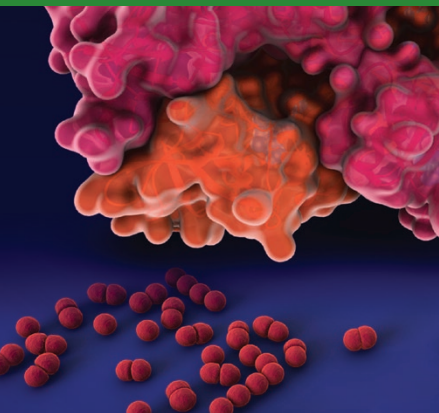


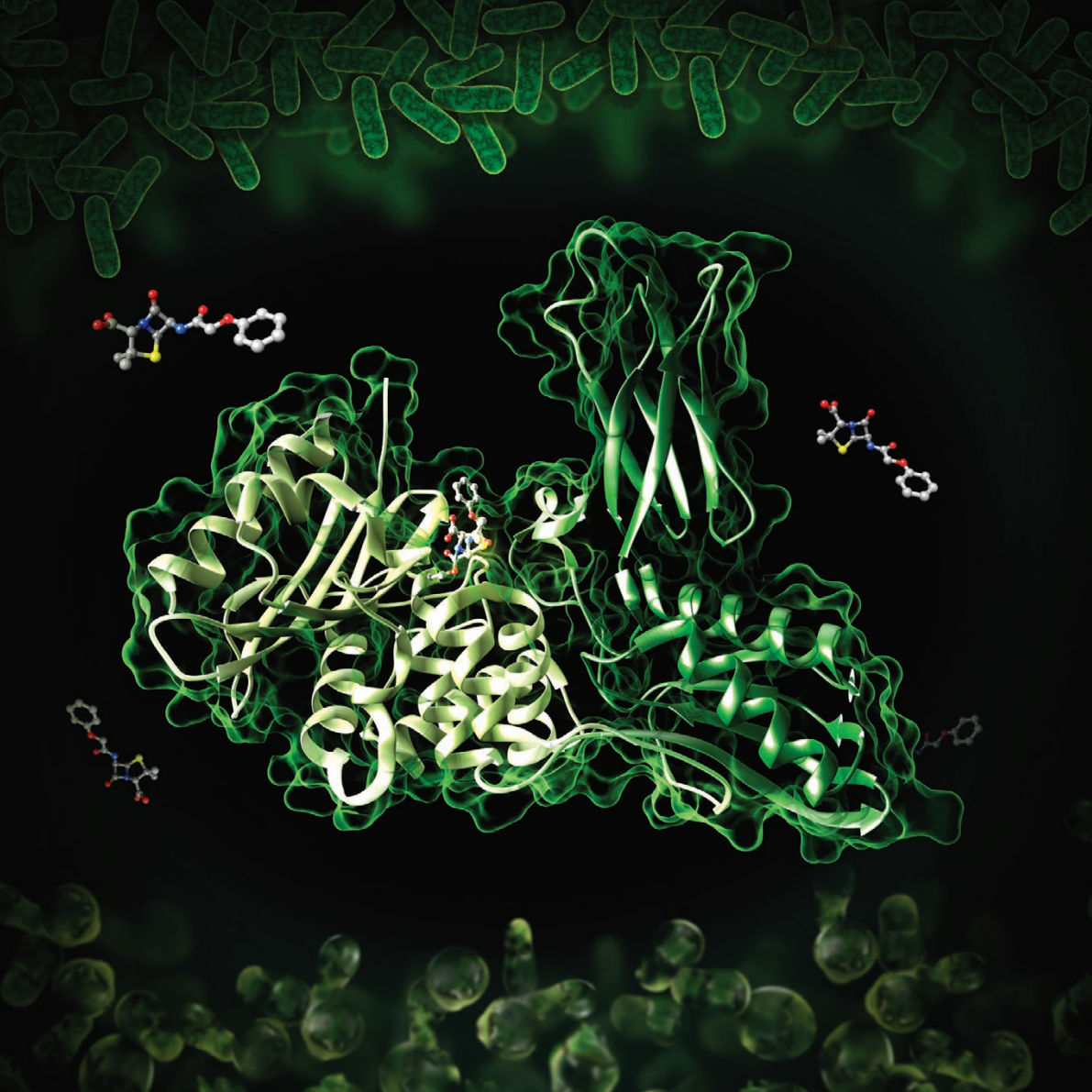
# MECHANISMS OF ANTIMICROBIAL RESISTANCE

**2018 Calendar**



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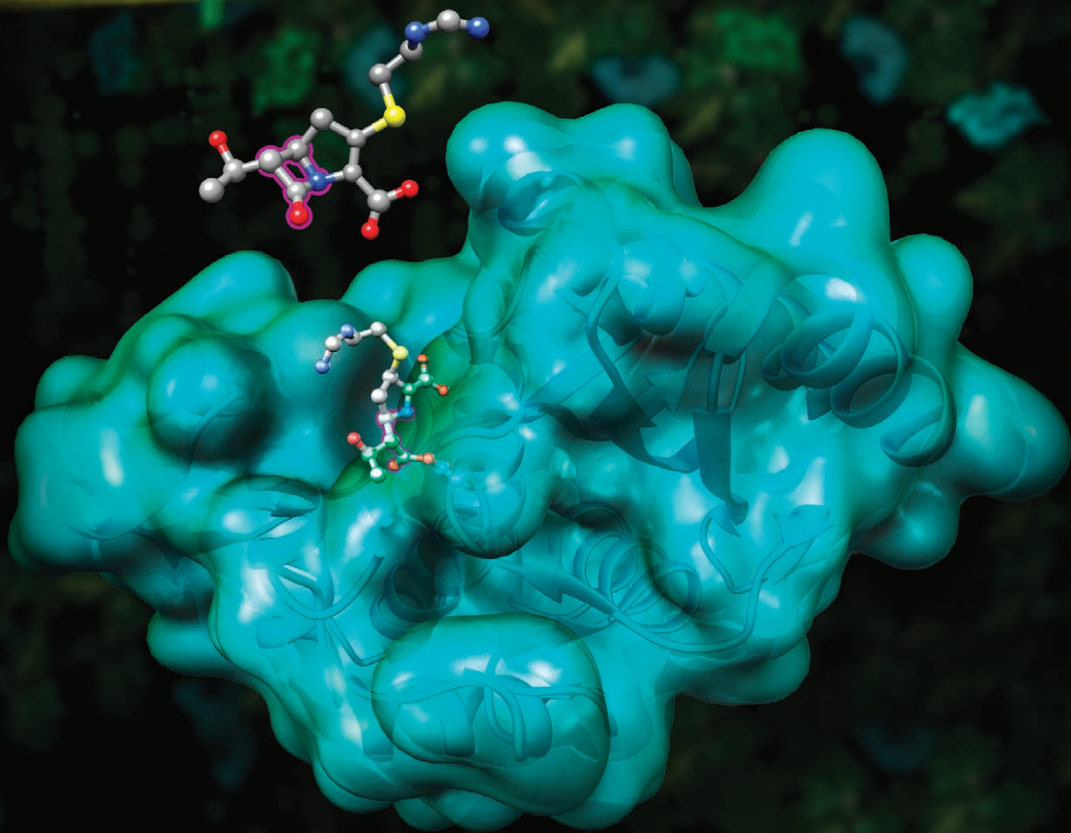


