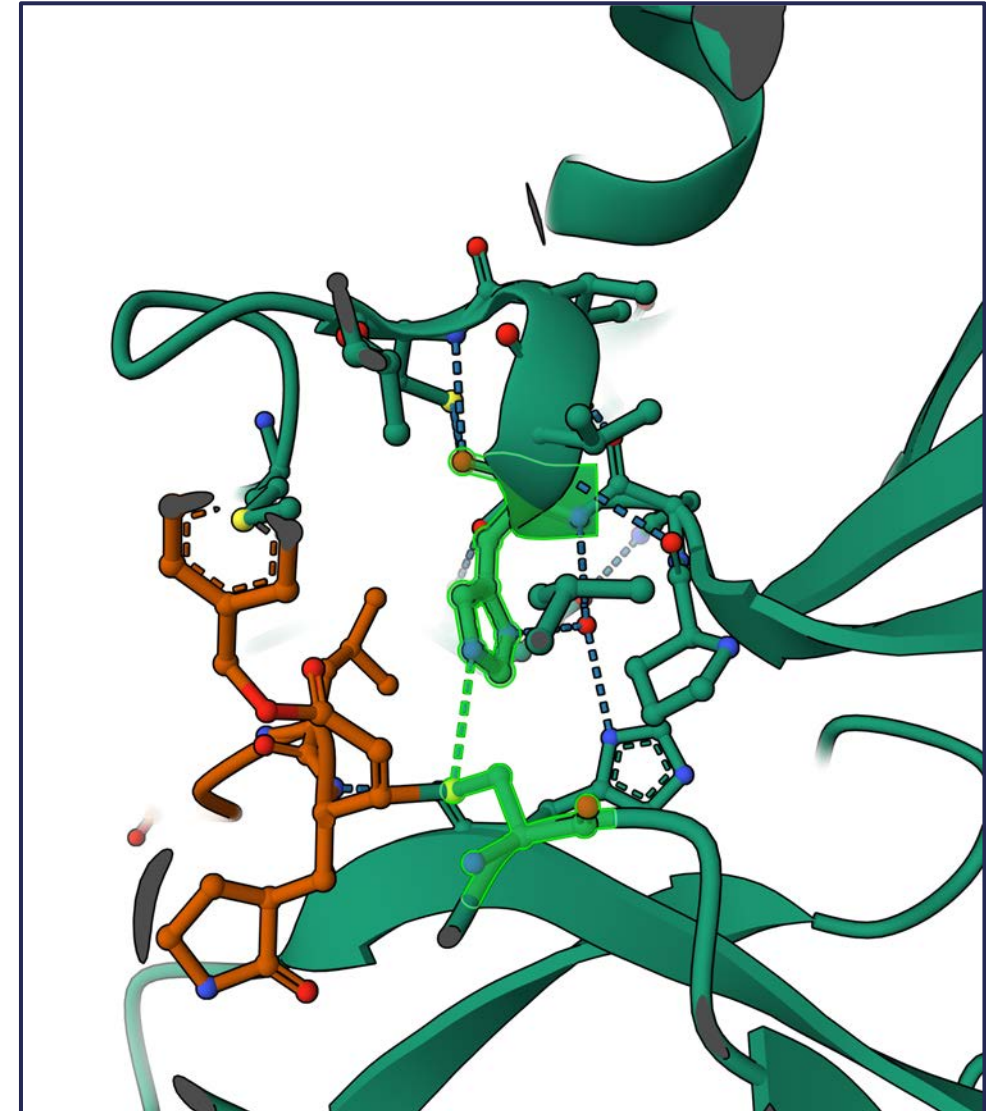
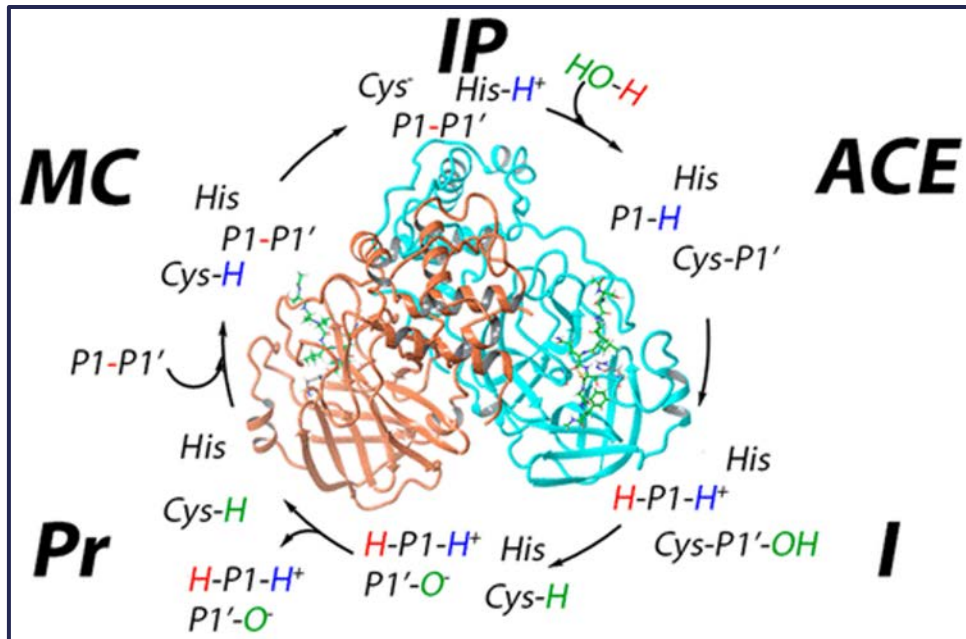


