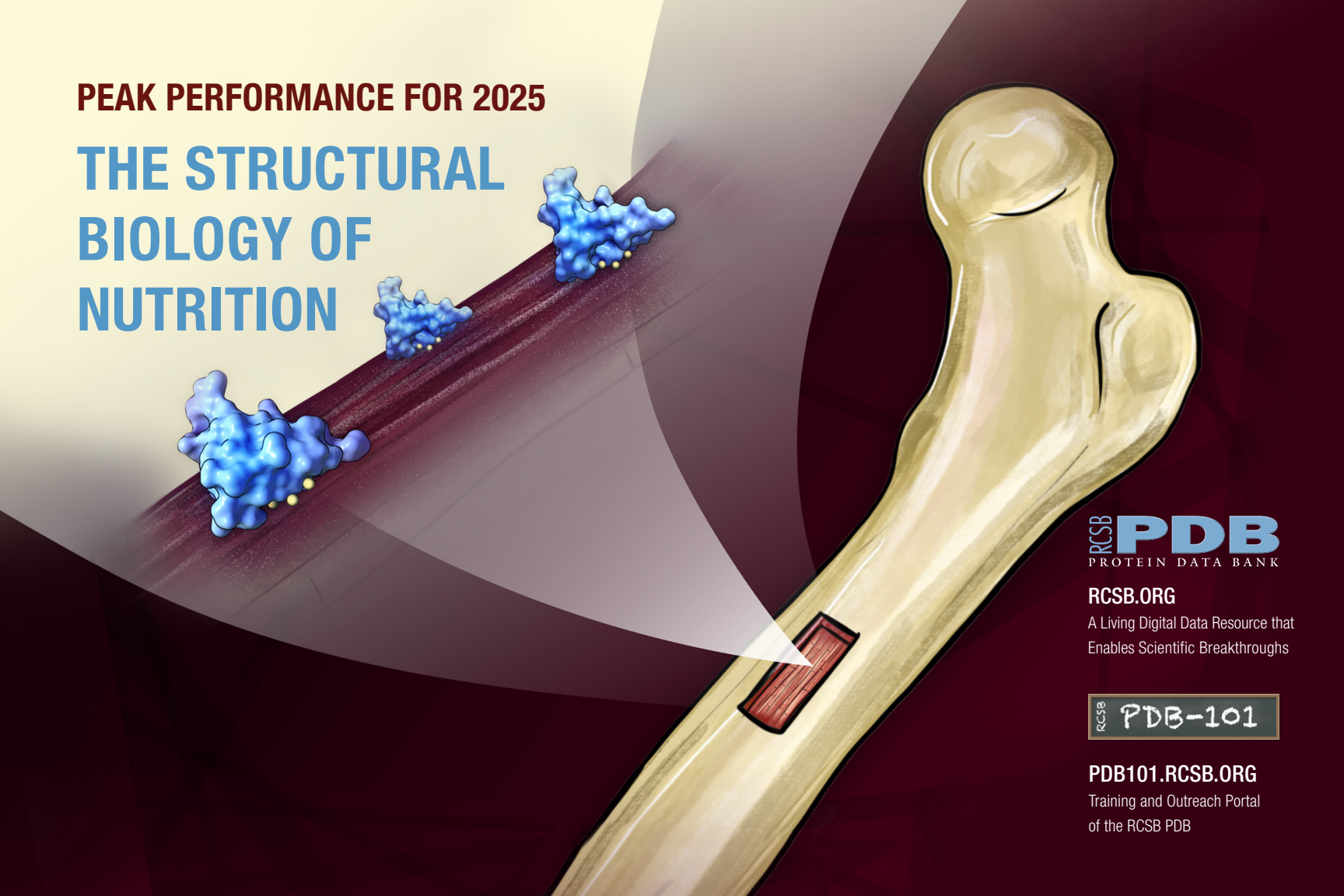
PEAK PERFORMANCE FOR 2025

THE STRUCTURAL BIOLOGY OF NUTRITION



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PEAK PERFORMANCE

THE STRUCTURAL BIOLOGY OF NUTRITION

The food that we eat contains four major classes of molecules–proteins, nucleic acids, lipids, and carbohydrates–as well as many micronutrients like vitamins and minerals. Our bodies contain thousands of different proteins that interact with and utilize these nutrients to build up our bodies and provide the energy we need to live.

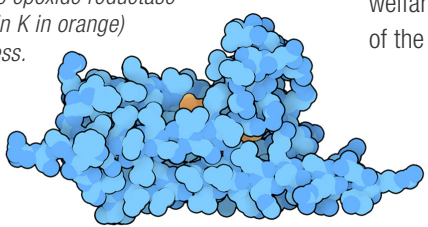
By understanding the structure and function of these protein-nutrient interactions, we can ensure that our body is performing at its peak. This knowledge informs the ways that we all can live our best lives, at all stages of our lives.

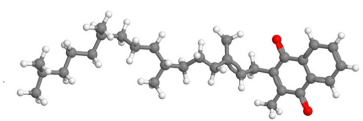
PDB-101 (**pdb101.rcsb.org**) adopts a biennial *Health Focus* and develops learning materials that highlight the connection of structural biology to health and medicine. The theme for 2024-2025 is *Peak Performance*.

These resources include *Molecule of Month* articles and educational resources.

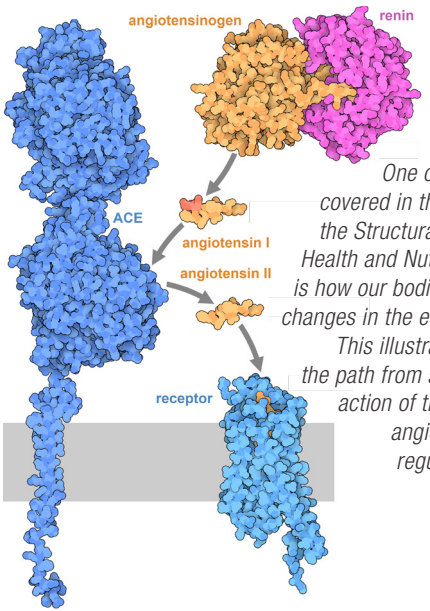
Molecule of the Month is a monthly column that includes an introduction to the structure and function of the molecule, a discussion of the relevance of the molecule to human health and welfare, and serves as a gateway for exploration of the structural data on **RCSB.org** in 3D.

Vitamin K (right) is used by enzymes that modify glutamate amino acids in proteins involved in blood clotting. The enzyme epoxide reductase (left, with the vitamin K in orange) assists in this process. Illustration from the December 2023 Molecule of the Month on Vitamins.





Educational resources include videos, posters, paper models, and an illustrated guide *Exploring the Structural Biology of Health and Nutrition.* This guide explains how proteins deliver and metabolize the various nutrients our bodies need to function.

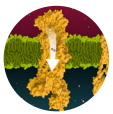


One of the topics covered in the Exploring the Structural Biology of Health and Nutrition guide is how our bodies adjust to changes in the environment. This illustration shows the path from synthesis to action of the hormone angiotensin that regulates blood pressure.

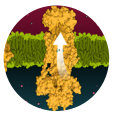
All *Peak Performance* resources are accessible on **pdb101.rcsb.org**. Use the *Browse* link from the top menu then choose *Health and Disease > Peak Performance* or scan the code.

The images in this calendar are based on structural data from the Protein Data Bank. Visit **RCSB.org** and use the PDB IDs provided here to explore the proteins in 3D.

JANUARY Sodium/Potassium and Neuronal Signaling

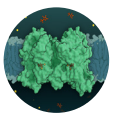


PDB ID 2zxe
T. Shinoda *et al.*, Crystal structure of the sodium-potassium pump at 2.4 Å resolution. *Nature* **459**, 446-450 (2009).



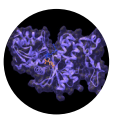
PDB ID 4hqj
M. Nyblom *et al.*, Crystal structure of Na+, K(+)-ATPase in the Na(+)-bound state. *Science* **342**, 123-127 (2013).

FEBRUARY Vitamin C Transport



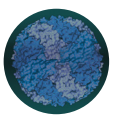
PDB ID 7ytw
M. Wang *et al.*, Structural basis of vitamin C recognition and transport by mammalian SVCT1 transporter. *Nature Communications* **14**, 1361 (2023).