Bacteria build a tough network of peptidoglycan to support their cell walls. Penicillin V (a beta-lactam antibiotic shown in ball and stick representation) blocks one of the enzymes that builds this peptidoglycan sheath. Penicillin binds to the portion shown in light green.

## January 2018

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
31	1 New Year's Day	2	3	4	5	6
7	8	9	10	11	12	13
14 Martin Luther King Jr. Day	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31	1	2	3

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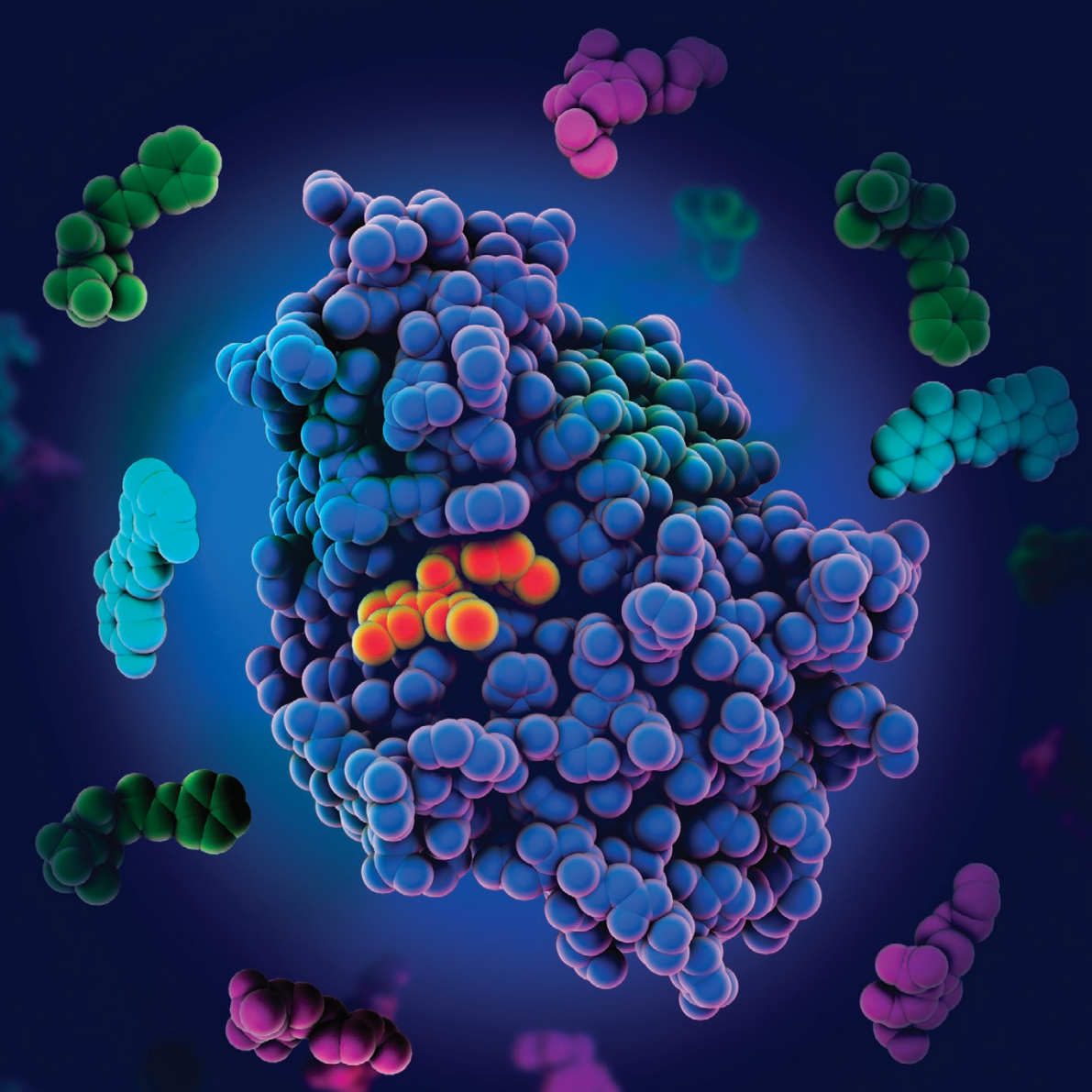
Bacteria have become remarkably adept at overcoming the effects of even our most powerful antibiotics. Many bacteria now possess enzymes (beta-lactamases) capable of opening up the beta-lactam ring (highlighted in magenta), thereby inactivating the drug.

## February 2018

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
28	29	30	31	1	2 Groundhog Day	3
4	5	6	7	8	9	10
11	12	13	14 Valentine's Day	15	16 Lunar New Year	17
18	19 Presidents' Day	20	21	22	23	24
25	26	27	28	1	2	3

