2019 CALENDAR

WHAT IS A PROTEIN?

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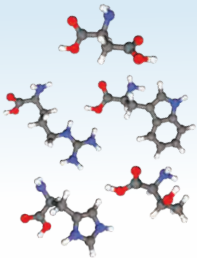
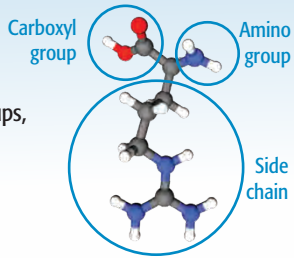
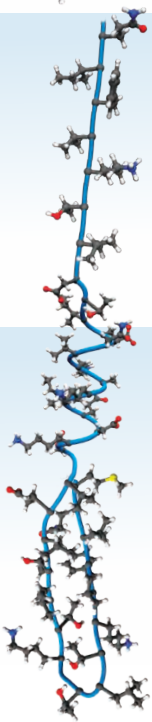
WHAT IS A PROTEIN?



BUILDING BLOCKS

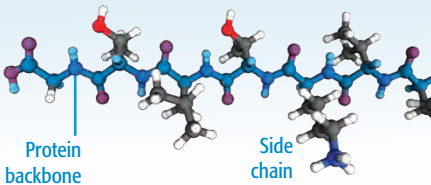
Proteins are large biomolecules built from twenty-one standard amino acids. Each amino acid contains amino and carboxyl groups, and an identifying side chain. These side chains determine the unique final shape of a protein. Some amino acids will hide away from the surrounding water, while others will interact with water, each other, or other molecules.





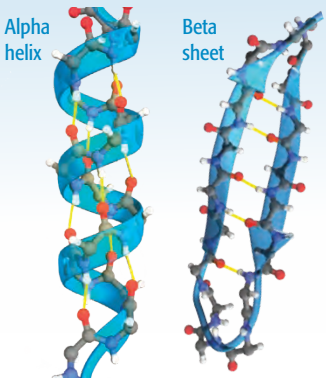
PRIMARY STRUCTURE

Primary structure is the linear sequence of amino acids as encoded by DNA. This sequence defines how the protein will fold and therefore how it will function. The linked series of residual carboxyl and amino groups are known as the protein backbone (shown in blue as a pipe on the left, and as atoms on the right).



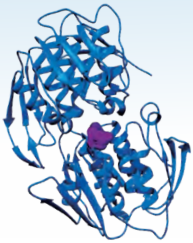
SECONDARY STRUCTURE

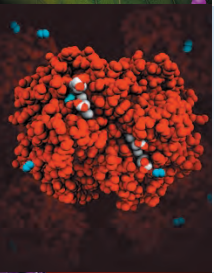
Hydrogen bonds between amino acids form two particularly stable structural elements in proteins: alpha helices and beta sheets. To illustrate these patterns, the side chain atoms are shown (left) and hidden (right). The hydrogen bonds are shown right in yellow.



TERTIARY STRUCTURE

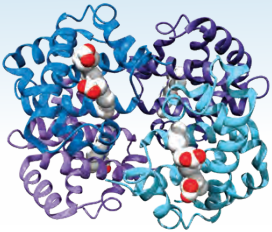
Protein chains fold into organized 3D structures (shapes) made up of secondary structural elements connected by random coil segments as seen in enzyme EPSP Synthase (all atoms represented as spheres, left; backbone represented as ribbon, right).

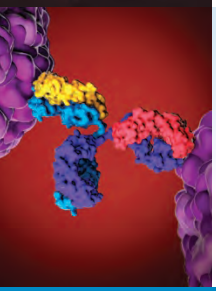




QUATERNARY STRUCTURE

Two or more polypeptide chains can come together to form one functional molecule with several subunits. The four subunits of hemoglobin cooperate so that the complex picks up and delivers more oxygen than is possible with single subunits.





