### PSI nature StructuralGenomicsKnowledgebase



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# 2010 Calendar

### Contacts

### **About this calendar**

#### **ON THE COVER**

Research in bioinformatics has shown that proteins are often modular, and that these modules are often mixed and matched to form new proteins. Researchers at the PSI Midwest Center for Structural Genomics have determined the structure of the novel protein TA0289, now called Cystathionine Beta-Synthase Domain (CBS) protein, was made from a new combination of two familiar modules. Its structural determination was the first step towards uncovering the function of this unusual new family of proteins.

#### Read about this protein and more at: kb.psi-structuralgenomics.org/structures.jsp

Proudfoot, Sanders, Singer, Zhang, Brown, Binkowski, Xu, Lukin, Murzin, Joachimiak, Arrowsmith, Edwards, Savchencko, Yakunin. (2008) Biochemical and structural characterization of a novel family of cystathionine beta-synthase domain proteins fused to a Zn ribbon-like domain. J Mol Biol 375, 301-315. PDB ID: 2qh1

#### **ABOUT THE PSI SGKB**

The Protein Structure Initiative Structural Genomics Knowledgebase (PSI SGKB, **kb.psi-structuralgenomics.org**) is a free online resource that enables users to discover how amino acid sequences, 3D structures, and theoretical models help us understand protein function. A single search of the SGKB will provide links to 3D structures, pre-built models, annotations, target information, protocols, and access to DNA clones. The site offers an easy way to keep abreast of developments both by the PSI and more generally in the fields of structural genomics and structural biology.

#### **ABOUT THIS CALENDAR**

The 2010 PSI SGKB Calendar is composed of selections from the PSI Featured Molecule series, written and illustrated by David Goodsell (The Scripps Research Institute) especially for the SGKB. For each month, we present a space-filling representation, like the image below which shows the overall shape and volume of the biomolecule, a ribbon diagram to show how the amino acid sequence folds into the presented 3D shape, and an explanation about the biological and/or biomedical relevance of this protein structure for readers of all ages and backgrounds.

#### ABOUT THE PSI FEATURED MOLECULE

The PSI Featured Molecule (kb.psi-structuralgenomics.org/ featured\_molecule\_latest.html) is a monthly article about one of the many protein structures solved by the PSI structural genomics efforts. Molecular images are created by the Python Molecular Viewer (mgltools.scripps.edu). In addition to the images and article mentioned above, the PSI Featured Molecule includes an interactive view of the protein structure to allow users to explore the 3D structure in their web browser.

#### PSI | nature StructuralGenomicsKnowledgebase

The Structural Genomics Knowledgebase is produced in a collaboration between the Protein Structure Initiative (PSI) and Nature Publishing Group (NPG). Funding is provided by the National Institute of General Medical Sciences.

#### THE PROTEIN STRUCTURE INITIATIVE

The PSI is a federal, university, and industry effort aimed at dramatically reducing the costs and lessening the time it takes to determine a three-dimensional protein structure. The long-range goal of the PSI is to make the 3D atomic-level structures of most proteins easily obtainable from knowledge of their corresponding DNA sequences.

#### NATURE PUBLISHING GROUP

NPG is the scientific publishing arm of Macmillan Publishers Ltd. It publishes journals and online databases across the life, physical and applied sciences and, most recently, clinical medicine. Content encompasses daily news from award-winning journalists, expert opinion and practical methodology, and high impact research and reviews.

#### **CONTACT US**

For questions or comments regarding the PSI SGKB, feel free to write us at:

comments@psi-structuralgenomics.org





# Aquaglyceroporin

doi:10.3942/psi sgkb/fm 2009 3

3c02

Malarial parasites must build a lot of membrane as they multiply, which requires a constant supply of fatty acids and glycerol, the building blocks of lipids. A recent study of the genome of the malaria parasite discovered an aquaglyceroporin, revealing that the parasite may get most of its glycerol directly from the host rather than building it itself using precursors from glycolysis.

#### **CHANNELING GLYCEROL**

Aquaglyceroporin is a passive channel, allowing glycerol and water to pass through the membrane from regions of higher concentration (outside the cell) to regions with lower concentration (inside the cell). It is a tetramer of identical subunits, arranged in a ring, with a channel running through the middle of each subunit. There is also a second set of pores formed in the middle of each of the four subunits, but they are sealed by four tyrosines, which together form a watertight fireman's grip that blocks the channel.

#### THE SPECIFICITY FILTER

Aquaglyceroporin is a member of a larger family of aquaporins ("water passage" proteins) that have the remarkable capability of allowing water and glycerol to pass through the membrane while restricting the passage of smaller protons and ions, essential players in energy management and signaling. This specificity is accomplished through the use of a specificity filter, a ring of amino acids that recognize the molecules being passed, and exclude all others.

#### **DUAL SPECIFICITY**

The structure of the malaria parasite aquaglyceroporin, solved by researchers at the PSI Center for Structures of Membrane Proteins (PDB entry 3c02), gives a close-up look at how its dual specificity for glycerol and water is achieved. The filter includes an arginine that forms hydrogen bonds with glycerol and water, and two aromatic amino acids that cradle the hvdrophobic face of glycerol. Typical waterspecific aquaporins have a channel too narrow for glycerol to pass, and the arginine is tightly hydrogen-bonded to neighboring amino acids, reducing the energetic cost of desolvation. Glycerol-specific channels, on the other hand, have a wider channel to accommodate the larger glycerol molecule, and the arginine forms fewer hydrogen bonds with the surrounding protein, presumably increasing the energetic cost of desolvation and reducing the flow of water through the channel. The bifunctional aquaglyceroporin combines both of these traits: it has a wider channel that allows passage of glycerol, and a tightly hydrogen-bonded arginine to assist with water passage.

Newby, O'Connell, Robles-Colmenares, Khademi, Miercke, Stroud. (2008) Crystal structure of the aquaglyceropoin PfAQP from the malarial parasite *Plasmodium falciparum. Nat Struct Mol Biol* **15**, 619-625. **PDB ID: 3c02** 

Hansen, Kun, Schultz, Beitz. (2002) A single, bi-functional aquaglyceroporin in blood-stage *Plasmodium falciparum* malaria parasite. *J Biol Chem* **277**, 4874-4882.