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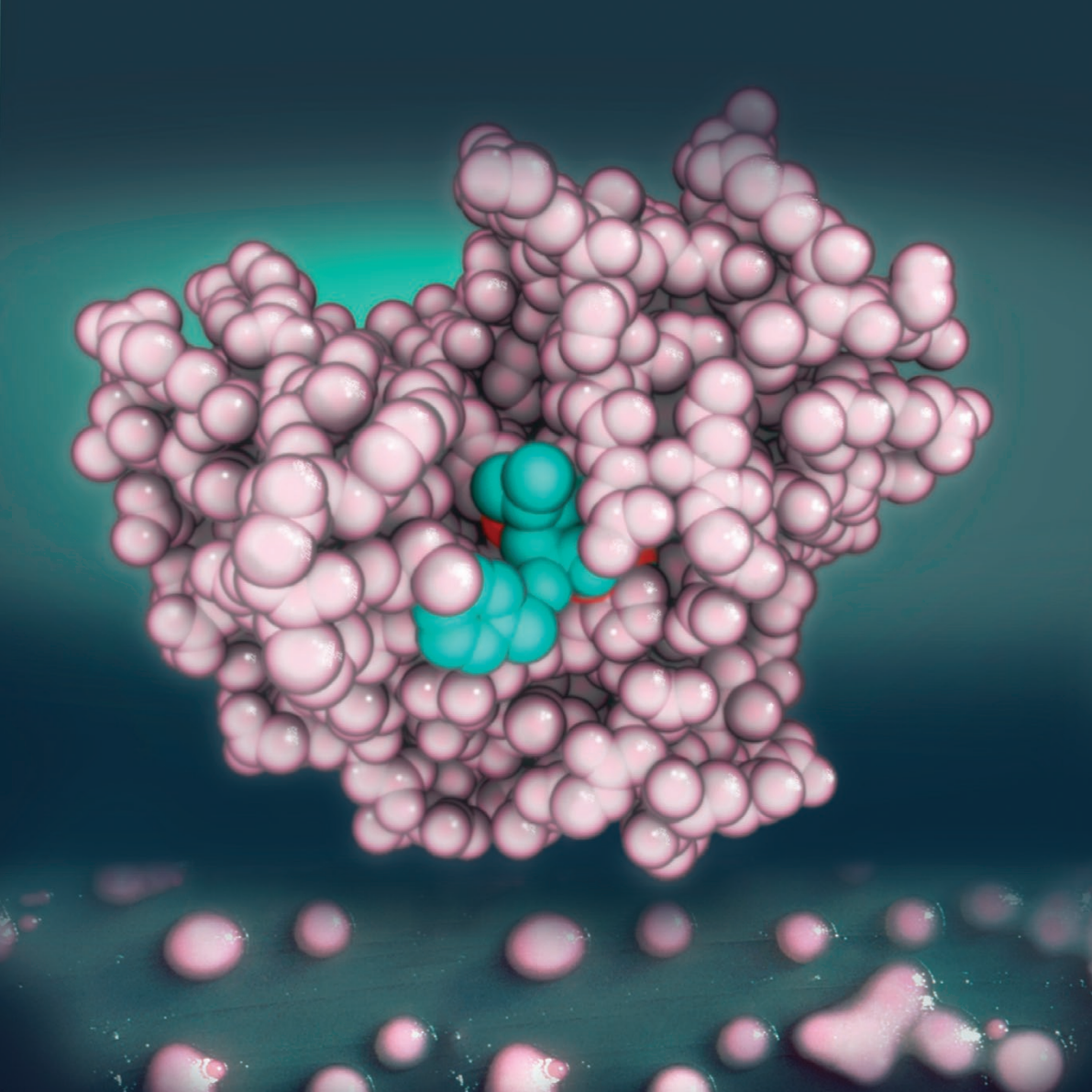


KPC-2 is another “versatile beta-lactamase”, with a large and shallow active site that breaks down nearly all known beta-lactam antibiotics. This structure captures the enzyme after it has destroyed a molecule of the broad-spectrum antibiotic cefotaxime.

## March 2018

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
26	25	27	28	1	2	3
4	5	6	7	8	9	10
11 Daylight Saving Time begins (US)	12	13	14 Pi Day	15	16	17
18	19	20	21	22	23	24
25 Summer Time begins (Europe)	26	27	28	29	30	31 Passover

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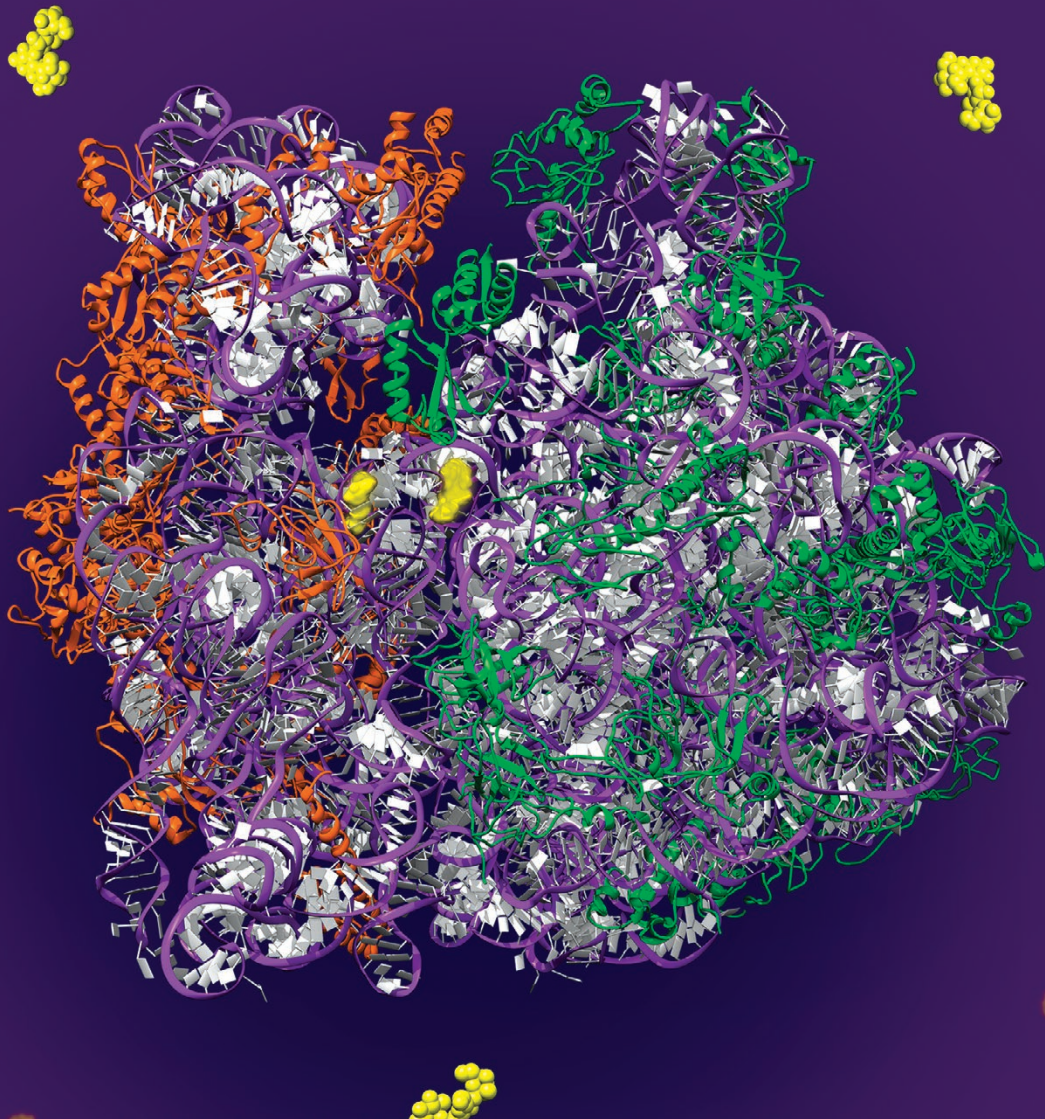


