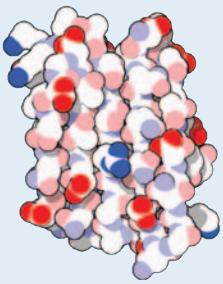
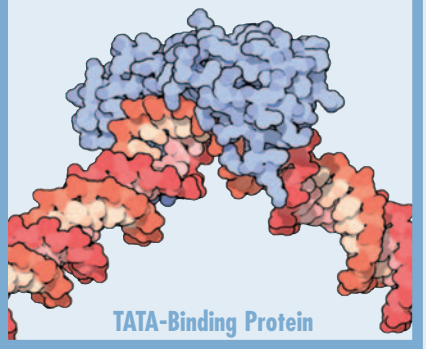
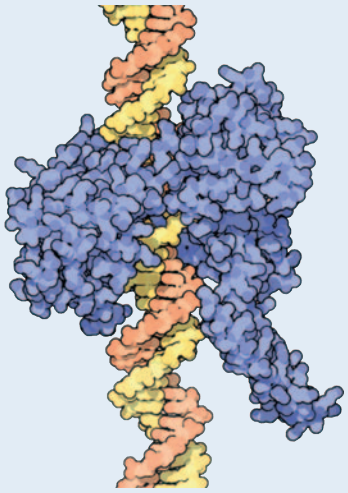


Designer Proteins

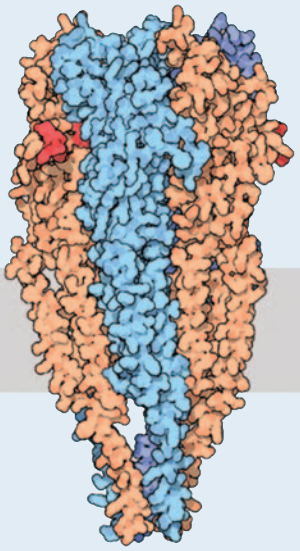


TATA-Binding Protein

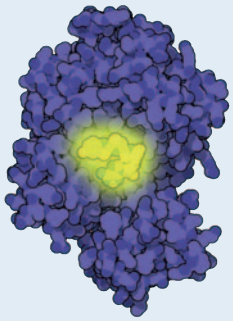
RCSB PDB
PROTEIN DATA BANK



Topoisomerases



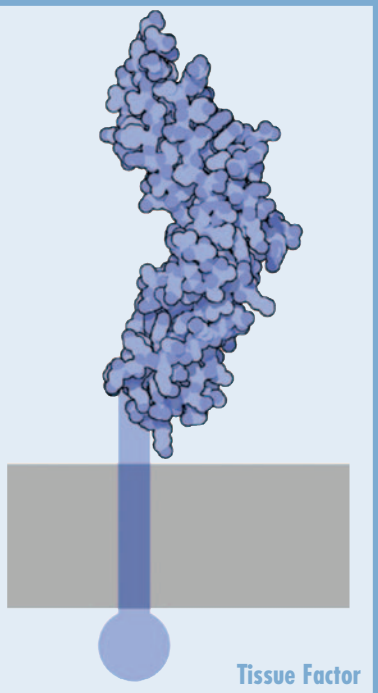
Acetylcholine Receptor



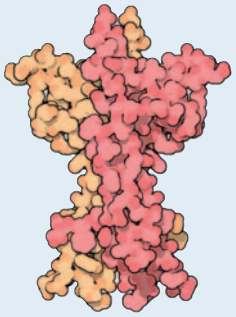
Luciferase

ANNUAL REPORT

July 2005 – June 2006

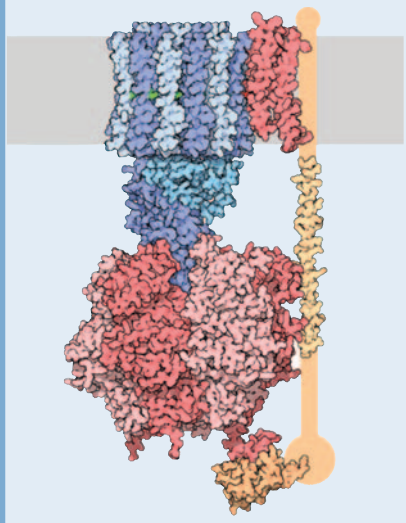


Tissue Factor

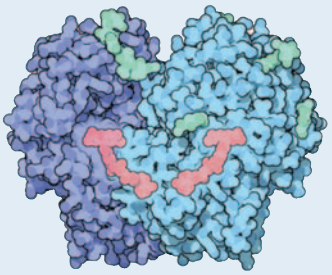


Neurotrophins

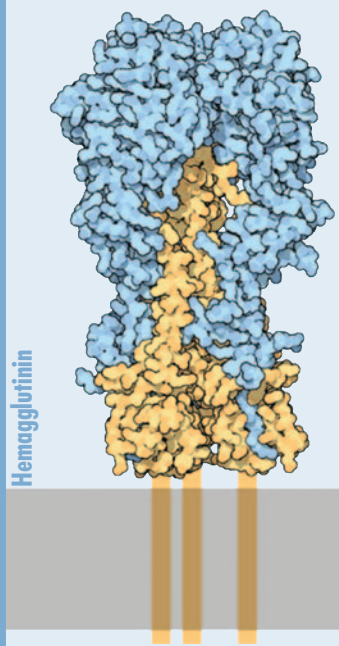
Cholera Toxin



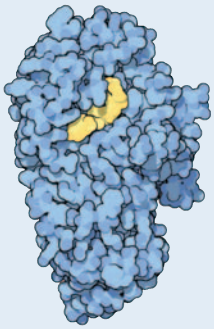
ATP Synthase



Glucose Oxidase



Hemagglutinin



Alpha-amylase

RESEARCH COLLABORATORY FOR STRUCTURAL BIOINFORMATICS
Rutgers, The State University of New Jersey
San Diego Supercomputer Center & Skaggs School of Pharmacy & Pharmaceutical Sciences,
University of California, San Diego

About the Cover

The *Molecule of the Month* series by David S. Goodsell (The Scripps Research Institute) presents short accounts about selected molecules from the PDB archive. Each installment introduces readers to the structure and function of the molecule, and discusses the relevance of the molecule to human health and welfare.

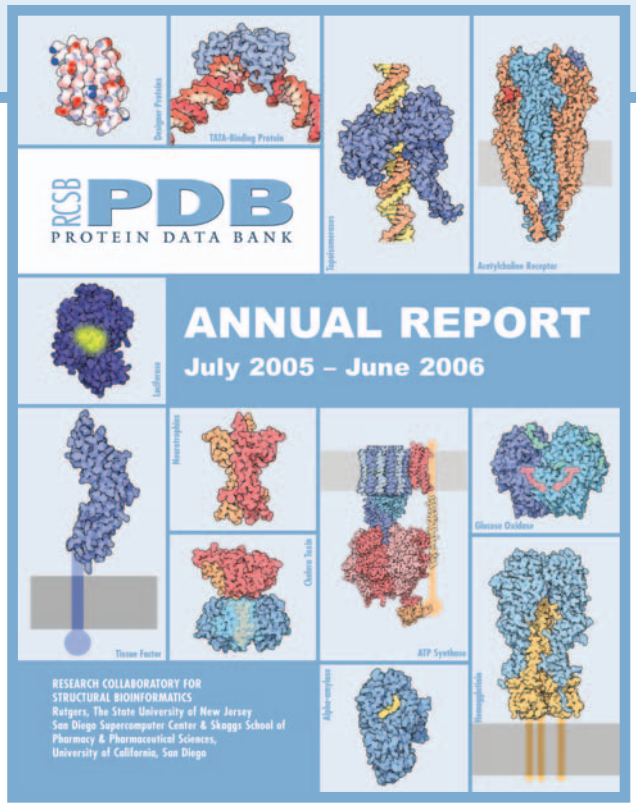
This cover highlights the molecules that have been featured during the period of the report.