MARCH Vitamin B5 and Energy Production



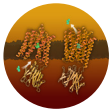
PDB ID 5kpr
C. Subramanian *et al.*, Allosteric Regulation of Mammalian Pantothenate Kinase. *J Biol Chem* **291**, 22302-22314 (2016).

APRIL Iron Storage and Ferritin



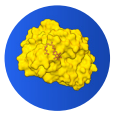
PDB ID 1fha
D. M. Lawson *et al.*, Solving the structure of human H ferritin by genetically engineering intermolecular crystal contacts. *Nature* **349**, 541-544 (1991).

MAY Protein Peptides Transport



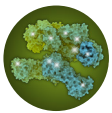
PDB ID 7pmx, 7pmy
M. Killer *et al.*, Structural snapshots of human PepT1 and PepT2 reveal mechanistic insights into substrate and drug transport across epithelial membranes. *Sci Adv* **7**, eabk3259 (2021).

JUNE Vitamin E Storage and Transport



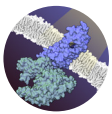
PDB ID 1oip
R. Meier *et al.*, The molecular basis of vitamin E retention: structure of human alpha-tocopherol transfer protein. *J Mol Biol* **331**, 725-734 (2003).

JULY Fatty Acids Synthesis



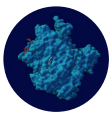
PDB ID 2vz9
T. Maier *et al.*, The crystal structure of a mammalian fatty acid synthase. Science 321, 1315-1322 (2008).

AUGUST Vitamin A and Vision



PDB ID 6oy9
Y. Gao *et al.*, Structures of the Rhodopsin-Transducin Complex: Insights into G-Protein Activation. *Mol Cell* **75**, 781-790 e783 (2019).

SEPTEMBER Glucose Release from Glycogen

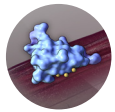


PDB ID 6gpb
L. N. Johnson *et al.*, Refined crystal structure of the phosphorylase-heptulose 2-phosphate-oligosaccharide-AMP complex. *J Mol Biol* **211**, 645-661 (1990).

OCTOBER Sodium and Action Potential

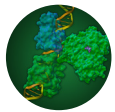
PDB ID 6j8j
H. Shen *et al.*, Structures of human Na(v)1.7 channel in complex with auxiliary subunits and animal toxins. *Science* **363**, 1303-1308 (2019).

NOVEMBER Osteocalcin and Bone Health



PDB ID 1q8h
Q. Q. Hoang *et al.*, Bone recognition mechanism of porcine osteocalcin from crystal structure. *Nature* **425**, 977-980 (2003).

DECEMBER Vitamin D and Calcium Regulation



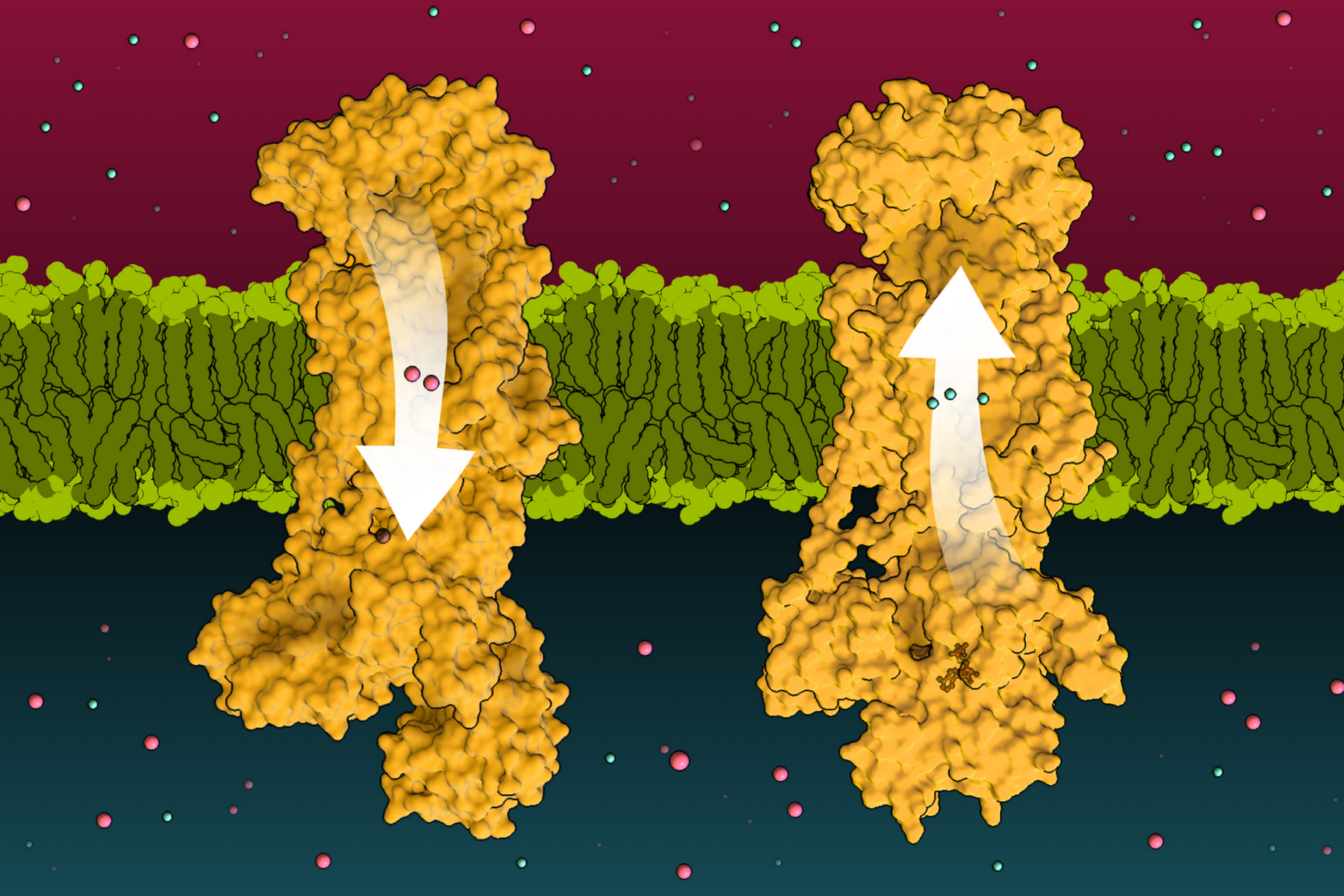
PDB ID 3c6g
N. Strushkevich *et al.*, Structural analysis of CYP2R1 in complex with vitamin D3. *J Mol Biol* **380**, 95-106 (2008).

PDB ID 1ynw
P. L. Shaffer *et al.*, Structural analysis of RXR-VDR interactions on DR3 DNA. *J Steroid Biochem Mol Biol* **89-90**, 215-219 (2004).

3DEM Map EMD-1985 *(reference, not shown)*
I. Orlov *et al.*, Structure of the full human RXR/VDR nuclear receptor heterodimer complex with its DR3 target DNA. *EMBO J* **31**, 291-300 (2012).

The illustrations in this calendar were created by Spring 2024 RCSB PDB intern Xinyi Christine Zhang. Christine is a first-year student at Harvard College pursuing a concentration in computational neuroscience. She is passionate about science, art, and advancing scientific communication. Her achievements include being named an MIT THINK Scholar, NJ Governor's School in the Science Scholar, and NJ Governor's STEM Scholar. Her artistic work has been recognized on the national level by organizations such as the National Institutes of Health, RCSB PDB, the Scholastic Art and Writing Awards, the *Adroit Journal*, and the *Washington Post.*

The images of PDB structures in this calendar were created using UCSF Chimera X (E. C. Meng *et al.*, UCSF ChimeraX: Tools for structure building and analysis. *Protein Sci.* **32**, e4792 (2023).)