PROTEIN FUNCTION

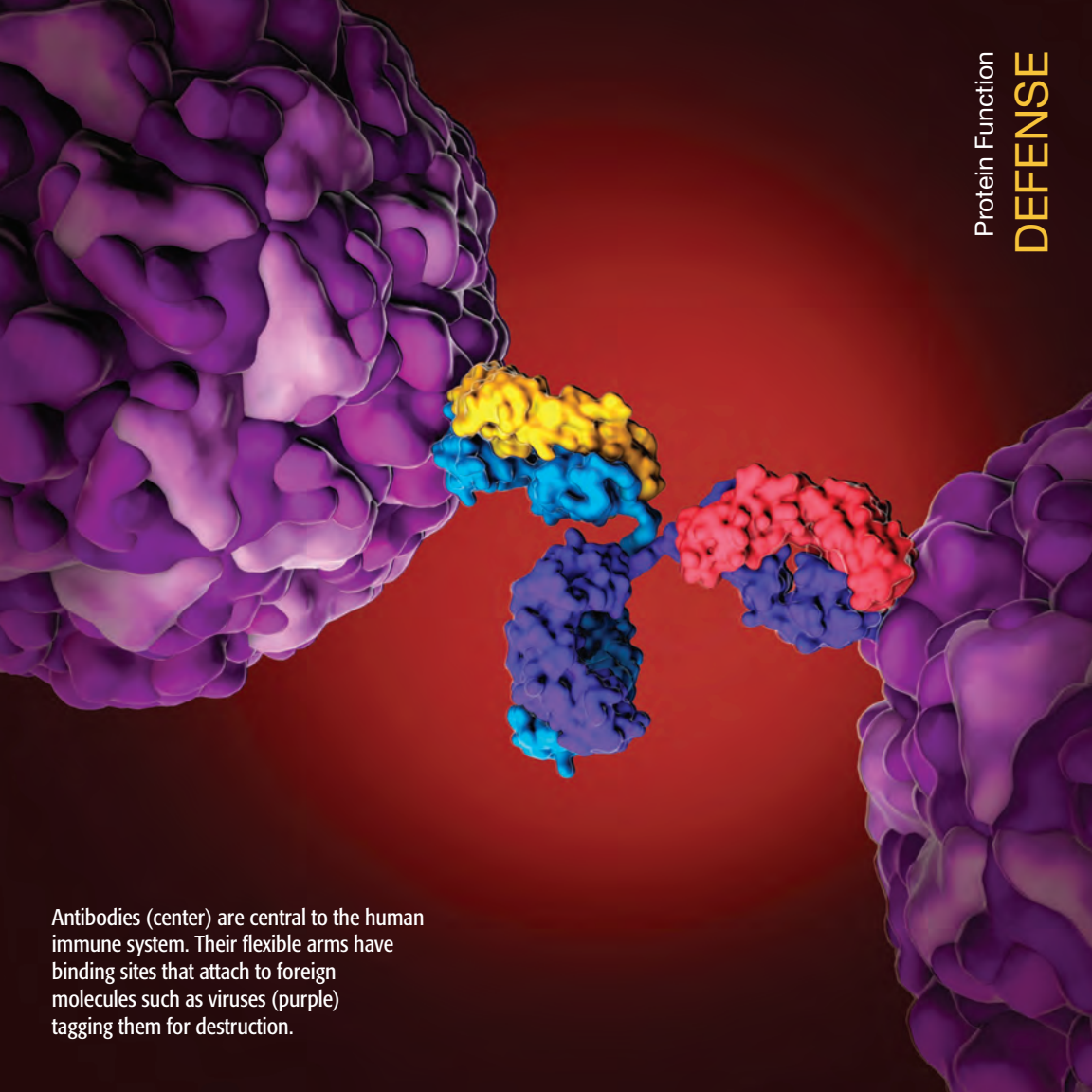
Proteins play vital roles in all living organisms. Their specific amino acid sequences give proteins their distinct shapes and chemical characteristics. Proteins rely on the recognition of specific 3D molecular shapes to function correctly for DEFENSE, TRANSPORT, ENZYMES, STRUCTURE, STORAGE, and COMMUNICATION.

These protein shapes and functions are highlighted in this calendar.

ABOUT THIS CALENDAR

This calendar is based on the PDB-101 educational video by Maria Voigt and David Goodsell *What is a Protein?* available at **pdb101.rcsb.org**.

Molecular images were created using UCSF Chimera (E. F. Pettersen *et al.* (2004) Chimera–a visualization system for exploratory research and analysis. *J Comput Chem* **25:** 1605-1612) and Molecular Maya, a free plugin for Autodesk Maya that lets users import, model and animate molecular structures available at clarafi.com.



Antibodies (center) are central to the human immune system. Their flexible arms have binding sites that attach to foreign molecules such as viruses (purple) tagging them for destruction.