The *Molecule of the Month* is a great place for users of all levels to start exploring the RCSB PDB resource. Since the first installment of the series in January 2000, it has served as an entertaining way to explore the structures in the PDB. Each installment uses 4-5 PDB entries (out of the many choices available) to highlight the functional features being described.

The images shown here, like most of the illustrations in the series, are created with a computer program developed by Goodsell. This representation of molecules in flat colors and black outlines simplifies the overall shape and form of the molecule while depicting individual atoms at the same time.

Each feature has an image created using RasMol[1,2] to gives visitors an idea of the kinds of pictures that they can create themselves with off-the-shelf software, and ends with recommendations of resources to use to further explore the structure.

This popular series is used by students, teachers, researchers, and the general public. It is accessible from the RCSB PDB home page and available as a PDF download.



The structures used to create these images were: **acetylcholine receptor**, 2bg9[3]; **alpha-amylase**, 1ppi[4]; **ATP synthase**, 2a7u[5], 1l2p[6], 1c17[43], 1e79[44]; **cholera toxin**, 1xtc[7]; **designer proteins**, 1qys[8]; **glucose oxidase**, 1gpe[9]; **hemagglutinin**, 1ruz[10]; **luciferase**, 2d1s[11]; **neurotrophin**, 1bet[12]; **TATA-binding protein** 1ytb[13], 1tgh[14], 1cdw[15]; **tissue factor**, 2hft[16]; **topoisomerases**, 1a36[17].

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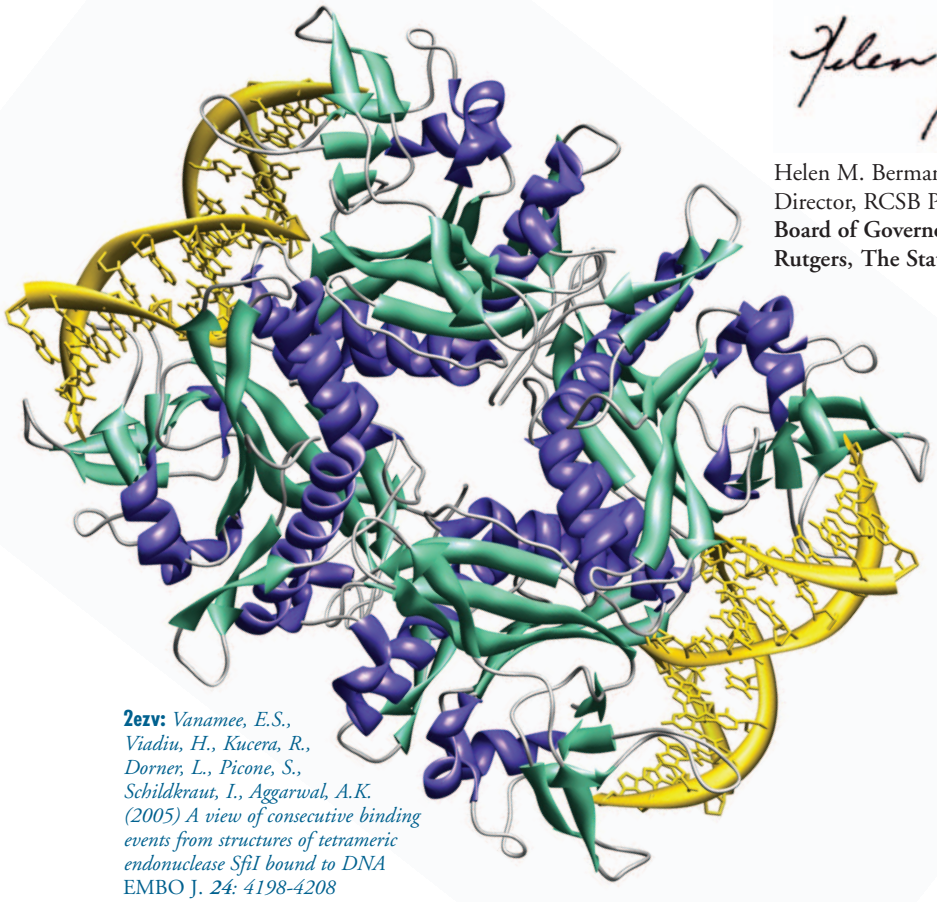
Message from the Director

The PDB archive, with over 37,000 structures of biological macromolecules, is a rich source of data for students, teachers, researchers, and the general public. These structures serve as important reference points for understanding subjects such as chemistry, structural biology, computational biology, and pharmacology, and experimental techniques such as X-ray crystallography, NMR, and three-dimensional electron microscopy. The RCSB PDB is dedicated to promoting methods of opening the database up for further understanding and study.

This year, the RCSB PDB released a new website and database that provides a powerful portal for studying the structures of biological macromolecules and their relationships to sequence, function, and disease. The new features of this site build upon already established resources, such as *Molecule of the Month* and deposition services.

During the period of this report, we expanded our education programs to make the molecules found in the PDB "hands-on" through efforts such as the New Jersey Science Olympiad and ImmersivePDB. Students and teachers have visited the RCSB PDB to learn more about protein and nucleic acid structure from the people who work with the PDB every day.

These outreach activities, as described in this report, are core to our efforts to make the RCSB PDB accessible to a broad community of users. This annual report also describes the many activities in the areas of data deposition and data access, which provide the basis for all of our education projects. We hope you enjoy reading about them.



2ezv: *Vanamee, E.S., Viadiu, H., Kucera, R., Dorner, L., Picone, S., Schildkraut, I., Aggarwal, A.K. (2005) A view of consecutive binding events from structures of tetrameric endonuclease SfiI bound to DNA* EMBO J. ***24****: 4198-4208*

Helen M. Berman
Director, RCSB PDB
Board of Governors Professor of Chemistry and Chemical Biology
Rutgers, The State University of New Jersey

About the RCSB PDB

The RCSB PDB (Research Collaboratory for Structural Bioinformatics) works through joint grants to provide free structural biology resources to further the fields of bioinformatics and biology.

The online PDB archive is a repository for the coordinates and related information for more than 37,000 structures, including proteins, nucleic acids, and large macromolecular complexes. The structures of these macromolecules have been determined using X-ray crystallography, nuclear magnetic resonance (NMR), and three-dimensional electron microscopy (3D EM) techniques.

These three-dimensional structures of biological macromolecules hold significant promise for the pharmaceutical and biotechnology industries in the search for new drugs and in the effort to understand the mystery of human disease. The understanding of what a structure looks like aids in understanding how it functions.

The RCSB PDB website provides a relational database and almost a thousand curated web pages. The RCSB PDB provides several tools for searching and creating tabular and graphical reports. Other resources for associated aspects of structural biology, including structural genomics, data representation formats, and visualization tools, are made available. The website includes a variety of materials for learning about structural biology and for interacting with the multifaceted interests of the international PDB user community.

PDB Users

PDB user and depositor Andrzej Joachimiak, the director of Argonne National Laboratory's Structural Biology Center (SBC), poses in front of structures determined at SBC and deposited to the PDB archive. (Photo credit: Argonne National Laboratory)

The PDB archive is a critical resource for researchers in academia and in the pharmaceutical and biotechnology industries. Structural biologists who focus on structure determinations in their research work with PDB staff to make these data available in the archive. Researchers from a wide variety of disciplines then use these data in their own studies, which can range from structural genomics to computational biology to structural biology and beyond.

Students and teachers also use the RCSB PDB's collection of resources to become scientifically literate in areas ranging from biotechnology to structural biology.

SNAPSHOT — JULY 1, 2006

37,392 released atomic coordinate entries

Molecule Type

34,221 proteins, peptides, and viruses
1,627 nucleic acids
1,510 protein/nucleic acid complexes
34 other

Experimental Technique

31,655 X-ray
5,531 NMR
126 Electron Microscopy
80 Other

21,163 structure factor files
3,014 NMR restraint files

Biological Macromolecules in the PDB

The structures housed in the PDB range from small pieces of DNA or protein to complex machines, such as viruses and ribosomes. Each molecule plays a role in at least one biological process and each has value in helping scientists unravel the mysteries of life.