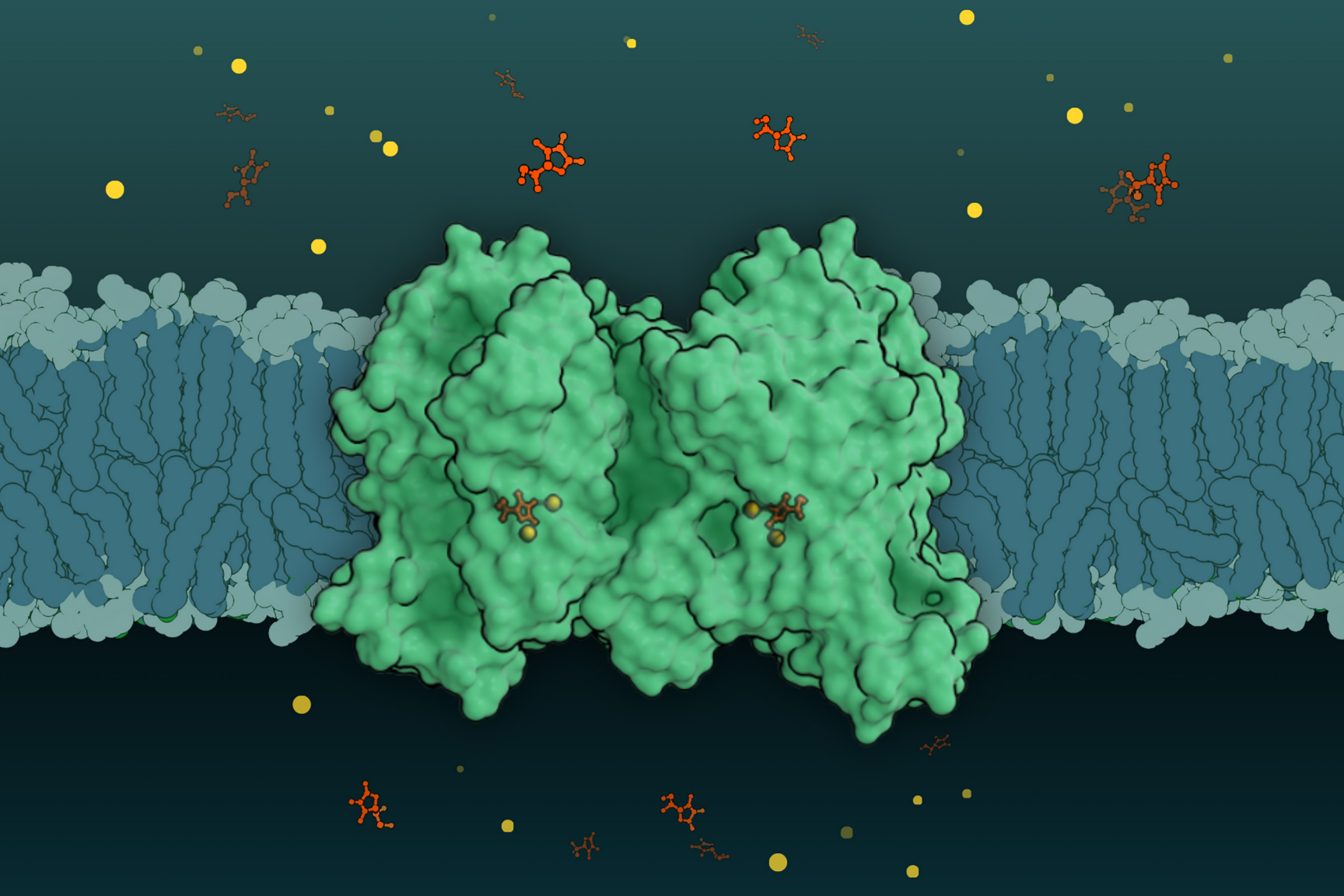
JANUARY 2025

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

Sodium/Potassium and Neuronal Signaling

The correct balance of sodium and potassium ions across the neuronal membrane is essential for neuronal signaling. When the neuron is at rest, there is a higher concentration of sodium outside the cell and a higher concentration of potassium inside. Each time a neuron propagates an action potential, this balance is temporarily disrupted: sodium ions rush into the cell while potassium ions exit to restore the membrane potential. To restore the sodium-potassium equilibrium necessary for neuronal signaling, a Na/K pump serves as an effective solution to this problem. It shuttles two potassium ions (pink) into the cell (navy) while ushering three sodium ions (blue) out (red).

Learn more: **pdb101.rcsb.org**



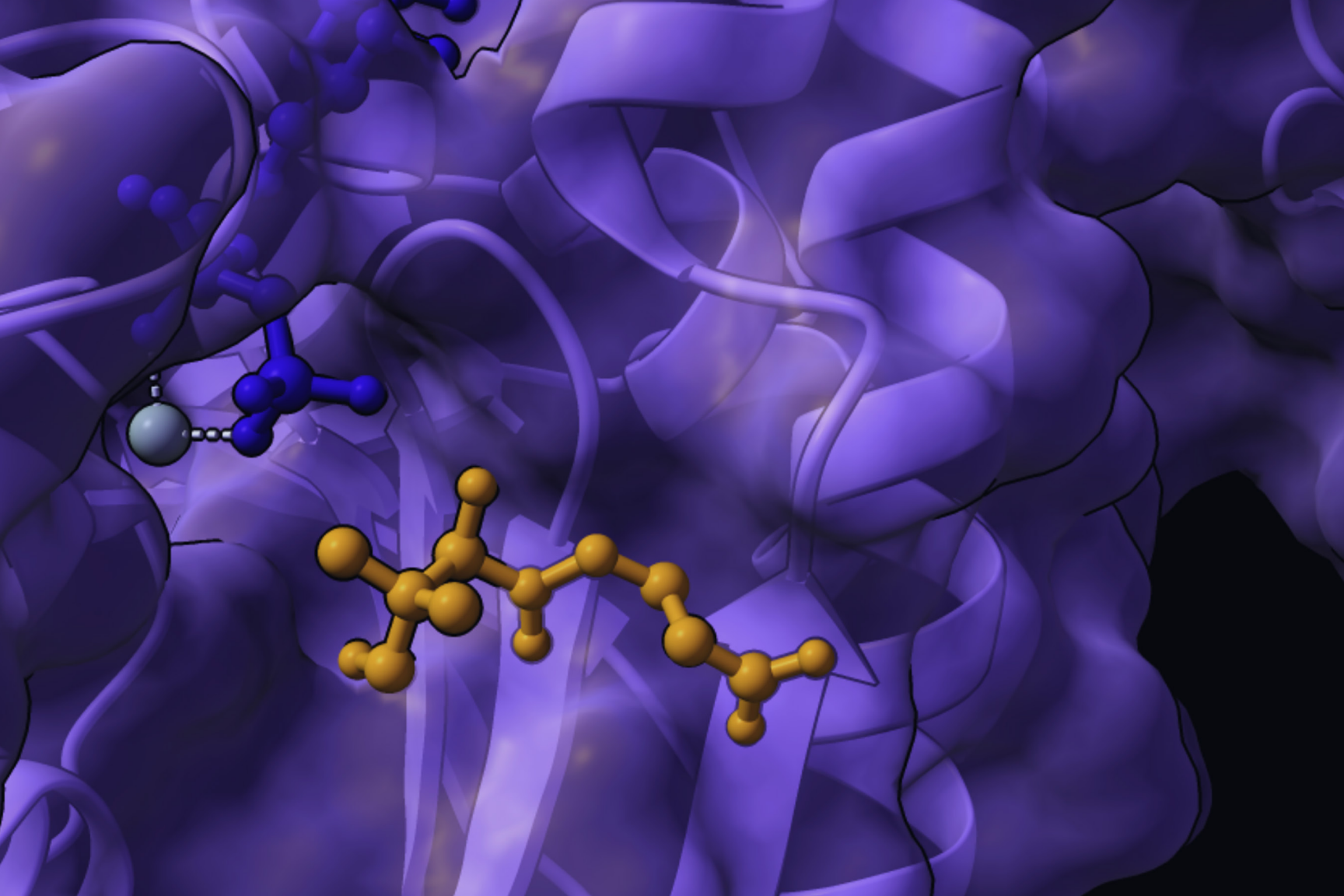
FEBRUARY 2025

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

Vitamin C Transport

Sodium-dependent vitamin C transporters (green) serve as the gatekeepers for the uptake of vitamin C, also known as ascorbic acid (red). As two sodium ions (yellow) travel down their concentration gradient through the protein, they provide the necessary energy to ferry one molecule of vitamin C across the cell membrane. Once inside the bloodstream, vitamin C journeys through the body and is distributed to various tissues, where it aids in growth and tissue repair.