PDB Structure **1igt**
L. J. Harris *et al.* (1997) Refined structure of an intact IgG2a monoclonal antibody. *Biochemistry* **36**: 1581-1597

PDB Structure **4rhv**
E. Arnold *et al.* (1988) The use of molecular-replacement phases for the refinement of the human rhinovirus 14 structure. *Acta Crystallogr., Sect.A* **44**: 270-282

January 2019

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

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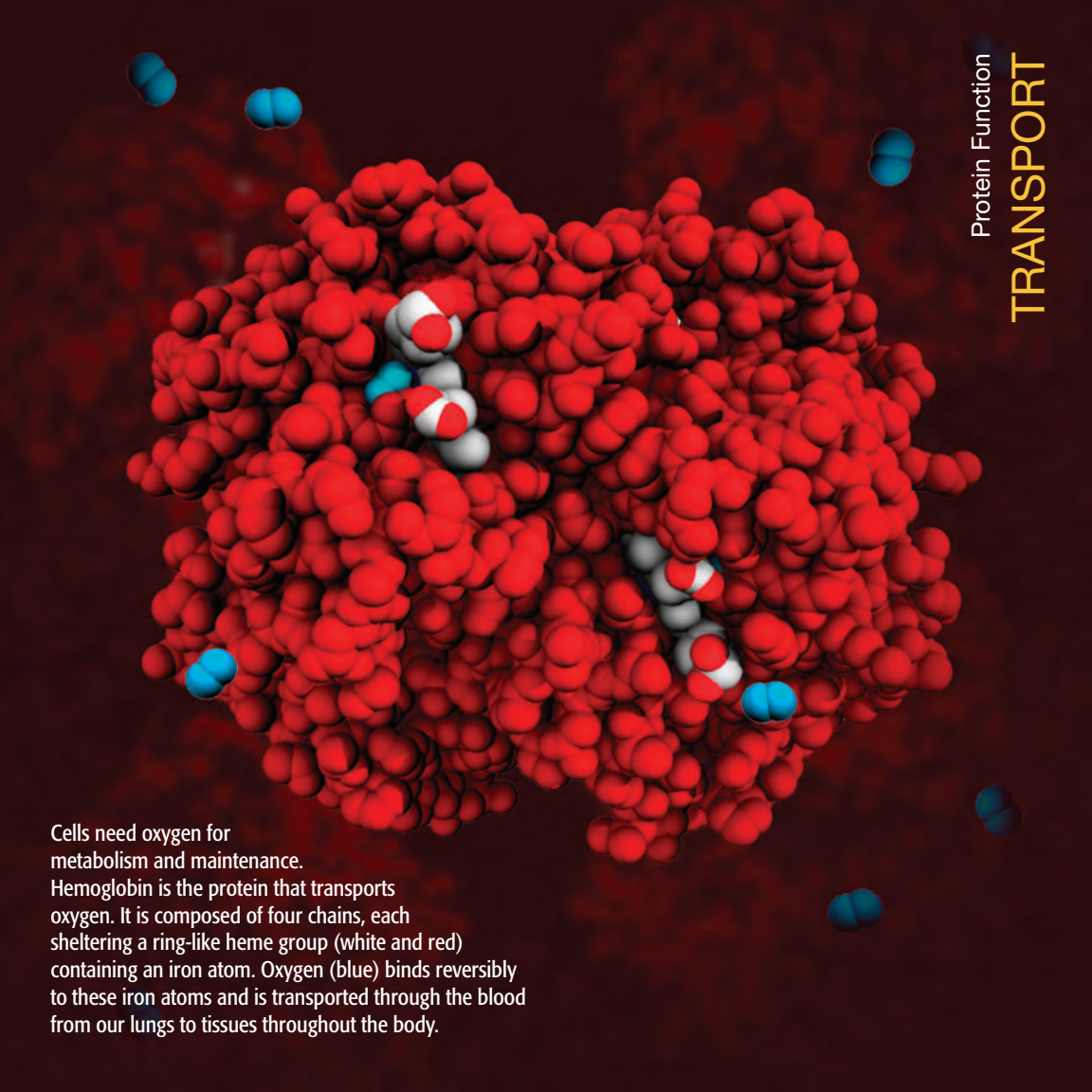

Cells need oxygen for metabolism and maintenance. Hemoglobin is the protein that transports oxygen. It is composed of four chains, each sheltering a ring-like heme group (white and red) containing an iron atom. Oxygen (blue) binds reversibly to these iron atoms and is transported through the blood from our lungs to tissues throughout the body.