Sequence Annotations



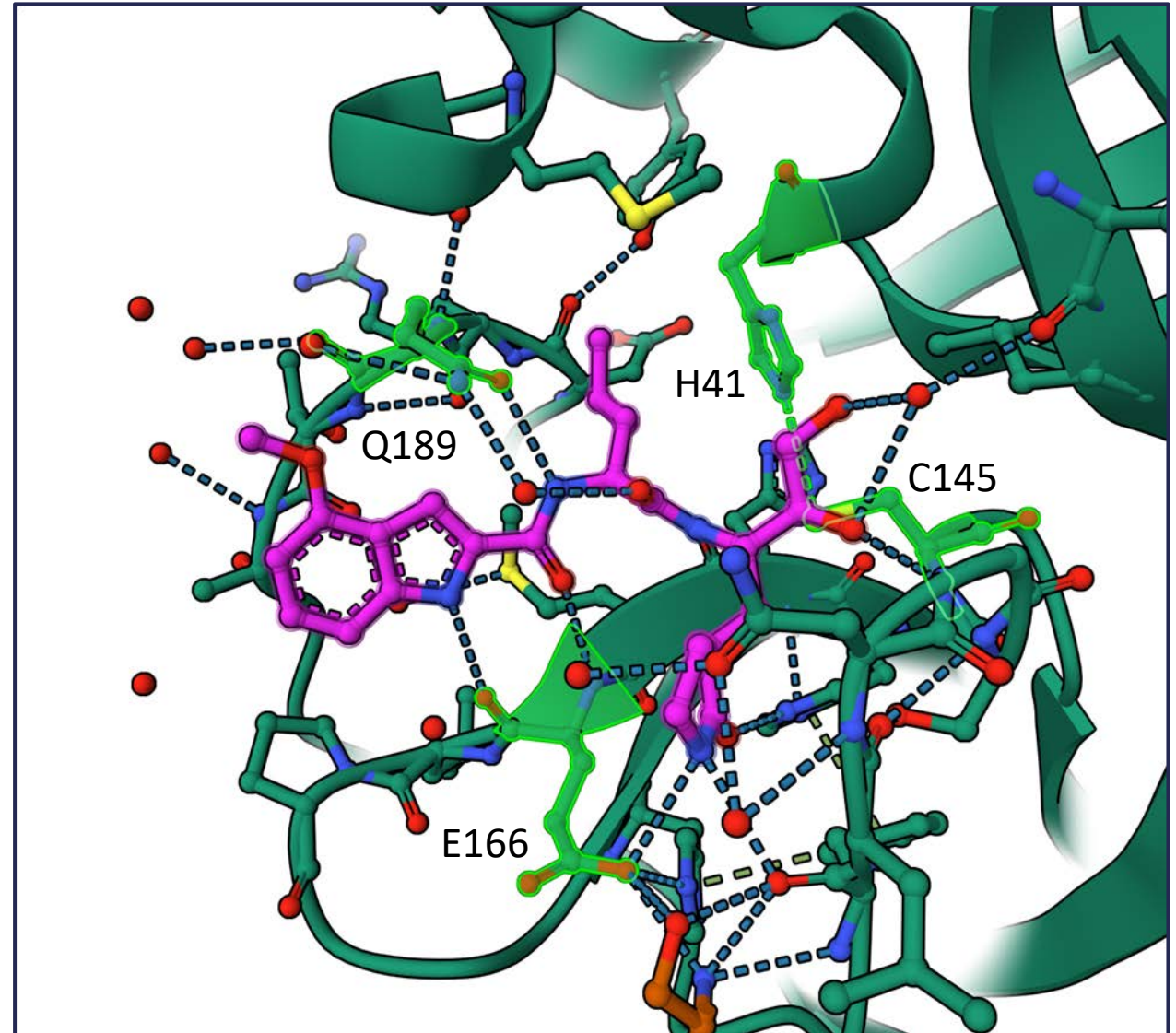
Teaching Enzymology: Basic Concepts

- Overall shape substrate binding
- Active site & catalytic residues
- Mechanism of enzyme catalysis



Blocking Catalysis with a Covalent Inhibitor

- PDB ID 6xhm
SARS-CoV-2 Mpro
bound to PF-00835231
- Catalytic residues
 - His 41
 - Cys 145
- Other interactions
 - Glu 166
 - Gln 189



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- Making connections using [RCSB.org](https://www.rcsb.org)
 - Shuchismita Dutta, Ph.D. - RCSB Protein Data Bank
 - Explore the structures of other enzymes like SARS-CoV-2 MPro
 - Use prior knowledge to develop a drug for SARS-CoV-2
 - Prepare to deal with future SARS-CoV like pandemics
- Discussions

Learning About the Enzyme (Target)

Macromolecules

Find similar proteins by: [Sequence](#) (by identity cutoff) | [3D Structure](#)

Entity ID: 1

Molecule	Chains ⁱ	Sequence Length	Organism	Details	Image
3C-like proteinase	A	306	Severe acute respiratory syndrome coronavirus 2	Mutation(s): 0 ⁱ Gene Names: rep_1a-1b EC: 3.4.22.69	

UniProt

Find proteins for [P0DTD1](#) (*Severe acute respiratory syndrome coronavirus 2*) Explore [P0DTD1](#) ⁱ Go to UniProtKB: [P0DTD1](#)

Entity Groups ⁱ

Sequence Clusters [30% Identity](#) [50% Identity](#) [70% Identity](#) [90% Identity](#) [95% Identity](#) [100% Identity](#)