# January 2010

SGKB Quick Fact The **SGKB Database** is updated weekly with new targets, structures, methods, and annotations. Learn about all this, and how to subscribe to RSS feeds and E-alerts, at

kb.psi-structuralgenomics.org/KB/

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
DECEMBER 2009    S  M  T  W  T  F  S    1  2  3  4  5    6  7  8  9  10  11  12    13  14  15  16  17  18  19    20  21  22  23  24  25  26    27  28  29  30  31	FEBRUARY    S  M  T  W  T  F  S    1  2  3  4  5  6    7  8  9  10  11  12  13    14  15  16  17  18  19  20    21  22  23  24  25  26  27    28				<b>1</b> New Year's Day	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	<b>18</b> Martin Luther King Jr. Day	19	20	21	22	23
24 31	25	26	27	28	29	30

### SARS Coronavirus Nonstructural Protein 1

doi:10.3942/psi\_sgkb/fm\_2008\_6

2hsx

Researchers at the PSI Joint Center for Structural Genomics have obtained the first look at nsp1 (nonstructural protein 1), a major factor in the pathogenicity of the coronavirus that causes SARS (severe acute respiratory syndrome). Ever since the international outbreak of the virus in 2003, researchers have been studying this virus, hoping to find methods to fight it if it re-emerges in the future.

#### THE CORONAVIRUS PROTEOME

The genome of the SARS coronavirus encodes 28 proteins that orchestrate its lifecycle of cell death, with sixteen of these coding for nonstructural proteins involved in replication (named nsp1-nsp16). Some of the nonstructural proteins have familiar functions common to many viruses, such as a polymerase that replicates the RNA genome and proteases that cleave the viral polyproteins into functional pieces. Others, including nsp1, play supporting roles by suppressing the normal processes of the cell and blocking the normal defenses. Nsp1 is an attractive target for therapy since it plays a role early in infection: it is one of the first proteins produced by the virus and it has been shown to be important for the pathogenicity of the virus.

#### THE FIGHT AGAINST SARS

Based on studies of viruses that are missing nsp1, researchers now think that nsp1 blocks the normal innate immune response that protects us from viral infection. This allows the SARS coronavirus to infect cells and replicate, free from our normal defenses. Researchers have designed a vaccine by engineering a coronavirus that is missing nsp1. This mutant coronavirus is weakened, much like the attenuated polioviruses used in the polio vaccine, allowing them to stimulate the immune response without leading to a full infection of SARS.

#### A NEW FOLD

The structure of nsp1 yielded another dividend: a new fold. Nsp1 is a small protein with 179 amino acids. Both ends of the chain are disordered, but the center (residues 13 to 128) forms a stable folded structure. The NMR structure obtained by PSI Joint Center for Structural Genomics (PDB entry 2hsx) reveals an entirely new fold composed of an irregular six-stranded beta barrel with a bridging alpha helix. The SARS coronavirus has actually been the source of a surprising number of new protein folds: of the 16 structures that are currently available, 8 show a new fold. This may be a reflection of the rapid evolution of viruses, which allows more room for natural experimentation with new protein folds.

Almeida, Johnson, Herrmann, Geralt, Wüthrich. (2007) Novel β-barrel fold in the nuclear magnetic resonance structure of the replicase nonstructural protein 1 from severe acute respiratory syndrome coronavirus. *J Virol* 81, 3151-3161. **PDB** ID: **2**hsx Bartlam, Xu, Rao. (2007) Structural proteomics of the SARS coronavirus: a model response to emerging infectious disease. *J Struct Funct Genomics* **8**, 85-97.

# February 2010

SGKB Quick Fact The Protein Structure Initiative encourages scientists to submit protein sequences for structural determination. Read the PSI policies about **Community-Nominated Targets** and make your nominations now at

cnt.psi-structuralgenomics.org/CNT/

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	1	2	3	4	5	6
7	8	9	10	11	12	13
<b>14</b> Valentine's Day Chinese New Year	<b>15</b> Presidents' Day	16	17	18	19	20
21	22	23	24	25	26	27
28					JANUARY    S  M  T  W  T  F  S    1  2  3  4  5  6  7  8  9    10  11  12  13  14  15  16    17  18  19  20  21  22  23    24  25  26  27  28  29  30    31	MARCH    S  M  T  W  T  F  S    1  2  3  4  5  6    7  8  9  10  11  12  13    14  15  16  17  18  19  20    21  22  23  24  25  26  27    28  29  30  31

### **Salicylic Acid Binding Protein 2**

doi:10.3942/psi sqkb/fm 2009 8

Centuries ago, the ancient Greeks and Native Americans discovered that willow bark dulls pain. The pain-killing molecule is salicylic acid, the inspiration for aspirin, but why plants make this molecule has been a mystery until now.

#### **DEFENSIVE ACTION**

Plants have developed a complex and multi-layered system to protect themselves from attack by bacteria and viruses. When a leaf gets infected, for instance by tobacco mosaic virus, the local cells make the ultimate sacrifice, inducing a form of programmed cell death. This helps control the spread of the virus by proactively removing all infectable cells in the neighborhood. At the same time, the plant launches a more systemic defense. It sends a signal to all of its distant parts, telling them to build defensive proteins and ready themselves for attack. These defenses are costly, and may result in stunted growth, but this is better than completely losing the battle against the attacker.

#### **AROMATIC SIGNALS**

sistance. J Biol Chem 284, 7307-7317.

Methyl salicylate, the methyl ester of salicylic acid, is used as a neutral messenger, created by cells under attack and delivered to cells throughout the plant. Then, the enzyme SABP2 (salicylic acid

binding protein 2) takes methyl salicylate and cleaves off the methyl group, releasing active salicylic acid, which stimulates the production of defensive proteins in the target cells.

#### **SABP2 IN ACTION**

SABP2 was originally discovered by its ability to bind to salicylic acid (hence its name), but the structure of the protein solved by researchers at the PSI Northeast Structural Genomics Consortium revealed its role in cleavage of methyl salicylate and inhibition of the reaction by the product, salicylic acid. The structure (PDB entry 1y7i) shows that SABP2 is one of a class of alpha/beta hydrolase enzymes that cleave small esters and other molecules. The active site completely surrounds the molecule, recognizing both the distinctive aromatic ring and the acidic group. A catalytic triad reminiscent of the digestive serine proteases performs the cleavage reaction.

Forouhar, Yang, Kumar, Chen, Fridman, Park, Chiang, Acton, Montelione, Pichersky, Klessig, Tong. (2005) Structural and biochemical studies identify tobacco SABP2 as a methyl salicylate esterase and implicate it in plant innate immunity. Proc Natl Acad Sci USA 102, 1773-1778. PDB ID: 1y7i

analog to investigate the roles of methyl salicylate and its esterases in plant disease re-

Park, Kaimoyo, Kumar, Mosher, Klessig. (2007) Methyl salicylate is a critical mobile signal for plant systemic acquired resistance. Science 318, 113-116.

Loake, Grant. (2007) Salicylic acid in plant defense--the players and protagonists Curr Op Plant Biol 10, 456-472.