PDB Structure **4hhb**
G. Fermi *et al.* (1984) The crystal structure of human deoxyhaemoglobin at 1.74 Å resolution. *J.Mol.Biol.* **175**: 159-174

February 2019

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

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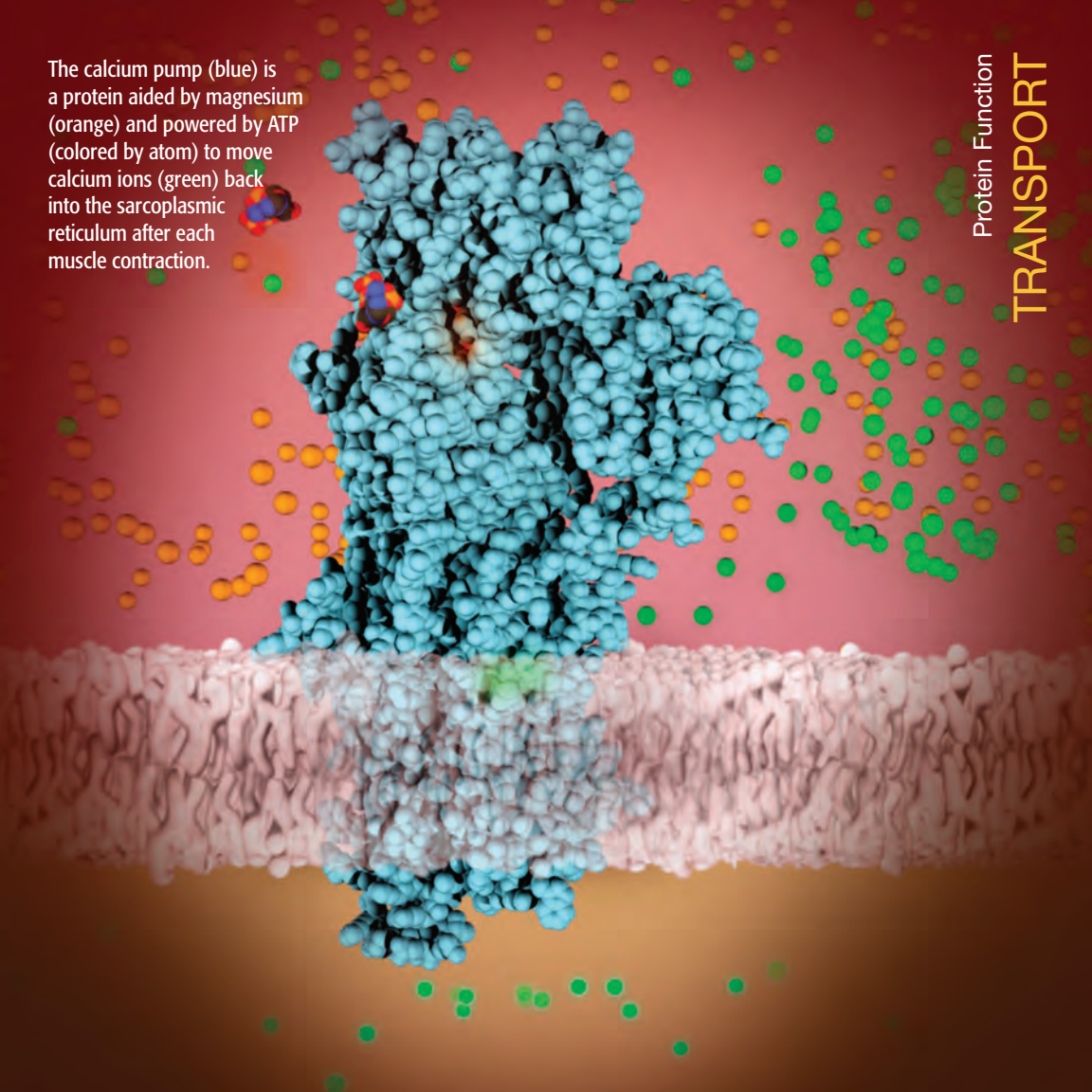

The calcium pump (blue) is a protein aided by magnesium (orange) and powered by ATP (colored by atom) to move calcium ions (green) back into the sarcoplasmic reticulum after each muscle contraction.