UniProt Group [P0DTD1](#)

Scientific Name of Source Organism

- ☒ Severe acute respiratory syndrome coronavirus 2 (1,421)
- ☒ Severe acute respiratory syndrome-related coronavirus (50)
- ☐ synthetic construct (35)
- ☐ Homo sapiens (16)
- ☒ Middle East respiratory syndrome-related coronavirus (16)
- ☒ Severe acute respiratory syndrome coronavirus (10)
- ☒ Bat SARS CoV Rf1/2004 (2)
- ☒ Betacoronavirus England 1 (2)
- ☐ Camelus bactrianus (2)
- ☐ Murine hepatitis virus strain A59 (2)
- ☐ Mus musculus (2)
- ☒ SARS coronavirus Sin2774 (2)
- ☒ SARS coronavirus Urbani (2)
- ☒ Tylonycteris bat coronavirus HKU4 (2)
- ☐ Bos taurus (1)
- ☐ Escherichia coli (1)
- ☒ Human coronavirus OC43 (1)
- ☐ Rousettus bat coronavirus HKU9 (1)
- ☐ Streptomyces exfoliatus (1)
- ☐ Streptomyces roseus (1)

Learning About the Enzyme (Target)

RCSB PDB PROTEIN DATA BANK

222,415 Structures from the PDB
1,068,577 Computed Structure Models (CSM)

3D Structures ? Enter search term(s), Entry ID(s), or sequence Include CSM ? Help

Advanced Search | Browse Annotations

PDB-101 PDB EMDatResource NAKB wwPDB Foundation PDB-Dev

Search Query History Browse Annotations MyPDB

ATC Biological Process CARD CATH Cellular Component Disease Ontology ECOD Enzyme Classification Genome Location MeSH Molecular Function mpstruc OPM Protein Symmetry

SCOP-e SCOP2 Source Organism

Enzyme Classification Browser

Help

The EC (Enzyme Commission) browser presents proteins in the PDB based on the type of enzyme function it performs. Enzymes are classified based on the recommendations of the Nomenclature Committee of the International Union of Biochemistry and Molecular Biology (IUBMB). For each enzyme in the archive an EC number has been provided (see EC). These assignments are based on UniProtKB/GenBank/KEGG/author specified mapping of the enzyme to EC numbers.

Here you can **browse** the EC tree by an enzyme or enzyme class name, **view** the number of associated PDB proteins, and **search** for the specific associated structures either by enzyme name or by partial/full EC number.

Enter a word or phrase to search the tree.

- ▶ Oxidoreductases (1) - [19,725 Polymer Entities]
- ▶ Transferases (2) - [36,762 Polymer Entities]
- ▶ **Hydrolases (3) - [48,677 Polymer Entities]**
- ▶ Lyases (4) - [7,895 Polymer Entities]
- ▶ Isomerases (5) - [4,037 Polymer Entities]
- ▶ Ligases (6) - [3,719 Polymer Entities]
- ▶ Translocases (7) - [3,644 Polymer Entities]