Bacteria that possess NDM-1 metallo-lactamase enzymes pose a great danger because they can inactivate all approved penicillin-like antibiotics, including our most advanced carbapenems. PDB structures, such as this one with benzylpenicillin, have revealed that NDM-1 uses zinc in its active site to inactivate a wide range of different antibiotics.

## April 2018

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1 Easter	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22 Earth Day	23	24	25 DNA Day	26	27	28
29	30	1	2	3	4	5

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Aminoglycosides are effective broad-spectrum antibiotics, because they target ribosomes in many types of bacteria. This structure shows how neomycin (yellow) binds to ribosomes and shifts their structure, blocking recycling of ribosomes after they finish building a protein.

## May 2018

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
29	30	1	2	3	4	5
6	7	8	9	10	11	12
13 Mother's Day	14	15	16 Ramadan begins	17	18	19
20	21	22	23	24	25	26
27 Memorial Day	28	29	30	31	1	2

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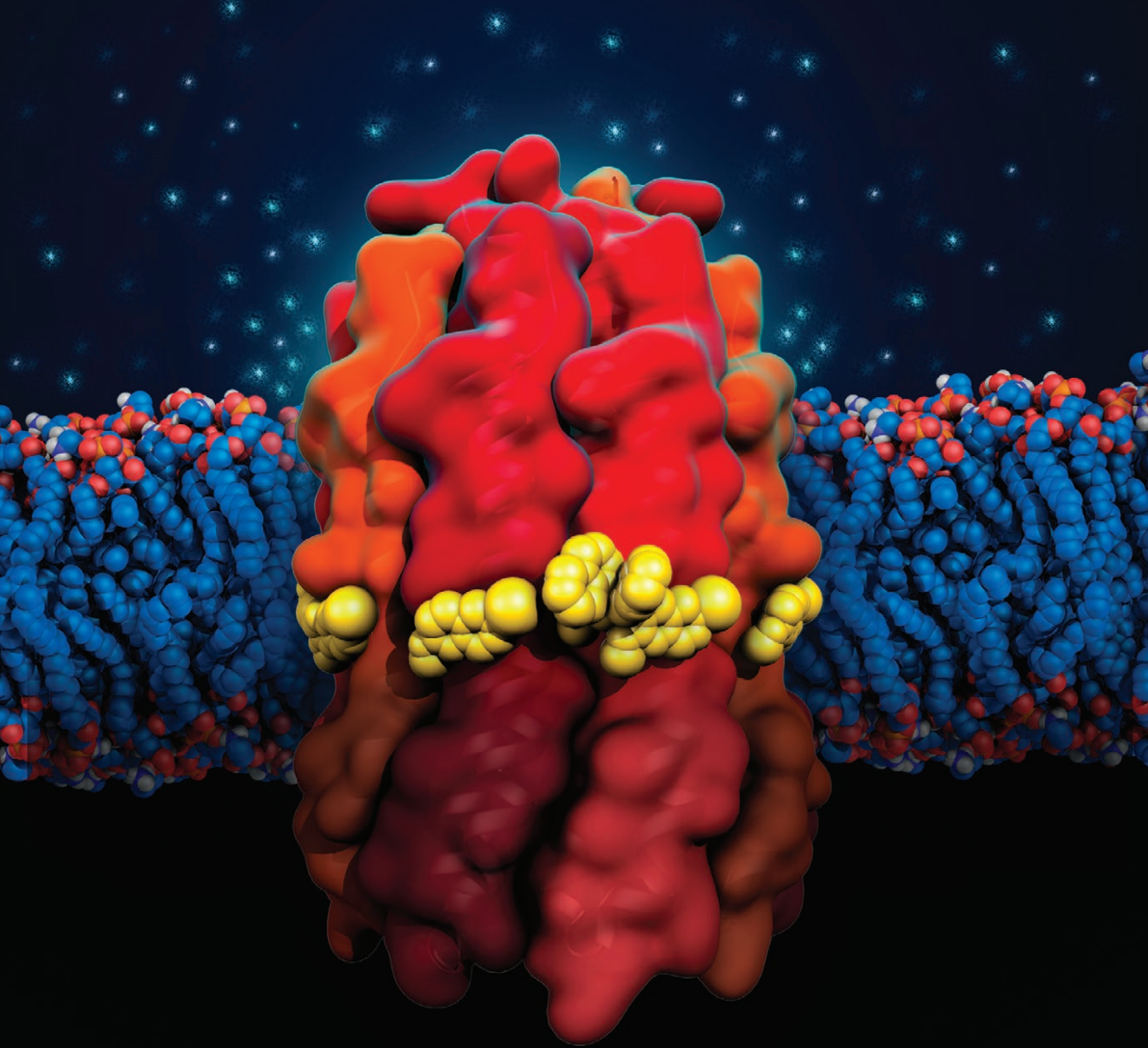


Resistant bacteria block the function of aminoglycoside antibiotics by attaching adenosine nucleotides to them. Structures of the enzymes that perform this reaction may help researchers discover new aminoglycosides that are not susceptible to inactivation.