The PDB archive include a wide variety of medically important structures, including proteins associated with viruses ranging from the common cold to the avian flu; HIV; West Nile virus; parts of prion proteins; the amyloid peptide associated with Alzheimer's disease; and structures relating to a wide variety of cancers, such as the p53 tumor-suppressor protein and proteins from human papillomavirus (HPV).

PDB structures provide insight into the roles of these molecules in fundamental biological processes and, in some cases, into their possible roles in disease or drug interactions.

PDB History

Early in the history of structural biology, it was recognized that these data need to be freely available to people in all disciplines. In 1971, the Protein Data Bank (PDB) was founded at Brookhaven National Laboratory[18] as the sole international repository for three-dimensional structure data of biological macromolecules. In 1999, management was assumed by the Research Collaboratory for Structural Bioinformatics.[19]

The Worldwide PDB (wwPDB) was established in 2003 to formally recognize the international nature of the PDB archive.[20] All wwPDB sites share responsibilities in data deposition, processing, and distribution of the PDB archive, and agree to support a single, standardized archive of structural data (**see also page 6**).

Funding

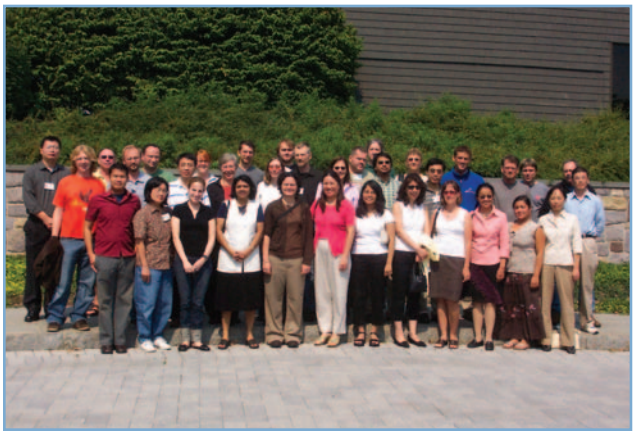
The RCSB PDB is supported by funds from the National Science Foundation (NSF), the National Institute of General Medical Sciences (NIGMS), the Office of Science, Department of Energy (DOE), the National Library of Medicine (NLM), the National Cancer Institute (NCI), the National Center for Research Resources (NCRR), the National Institute of Biomedical Imaging and Bioengineering (NIBIB), the National Institute of Neurological Disorders and Stroke (NINDS), and the National Institute of Diabetes & Digestive & Kidney Diseases (NIDDK).

About the RCSB PDB

The Mission of the RCSB PDB Team

The RCSB PDB seeks to enable science worldwide by offering a variety of resources to improve the understanding of structure-function relationships in biological systems. The RCSB PDB believes that the availability of consistent, well-annotated three-dimensional data will facilitate new scientific advances. For the data to be truly useful, we must deliver it in a timely and efficient manner. To fulfill this mission, the capabilities of the RCSB PDB are continually being upgraded and significantly extended.

The RCSB PDB also works with the wwPDB to maintain a uniform PDB archive of macromolecular structural data that is freely and publicly available to the global community.



The RCSB PDB Team

RCSB PDB Management

The RCSB PDB is managed by Rutgers, The State University of New Jersey and the San Diego Supercomputer Center (SDSC) and the Skaggs School of Pharmacy and Pharmaceutical Sciences (SSPPS) at the University of California, San Diego (UCSD) – two member institutions of the RCSB.

Helen M. Berman, a Board of Governors Professor of Chemistry and Chemical Biology at Rutgers, is the Director of the RCSB PDB. She was part of the original team that developed the PDB at Brookhaven National Laboratory, and is a co-founder of the Nucleic Acid Database. Co-Director Philip E. Bourne is a Professor of Pharmacology at UCSD and an Adjunct Professor at The Burnham Institute & The Keck Graduate Institute.

Advisory Committees

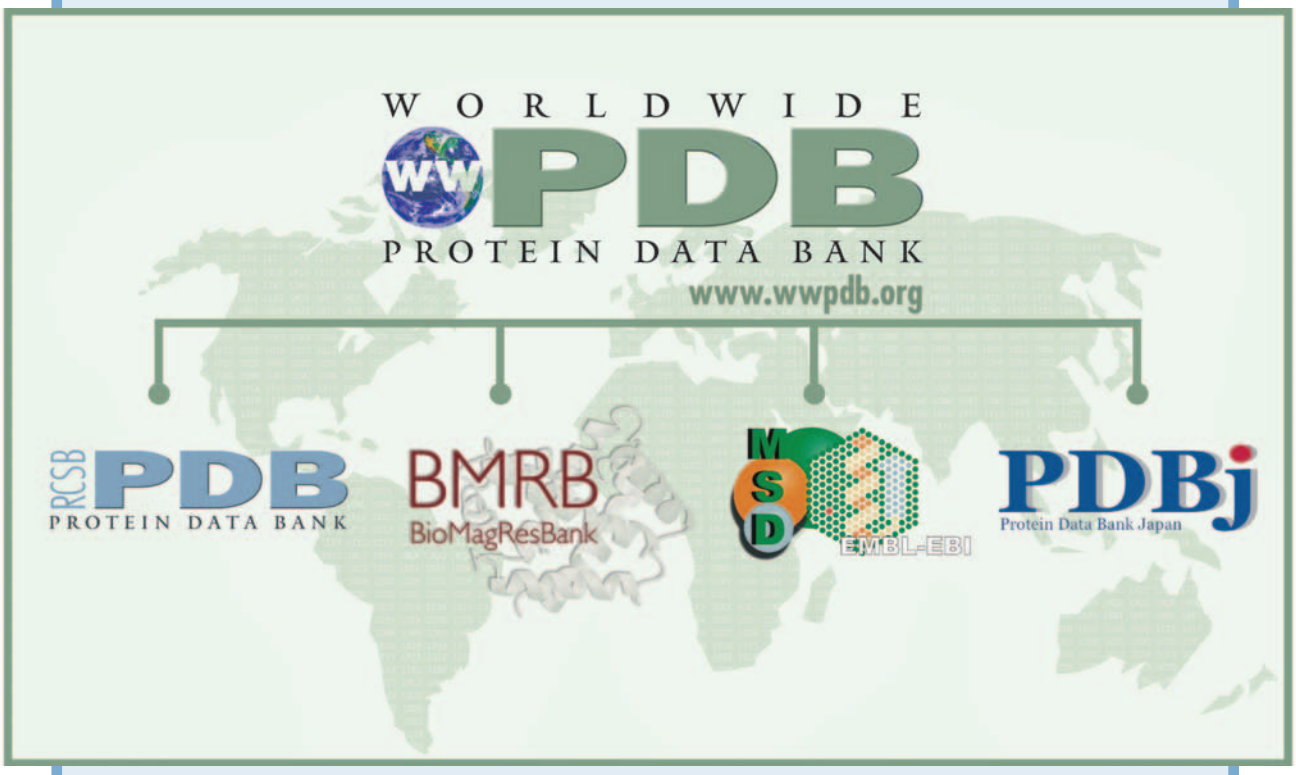
The RCSB PDB directors receive advice from a variety of advisory committees and through interactions with the user communities (at workshops, meetings, and help desks) that help to guide the direction of the RCSB PDB. The RCSB PDB/BMRB NMR Task Force meets to discuss issues surrounding the deposition and representation of data from NMR experiments.

The PDB Advisory Committee (PDBAC) is an international team of experts in X-ray crystallography, NMR, 3D EM, bioinformatics, and education. They meet yearly with the RCSB PDB to review recent progress and to help plan for the ever-changing future.