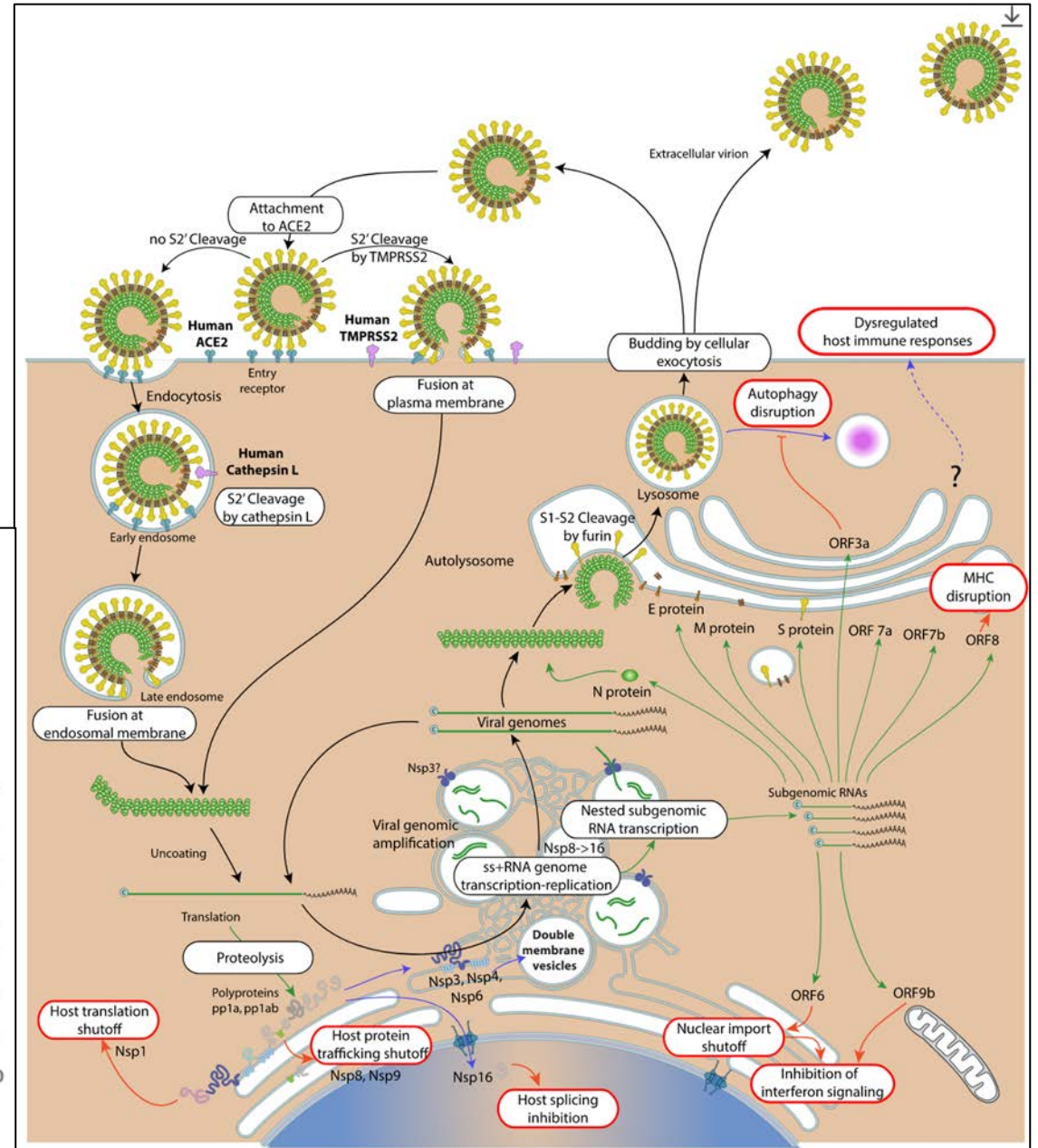
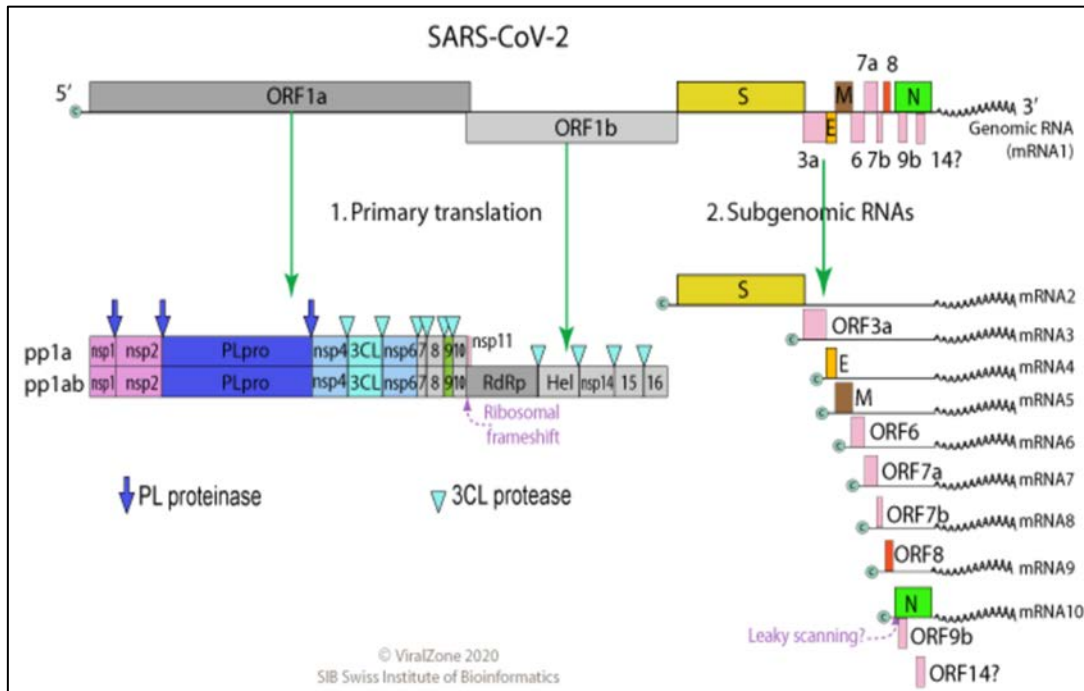
■ Data from external resource.

SARS coronavirus main proteinase (3.4.22.69) - [1,523 Polymer Entities]

Scientific Name of Source Organism

- Severe acute respiratory syndrome coronavirus 2 (1,431)
- Severe acute respiratory syndrome-related coronavirus (50)
- Middle East respiratory syndrome-related coronavirus (16)
- Severe acute respiratory syndrome coronavirus (10)
- SARS coronavirus Urbani (3)
- Bat SARS CoV Rf1/2004 (2)
- Betacoronavirus England 1 (2)
- Human coronavirus OC43 (2)
- Murine hepatitis virus strain A59 (2)
- SARS coronavirus Sin2774 (2)
- Typoncyteris bat coronavirus HKU4 (2)
- Rousettus bat coronavirus HKU9 (1)

A Conserved Target



From Pandemic to Paxlovid (Nirmatrelvir)

Q: *When did you first get the inspiration to look at leads from previous antiviral programs that you were a part of?*

Dr. Owen's reply: PF-835231 (PF-00835231) was the culmination of our SARS program from 2003/4. It was designed for IV dosing and yet thankfully the SARS outbreak had been effectively contained by the time we had the molecule ready for evaluation in the clinic in 2004. There were no subjects for a clinical trial, so we were not able to clinically evaluate the compound. Following the outbreak of Covid-19, the protein sequences from the SARS-CoV-2 viral genome were in the public domain by February 2020. Given Pfizer's experience in viral protease research, our leadership planned and proposed an oral protease inhibitor program. The critical SARS-CoV-2 main protease catalytic site, when compared to SARS main protease from 17 years earlier, was identical. We quickly showed that PF-835231 (PF-00835231) was therefore a potent in vitro inhibitor of the SARS-CoV-2 main protease and it became the starting point for designing an oral protease inhibitor, specifically for Covid-19.