Park, Liu, Forouhar, Vlot, Tong, Tietjen, Klessig. (2009) Use of a synthetic salicylic acid Durrant, Dong. (2004) System acquired resistance, Annu Rev Phytopathol 42. 185-209.

1v7i

# **March 2010**

SGKB Quick Fact Browse over 2000 publications about new structures, methods, and technologies, organized by biological category, in the **SGKB Research Library at** 

kb.psi-structuralgenomics.org/update/library.html

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17 St. Patrick's Day	18	19	20 Spring begins
21	22	23	24	25	26	27
<b>28</b> Palm Sunday	29	30 Passover	31		FEBRUARY    S  M  T  W  T  F  S    1  2  3  4  5  6    7  8  9  10  11  12  13    14  15  16  17  18  19  20    21  22  23  24  25  26  27    28	A PRIL    S  M  T  W  T  F  S    1  2  3  4  5  6  7  8  9  10    11  12  13  14  15  16  17    18  19  20  21  22  23  24    25  26  27  28  29  30

### Bacteriophage Lambda cll Protein

doi:10.3942/psi\_sgkb/fm\_2008\_10

1zs4

Living cells are constantly making decisions: when to eat, when to move, even when to die. Viruses must also make decisions, but at a much simpler level. This simplicity makes them the perfect subjects for study of regulatory networks. The lambda bacteriophage has been a favorite of scientists, since it only needs to make one big decision during its life cycle. Usually, it follows a lytic life cycle: it enters cells, forces the cell to make many copies of itself, and finally bursts out of the cell, ready to infect more cells. However, if times are lean, the bacteriophage can decide to switch to a less violent approach. In the lysogenic phase, it integrates its genome into the bacterial genome, and then it is replicated each time the bacteria divides. It hitchhikes in the bacterial genome until some signal, such as DNA damage, causes it to switch back to the lytic phase and continue its campaign of destruction.

#### **DECISIONS, DECISIONS**

Several proteins together make the decision about which type of life cycle is best for the current situation. At the center of this regulatory network are the cl repressor and cro proteins. Together they form a switch, with cl repressor maintaining the lysogenic state and cro initiating the lytic state. The cll protein is the "final arbiter" of the decision, flipping this switch to the lysogenic state if the conditions warrant it. When the time is right, cll protein binds to three promoters in the bacteriophage genome, which leads to expression of the cl repressor and a DNA integrase enzyme, and inhibition of Q, a key protein in the lytic state, and the DNA excision enzyme.

#### **BREAKING SYMMETRY**

The cll protein poses two mysteries in molecular recognition. It is a tetramer of four identical chains, but it binds to promoters with only two repeats, with the sequence TTGCNNNNNTTGC. Also, since these two repeats are tandem repeats, and not palindromic, the protein can't be perfectly symmetrical. In collaboration with Seth Darst's laboratory at Rockefeller University, researchers at the PSI Midwest Center for Structural Genomics determined how this protein recognizes its DNA promoter in PDB entry 1zs4. The cll protein contains DNA-binding domains that are connected together with flexible linkers that allow them to break symmetry and find the best orientation on the two TTGC repeats. The four chains associate into two dimers, and in each dimer, only one of the chains actually contacts the DNA.

Jian, Kim, Maxwell, Beasley, Zhang, Gussin, Edwards, Darst. (2005) Crystal structure of bacteriophage lambda cll and its DNA complex. *Mol Cell* 19, 259-269. PDB ID: 1254, 12pq Oppenheim, Kobiler, Stavans, Court, Adhya. (2005) Switches in bacteriophage lambda development. Annu Rev Genet 39, 409-429.

Dodd, Shearwin, Egan. (2005) Revisited gene regulation in bacteriophage lambda *Curr Opin Genet Dev* **15**, 145-152.

on in bacterionbage lambda

# **April 2010**

The PSI **Sequence Comparison and Analysis tool** finds similar protein structures, protein targets, and theoretical models, and also calculates crystallization propensities. Try it now at

#### cnt.psi-structuralgenomics.org/CNT/

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
MARCH    S  M  T  W  T  F  S    1  2  3  4  5  6    7  8  9  10  11  12  13    14  15  16  17  18  19  20    21  22  23  24  25  26  27    28  29  30  31	MAY    S  M  T  W  T  F  S    1  2  3  4  5  6  7  8    9  10  11  12  13  14  15    16  17  18  19  20  21  22    23  24  25  26  27  28  29    30  31			1	2 Good Friday	3
4 Easter	5	6	7	8	9	10
11	12	13	14	15	16	<b>17</b> Earth Day
18	19	20	21	22	23	24
<b>25</b> DNA Day	26	27	28	29	30	

### Ribonuclease and Ribonuclease Inhibitor

doi:10.3942/psi\_sgkb/fm\_2009\_4

1z7x

The complex between ribonuclease and ribonuclease inhibitor is one of the tightest known intermolecular interactions, but researchers at the PSI Center for Eukaryotic Structural Genomics are trying to change that. Ribonuclease is a small but destructive enzyme that is secreted by the pancreas and used to chew up RNA in our diet. Occasionally, however, it finds its way inside cells where it can wreak havoc on our cellular RNA molecules. To protect against this, our cells build a specific inhibitor protein that fights rogue ribonuclease molecules one-on-one.

#### A TIGHT EMBRACE

The structure solved by researchers at PSI Center for Eukaryotic Structural Genomics (PDB entry 1z7x) shows how the human form of ribonuclease inhibitor works. As with the similar inhibitors from other organisms, human ribonuclease inhibitor (shown in blue in the top image) is a horseshoeshaped protein that surrounds ribonuclease (shown in red above) and blocks its active site. The strong binding is due in part to the large area of contact between the two proteins, and is augmented by strong electrostatic interactions. In mutagenesis studies, two amino acids in the ribonuclease sequence have been implicated in its inhibition: arginine 39 and arginine 91. In the complex, these form tight salt bridges with two glutamate amino acids in the inhibitor. These charged amino acids may also act as "electrostatic steering residues" that guide the inhibitor to its proper binding site on the ribonuclease.

#### **EVADING PROTECTIONS**

The tight binding of ribonuclease with its inhibitor is a great advantage to the cell, since it effectively detoxifies the ribonuclease. In some cases, however, this is not the result that we want. Ribonuclease is toxic to cancer cells and is being tested as a possible therapy. Cancer cells, however, contain the inhibitor and guickly inactivate ribonuclease before it has a chance to kill the cell. Researchers have tried two approaches to solve this problem. First, they have tried using ribonucleases from other organisms, which are structurally different than our own ribonuclease and not strongly blocked by the inhibitor. However, they can also cause side effects because they are foreign to the human body. The second, successful approach is to change the human ribonuclease enough to block its interaction with the inhibitor, thus allowing the RNA-cleavage reaction to continue with minimal interference from the inhibitor due to decreased binding.