PDB Structure **2zbd**
C. Toyoshima *et al.* (2004) Lumenal gating mechanism revealed in calcium pump crystal structures with phosphate analogues. *Nature* **432**: 361-368

March 2019

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

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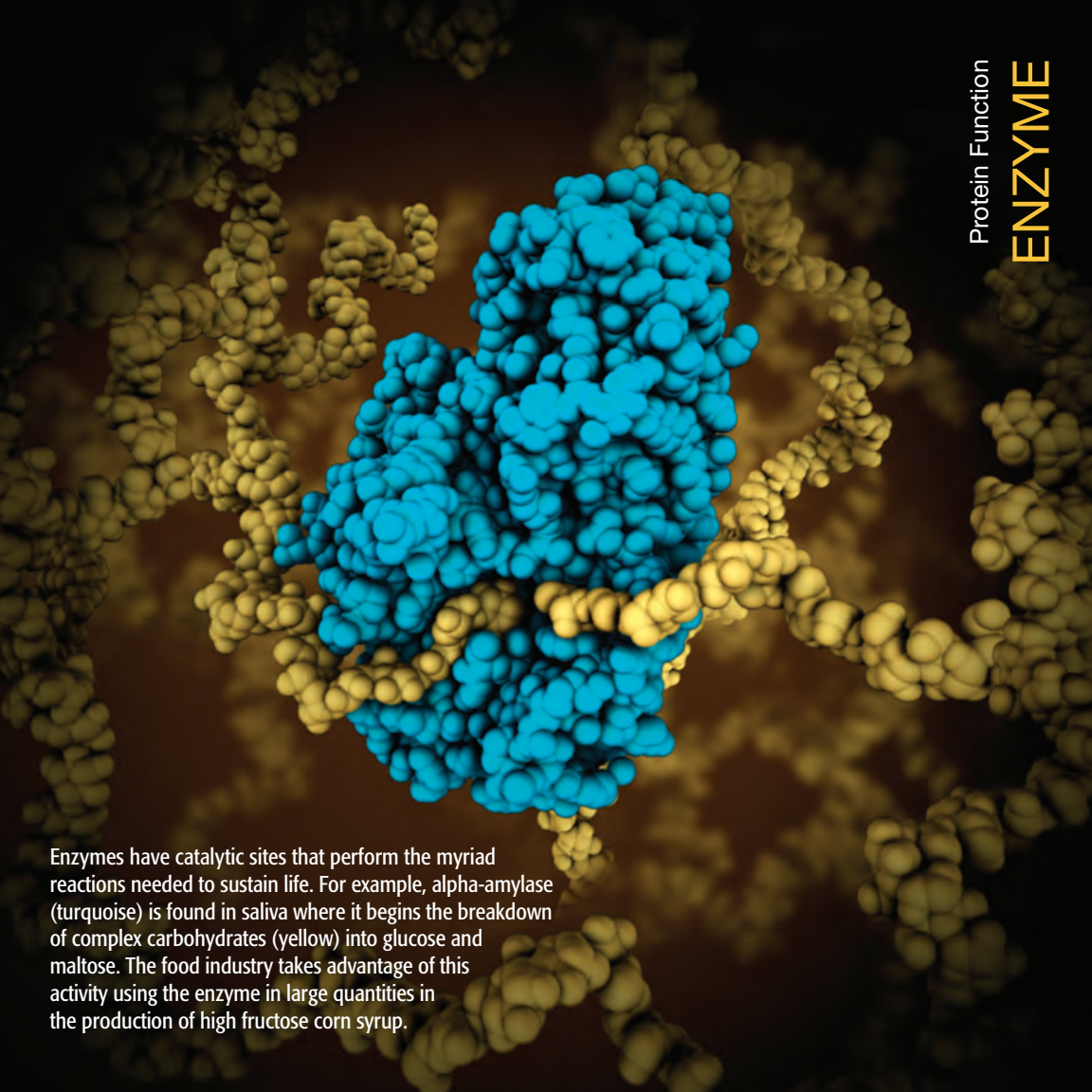

Protein Function

ENZYME

Enzymes have catalytic sites that perform the myriad reactions needed to sustain life. For example, alpha-amylase (turquoise) is found in saliva where it begins the breakdown of complex carbohydrates (yellow) into glucose and maltose. The food industry takes advantage of this activity using the enzyme in large quantities in the production of high fructose corn syrup.