Learn more: **pdb101.rcsb.org**



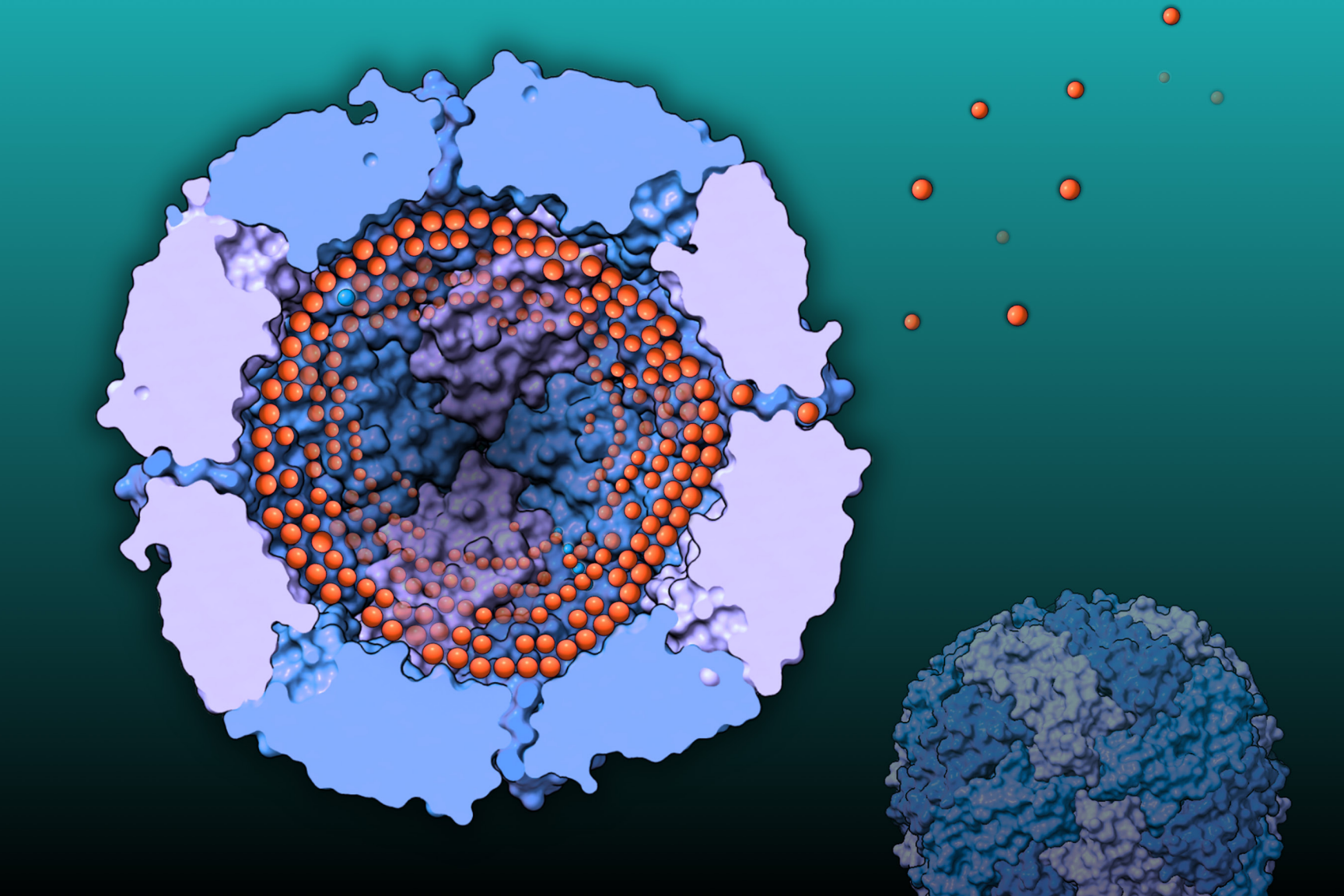
MARCH 2025

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

Vitamin B and Energy Production

Behind the scenes of your body's energy production lies Vitamin B5 (yellow), which plays a vital role in converting nutrients such as carbohydrates and fat into usable energy. This process is facilitated by pantothenate kinase (purple), which phosphorylates Vitamin B5 to form 4'-phosphopantothenate. However, this chemical transformation is not free; it requires a molecule of adenosine triphosphate (ATP), represented here in another form (blue). After additional steps, 4'-phosphopantothenate is converted to coenzyme A, an essential molecule for countless biochemical reactions including the synthesis of ATP and fatty acids.

Learn more: **pdb101.rcsb.org**



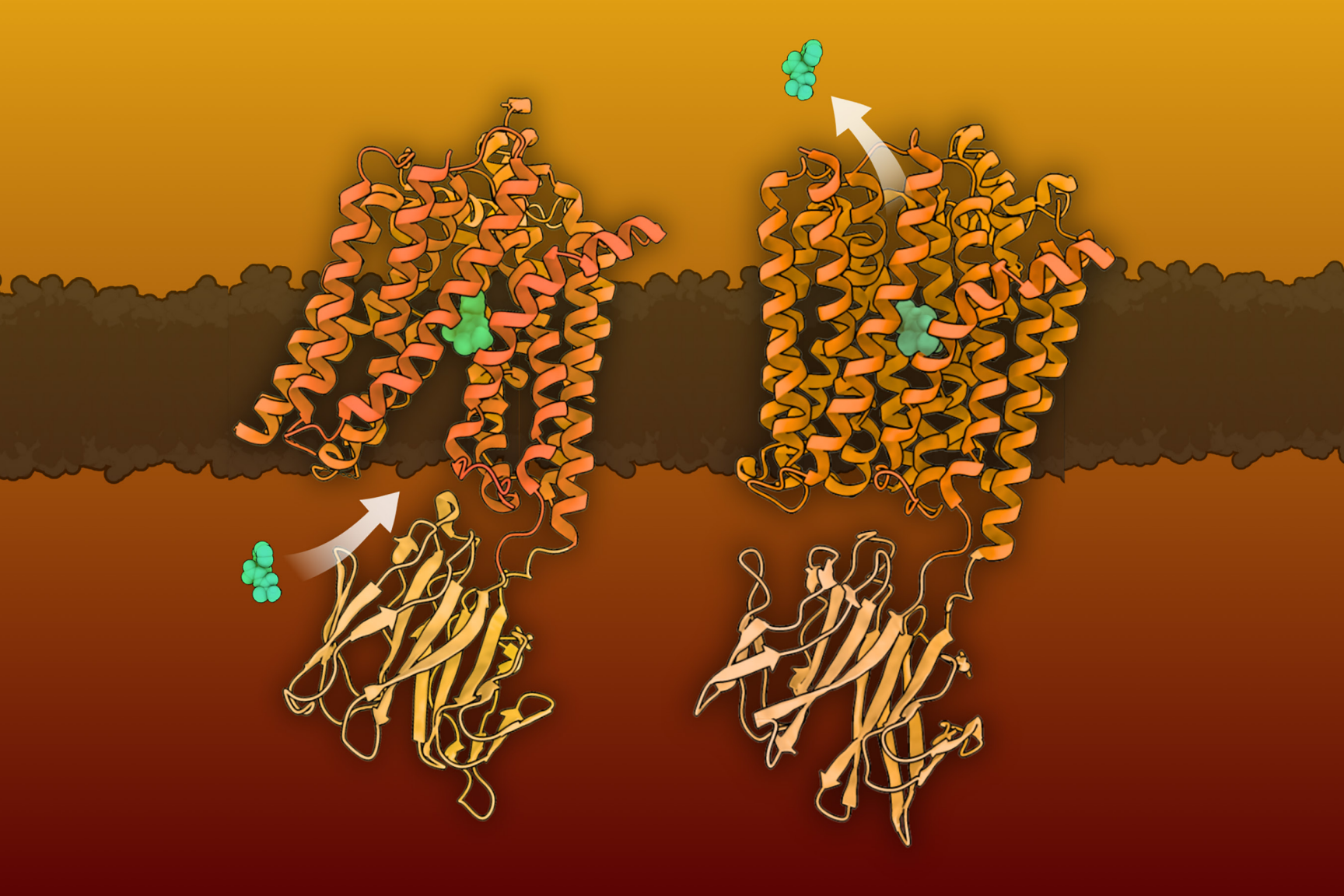
APRIL 2025

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

Iron Storage and Ferritin

Hemoglobin, which ferries oxygen in our blood, and myoglobin, which stores oxygen ready for use in muscle cells, both require iron to function. However, the water and oxygen in our bodies may convert the iron ions to an unusable rust-like state. Our bodies maintain a store of usable iron by sheltering these ions inside ferritin, a hollow, spherical protein shown as a cross-section in this visualization. Once the iron ions (red) enter ferritin through tiny pores, they are converted to a different state and form a shell attached to the interior of the protein. An impressive 4500 iron ions can fit inside a single molecule of ferritin.