## June 2018

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
27	28	29	30	31	1	2
3	4	5	6	7	8	9
10	11	12	13	14	15 Eid al-Fitr	16
17 Father's Day	18	19	20	21	22	23
24	25	26	27	28	29	30

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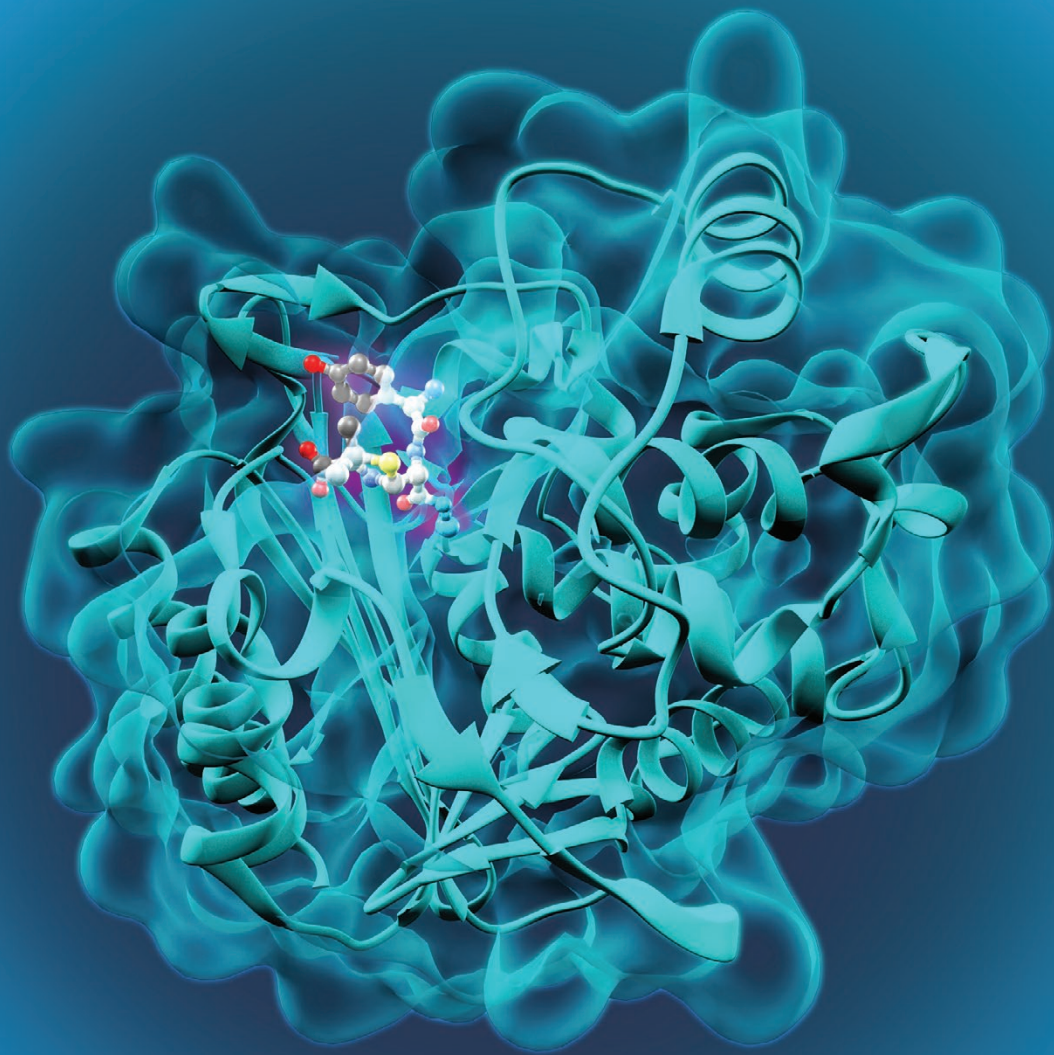


After 40 years of searching, researchers have discovered bedaquiline (shown in yellow), a new drug now approved for the treatment of multidrug-resistant tuberculosis. It binds to the rotor of ATP synthase, blocking the central energy-production machinery of mycobacteria.

## July 2018

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
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	1	2	3	4

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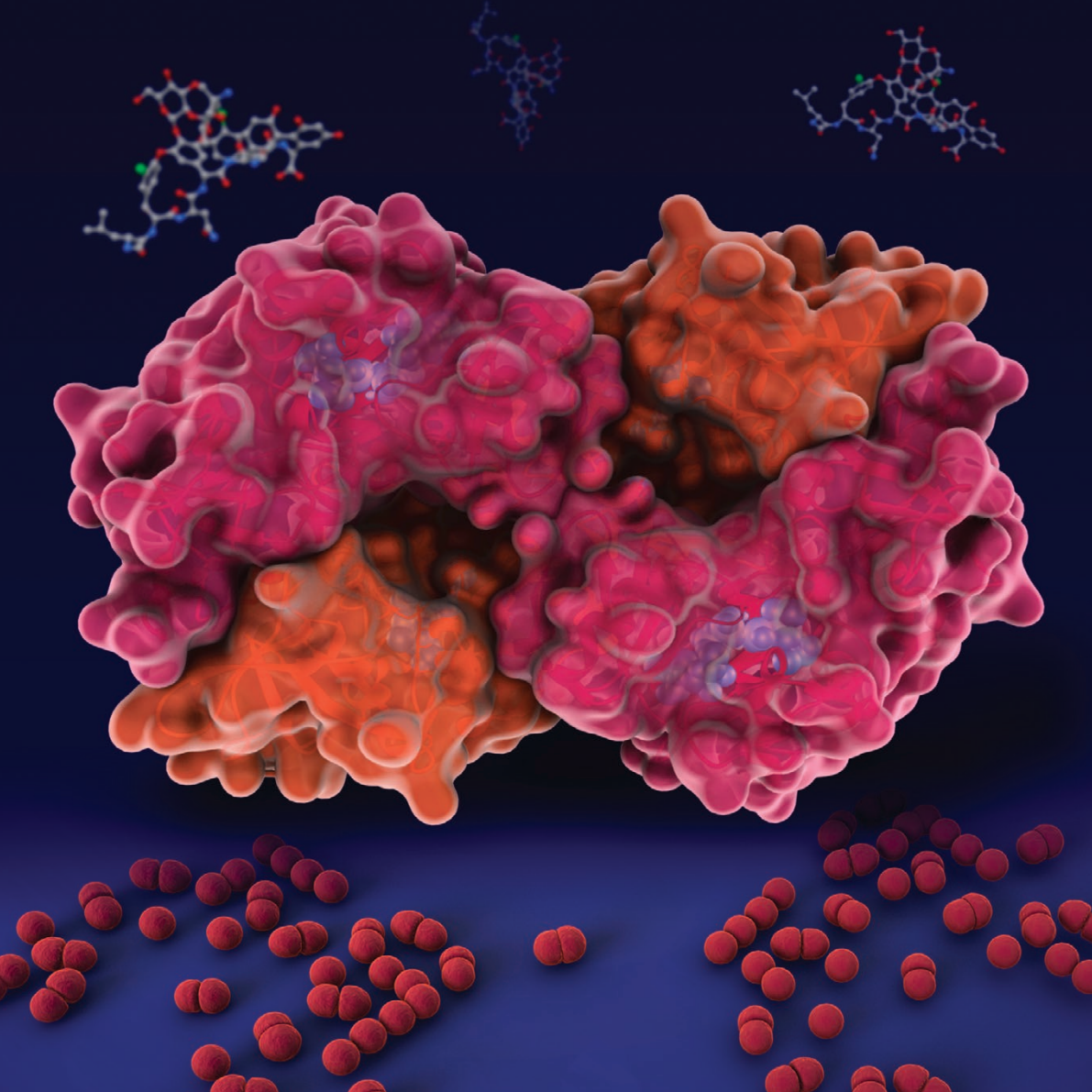