The current membership includes Frank Allen (Executive Director, Cambridge Crystallographic Data Centre), Edward N. Baker (Professor, University of Auckland), Manju Bansal (Professor, Indian Institute of Science), Stephen K. Burley (PDBAC Chair, Chief Scientific Officer and Senior Vice President, Research, SGX Pharmaceuticals, Inc.), Wah Chiu (Professor, Baylor College of Medicine), Paul Craig (Professor, Rochester Institute of Technology), Juli Feigon (Professor, University of California, Los Angeles), Andrzej Joachimiak (Director, SBC at Argonne National Laboratory), Robert Kaptein (Professor, Utrecht University), Anthony J. Pawson (Professor, University of Toronto), Seth Pinsky (Director, Discovery Informatics, Abbott Laboratories), Andrej Sali (Professor, University of California, San Francisco), David Searls (Senior Vice-President of Bioinformatics, GlaxoSmithKline), and Cathy Wu (Professor, Georgetown University Medical Center). Past members include Nobuhiro Go (Professor, Japan Atomic Energy Research Institute), Barry Honig (Professor, Columbia University), Sung-Ho Kim (Professor, University of California, Berkeley), and Judith Voet (Professor, Swarthmore College).

2ahz: *Shi, N., Ye, S., Alam, A., Chen, L., Jiang, Y. (2006) Atomic structure of a Na+- and K+-conducting channel.* Nature ***440:*** *570-574*

wwPDB: The Worldwide PDB



The Worldwide Protein Data Bank (wwPDB) consists of organizations that act as deposition, data processing and distribution centers for PDB data. The founding members are the RCSB PDB, the Macromolecular Structure Database at the European Bioinformatics Institute (MSD-EBI), and the Protein Data Bank Japan (PDBj) at Osaka University. BioMagResBank (BMRB) at the University of Wisconsin-Madison became a member in 2006. The mission of the wwPDB is to maintain a single Protein Data Bank archive of macromolecular structural data that is freely available to the global community.[20]

Data deposited to the archive are processed using agreed-upon standards for full validation of the data. These data are forwarded to the RCSB PDB for release into the archive. wwPDB members also maintain websites that provide different views of the data.

wwPDB members collaborate on projects to ensure the uniformity of the PDB archive. The PDB Exchange Dictionary consolidates content from a variety of dictionaries and includes extensions to describe NMR, 3D EM, and protein production data. PDB data processing, exchange, annotation, and database management operations all make heavy use of the content of this dictionary.

As part of the wwPDB collaboration, MSD-EBI, PDBj and RCSB are working to integrate all remediation efforts into a single consistent collection of data files. This work includes improving the representation of PDB small molecule data, assessing the required chemical definitions and their correspondences in PDB entries, resolving any remaining differences in the macromolecular sequences assigned by each group, and resolving differences in primary citation assignments (**see also page 14**).

The wwPDB meets with regularly with an advisory board for guidance.

RCSB PDB Services: Data Deposition

Data Input: Deposition, Validation, and Annotation

A key component of the wwPDB is the efficient capture (deposition) and curation (validation and annotation) of experimental structural data. Scientists contribute data produced from structure determination experiments using deposition tools available from the wwPDB partners. These data are then validated and annotated before being made publicly available. Data processed at the other wwPDB sites are forwarded to the RCSB PDB for inclusion in the archive.

Before depositing a structure, users have the option of independently performing many of the same checks as the annotation staff using the validation option of ADIT. Using the ADIT editor, information about the structure and the experiment is entered. The structure is then immediately assigned its own unique PDB ID. Staff then perform checks, annotate the deposited data, and send validation reports and the completed coordinate file in mmCIF and PDB formats to the depositor for review. When finalized, the complete entry, including its status information and PDB ID, is loaded into a relational database. Depending upon the hold status selected by the depositor, data release occurs when a depositor gives approval to the annotated entry (REL), the hold date has expired (HOLD), or the journal article has been published (HPUB). If the citation for a structure is not published within a one-year period, depositors are given the option to immediately release the structure or withdraw the deposition.

Joint BMRB/PDB Deposition System

Currently, the structural data for biological macromolecules determined using NMR are deposited to the PDB, while the experimental data for the same molecule is either forwarded by the RCSB PDB or deposited at the BMRB using ADIT-NMR. The RCSB PDB and BMRB have developed a single tool for depositing these data. The next version of ADIT-NMR will serve as a joint deposition tool for all the NMR-related data. The new deposition system will accept structural and experimental NMR data files, including coordinates, constraints, chemical shifts, coupling constants, relaxation data, pKa, *etc.*, at a single site. Once deposited, the structural data will be processed at the RCSB PDB and the experimental data at the BMRB. These data will then be available for download from their respective public domains.

Software for Deposition and Validation

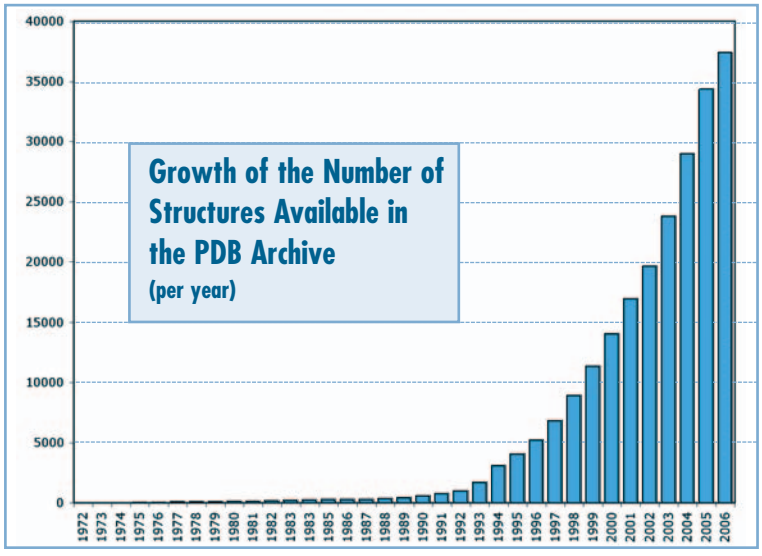
The RCSB PDB has developed a variety of tools to facilitate data annotation and validation by the depositor community (deposit.pdb.org).

pdb_extract[22] helps prepare depositions from X-ray crystallography and NMR. This software tool automatically extracts information needed for deposition from the output files produced by many applications used for structure determination. The collected information is organized into a file that is ready for ADIT deposition. Using pdb_extract saves time and minimizes errors in the deposition process. pdb_extract can be downloaded in source and binary versions. It is also part of the CCP4i interface.

The RCSB PDB Validation Suite[23] can be used to check the coordinate format and validate the overall structure before deposition. The validation report contains geometrical and experimental checks from the programs MolProbity,[24] NUCheck, PROCHECK,[25] and SFCHECK.[26] Sequence/coordinate alignment, missing and extra atoms or residues, and data inconsistencies are also reported. The Validation Suite can also be used to check on the quality of any released structure before using the data in other research.

Ligand Depot[27] is a data warehouse that integrates databases, services, tools and methods to provide chemical and structural information about the small molecules bound to macromolecules in the PDB. It can be used to find codes for existing ligands, to link to other entries with a particular ligand, and to search for substructures.

The deposition tool ADIT is available online from the RCSB PDB and PDBj, and is also available as a software download for standalone desktop use. ADIT provides access to a collection of programs for data input, validation, annotation, and format exchange. The ADIT system uses the PDB exchange format that is based on the macromolecular Crystallographic Information File (mmCIF) dictionary[28] (**see also page 13**).



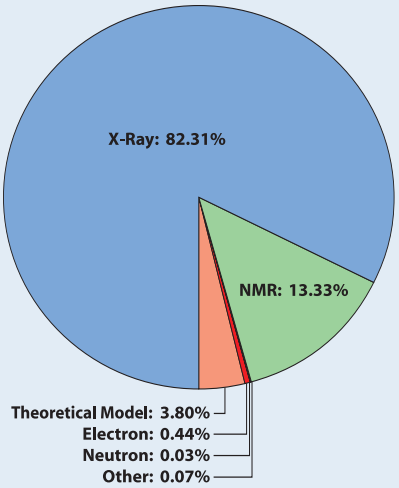
RCSB PDB Services: Data Deposition

Statistics

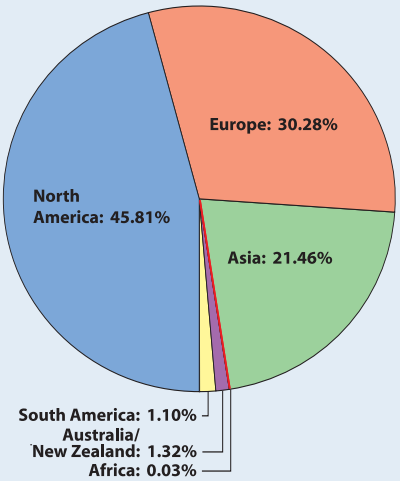
During the period covered by this report, 6987 files were deposited to the wwPDB from around the world. Of these structures, approximately 82% were deposited with experimental data. Sequence data for about 60% of the depositions were released prior to the structure's release. More than half of the structures deposited to the PDB archive were processed by the RCSB PDB.