Learn more: **pdb101.rcsb.org**



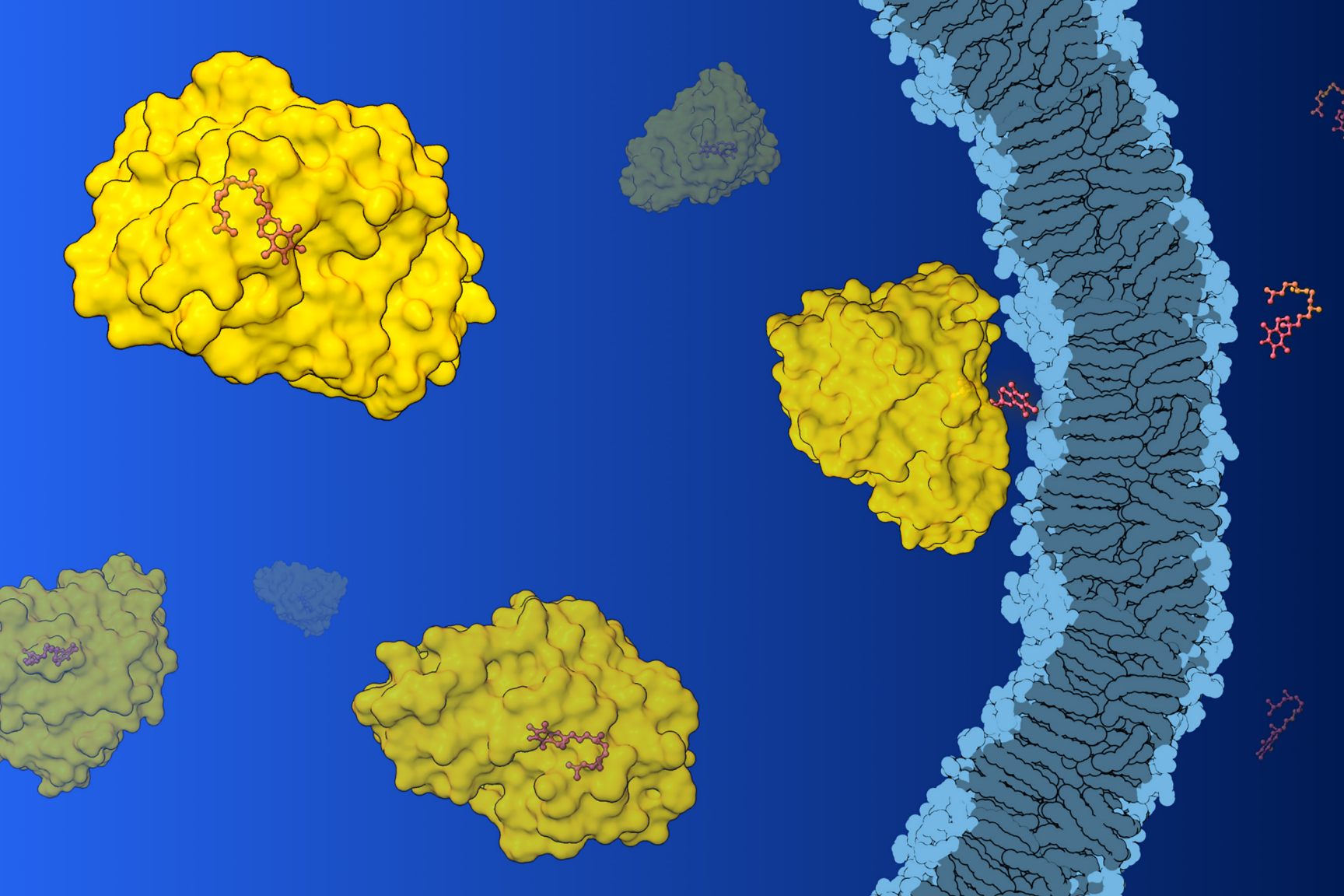
MAY 2025

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

Protein Peptide Transport

After you eat, dietary proteins that made up your meal are broken down in your body into smaller components. Peptide transporter 1, shown in two confirmations, transports small peptides–short protein chains, two to three amino acids in length–into intestinal cells (represented in lighter orange above the membrane). On the left, the transporter adopts an outward-facing, open conformation that is ready to capture peptides (cyan). Then, as shown on the right, the transporter flips into an inward-facing, partially occluded conformation to release the peptides towards the interior of the cell.