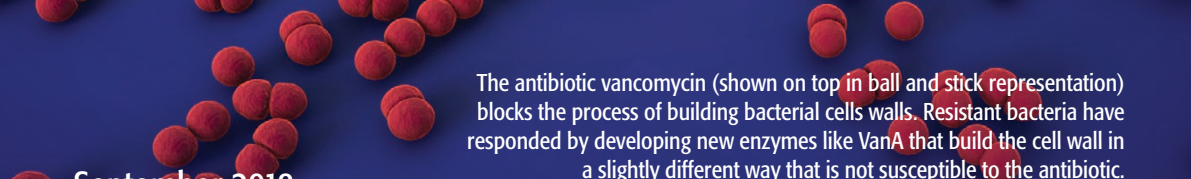


Beta-lactamases usually confer resistance by breaking the beta-lactam ring of penicillin-like antibiotics. To overcome resistance, researchers are working to design inhibitors of beta-lactamases that can be given together with established beta-lactam antibiotics.

## August 2018

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
29	30	31	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





The antibiotic vancomycin (shown on top in ball and stick representation) blocks the process of building bacterial cells walls. Resistant bacteria have responded by developing new enzymes like VanA that build the cell wall in a slightly different way that is not susceptible to the antibiotic.

## September 2018

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
25	26	27	28	29	30	1
2	3 Labor Day	4	5	6	7	8
9	10 Rosh Hashanah	11	12	13	14	15
16	17	18	19 Yom Kippur	20	21	22
23	24	25	26	27	28	29
30						





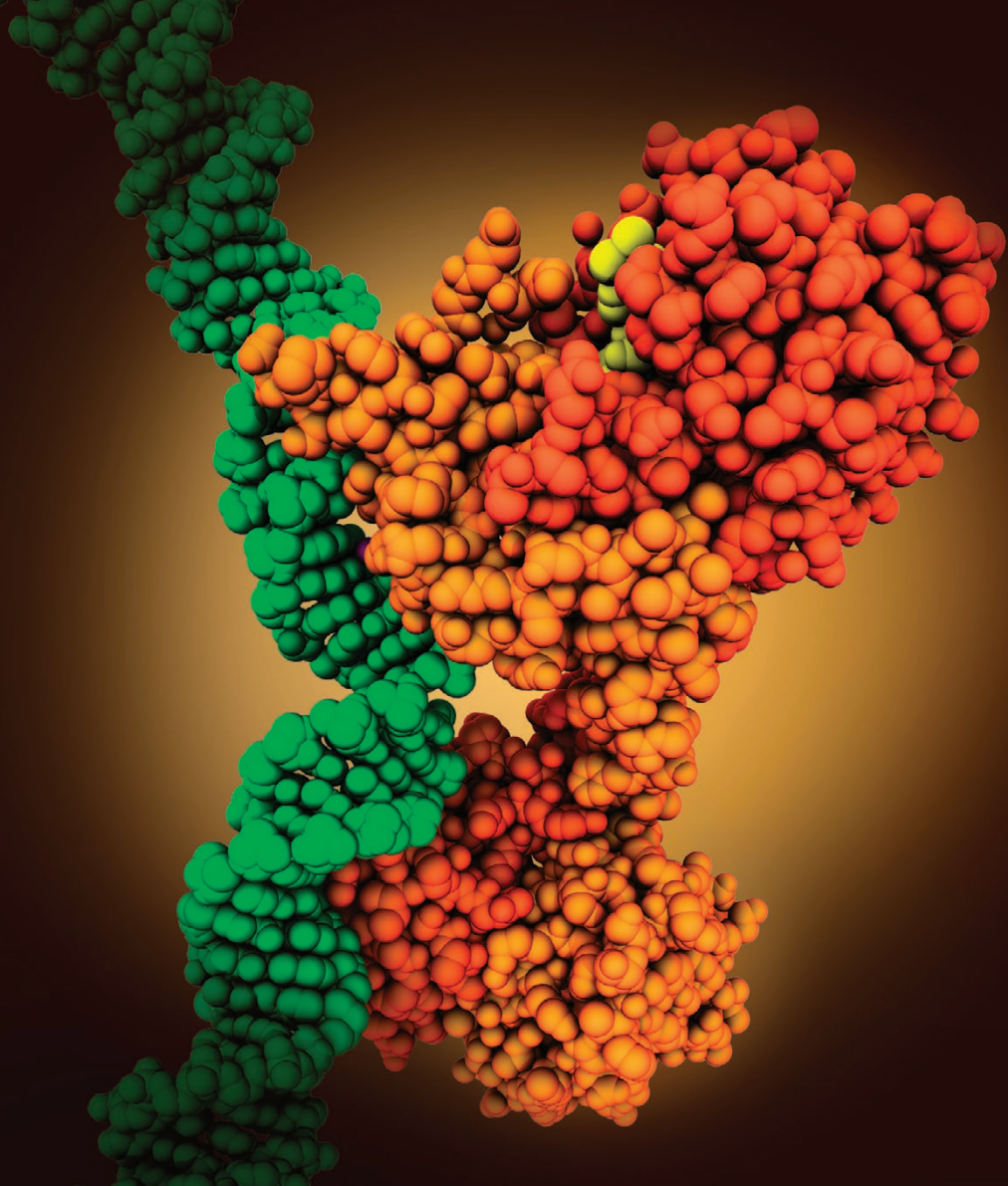


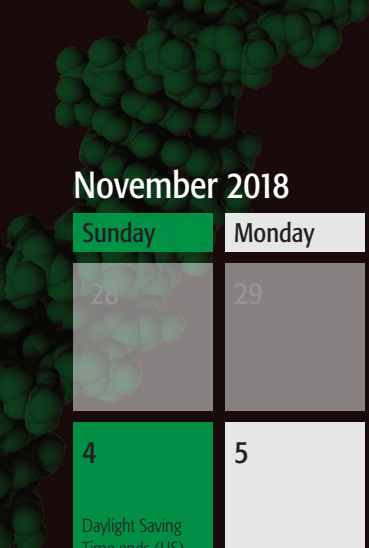
The war of antibiotics and resistance began long before medical science discovered the utility of antibiotics. Researchers reconstructed the vancomycin-resistance enzyme VanA from a 30,000 year old bacterium found in Arctic permafrost, showing it to be very similar to VanA enzymes made by modern bacteria.