Structures Deposited to the PDB Archive (July 2005 – June 2006)

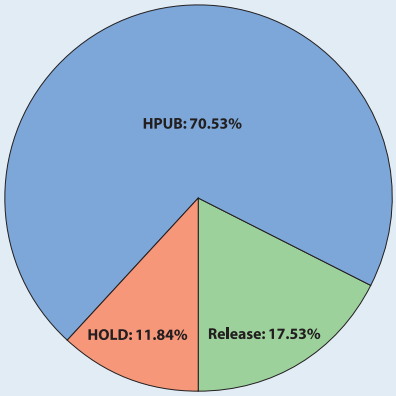
Structure Source



Continent of Origin



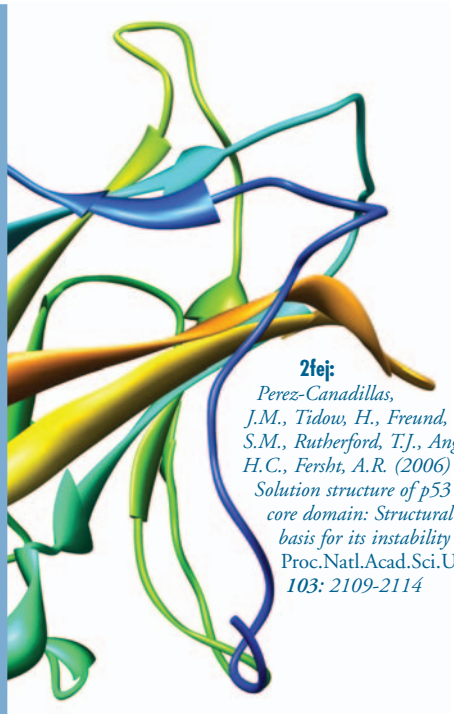
Author-Defined Release Status



Annotators...

- Review entry for self-consistency
- Match given title to structure
- Correct format errors in data and coordinates
- Check sequence (using BLAST)[21]
- Insert sequence database references
- Provide protein name and synonyms
- Check scientific name of source organism
- Confirm chemical consistency between ligand name and coordinates
- Add biological unit information
- Check entry visually
- Generate validation reports
- Find citation references with PubMed[21]

... to represent PDB data in the best possible way



2fej:
Perez-Canadillas, J.M., Tidow, H., Freund, S.M., Rutherford, T.J., Ang, H.C., Fersht, A.R. (2006) Solution structure of p53 core domain: Structural basis for its instability Proc.Natl.Acad.Sci.USA *103: 2109-2114*

RCSB PDB Services: Data Query, Reporting & Access

Data Distribution and Access

RCSB PDB services and data from the PDB archive are freely available through the internet. The main RCSB PDB website is visited by over 150,000 individual users each month, ranging from high school students to scientific experts in a variety of fields. On average, more than two structure files are downloaded each second for local analysis by users. The RCSB PDB website is maintained 24 hours a day, seven days a week. A failover system automatically redirects internet traffic to a mirror site, if needed.

New structures are added to the RCSB PDB website and FTP archive by 1:00 a.m. Pacific Time every Wednesday, 52 weeks per year. The structures included in each release are highlighted on the home page and clearly defined on the FTP site. During the period of this report, 6157 coordinate files were released into the archive, along with 4467 structure factor files, and 470 NMR constraint files.

Data Query and Reporting

Visitors to the RCSB PDB website can perform simple and complex queries on more than 37,000 structures and explore more than 900 curated web pages.

The goal of the RCSB PDB website is to make every structure accessible and comprehensible to all of our data users – students and teachers, biologists, structural biologists, computational biologists and the public at large.

Whether looking for individual or multiple structures, users have a variety of options for searching and viewing structures. Each individual entry has a page that provides summary information, static and interactive images of the molecule, and links to other sources. A variety of reports can be created for a group of structures resulting from any query. Options to refine the query or create tabular reports from the search results are also available. Any structure can be downloaded in PDB, mmCIF or PDBML/XML format from the RCSB PDB web or FTP site.

In January 2006, the RCSB PDB released a newly designed website with a completely reengineered database.[29] The new site is characterized by a faster response time. It offers a broader set of data, and more features about each structure are available.

The redesign of the website offers improved accessibility and navigation, and allows for the rapid addition of new features and resources to the RCSB PDB. Enhancements have been made to keep the resources and tools related to structural genomics, education, and software within easy reach.

Since the new database utilizes PDB data that has been remediated and standardized, it supports improved searches and reports. The site offers improved simple keyword searches and advanced searches on a variety of features. The results of one search can immediately be used as input to a refined search and the final results can be analyzed and displayed in a variety of ways.

The new visualization tool Protein Workshop uses the molecular biology toolkit (**mbt.sdsc.edu**)[30] to help novice and expert users explore the features of a structure, such as protein-ligand interactions.

Associated data taken from the DBsnp[21] maps Single Nucleotide Polymorphisms (SNPs) to structures and indicates how structures are related to disease and our basic genomic make-up.

A clear distinction between the reported primary and derived data is made, and external data resources (such as SCOP[31], CATH[32], and chromosome location from Entrez[21]) have been integrated. A permanent search tab offers different ways of accessing the database, including a method for "browsing" through structures grouped in categories (related to, for example, medical subject heading,[21] molecular function, biochemical process, or cellular location[33]).

A narrated presentation (in Flash) guides users through searching, navigating, generating reports, visualizing structures, and browsing PDB data on the new site. A searchable help system, tutorials, and user guides provide detailed information for accessing the website, database, and for understanding PDB data.

Thanks to comments sent from users, this website is constantly being refined and enhanced. Feedback comes from the PDB help desk, conference attendance, focus groups, advisory meetings, and other personal interactions between RCSB PDB users and staff.

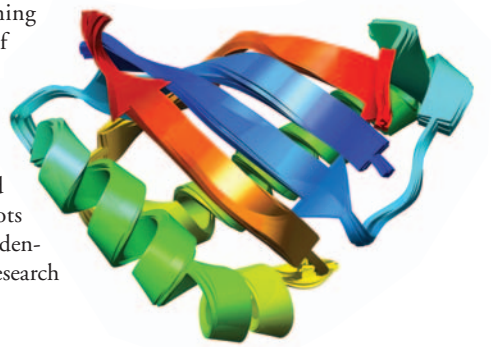
2006 Statistics

Web query statistics for the RCSB PDB website (**www.pdb.org**):

Month	Unique Visitors	Number of Visits	Bandwidth
Jan	99418	180619	537.96 GB
Feb	103250	216373	679.88 GB
Mar	124000	263997	601.60 GB
Apr	152465	318730	654.20 GB
May	157055	336815	539.67 GB
Jun	184812	398210	547.05 GB

Time-stamped Copies of PDB Archive

As part of a wwPDB initiative, time-stamped snapshots of the PDB archive are added each year to **ftp://snapshots.rcsb.org**. It includes a directory containing the 34,421 experimentally-determined coordinate files that were current (*i.e.* not obsolete) and related data as of January 3, 2006, and a directory containing the FTP content as of January 6, 2005. Scripts are available to assist in the automated download of these data. It is hoped that these snapshots will provide readily identifiable data sets for research on the PDB archive.