Johnson, McCoy, Bingman, Phillips, Raines. (2007) Inhibition of human pancreatic ribonuclease by the human ribonuclease inhibitor protein. J Mol Biol 368, 434-449. PDB ID: 127x

Dickson, Haigis, Raines. (2005) Ribonuclease inhibitor: structure and function. Prog Nucleic Acid Res Mol Biol 80, 349-374.



#### SGKB Quick Fact

Still new to our online resource? Learn how to search and navigate the SGKB by visiting our **walkthrough and FAQs** at

kb.psi-structuralgenomics.org/about/getting\_started.html

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
APRIL    S  M  T  W  T  F  S    1  2  3  1  2  3    4  5  6  7  8  9  10    11  12  13  14  15  16  17    18  19  20  21  22  23  24    25  26  27  28  29  30	S  M  T  W  T  F  S    1  2  3  4  5    6  7  8  9  10  11  12    13  14  15  16  17  18  19    20  21  22  23  24  25  26    27  28  29  30  30  30					1
2	3	4	5	6	7	8
9 Mother's Day	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31 Memorial Day					

### Chronophin

doi:10.3942/psi sgkb/fm 2008 5

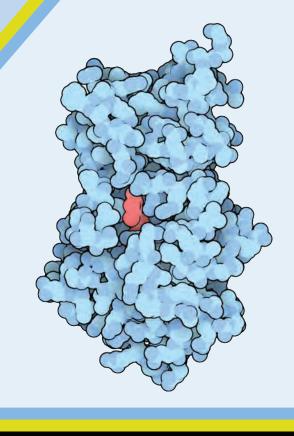
The cell is a busy place with thousands of things happening at once. Phosphorylation is a perfect way to control these many simultaneous molecular tasks. Phosphates display a distinctive molecular signal – they carry a strong negative charge, so they are easy to recognize. This makes them ideal for use in signaling networks, where the presence or absence of a phosphate can toggle a protein from on to off. Phosphates also interact strongly with protein chains, so an added phosphate can cause a protein to fold in a specific way or can stabilize a complex between two proteins. Inside cells, a large collection of kinases and phosphatases control a flurry of phosphate-centered signals. The kinases add phosphates when needed, and phosphatases remove them when the job is finished.

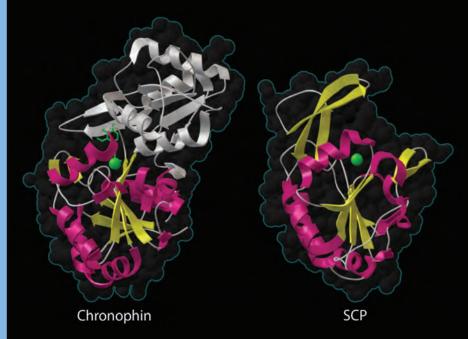
#### TWO PHOSPHATASES FOR THE PRICE OF ONE

Chronophin is a phosphatase that performs two entirely different jobs. As chronophin, it works with LIM kinase to control the assembly of actin. The small protein cofilin breaks actin filaments as part of the constantly changing dynamics of the cytoskeleton. Cofilin is in turn controlled by phosphorylation: LIM kinase shuts it down by adding a phosphate, and chronophin removes the phosphate to create the active form. Chronophin also performs a second job, under the name of pyridoxal phosphatase. When wearing this hat, the enzyme removes a phosphate from pyridoxal-5'-phosphate, also known as vitamin B6. This is part of a complicated pathway for degradation of the vitamin. The structure solved by PSI New York SGX Research Center for Structural Genomics (PDB entry 2p69) shows the enzyme at work in this job, with vitamin B6 (shown in red in the top image or green sticks in bottom image) bound in the active site.

#### PROTEIN PHOSPHATASES

Many protein phosphatases have a distinctive catalytic domain, comprised of a beta sheet (shown in yellow) sandwiched between alpha helices (shown in magenta). The active site contains a magnesium ion (green sphere) that assists with the phosphate-cleaving reaction. The enzyme on the right, small C-terminal domain phosphatase (SCP, PDB entry 2q5e) is very typical of the protein phosphatases. It has a wide-open active site that easily accommodates the protein chain that will be dephosphorylated. Chronophin, on the other hand, is unusual. As shown on the bottom left (PDB entry 2p69), it has a large domain that covers the active site (shown in white). This is typical for phosphatases that act on small molecules, which usually have extra domains that create a tighter active site, and is probably necessary for the moonlighting job of the enzyme in vitamin B6 metabolism. However, the active site must flex open when it is removing a phosphate from the bulkier protein chain of cofilin.





2p69

Almo, Bonanno, Saunder, Entage, Dilorenzo, Malashkevich, Wasserman, Swaminathan, Eswaramoorthy, Agarwal, Kumaran, Madegowda, Ragumani, Patskovsky, Alvarado, Ramagopal, Faber-Barata, Chance, Sali, Fiser, Zhang, Lawrence, Burley (2007) Structural genomics of protein phosphatases. J Struct Funct Genomics 8, 121-140. PDB ID: 2p69, 2q5e

### June 2010

SGKB Quick Fact The **Protein Models Portal**, a module of the SGKB, stores millions of pre-computed model structures. You can search for models through the SGKB search box or visit the Models Portal directly at

www.proteinmodelportal.org

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
MAY    S  M  T  W  T  F  S    2  3  4  5  6  7  8    9  10  11  12  13  14  15    16  17  18  19  20  21  22    23  24  25  26  27  28  29    30  31	JULY    S  M  T  W  T  F  S    1  2  3  1  2  3    4  5  6  7  8  9  10    11  12  13  14  15  16  17    18  19  20  21  22  23  24    25  26  27  28  29  30  31	1	2	3	4	5
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<b>20</b> Father's Day	21 Summer begins	22	23	24	25	26
27	28	29	30			

### LeuT

doi:10.3942/psi\_sgkb/fm\_2009\_5

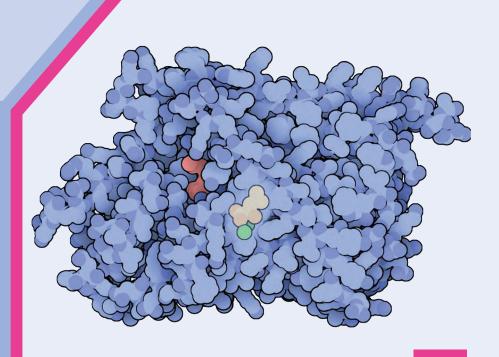
Many antidepressant drugs, as well as drugs of abuse such as cocaine, block the traffic of neurotransmitters across the cell membrane of nerve axons and glial cells. They bind to a specific transport protein that clears the synapse after a nerve signal, transporting neurotransmitters back into the axon and making it ready for another signal. Researchers at the PSI New York Consortium on Membrane Protein Structure have made the first steps towards understanding this transporter at the atomic level, by looking to bacteria for help.