## October 2018

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
30	1	2	3	4	5	6
7	8 Columbus Day	9	10	11	12	13
14	15	16	17	18	19 Diwali	20
21	22	23	24	25	26	27
28 Summer Time ends (Europe)	29	30	31 Halloween	1	2	3

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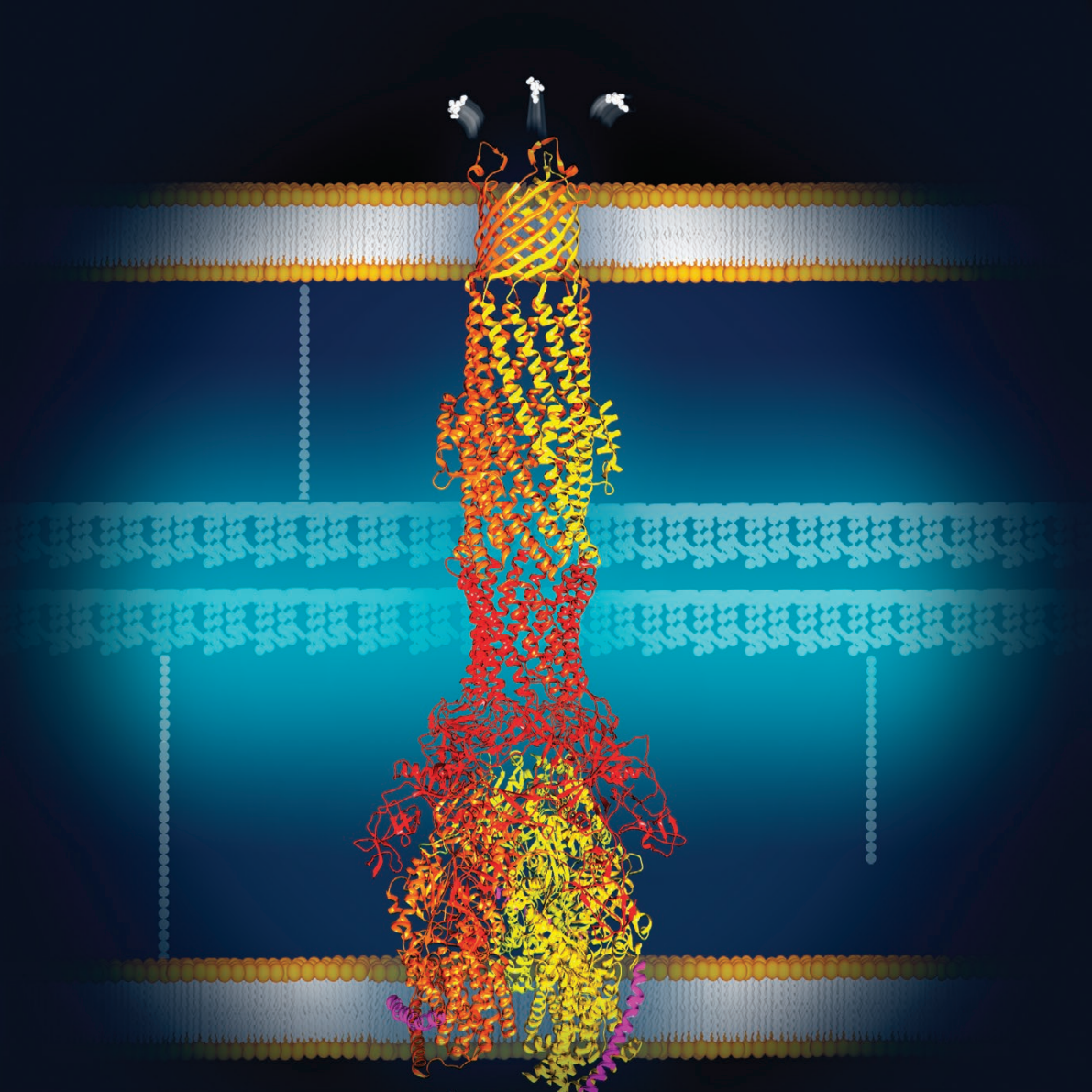


The gene regulator BmrR senses when antibiotics (such as puromycin, in yellow) get into a bacterial cell, directing the synthesis of multidrug efflux pumps to eject them out of the cell.

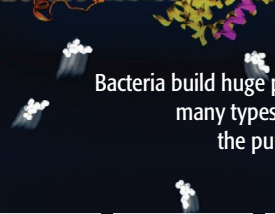
## November 2018

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
28	29	30	31	1	2	3
4 Daylight Saving Time ends (US)	5	6	7	8	9	10
11 Veterans Day	12	13	14	15	16	17
18	19	20	21	22 Thanksgiving	23	24
25	26	27	28	29	30	1

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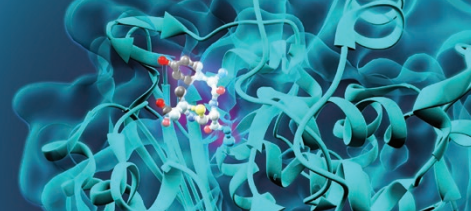


Bacteria build huge protein pumps that span their cell walls and expel many types of antibiotics. This cryoEM structure reveals how the pump works to expel antibiotics from bacterial cells.

## December 2018

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
25	26	27	28	29	30	1
2	3 Hanukkah	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 New Year's Eve	Christmas	Kwanzaa			

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## PDB AND ANTIMICROBIAL RESISTANCE (AMR)

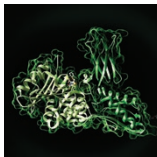
Antibiotics have saved countless lives, but pathogens are quickly finding ways to survive antibiotic treatment. Antibiotic-resistant bacteria are predicted to become the leading cause of death worldwide, with an expected death rate of 10 million people, annually, by 2050.<sup>1</sup>

They take many approaches: pumping antibiotics out of their cells, altering the molecular machinery that the antibiotics target, and attacking the antibiotics directly. Atomic structures publicly available in the PDB are revealing the details of drug resistance and providing new ways to combat it.