2acm: *Macao, B., Johansson, D.G.A., Hansson, G.C., Hard, T. (2006) Autoproteolysis coupled to protein folding in the SEA domain of the membrane-bound MUC1 mucin* Nat.Struct.Mol.Biol. ***13:*** *71-76*

Structural Genomics

Structural genomics efforts located around the globe are focused on determining a large number of structures in a high throughput mode. As the PDB is the repository for these protein structures, an emphasis is made on developing resources that facilitate ways to deposit, track, and access structural genomics data. The RCSB PDB is actively involved in developing the informatics infrastructure needed for these projects, including the maintenance of data dictionaries describing these experiments. An online information portal also offers online tools, summary reports, and target information related to structural genomics at **sg.pdb.org**.[34]

Information and links are provided for the structural genomics initiatives located worldwide, including reports for each center that provide target lists, target status progress, targets in the PDB, and sequence redundancy analyses.

Databases are available to provide current information about the progress of protein production and structure solution at the various worldwide structural genomics centers. These resources facilitate the coordination needed between the different centers to promote efficient structure solution. The Target Registration Database (TargetDB; **targetdb.pdb.org**)[35] contains information about the progress of the production and solution of structures. The Protein Expression Purification and Crystallization Database (PepcDB; **pepcdb.pdb.org**)[34] extends the content of TargetDB with status history, stop conditions, reusable text protocols and contact information collected from the Protein Structure Initiative Centers funded by the NIGMS.

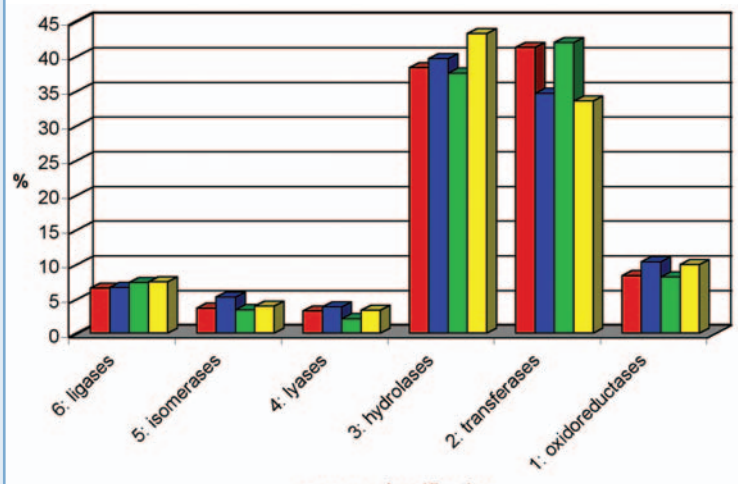
A tool is provided to explore the distributions of functions found among structural genomics structures, PDB structures, genomes, and homology models.[36] This functional coverage can be examined according to Enzyme Classification,[37] Gene Ontology (biological process, cell component, or molecular function)[33] and disease (**see box, this page**).[21]

The RCSB PDB is also involved with the structural genomics initiatives through active participation in task forces, meetings, workshops, and individual interactions with each of the structural genomics centers.

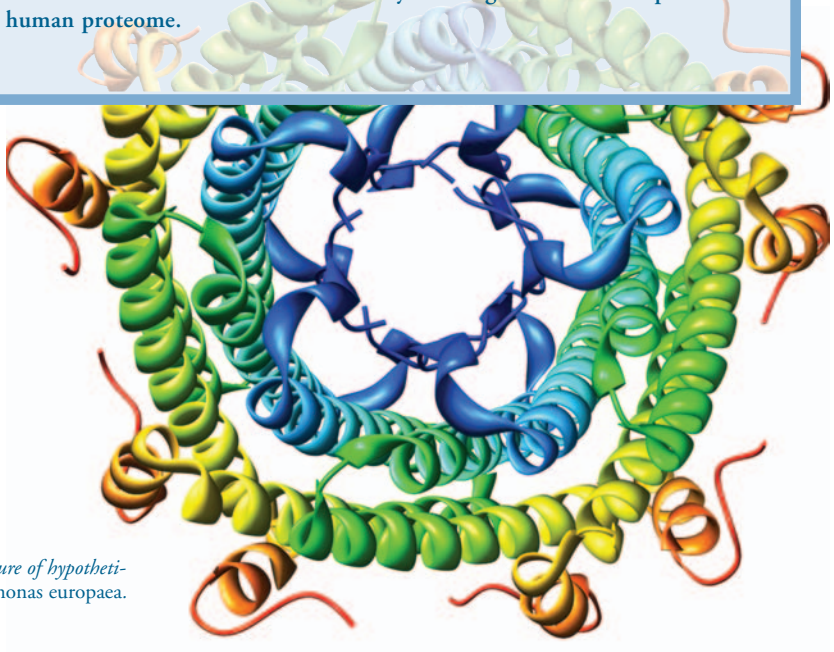
Functional Implications of Structural Genomics

Structural genomics – the effort to determine the three-dimensional structure of all proteins – is being conducted on a large scale by a number of centers worldwide. One of its goals is to improve the understanding of the relationship between biological structure and biological function. The Functional Distribution option of the RCSB PDB structural genomics portal offers a way to continually review the available experimental structures and how they are providing functional coverage of the human genome. This feature also reports on the number of related models available to provide a way of showing how the understanding of disease is being increased by the availability of these structures.

Enzyme Classification Distributions



Normalized distribution of different classes of enzymes, showing the human genome (red), structures in the PDB (blue), structural genomics targets (green), and structures that can be modeled (yellow). It shows that the available structures and models are not evenly covering the functional space of the human proteome.



1zpy: *Midwest Center for Structural Genomics. Crystal structure of hypothetical protein NE0167 from* Nitrosomonas europaea.

Educational Resources

RCSB PDB Tools to Browse, Search, and Visualize Proteins in the Classroom

- Different options to search for specific biological molecules
- Database browsable by function, source organism, or medical terms
- Interactive molecular viewers
- Resources to compare structures
- Links to scientific articles describing the molecules

Students learned how to build hands-on models of the common cold virus at the 2006 Science and Engineering Expo held at Princeton University

RCSB PDB in the Classroom

The RCSB PDB is used in classrooms all over the world. It offers a variety of features and activities that promote teaching and learning about structural biology for all levels of interest. These range from an online collection of educational resources, to the quarterly newsletter column describing how the RCSB PDB is used in the classroom, to a traveling *Art of Science* exhibit. The RCSB PDB has hosted field trips, participated in science fairs, and has been involved in educational curriculum development.

Molecule of the Month Series

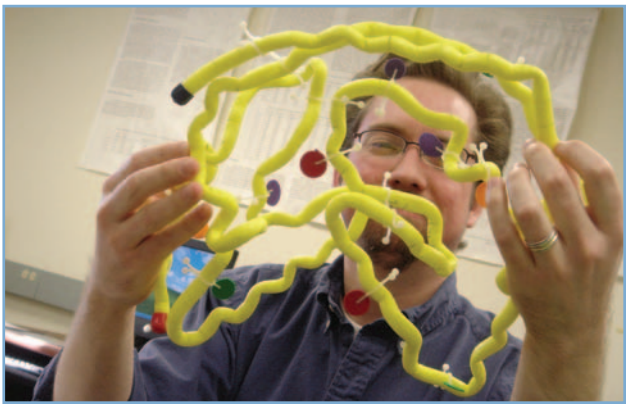
Accessible from the RCSB PDB homepage, the *Molecule of the Month* series describes selected molecules from the PDB archive. Each installment introduces the structure and function of a molecule, and relates it to human health and welfare. Special illustrations are used to compliment the text. Suggestions for viewing structures on the RCSB PDB website and for additional reading are also provided. Since the first installment in 2000, the *Molecule of the Month* has been a proven resource for the classroom. Recent features are highlighted on the cover of this report.

Science Olympiad

Several high school students competed in the protein modeling trial event at the 2006 New Jersey Northern Regional and State Science Olympiads (**education.pdb.org**). The event challenged students to explore protein structure and to study the relationship of structure to protein function using computer visualization programs, resources from the RCSB PDB, and physical modeling tools.