Learn more: **pdb101.rcsb.org**



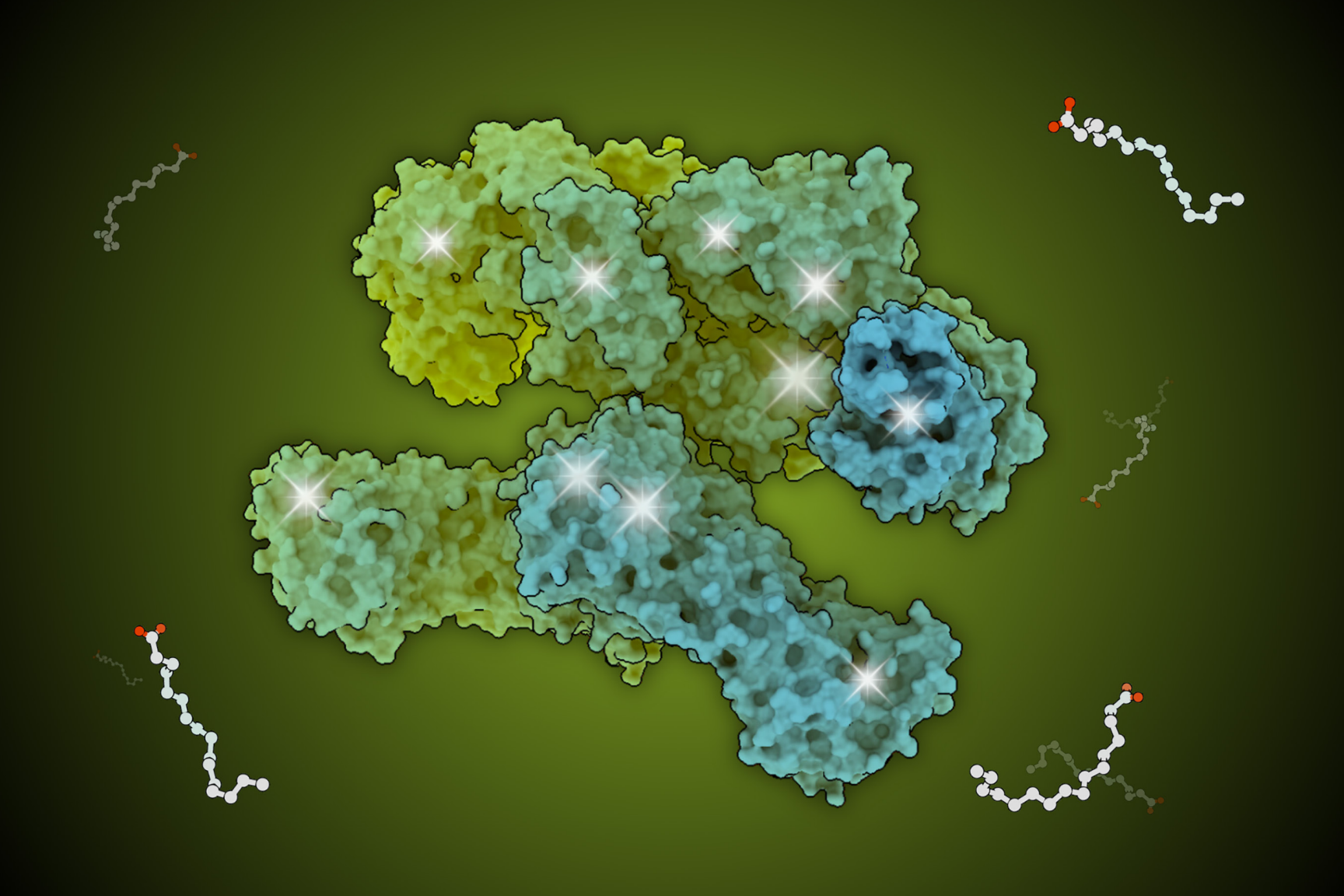
JUNE 2025

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

Vitamin E Storage and Transport

The liver absorbs vitamin E from the diet and selectively releases a specific form, α-tocopherol (pink), back into the bloodstream. α-Tocopherol transfer protein (yellow) is responsible for recognizing, storing, and transporting α-tocopherol out of liver cells. From there, α-tocopherol is carried to various parts of the body, functioning as an antioxidant and an immune system enhancer, among many other roles.

Learn more: **pdb101.rcsb.org**



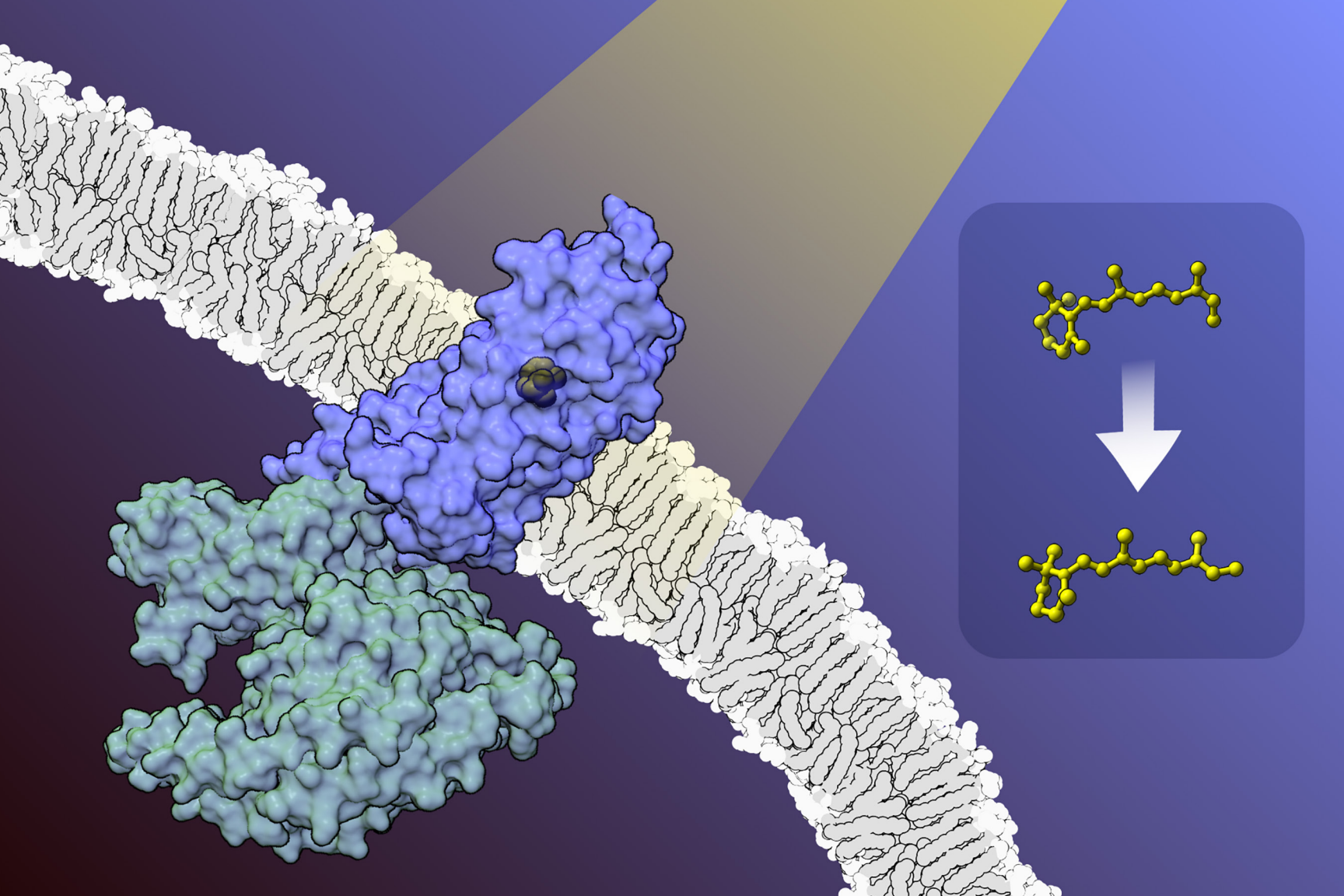
JULY 2025

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
30	1	2	3	4 Independence Day (USA)	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	6	7	8	9	10

Fatty Acids Synthesis

Fatty acids are essential for energy storage and are vital components of various tissues. Fatty Acid Synthase (FAS) is the master architect behind the construction of these fats. FAS is a sophisticated enzymatic system comprising two identical protein subunits, each folded into seven interconnected functional domains. It functions like an assembly line, with each domain catalyzing a distinct step in the reaction and with the growing fatty acid chain being transferred from one active site to the next. These active sites are marked with bright flashes.