#### SODIUM SYMPORT

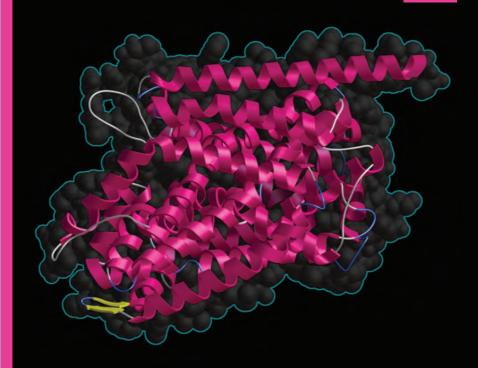
LeuT is one of dozens of transporters that shuttle amino acids in and out of bacterial cells. LeuT specializes in transporting small hydrophobic amino acids like leucine and alanine. The transport is powered by the gradient of sodium ions that is normally maintained by healthy cells across their membranes. LeuT acts as a symporter, which links the passage of a sodium ion across the membrane with the transport of the amino acid in the same direction.

#### **ROCKER BLOCKER**

The protein is thought to act like a rocker switch. Like the transporter in our nerves, it has a bundle of twelve alpha helices that form a transport channel through the membrane. LeuT (PDB entry 2giu) is more compact than our transporter, however, and is missing several extensions at the ends of the chain that interact with proteins in the nerve cell. It starts with an opening towards the outside of the cell. Leucine and sodium enter and bind, then the protein shifts to open inside the cell, releasing the amino acid and sodium. The protein recognizes all aspects of the amino acid, forming specific interactions with both the amino group and the acid group, and forming a hydrophobic pocket perfectly fitted to the small hydrophobic sidechain.



2qiu



Zhou, Zhen, Karpowich, Goetz, Law, Reith, Wang. (2007) LeuT-desipramine structure reveals how antidepressants block neurotransmitter reuptake. *Science* **317**; 1390-1393. **PDB IDs: 2q6h, 2q72, 2qb4, 2qei, 2qi**  Singh, Yamashita, Gouaux. (2007) Antidepressant binding site in a bacterial homologue of neurotransmitter transporters. *Nature* **448(7156)**; 952-6.

Singh. (2008) LeuT. Channels 2; 380-389.

# July 2010

SGKB Quick Fact

The PSI Network is made up of 12 Centers that concentrate on high-throughput protein production, structure determination, and computational modeling. Their structures have been selected for this calendar. Read more at

#### kb.psi-structuralgenomics.org/KB/psi\_centers.html

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
S  M  T  W  T  F  S    1  2  3  4  5    6  7  8  9  10  11  12    13  14  15  16  17  18  19    20  21  22  23  24  25  26    27  28  29  30	AUGUST    S  M  T  W  T  F  S    1  2  3  4  5  6  7    8  9  10  11  12  13  14    15  16  17  18  19  20  21    22  23  24  25  26  27  28    29  30  31			1	2	3
4 Independence Day	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

### **Aspartate Dehydrogenase**

doi:10.3942/psi\_sgkb/fm\_2008\_8

Aspartate dehydrogenase is a new enzyme discovered by the Joint Center of Structural Genomics and the PSI Northeast Structural Genomics Consortium. The path to discovery began with the genome of the bacterium *Thermotoga mar-itima*, a bacterium found in geothermally-heated sediments in the ocean. The gene for this protein was interesting for several reasons. First, similar proteins are found in many other organisms, and thus the protein may play an important role in cellular function. Also, the gene was found as part of a larger operon that includes two enzymes that are involved in the synthesis of nicotinamide rings. Many other bacteria have a similar operon, but it usually includes a gene that encodes aspartate oxidase instead of this new protein.

#### **PREDICTING FUNCTION FROM STRUCTURE**

The structure of this protein (PDB entry 1i5p) revealed a small protein with NAD bound in a deep pocket. The fold of the protein is a familiar Rossmann fold, which is common in enzymes that use NAD in their reactions, suggesting that the protein may be a dehydrogenase. Based on these observations, the enzyme was tested for function with a variety of substrates and cofactors, and it was found to be a dehydrogenase that uses NAD to oxidize aspartate. Further testing showed that it is highly specific for aspartate and doesn't oxidize the similar amino acids glutamate and asparagine. Based on these results, the new enzyme was named "asparate dehydrogenase."

#### **BUILDING NAD WITH NAD**

Our own cells are not able to build the nicotinamide ring in NAD, so we have to obtain this essential molecule in our diet as a vitamin. Most bacteria, however, are able to build it from scratch. The first step in this process is the oxidation of aspartate to iminoaspartate, which will ultimately form half of the nicotinamide ring. We now know that bacteria can use (at least) two ways to perform this reaction. For example, some bacteria use the enzyme aspartate oxidase, which uses an FAD cofactor and oxygen or fumarate. This new structure revealed that other bacteria, such as Thermotoga maritima, use a different route, using NAD as a cofactor in the first step towards creation of more NAD

1j5p

PDB ID: 1j5p. Joint Center for Structural Genomics (JCSG). Crystal structure of aspartate dehydrogenase (TM1643) from *Thermotoga maritima* at 1.9 Å resolution.

Yang, Savchenko, Yakunin, Zhang, Edwards, Arrowsmith, Tong. (2003) Aspartate dehydrogenase, a novel enzyme identified from structural and functional studies of TM1643. *J Biol Chem* 278, 8804-8808. PDB ID: 1h2h

# August 2010

SGKB Quick Fact The **PSI Technology Portal** provides access to the technologies catalyzed by the PSI research efforts. This information includes documentation, availability, center contacts and licensing terms. Read more at

technology.lbl.gov/portal/home/

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	2	3	4	5	6	7
8	9	10	<b>11</b> Ramadan begins	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31			S  M  T  W  T  F  S    1  2  3  3  3  3  3  1  2  3    4  5  6  7  8  9  10    11  12  13  14  15  16  17    18  19  20  21  22  23  24    25  26  27  28  29  30  31	SEPTEMBER    S  M  T  W  T  F  S    1  2  3  4    5  6  7  8  9  10  11    12  13  14  15  16  17  18    19  20  21  22  23  24  25    26  27  28  29  30

### **Toxin-antitoxin VapBC-5**

doi:10.3942/psi\_sgkb/fm\_2009\_9

The first toxin-antitoxin pair was discovered in *Escherichia coli*. The toxinantitoxin operon was found on a large plasmid that normally occurs in low copy numbers, and its function is to ensure the continued propagation of the plasmid. The trick to this is in the antitoxin. The antitoxins are typically less stable than the toxins and are degraded by cellular proteases more quickly than the toxins. When a cell divides, each daughter ideally gets a copy of the plasmid along with a bunch of toxin-antitoxin complexes. If, however, one daughter doesn't get a copy of the plasmid, the leftover antitoxins are eventually degraded, releasing active toxin that destroys the cell. This drastic approach to quality control has been termed "plasmid addiction."