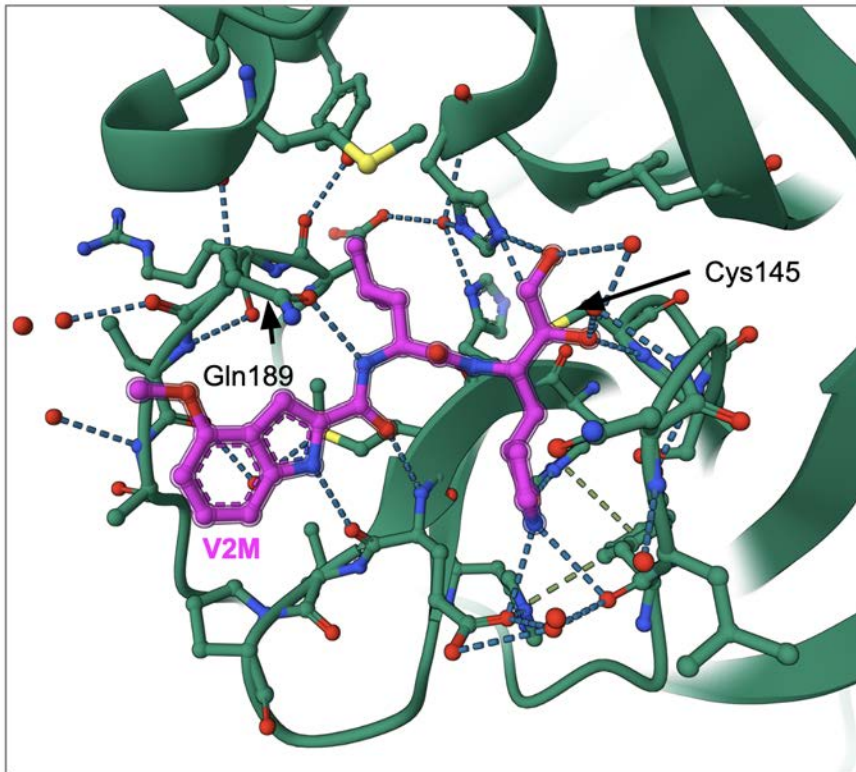
Source: An Interview With The Team Leader For The Scientific Discovery Of Pfizer's Covid-19 Drug, Paxlovid, John LaMattina, Jan 6, 2022



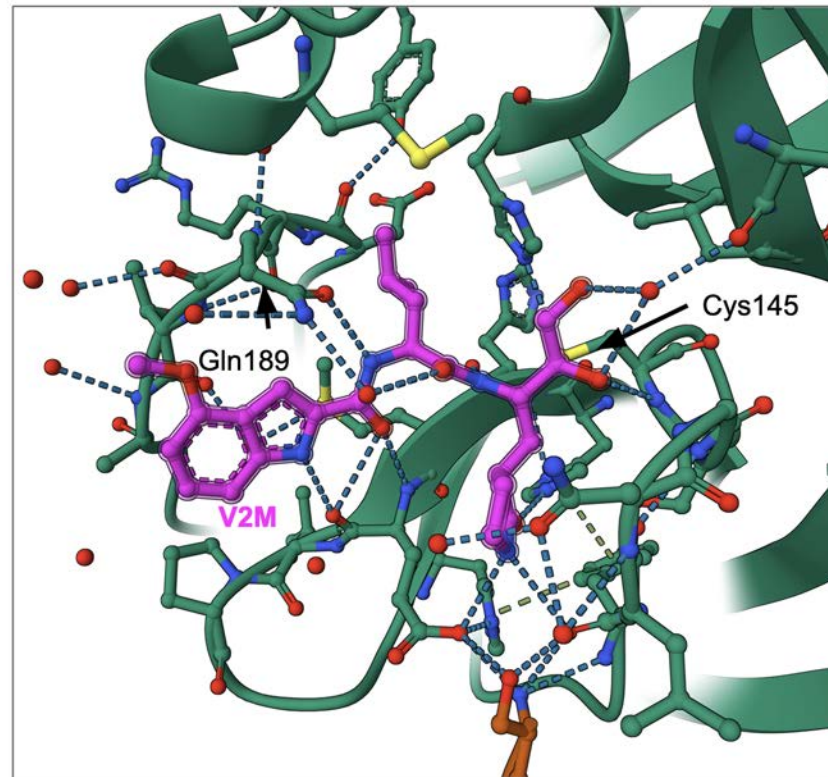
Team of Pfizer scientists who developed Paxlovid, led by Dr. Dafydd Owen.
Source: Pfizer - 2022 Heroes of Chemistry, <https://youtu.be/e2rRGoSyC5U>.

On Friday March 13th 2020, our CEO published a five-point plan for our response to Covid-19. One of those was 'marshalling our people'. That was the day I was asked to plan some specifics for the potential program. I was asked **'What would you need and how would you prosecute an oral protease inhibitor program?'**.