Learn more: **pdb101.rcsb.org**



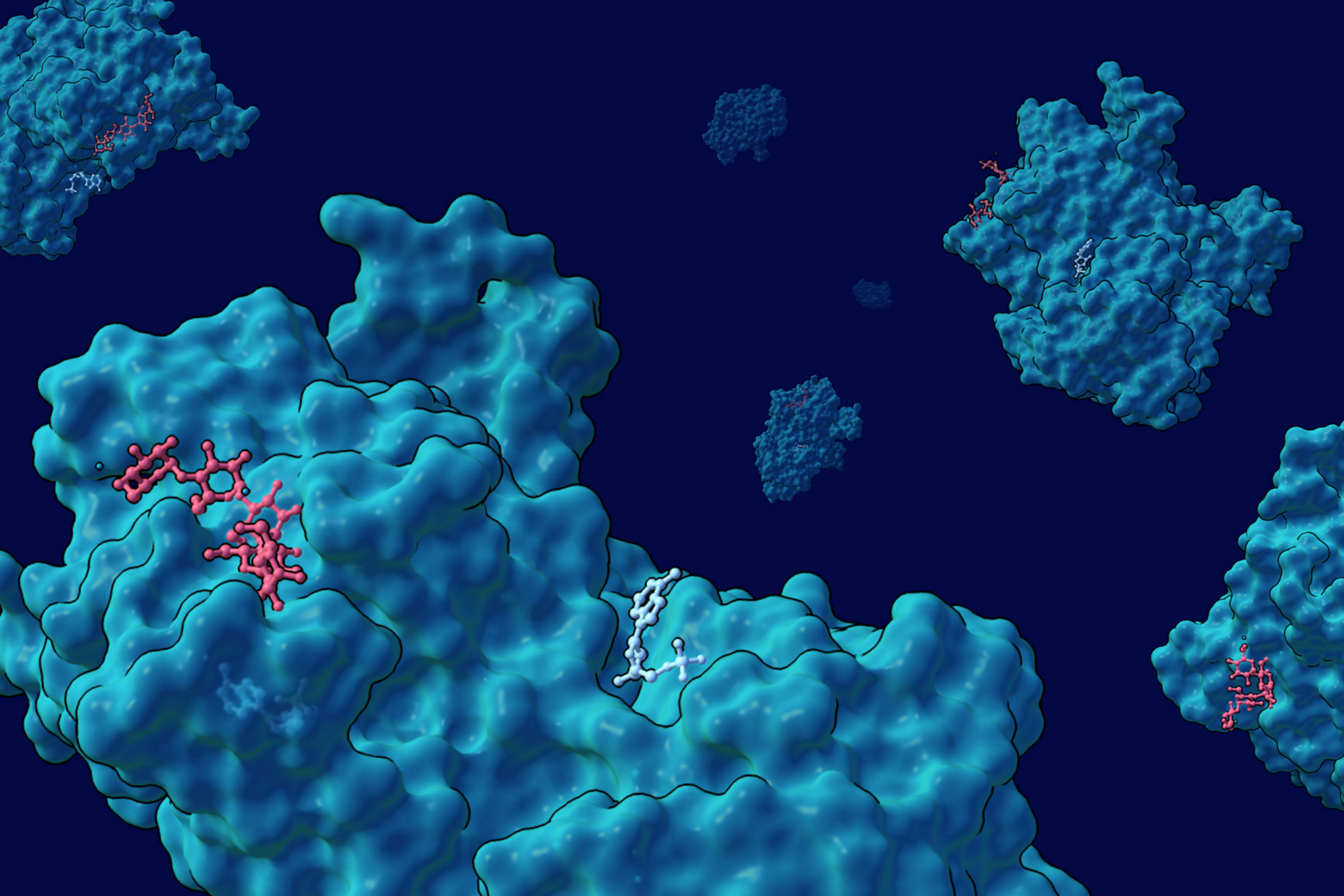
AUGUST 2025

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	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31	1	2	3	4	5	6

Vitamin A and Vision

Vitamin A plays a crucial role in vision by converting light into electrical signals. At the heart of this process are rhodopsin proteins (purple) found in the retina, a light-sensing tissue at the back of the eye. Vitamin A is the precursor to retinal (yellow), which is nestled within the active site of rhodopsin. When light strikes retinal, it transforms from its cis form to its trans form (see inset), allowing rhodopsin to bind and activate its associated G-protein complex (green). This process sets off a cascade of events that ultimately leads to the perception of light.

Learn more: **pdb101.rcsb.org**



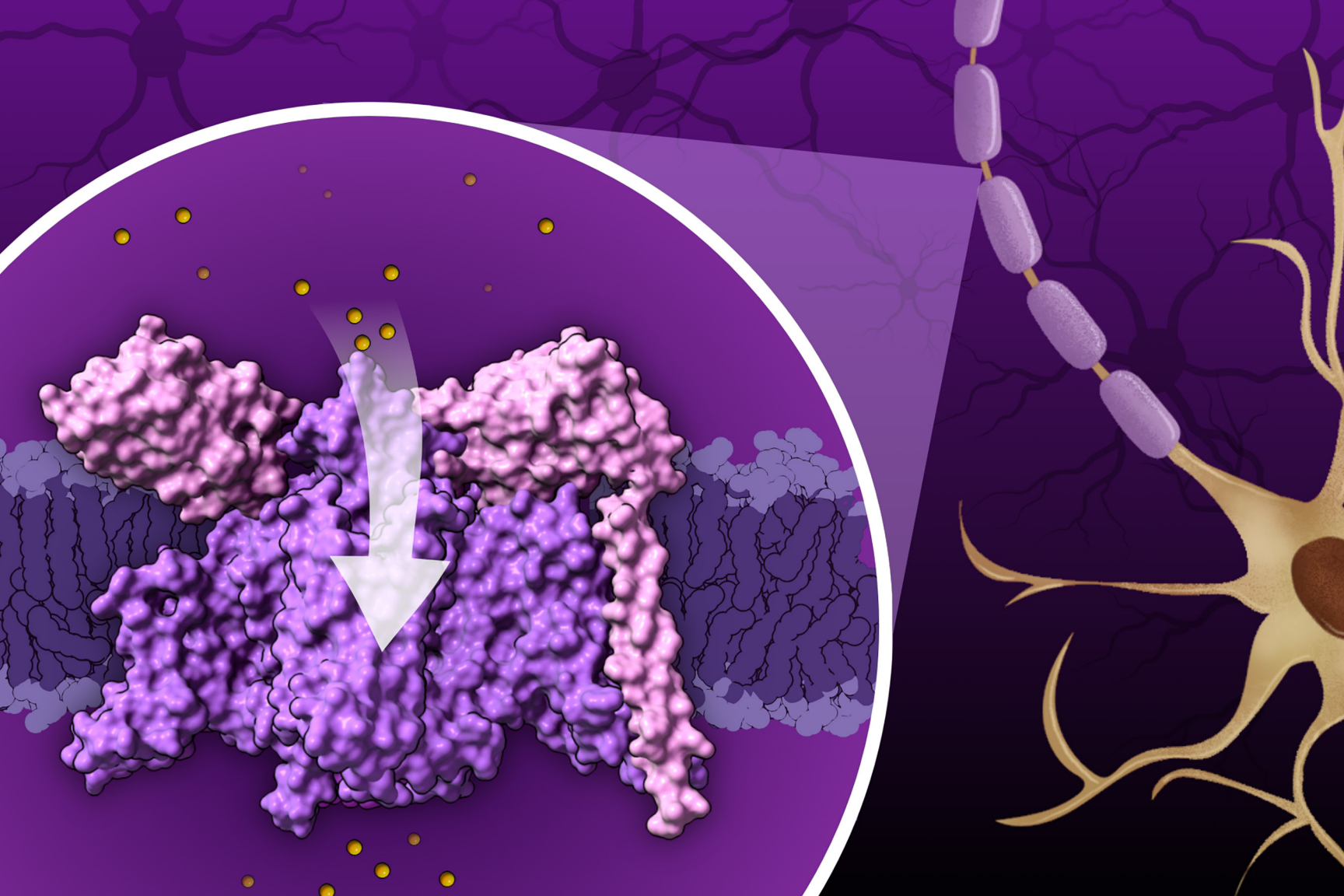
SEPTEMBER 2025

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

Glucose Release from Glycogen

Within the body, carbohydrates undergo a series of transformations that culminate in the production of glucose, the source of energy for numerous metabolic pathways. Excess glucose is stockpiled within the liver and muscles as glycogen (red). When the body requires a boost of energy, it can access stored glycogen. AMP (white) binds to and activates glycogen phosphorylase (blue), which triggers the breakdown of glycogen, thus providing the glucose supply for energy production.