#### **SLOW AND STEADY**

Toxin-antitoxin pairs are also widely found in bacterial chromosomes. Their function is not as well defined, but they are thought to be a mechanism to control growth in hard times. When cells are stressed, for instance by starvation or antibiotics, specific proteases are activated that destroy the antitoxins. The toxins then do their job and slow protein synthesis, ultimately arresting the growth of the cell until the trouble has passed. In these cases, the toxins are not deadly to the cell. Instead, they just put the brakes on growth.

#### **STRUCTURE AND FUNCTION**

Researchers at the PSI Integrated Center for Structure and Function Innovation have revealed the first structure of a toxin-antitoxin pair from the

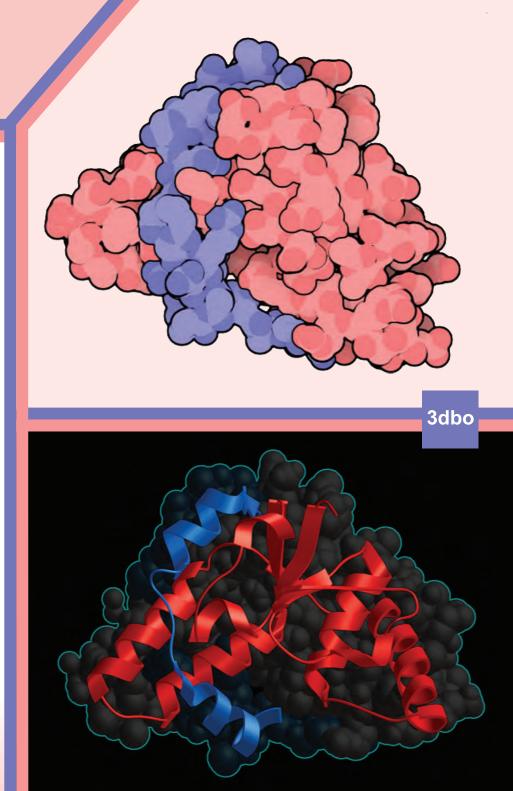
bacterium that causes tuberculosis. shown here from PDB entry 3dbo. The toxin and the antitoxin are both small proteins that form an intimate association in the complex. Based on the structure, PSI researchers have proposed that the toxin, shown here in pink, is a ribonuclease that uses magnesium ions to cleave RNA. The presumed active site is in a deep cleft on the surface. The antitoxin, shown here in blue, wraps nearly all the way around the toxin, blocking the active site. A portion of the antitoxin, which associates with DNA when it acts as a repressor, is not seen in this structure. The critical instability of the antitoxin is easily explained by the structure, since the antitoxin adopts an extended structure that would not be stable in the absence of the toxin.

Miallau, Faller, Chiang, Arbing, Guo, Cascio, Eisenberg. (2009) Structure and proposed activity of a member of the VapBC family of toxin-antitoxin systems. *J Biol Chem* **284**, 276-283. **PDB ID: 3dbo** 

Makarova, Wolf, Koonin. (2009) Comprehensive comparative-genomic analysis of type 2 toxin-antitoxin systems and related mobile stress response systems in prokaryotes. *Biol Direct* 4:19. Magnuson. (2007) Hypothetical functions of toxin-antitoxin systems.  $J\,Bacteriol$   ${\bf 189},\,6089{-}6092.$ 

Buts, Lah, Dao-Thi, Wyns, Loris. (2005) Toxin-antitoxin modules as bacteria stress managers. *Trends Biochem Sci* **30**, 672-679.

Gerdes, Christensen, Lobner-Olesen. (2005) Prokaryotic toxin-antitoxin stress response loci. Nat Rev Microbiol 3, 371-382.



### September 2010

**TargetDB** tracks the progress of protein targets selected for structural determination by over 25 structural genomics centers worldwide. You can search for target information through the SGKB search box or visit the TargetDB directly at

#### targetdb.pdb.org

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
AUGUST    S  M  T  W  T  F  S    1  2  3  4  5  6  7    8  9  10  11  12  13  14    15  16  17  18  19  20  21    22  23  24  25  26  27  28    29  30  31	OCTOBER    S  M  T  W  T  F  S    3  4  5  6  7  8  9    10  11  12  13  14  15  16    17  18  19  20  21  22  23    24  25  26  27  28  29  30    31		1	2	3	4
5	<b>6</b> Labor Day	7	8	<b>9</b> Rosh HaShanah Eid al-Fitr	10	11
12	13	14	15	16	17	<b>18</b> Yom Kippur
19	20	21	<b>22</b> Autumn begins	23	24	25
26	27	28	29	30		

### Lysostaphin

doi:10.3942/psi\_sgkb/fm\_2009\_7

Antibiotics are one of the major triumphs of twentieth-century science, but unfortunately, the bacteria are fighting back. Drug-resistant strains are continually emerging as bacteria evolve and share new methods to shield their antibiotic-sensitive machinery, or destroy antibiotics directly. Today, we are searching for new approaches to fight our microscopic enemies using the tools of structural and molecular biology.

#### THE SEARCH FOR NEW AMMUNITION

#### **SPECIAL FORCES**

As with much of the earliest work in antibiotic discovery, researchers at the PSI New York SGX Research Center for Structural Genomics are looking to the microbial world for leads. They have solved the structure of lysostaphin from the bacterium Vibrio cholerae (PDB entry 2qu1). Like lysozyme, the original magic bullet explored by Alexander Fleming, lysostaphin is an enzyme that attacks the cell walls of bacteria. These cell walls are composed of long strings of sugars and amino acids, which are then crosslinked into a tough network that encloses the cell. Lysozyme and lysostaphin break linkages in this peptidoglycan network, and the cells burst under their own internal pressure.

Lysostaphin is a specialized killer, however. The crosslinks in the peptidoglycan come in many varieties. In some bacteria, the links are formed directly between amino acids in the peptidoglycan strands. In Staphylococcus aureus, however, a strand of five glycine amino acids is used as the linker. This is the weak point that is targeted by lysostaphin - it binds to the peptidoalycan sheath and clips these glycine crosslinkers. However, strains have been discovered that are less susceptible to lysostaphin, strains that either build a gluey polysaccharide capsule that shields their peptidoglycan, or strains that fortify the linkers in their peptidoglycan. The battle continues...