Working in teams, students visualized a protein structure on a computer, translated that image into a physical model, and identified key structural elements that contribute to the protein's function. The team score was based on the accuracy and completeness of the models and their answers to questions about the protein's structure.

The three-dimensional protein models of the TATA-binding protein, designer proteins, and cholera toxin were built by the students using Mini-Toober[a] kits provided by the RCSB PDB. A training workshop for teachers and students participating in the Science Olympiad was held at RCSB-Rutgers.



RCSB PDB annotator and NJ Science Olympiad judge Jeramia Ory examines one of the TATA-binding protein models

Students building a protein model at the NJ Regional Science Olympiad

[a]Mini-Toobers are products of 3D Molecular Designs: **www.3dmoleculardesigns.com**

Educational Resources

ImmersivePDB

The PDBAC explores ImmersivePDB at UCSD

ImmersivePDB (formerly PDB-in-a-CAVE) is a software application used for visualizing molecular structures in an immersive virtual reality environment. The first version was released in collaboration with the California Institute for Telecommunications and Information Technology (Calit2) this year. Wearing stereoglasses, the viewer can move through and around a structure that is projected in the CAVE using ImmersivePDB. With over 100 CAVE environments around the world, users may now download and visualize any PDB structure while in this unique environment.

Art of Science

The *Art of Science* exhibit is designed to introduce viewers to the beauty found in structural biology. Intended for all audiences, the show includes pictures available from the RCSB PDB website and *Molecule of the Month* features. Since its beginnings at Rutgers University in New Jersey in 2002, the show has traveled to Calit2 at UCSD; Virginia Polytechnic Institute and State University; Texas A & M University; EMBL-Hamburg, Germany; University of Wisconsin-Madison; California State University, Fullerton; Purdue University; and Hyderabad, India. The RCSB PDB would like to see the *Art of Science* travel to other places. If you would be interested in sponsoring this exhibit at your institution, please let us know at info@rcsb.org.

RCSB PDB Newsletter

Published quarterly in print and online, the RCSB PDB Newsletter highlights recent RCSB PDB activities. It also hosts an *Education Corner* that describes how the PDB archive and RCSB PDB resources are used by teachers and students, and features a *Community Focus* interview with many of the scientific luminaries in the PDB user community.

RECENT PUBLICATIONS

Berman, H. M., R. C. Dreyfuss (2006). "Reflections on the science and law of structural biology, genomics, and drug development" *UCLA Law Review* **53**:871-908.

Berman, H. M., K. Henrick, H. Nakamura and E. Arnold (2006). "Is one solution good enough? (response)." *Nature Structural & Molecular Biology* **13**: 185.

Fitzgerald, P. M. D., J. D. Westbrook, P. E. Bourne, B. McMahon, K. D. Watenpaugh and H. M. Berman (2005). Classification and use of macromolecular data. *International Tables for Crystallography.* S. R. Hall and B. McMahon. Dordrecht, The Netherlands, Springer. **G.** Definition and exchange of crystallographic data: 144-198.

Fitzgerald, P. M. D., J. D. Westbrook, P. E. Bourne, B. McMahon, K. D. Watenpaugh and H. M. Berman (2005). Macromolecular dictionary (mmCIF). *International Tables for Crystallography.* S. R. Hall and B. McMahon. Dordrecht, The Netherlands, Springer. **G.** Definition and exchange of crystallographic data: 295-443.

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Westbrook, J., N. Ito, H. Nakamura, K. Henrick and H. M. Berman (2005). "PDBML: The representation of archival macromolecular structure data in XML." *Bioinformatics* **21**: 988-992.

Westbrook, J., H. Yang, Z. Feng and H. M. Berman (2005). The use of mmCIF architecture for PDB data management. *International Tables for Crystallography.* S. R. Hall and B. McMahon. Dordrecht, The Netherlands, Springer. **G.** Definition and exchange of crystallographic data: 539-543.

Westbrook, J. D., H. M. Berman and S. R. Hall (2005). Specification of a relational Dictionary Definition Language (DDL2). *International Tables for Crystallography.* S. R. Hall and B. McMahon. Dordrecht, The Netherlands, Springer. **G.** Definition and exchange of crystallographic data: 61-72.

Xie, L. and P.E. Bourne, (2005) "Functional coverage of the human genome by existing structures, structural genomics targets, and homology models." *PLoS Comp Biol.* **1**: e31.

Related Resources

Data Dictionaries: mmCIF and the PDB Exchange Dictionary

The RCSB PDB uses mmCIF data dictionaries to describe the information content of PDB entries. The mmCIF dictionary is an ontology of more than 3,900 terms defining macromolecular structure and its related experiments (**mmcif.pdb.org**).[28, 38]

The PDB Exchange Dictionary consolidates content from a variety of data dictionaries and includes extensions to describe NMR, 3D EM, and protein production data. PDB data processing, data exchange, annotation, and database management operations all make heavy use of the mmCIF data format and the content of the PDB Exchange Dictionary.[39]

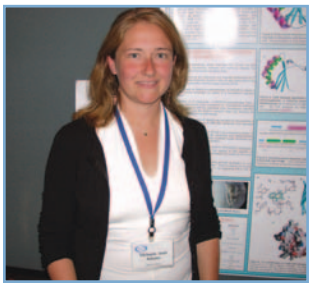
PDB entries can be downloaded from the RCSB PDB website or by ftp in mmCIF, PDB, and PDBML/XML[40] formats. Software tools are available for preparing and editing files for new depositions, and for converting mmCIF data files to PDB and PDBML/XML formats.

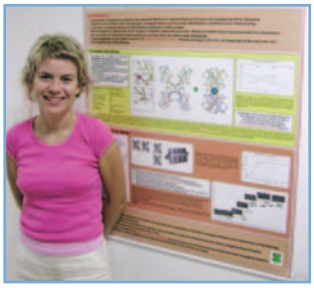
Community Interactions

The RCSB PDB has a diverse user community of depositors, data users, students, teachers, and the general public. Through exhibits, publications, and an active help desk, we gain feedback for further development of the RCSB PDB while providing materials that promote scientific literacy and a broader understanding of structural biology.

Several exhibit booths and posters were presented to interact with the various members of the RCSB PDB user communities – depositors (*e.g.* International Union of Crystallographers (IUCr)), data users (Biophysical Society, Intelligent Systems for Molecular Biology), structural genomists (Frontiers in Structural Biology/Structural Genomics), and educators (New Jersey Science Convention, National Science Teachers Association).

The RCSB PDB awards a poster prize for the best student poster presentation at a number of different meetings throughout the year. In 2005, the prize was awarded at the American Crystallographic Association Meeting (ACA), the IUCr Congress and General Assembly, and the International Conference on Research in Computational Molecular Biology (RECOMB).





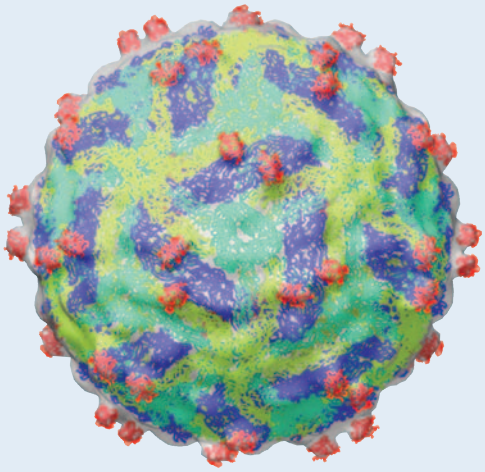
The 2005 RCSB PDB Poster Prize winners: Melanie A. Adams (Queens University, Canada) at ACA and Saša Jenko Kokalj (Jožef Stefan Institute, Slovenia) at IUCr. (Not pictured: Andrew V. McDonnell (MIT) and Alexandra Shulman-Peleg (Tel-Aviv University), co-winners at RECOMB)

The website at **www.pdb.org** is updated weekly with news, recent developments, new resources, and improvements to existing documents. Educational features, such as new *Molecule of the Month* installments, are posted regularly.