## 2018 VIDEO CHALLENGE FOR HIGH SCHOOL STUDENTS

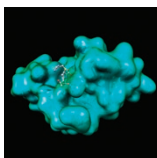
Every year since 2013, the RCSB PDB invites high school students across the USA to create short videos that tell a molecular story of health and disease. The 2018 video challenge will focus on Antimicrobial Resistance.

## REFERENCES & IMAGE CREDITS



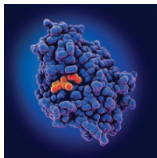
### January | PDB ID 2ex9

Kishida, H. *et al.* Crystal structure of penicillin binding protein 4 (dacB) from *Escherichia coli*, both in the native form and covalently linked to various antibiotics. *Biochemistry* **45**, 783-792 (2006)



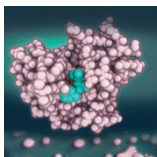
### February | PDB ID 5eph

Pozzi, C. *et al.* Crystal structure of the *Pseudomonas aeruginosa* BEL-1 extended-spectrum beta-lactamase and its complexes with moxalactam and imipenem. *Antimicrob Agents Chemother* **60**, 7189-7199 (2016)



### March | PDB ID 5uj3

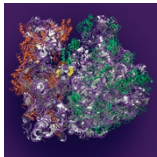
Pemberton, O.A. *et al.* Molecular basis of substrate recognition and product release by the *Klebsiella pneumoniae* carbapenemase (KPC-2). *J Med Chem* **60**, 3525-3530 (2017)



### April | PDB ID 4eyf

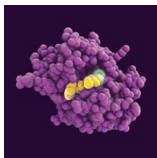
King, D.T. *et al.* New Delhi metallo-beta-lactamase: structural insights into beta-lactam recognition and inhibition. *J Am Chem Soc* **134**, 11362-11365 (2012)

Background Image: *Klebsiella pneumoniae*, the bacterium in which NDM-1 was first identified, on agar plate. Source: Center for Disease Control and Prevention



### May | PDB ID 4v52

Borovinskaya, M.A. *et al.* Structural basis for aminoglycoside inhibition of bacterial ribosome recycling. *Nat Struct Mol Biol* **14**, 727-732 (2007)



### June | PDB ID 4wql

Cox, G. *et al.* Structural and molecular basis for resistance to aminoglycoside antibiotics by the adenylyltransferase ANT(2'')-Ia. *MBio* **6**, mBio.02180-14 (2015)

Visit [pdb101.rcsb.org](http://pdb101.rcsb.org) in February 2018 for complete details about the AMR-themed video challenge.

If you have any questions, or if you would like to receive a monthly newsletter with news and updates about the challenge, please email [info@rcsb.org](mailto:info@rcsb.org).

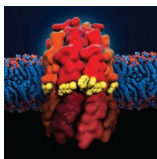
## ABOUT THIS CALENDAR

This calendar was created by RCSB PDB members Luigi Di Costanzo, Sutapa Ghosh, David S. Goodsell, Brian Hudson, Monica Sekharan, Maria Voigt, and Christine Zardecki, and undergraduate researchers Jenna Abyad and Priscilla Salcedo.

Molecular images were created using UCSF Chimera [Pettersen, E. F. *et al.* Chimera—a visualization system for exploratory research and analysis. *J Comput Chem* **25**, 1605-1612 (2004)], Molecular Maya, a plug-in for Autodesk Maya available at [clarafi.com](http://clarafi.com), and PyMOL (The PyMOL Molecular Graphics System, Version 1.7.4 Schrödinger, LLC).

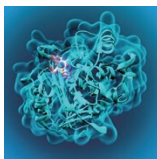
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<sup>1</sup> O'Neill J. Antimicrobial resistance: tackling a crisis for the health and wealth of nations. 2014. Review on Antimicrobial Resistance, London, United Kingdom [amr-review.org](http://amr-review.org)



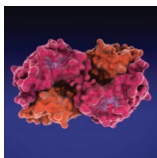
### July | PDB ID 4v1f

Preiss, L. *et al.* Structure of the mycobacterial ATP synthase Fo rotor ring in complex with the anti-TB drug bedaquiline. *Sci Adv* **1**, e1500106 (2015)  
Lipid bilayer model: Tieleman's Biocomputing Group, University of Calgary



### August | PDB ID 1ll9

Trehan, I. *et al.* Using steric hindrance to design new inhibitors of class C beta-lactamases. *Chem Biol* **9**, 971-980 (2002)



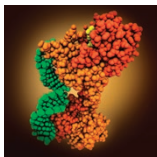
### September | PDB ID 1e4e

Roper, D.I. *et al.* The molecular basis of vancomycin resistance in clinically relevant Enterococci: crystal structure of D-alanyl-D-lactate ligase (VanA). *Proc Natl Acad Sci USA* **97**, 8921-8925 (2000)



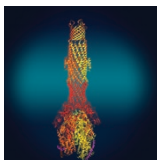
### October | PDB ID 3se7

D'Costa, V. M. *et al.* Antibiotic resistance is ancient. *Nature* **477**, 457-461 (2011)  
Background Photo: Erosion caused by thawing permafrost. Dentren/CC-BY-3.0



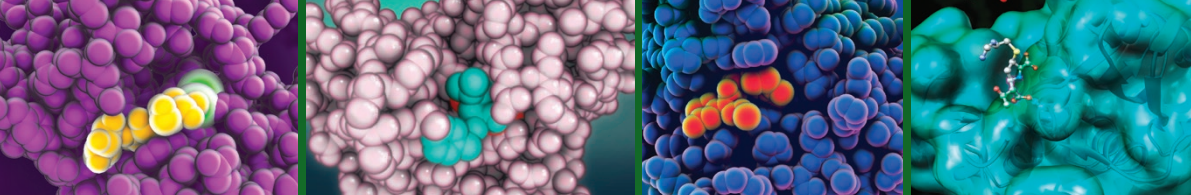
### November | PDB ID 3q3d

Bachas, S. *et al.* Structural contributions to multidrug recognition in the multidrug resistance (MDR) gene regulator, BmrR. *Proc Natl Acad Sci USA* **108**, 11046-11051 (2011)



### December | PDB ID 5o66

Wang, Z. *et al.* An allosteric transport mechanism for the AcrAB-TolC multidrug efflux pump. *Elife* **6**, eLife.24905 (2017)



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