2qu<sup>1</sup>

Ragumani, Kumaran, Burley, Swaminathan. (2008) Crystal structure of a putative lysostaphin peptidase from *Vibrio cholerae*. *Proteins* **72**, 1096-1103. **PDB entry: 2gu1**  Firczuk, Mucha, Bochtler. (2006) Crystal structures of active LytM. J Mol Biol 354, 578-590.

Bochtler, Odintsov, Marcyjaniak, Sabala. (2004) Similar active sites in lysostaphins and D-Ala-D-Ala metallopeptidases. *Prot Sci* **13**, 854-861

Kumar. (2008) Lysostaphin: an antistaphylococcal agent. Appl Microbiol Biotechnol 80, 555-561.

### October 2010

SGKB Quick Fact **PepcDB** contains experimental trial histories, protocols, stop conditions, and contact information collected from the PSI centers. Search for protocols through the SGKB search box or visit the PepcDB directly at

#### pepcdb.pdb.org

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
SEPTEMBER    S  M  T  W  T  F  S    1  2  3  4    5  6  7  8  9  10  11    12  13  14  15  16  17  18    19  20  21  22  23  24  25    26  27  28  29  30  Image: Second Secon	NOVEMBER    S  M  T  W  T  F  S    1  2  3  4  5  6    7  8  9  10  11  12  13    14  15  16  17  18  19  20    21  22  23  24  25  26  27    28  29  30				1	2
3	4	5	6	7	8	9
10	<b>11</b> Columbus Day	12	13	14	15	16
17	18	19	20	21	22	23
24 31 Halloween	25	26	27	28	29	30

### Scavenger Decapping Enzyme DcpS

doi:10.3942/psi\_sgkb/fm\_2008\_11

Messenger RNA (mRNA) molecules are temporary molecules. They typically last for ten hours, but this lifespan can vary between different messages. Some encode proteins with central house-keeping tasks, such as enzymes of biosynthesis and catabolism that last for days in the cytoplasm. Others encode proteins with more time-dependent tasks such as transcription factors that last for minutes before they are destroyed. The amount of a particular mRNA is modulated at the beginning of its life, by controlling the amount that is transcribed from the DNA, and by controlling how fast it is degraded when it is no longer needed.

#### **DEGRADING AND DECAPPING**

mRNA molecules are protected at both ends. The front end is protected by a molecular "cap" composed of an oddly-connected methylated guanine. The tail end of the strand is protected by a long string of adenine nucleotides. Cells use two different approaches to overcome these protections: both begin by removing the polyadenine tail from the end of the mRNA, but use different ways to deal with the cap. One pathway attacks the cap immediately, while the other pathway leaves the cap until the end. In this second pathway, exosomes clip away nucleotides from the end of the RNA strand. The exosome, however, has trouble finishing its task and leaves a short RNA strand with the capped guanine still intact. This is where the scavenger decapping enzyme DcpS comes in, breaking off the terminal cap and finishing the job of degradation.

#### **DECAPPING MACHINE**

DcpS is a dimeric protein complex with several moving parts. Each protein chain folds to form two large domains connected by flexible linkers, which then assemble side-by-side to form an enzyme with two active sites, located in the large grooves between the domains. The N-terminal domain, shown at the top here, grips the neighboring subunit with an extensive domain swapped interaction, gluing the entire complex together. When the protein is not bound to substrates, it forms a symmetrical structure, as revealed in a top structure solved by the PSI Joint Centers for Structural Genomics (PDB entry 1vlr).

#### THE SEARCH FOR INHIBITORS...

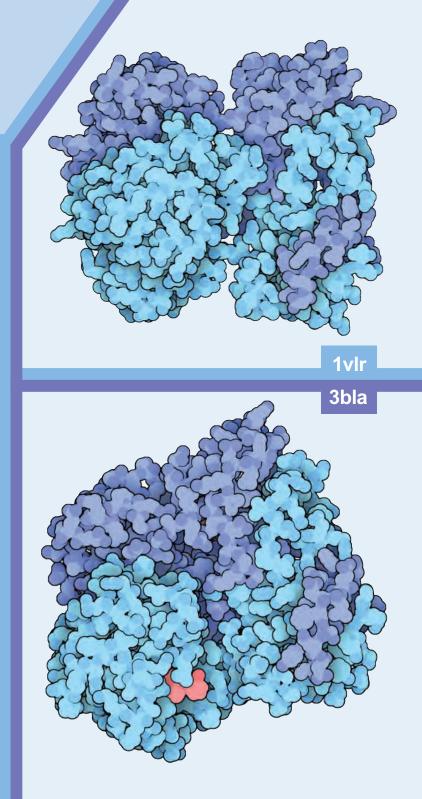
Structures of DcpS with substrates and with inhibitors have shown that the N-terminal domain rocks back and forth, closing the active site around the substrate on one side, and then opening when the reaction is finished. The first inhibitor structures were solved with the help of the PSI Accelerated Technologies Center for Gene to 3D Structure. In these structures, such as PDB entry 3bla in the image below, one active site is closed tightly around an inhibitor molecule, and the other side is trapped in an open, catalytically-incompetent conformation.

#### ...AND DRUGS

These inhibitors were found as part of a targeted search for drugs to fight spinal muscular atrophy. This disease is the most common cause of hereditary infant death, and is caused by defects in the SMN1 gene. Surprisingly, there is a second gene, SMN2, that can substitute for the SMN1 gene if it is activated over its normal levels. It was found that these inhibitors activate the SMN2 gene by blocking the action of DcpS, ultimately leading to increased levels of SMN mRNA.

Singh, Salcius, Liu, Staker, Mishra, Thurmond, Michaud, Mattoon, Printen, Christensen, Bjornsson, Pollok, Kiledjian, Stewart, Jarecki, Ourney. (2008) DcpS as a therapeutic target for spinal muscular atrophy. ACS Chem Biol, 3, 711-722. PDB ID: 3bla

msson, Pol-Han, Schwarzsenbacher, McMullan, Abdubek, Anbing, Avelrod, Biorac, Canaves, Chiu, Dai, Descon, DiDonate Elsliger, Godzik, Grittini, Grzechnik, Hale, Hampton, Haugen, Hornsby, Jaroszewski, Klock, Koesema, Kreusch Kuhn, Lesley, McPhillips, Miller, Moy, Nigoghossian, Paulsen, Quijano, Reyes, Spragon, Stevens, van den Bedem, Velasquez, Vincent, White, Wolf, Xu, Hodgson, Wooley, Wilson, (2005) Crystal structurer of an apo RNA decapping erzyme (DcpS) from mouse at 1.83 Ar esolution. *Proteins* **60**, 797-802. **PDB ID: 1vlr** 



Liu, Kiledjian. (2006) Decapping the message: a beginning or an end. Biochem Soc Trans 34, 35-38.