Inhibitor PF-00835231 Binding CoV MPros



PF-00835231 bound to SARS-CoV main protease
(PDB ID **6xhl**)



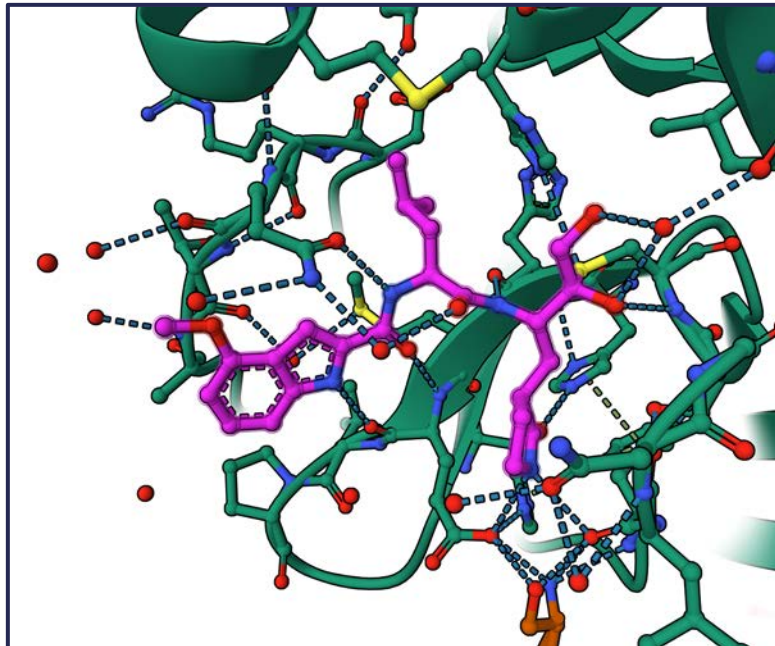
PF-00835231 bound to SARS-CoV-2 main protease
(PDB ID **6xhm**)



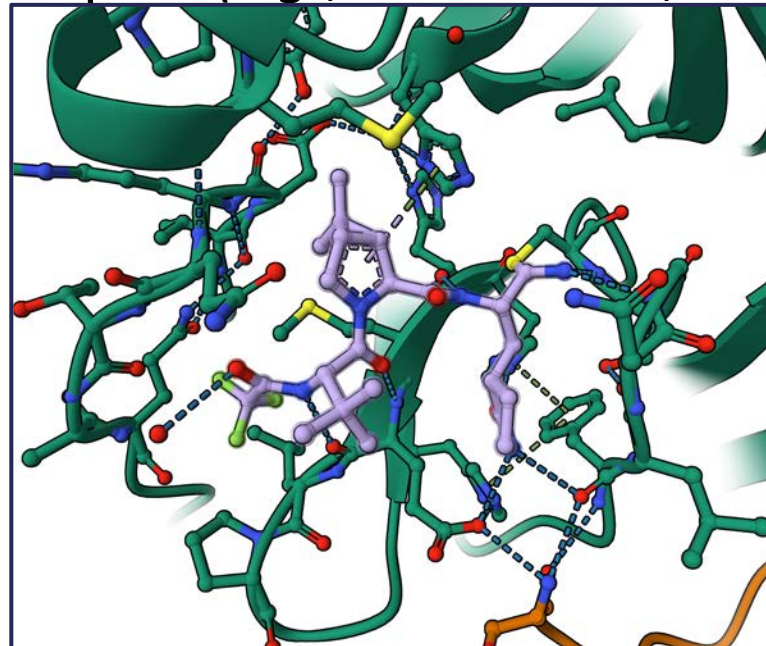
Compare main proteases (PDB
IDs **6xhl** and **6xhm**)

An oral SARS-CoV-2 Mpro inhibitor

- PF-00835231 (PDB ID 6xhm, left)
 - Intravenous administration only
- PF-07321332 or Nirmatrelvir (PDB ID 7rfw, right)
 - Administered orally, good selectivity and safety profiles
 - Inhibits other coronavirus Mpros (*e.g.*, SARS-CoV-1, MERS)



<https://www.rcsb.org/3d-view/6XHM?preset=ligandInteraction&label asym id=C>

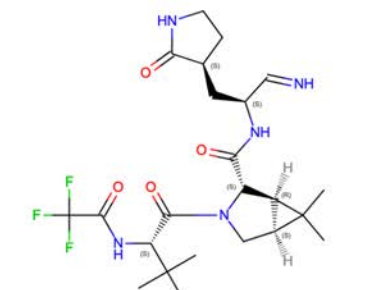


<https://www.rcsb.org/3d-view/7RFW?preset=ligandInteraction&label asym id=B>

Number/Structure	SARS-CoV2 M ^{pro} K _i (nM)*
1 (PF-00835231)	0.271 (0.155 – 0.471, n=6)
2	27.7 (18.4 – 41.7, n=5)
3	230 (181 – 292, n=4)
4	7.93 (3.62 – 17.4, n=5)
5	12.1 (8.05 – 18.1, n=7)
6 (PF-07321332)	3.11 (1.47 – 6.59, n=6)

Preparing for a Future Pandemic

- Search for Nirmatrelvir (bound) containing structures
- Group polymers in result by UniProt



Chemical structure of Nirmatrelvir, a 3D ball-and-stick model, and a 2D chemical structure diagram.

4WI

(1R,2S,5S)-N-((1E,2S)-1-imino-3-[(3-oxopyrrolidin-3-yl)propan-2-yl]-6,6-dimethyl-1-3-[3-methyl-N-(trifluoroacetyl)-L-valeryl]azabicyclo[3.1.0]hexane-2-carboxamide

Find entries where: 4WI

- ☒ is present as a standalone ligand in 16 entries
- ☒ as a non-polymer is covalently linked to polymer or other heterogen groups 31 entries

search

Scientific Name of Source Organism

- ☐ Severe acute respiratory syndrome coronavirus 2 (42)
- ☐ Human coronavirus 229E (1)
- ☐ Middle East respiratory syndrome-related coronavirus (1)
- ☐ Severe acute respiratory syndrome-related coronavirus (1)

Represent by: Resolution: Best

1 to 5 of 5 Groups

Page 1 of 1 25

Sort by: Group Score

Group Replicase polypeptide 1ab

Group Total Size: 2,742

Polymer Entities 41 matching query out of 2,742 in whole group

Best Example 8HVL_1 (Resolution: Best) Explore in 3D

Group ID P0DTC1

Description Multifunctional protein involved in the transcription and replication of viral RNAs. Co...