Cryo-EM Definition Development Project

The RCSB PDB and the MSD-EBI are working together to establish a "one-stop shop" for deposition and retrieval of cryo-electron microscopy (cryoEM) data. The goal is to create a robust system for the collection, validation, annotation, distribution and visualization of structures derived from cryo-EM experiments and analyses.

A comprehensive dictionary of cryo-EM data items is being developed. The present dictionary (**mmcif.pdb.org/dictionaries/mmcif_em.dic/Index**) includes 54 categories and more than 500 data items to describe different aspects of single particle, 2D electron diffraction, and helical diffraction cryo-EM experiments.



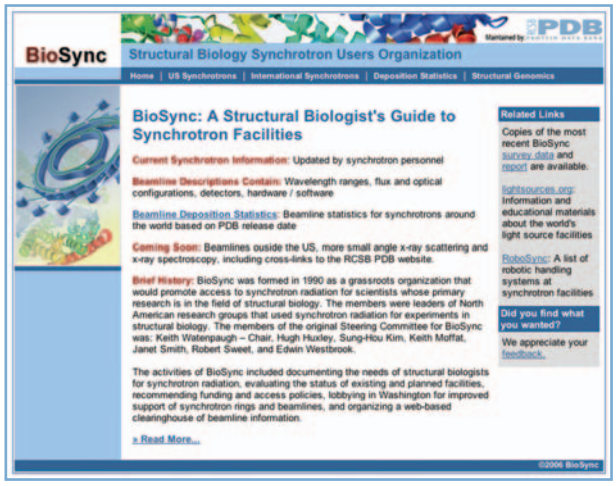
2b6b: *Pokidysheva, E., Zhang, Y., Battisti, A.J., Bator-Kelly, C.M., Chipman, P.R., Xiao, C., Gregorio, G., Hendrickson, W.A., Kuhn, R.J., Rossmann, M.G. (2006) Cryo-EM reconstruction of dengue virus in complex with the carbohydrate recognition domain of DC-SIGN* Cell ***124****: 485-493.*

Workshop on Biological Macromolecular Structure Models

In order to help resolve the many issues surrounding the archiving of and access to models, a workshop was held in November 2005. Participants included experimental biologists, scientists with expertise in structure determination by X-ray crystallography, NMR, and 3D EM, and computational biologists with expertise in modeling. The goal of this workshop was to open a dialog between experimentalists and modelers so that the PDB can most usefully meet the needs of the scientific community regarding models of biological macromolecules. The workshop explored: needs of the modeling community with respect to the archiving of models; needs of the experimentalists with respect to the availability of models; current limitations of theoretically derived models; how the scientific community at large can be best served with respect to the availability and annotation of models; and quantitative measures that should be used to assess the accuracy of models. The resulting white paper from this meeting was published in *Structure*.[41] The key recommendation was that PDB depositions should be restricted to atomic coordinates substantially determined by experimental measurements on specimens containing biological macromolecules.

Related Resources

BioSync



BioSync (Structural Biology Synchrotron Users Organization) was formed in 1990 as a grassroots organization intended to promote access to synchrotron radiation. It established a web-based clearinghouse for beamline information at synchrotron facilities. The BioSync resource, originally designed and hosted by USCD/SDSC, has been updated and is now being maintained by the RCSB PDB at **BioSync.rcsb.org**.

With its bright new look, the BioSync website currently contains updated descriptions of operational US synchrotron beamlines used for single crystal macromolecular crystallography. International sites and beamlines are listed and will go 'live' as data is added for each one. PDB deposition statistics are grouped by site and beamline, and are cross-linked to the RCSB PDB.

Comments and suggestions are welcome at **BioSync@deposit.pdb.org**.

Data Uniformity

Each of the wwPDB partners has independently undertaken efforts to remediate PDB data. As part of the wwPDB collaboration, the MSD-EBI, PDBj, and RCSB PDB are working to integrate this work into a single consistent collection of data files.

The RCSB PDB is continuing on-going work to improve the representation of small molecule data in the PDB, and has consolidated chemical definitions and assignments to accurately describe stereochemistry of small molecules in all PDB entries. This work includes the careful review of the 3D structure and associated literature. A full assessment of the required chemical definitions and their correspondences in PDB entries is currently underway. RCSB PDB is also collaborating with MSD-EBI on the resolving any remaining differences in the macromolecular sequences assigned by each group. RCSB PDB, MSD-EBI, and PDBj are all collaborating on resolving differences in primary citation assignments.

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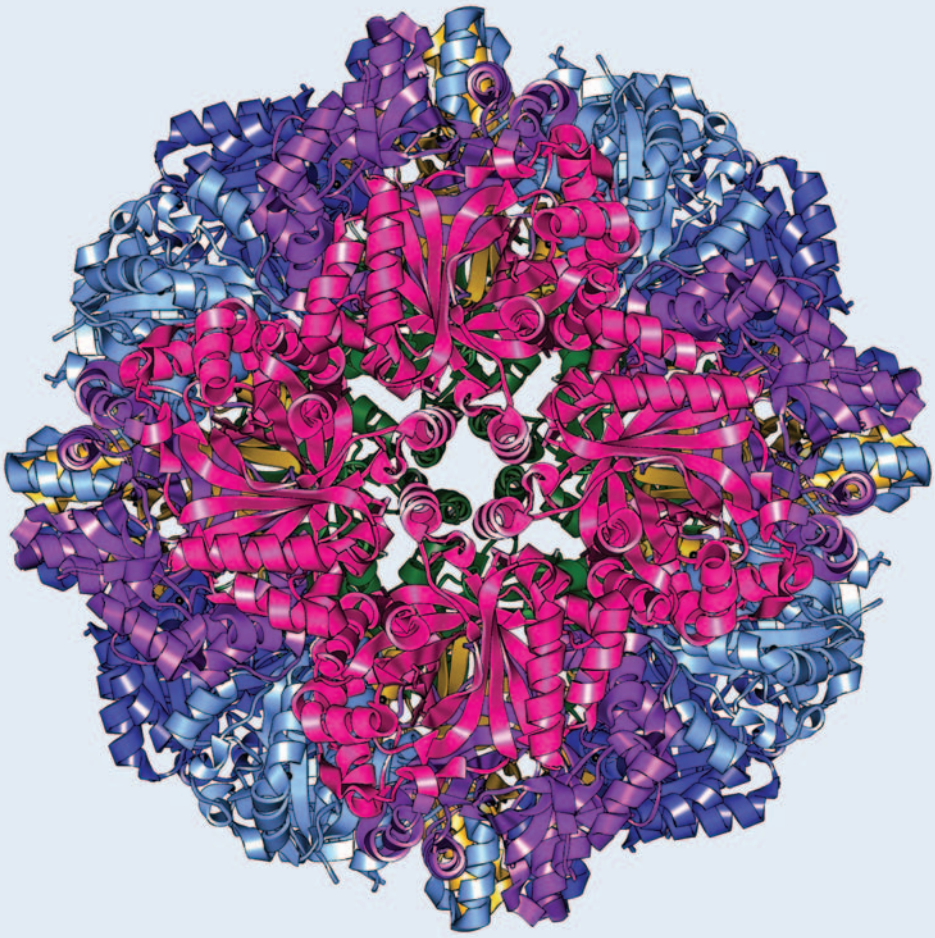
Images of the biological macromolecules in this report were created using CHIMERA.[42]



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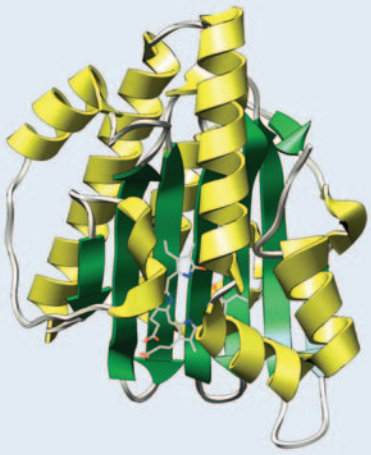

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