# November 2010

The **PSI Material Repository (PSI MR)** stores and distributes PSI DNA clones to the greater scientific community. Expedited materials transfer agreements ease the process. For more info, visit

psimr.asu.edu

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	1	2	3	4	5	6
7	8	9	10	<b>11</b> Veterans Day	12	13
14	15	16	17	18	19	20
21	22	23	24	25 Thanksgiving	26	27
28	29	30			OCTOBER    S  M  T  W  T  F  S    1  2  3  4  5  6  7  8  9    10  11  12  13  14  15  16    17  18  19  20  21  22  23    24  25  26  27  28  29  30    31	DECEMBER    S  M  T  W  T  F  S    1  2  3  4  5  6  7  8  9  10  11    12  13  14  15  16  17  18    19  20  21  22  23  24  25    26  27  28  29  30  31

# **Coenzyme F420 Synthesis**

doi:10.3942/psi\_sgkb/fm\_2008\_4

Unusual coenzymes are often needed to perform particularly difficult enzymatic tasks. For instance, methane-forming archaea must transfer electrons from hydrogen to carbon dioxide when they perform their major energy-producing reaction. However, the normal carriers of electrons, NAD and FAD, don't have the proper redox potential to perform this reaction. So, these archaea use the coenzyme F420, which is chemically similar to FAD, but with a few changes that tune the redox potential into the necessary range.

#### **A NEW FOLD**

One of the goals of structural genomics is to discover proteins with new folding patterns. Based on its amino acid sequence, researchers at PSI Midwest Center for Structural Genomics chose to study F420:gamma-glutamyl ligase because it was predicted to be different than any existing structures. When they solved the structure, it did show a new fold, and represents an entirely new family of enzymes.

#### **A CHEMICAL SPECIALIST**

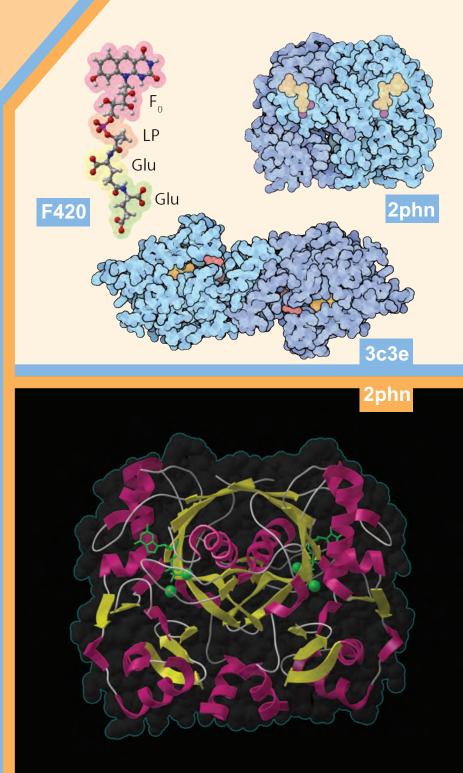
F420 (shown at upper left) is named for its strong absorbance of violet and ultraviolet light (~420 nm wavelength). When irradiated with ultraviolet light, it fluoresces with a blue-green light, a trademark of methanogenic bacteria which use F420 as their primary electron carrier. F420 is used for several specialized tasks that require its unique electron transfer properties. As mentioned above, in archaea it is an essential tool for the conversion of carbon dioxide to methane. Some bacteria use it in the synthesis of antibiotics like tetracycline and lincomycin. A modified form of the cofactor is used by cyanobacteria to repair DNA damage; the cofactor absorbs ultraviolet light and uses the energy to separate the bonded bases in pyrimidine dimers.

#### **BUILDING F420**

Structures of the two enzymes that perform the final steps of synthesis of F420 have been solved, giving us a look at how this unusual cofactor is constructed. F420 is composed of four parts: a flavin-like  $F_0$  ring, a phospholactate (LP), and two (or occasionally more) glutamate amino acids. The enzyme 2-phospho-L-lactate transferase (shown in PDB entry 3c3e, solved by the PSI Northeast Structural Genomics Consortium and collaborators) attaches the  $F_0$ ring to the phospholactate. It uses a GTPactivated form of the phospholactate to power the reaction. The structure includes the  $F_0$  ring (shown in pink) and a GDP (shown in orange), revealing the location of both substrates in the reaction. The final step in F420 synthesis is the addition of two glutamate amino acids to the cofactor, performed by the enzyme F420: gamma-glutamyl ligase (shown in PDB entry 2phn, solved by the PSI MCSG and collaborators). The structure shows a dimeric enzyme with two deep active site grooves. A GDP molecule is found in each groove (shown below in green), positioned by manganese ions (green spheres).

Nocek, Evdokimova, Proudfoot, Kudritska, Grochowski, White, Savchenko, Yakunin, Edwards, Joachimiak, (2007) Structure of an amide bond forming F420:gamma-glutamyl ligase from Archaeoglobus fulgidus: a member of a new family of non-ribosomal peptide synthases. J Mol Biol 372, 456-469. PDB ID: 2phn Forouhar, Abashidze, Xu, Grochowski, Ssetharaman, Hussain, Kuzin, Chen, Zhou, Xaio, Acton, Montelione, Galinier, White, Tong. (2008) Molecular insights into the biosynthesis of the F420 coenzyme. *J Biol Chem* 283, 11832-11840. PDB ID: 3C3e

DiMarco, Bobik, Wolfe. (1990) Unusual coenzymes of methanogenesis. Ann Rev Biochem 59, 355-394.



Graham, White. (2002) Elucidation of methanogenic coenzyme biosyntheses: from spectroscopy to genomics. *Nat Prod Rep* **19**, 133-147.

### **December 2010**

SGKB Quick Fact The *Featured PSI Molecule*, written and illustrated by David Goodsell, highlights protein structures solved by the PSI efforts. Examples of these stories have been used to illustrate this calendar. Check out other articles at

kb.structuralgenomics.org/KB/structures.jsp

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
NOVEMBER    S  M  T  W  T  F  S    1  2  3  4  5  6    7  8  9  10  11  12  13    14  15  16  17  18  19  20    21  22  23  24  25  26  27    28  29  30  30  30  30  30	JANUARY 2011    S  M  T  W  T  F  S    1  2  3  4  5  6  7  8    9  10  11  12  13  14  15    16  17  18  19  20  21  22    23  24  25  26  27  28  29    30  31		1	<b>2</b> Hanukkah begins	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	<b>21</b> Winter begins	22	23	24	25 Christmas
<b>26</b> Kwanzaa	27	28	29	30	31	

### **PSI Featured Molecules**