Learn more: **pdb101.rcsb.org**



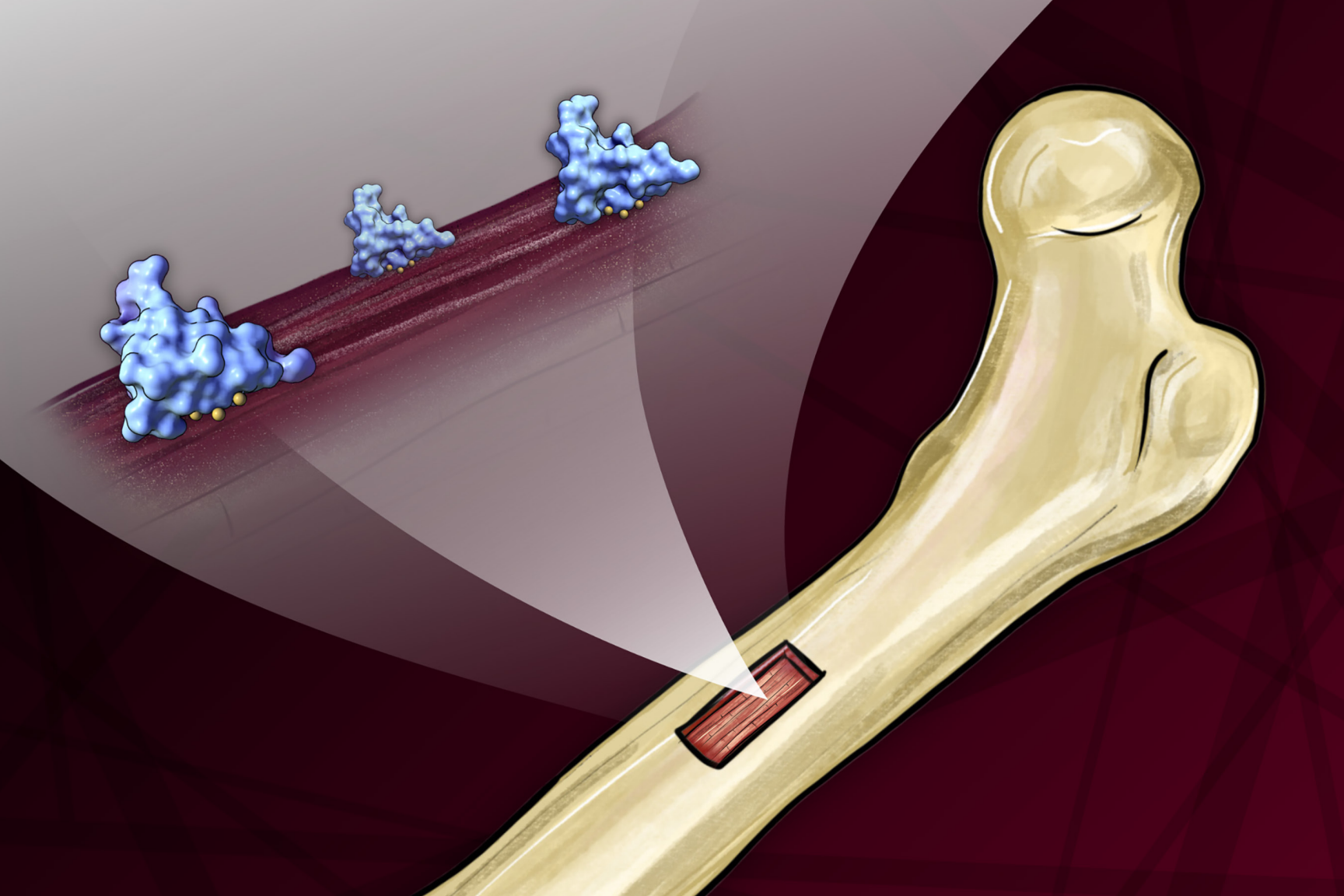
OCTOBER 2025

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
28	29	30	1 Yom Kippur begins	2	3	4
5	6	7	8	9	10	11
12	13 Indigenous Peoples' Day	14	15	16	17	18
19	20 PDB announced in 1971 Diwali	21	22	23	24	25
26	27	28	29	30	31 Halloween	1
2	3	4	5	6	7	8

Sodium and Action Potential

When a neuron is at rest, sodium ions (yellow) make the cell's exterior more positively charged than its interior. When the neuronal signal is initiated at the synapse, positively charged ions flow into the neuron. This causes the voltage-gated sodium channels to open, allowing the cell membrane to undergo rapid depolarization. This change in potential activates voltage-gated sodium channels, allowing sodium ions to pour into the cell, further depolarizing the cell and ultimately triggering an action potential.

Learn more: **pdb101.rcsb.org**



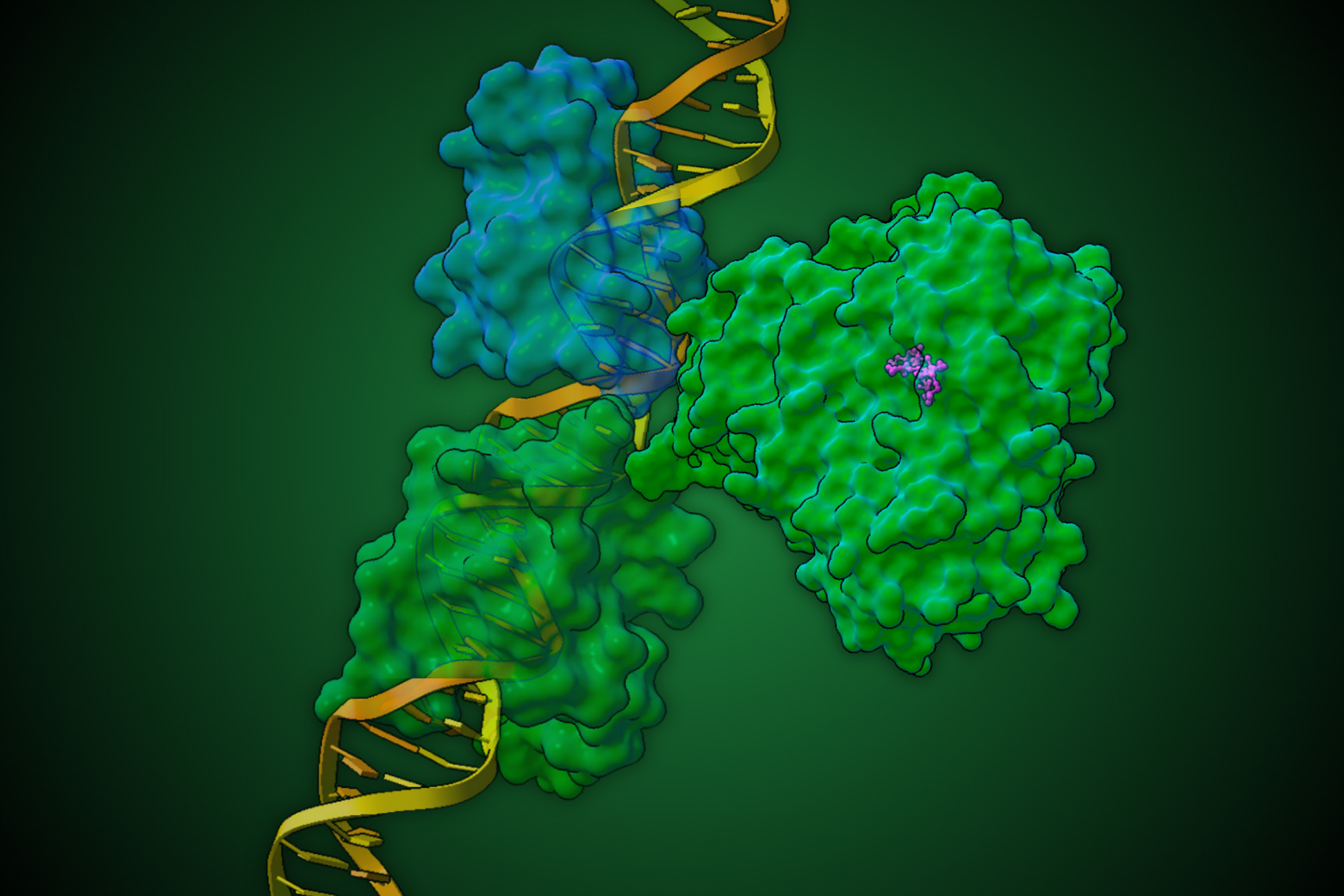
NOVEMBER 2025

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

Osteocalcin and Bone Health

Osteocalcin (blue) is essential for both bone growth and the development of bone strength. Within bone tissue, it forms bonds with the surface of calcium-containing crystals called hydroxyapatite by interacting with three calcium ions (yellow). Through these ionic bonds, osteocalcin can fine-tune the alignment of hydroxyapatite crystals to ensure they are parallel to collagen fibrils. This arrangement reinforces bone strength in the direction where they are subjected to significant stresses.

Learn more: **pdb101.rcsb.org**



DECEMBER 2025

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
30	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 Christmas Day	26 Kwanzaa	27
28	29	30	31 New Year's Eve	1	2	3
4	5	6	7	8	9	10

Vitamin D and Calcium Regulation

Vitamin D is converted into a hormone in the kidneys and is distributed throughout the body, where it notably governs intestinal calcium absorption and bone maintenance. This hormone (magenta) binds to Vitamin D receptors (green), which contain two distinct domains: one that binds to the hormone and one that binds to DNA. These receptor units team up with the 9-cis-retinoic acid receptor (blue) to interact with DNA, ultimately activating or repressing synthesis of crucial proteins involved in calcium regulation.

Learn more: **pdb101.rcsb.org**

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