Group Replicase polypeptide 1ab

Group Total Size: 140

Polymer Entity 1 matching query out of 140 in whole group

Best Example 7VLO_1 (Resolution: Best) Explore in 3D

Group ID P0C6X7

Description Multifunctional protein involved in the transcription and replication of viral RNAs. Co...

Group Replicase polypeptide 1a

Group Total Size: 35

Polymer Entity 1 matching query out of 35 in whole group

Best Example 7XB4_1 (Resolution: Best) Explore in 3D

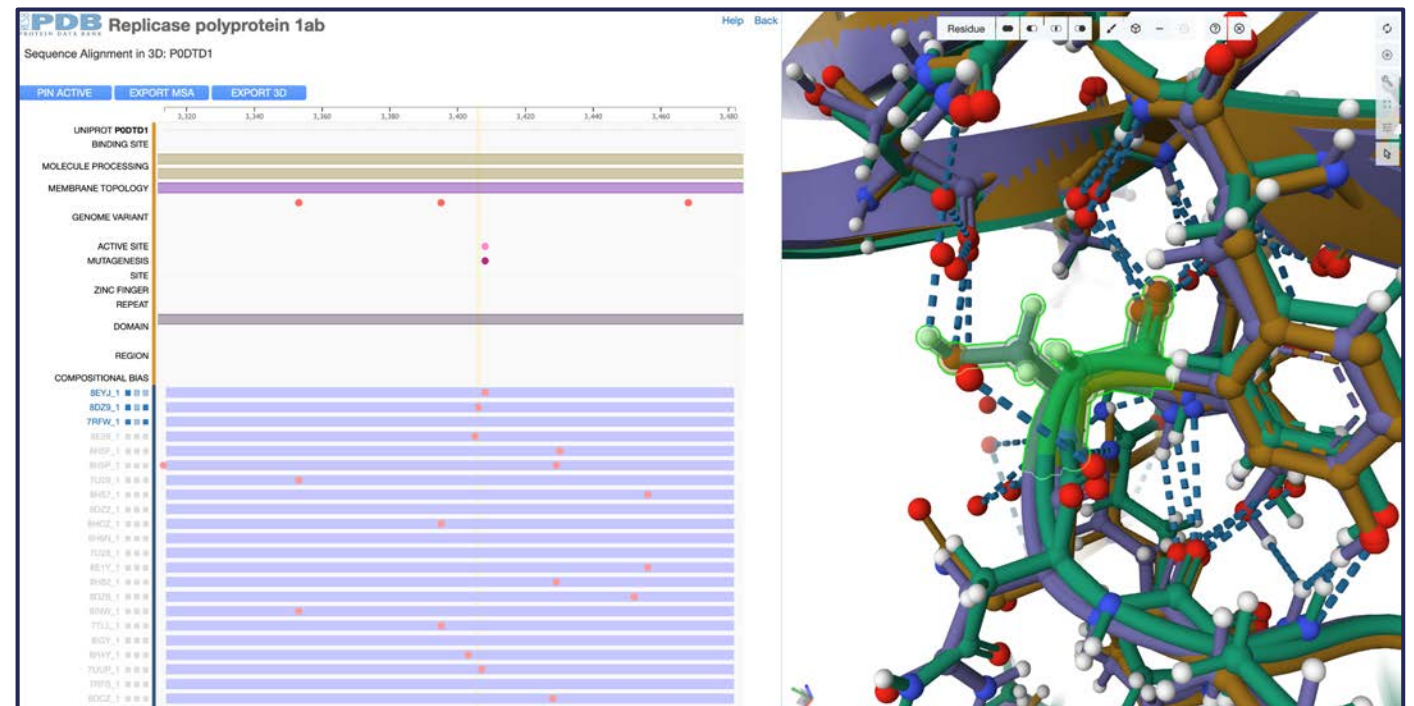
Group ID P0DTC1

Description Multifunctional protein involved in the transcription and replication of viral RNAs. Co...

Teaching Enzymology: Advanced Concepts

- Exploring conformational changes during enzyme activity
- Understanding mechanisms of enzyme action
- Designing inhibitors and allosteric regulators
- Understanding the impact of mutations/variants on enzyme activity

How would you use rcsb.org to explore/learn/teach about developing resistance, designing new drugs, and more?



Summary

- Introduction to the Protein Data Bank and SARS-CoV-2
 - Stephen K. Burley, M.D., D.Phil. - Director, RCSB Protein Data Bank
- Exploring the SARS-CoV-2 Main Protease using RCSB.org
 - Paul Craig, Ph.D. - Rochester Institute of Technology
- Teaching enzymology using [RCSB.org](https://www.rcsb.org)
 - Shuchismita Dutta, Ph.D. - RCSB Protein Data Bank
- Discussion

Exit Survey and Certificates of Completion

Please take the exit survey (<https://go.rutgers.edu/eenu6dq8>) to

- share what you liked about this webinar
- how we can improve this webinar
- tell us what other webinars you would be interested in

This survey will be closed on Tuesday, **August 6, 2024**.

Want to receive a certificate of completion?

You **MUST** complete the exit survey.

Please allow 4 weeks to receive the certificate.

Recordings will be added to PDB-101 in the fall (pdb101.rcsb.org)

Course Materials

Course recordings and presentations will be published at PDB-101.rcsb.org sometime in the Fall.

They will not be emailed separately.

The screenshot displays the PDB-101 website interface. At the top, a navigation bar includes links for PDB-101, Molecule of the Month, Browse, Learn, Train, Teach, Global Health, SciArt, Events, and About. A dropdown menu for the 'Train' link is open, showing options: Guide to Understanding PDB Data, Training Courses, Education Corner, and PDB and Data Archiving Curriculum. A red arrow points from the 'PDB-101' logo to the 'Train' dropdown. Below the navigation bar, a sidebar titled 'Train' lists the same four options with right-pointing arrows. The main content area is titled 'Train: All Training Courses' and features a grid of course cards. Each card includes a representative image, a title, and a brief description. The courses listed 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 sign-up link is provided: 'Sign up to receive email notifications about upcoming training courses.'

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 PDB PROTEIN DATA BANK

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

Train

Grid List

Train: All Training Courses

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

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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 PDB Team

 **RCSB.ORG**
info@rcsb.org

Core Operations Funding

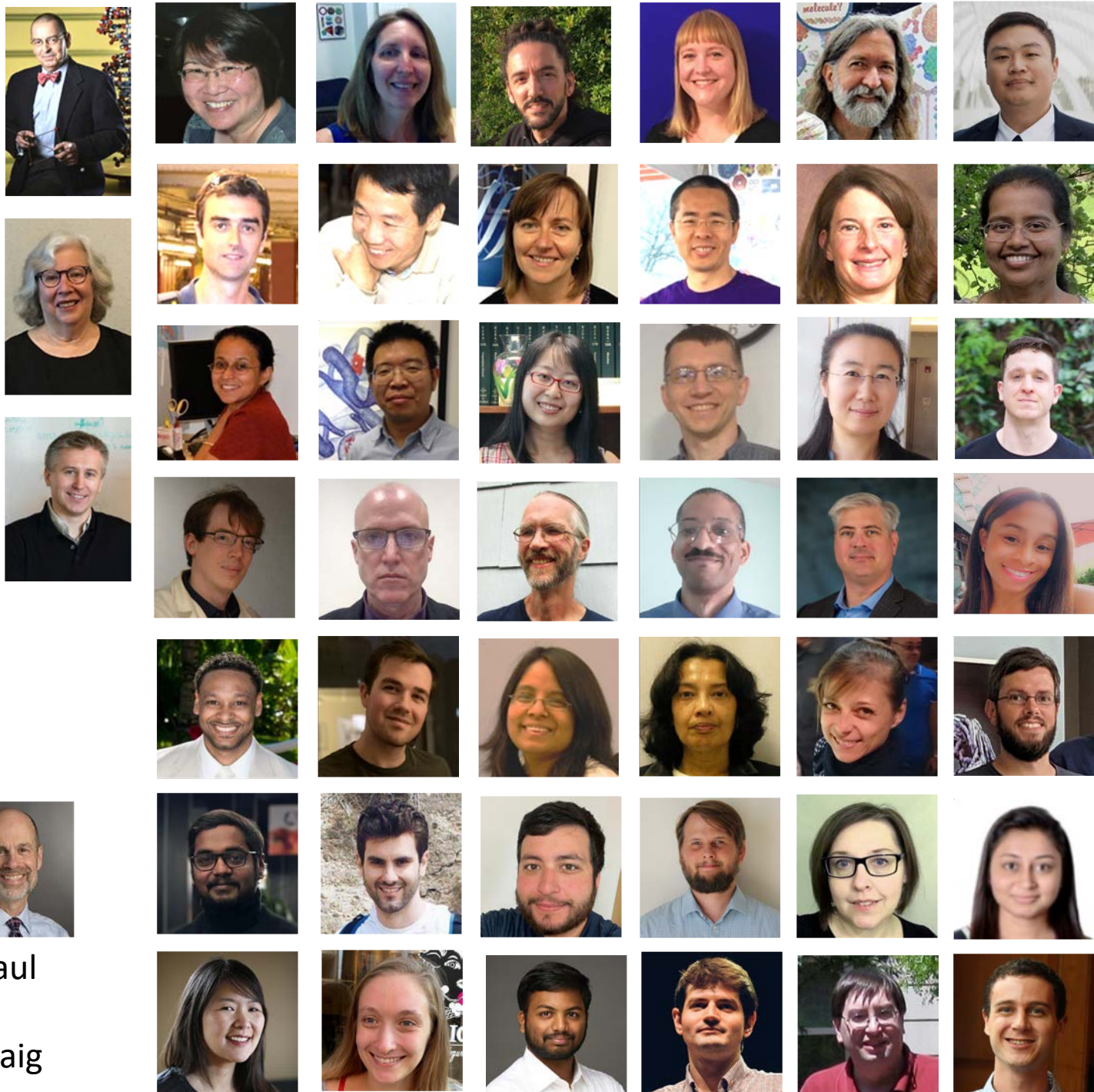
US National Science Foundation (DBI-2321666),
National Institute of General Medical Sciences,
National Institute of Allergy and Infectious Disease, and
National Cancer Institute (NIH R01GM133198), and the
US Department of Energy (DE-SC0019749)

Management



Member of the
Worldwide Protein Data Bank
(wwPDB; wwpdb.org)

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Paul

Craig

Training Resources on PDB-101

pdb101.rcsb.org > *Train*

Materials to help effectively use **RCSB.org** tools for searching, visualizing, and analyzing 3D biostructure data

- Guide to Understanding PDB Data
- Training Courses
- Education Corner
- PDB & Data Archiving Curriculum



Sign up for Training Event Announcements