PDB Structure **1ppi**
M. Qian *et al.* (1994) The active center of a mammalian alpha-amylase. Structure of the complex of a pancreatic alpha-amylase with a carbohydrate inhibitor refined to 2.2-Å resolution. *Biochemistry* **33**: 6284-6294

April 2019

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

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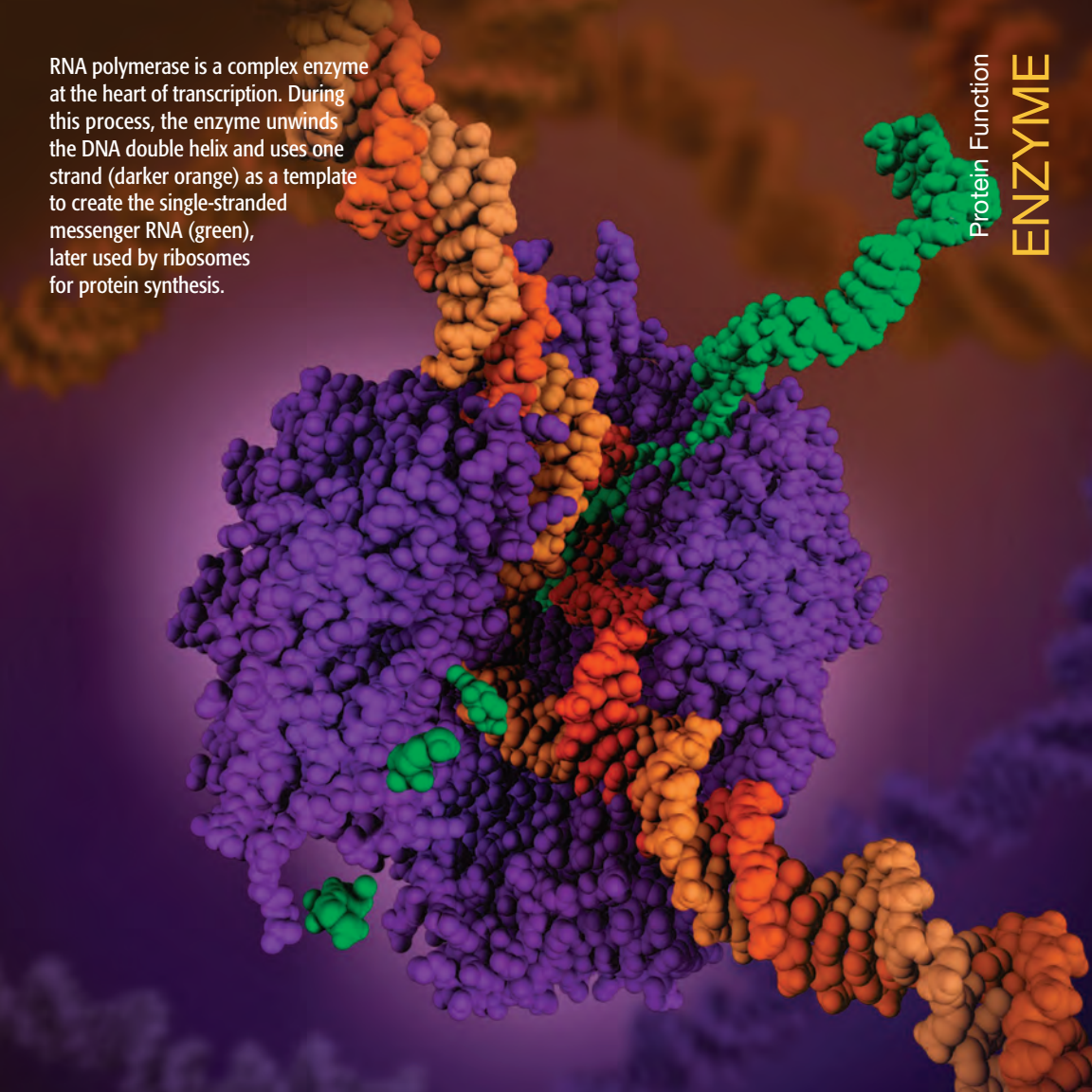

RNA polymerase is a complex enzyme at the heart of transcription. During this process, the enzyme unwinds the DNA double helix and uses one strand (darker orange) as a template to create the single-stranded messenger RNA (green), later used by ribosomes for protein synthesis.

PDB Structure **1i6h**
A. L. Gnatt *et al.* (2001) Structural basis of transcription: an RNA polymerase II elongation complex at 3.3 Å resolution. *Science* **292**: 1876-1882

PDB Structure **1bna**
H. R. Drew *et al.* (1981) Structure of a B-DNA dodecamer: conformation and dynamics. *Proc.Natl.Acad.Sci.USA* **78**: 2179-2183

May 2019

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

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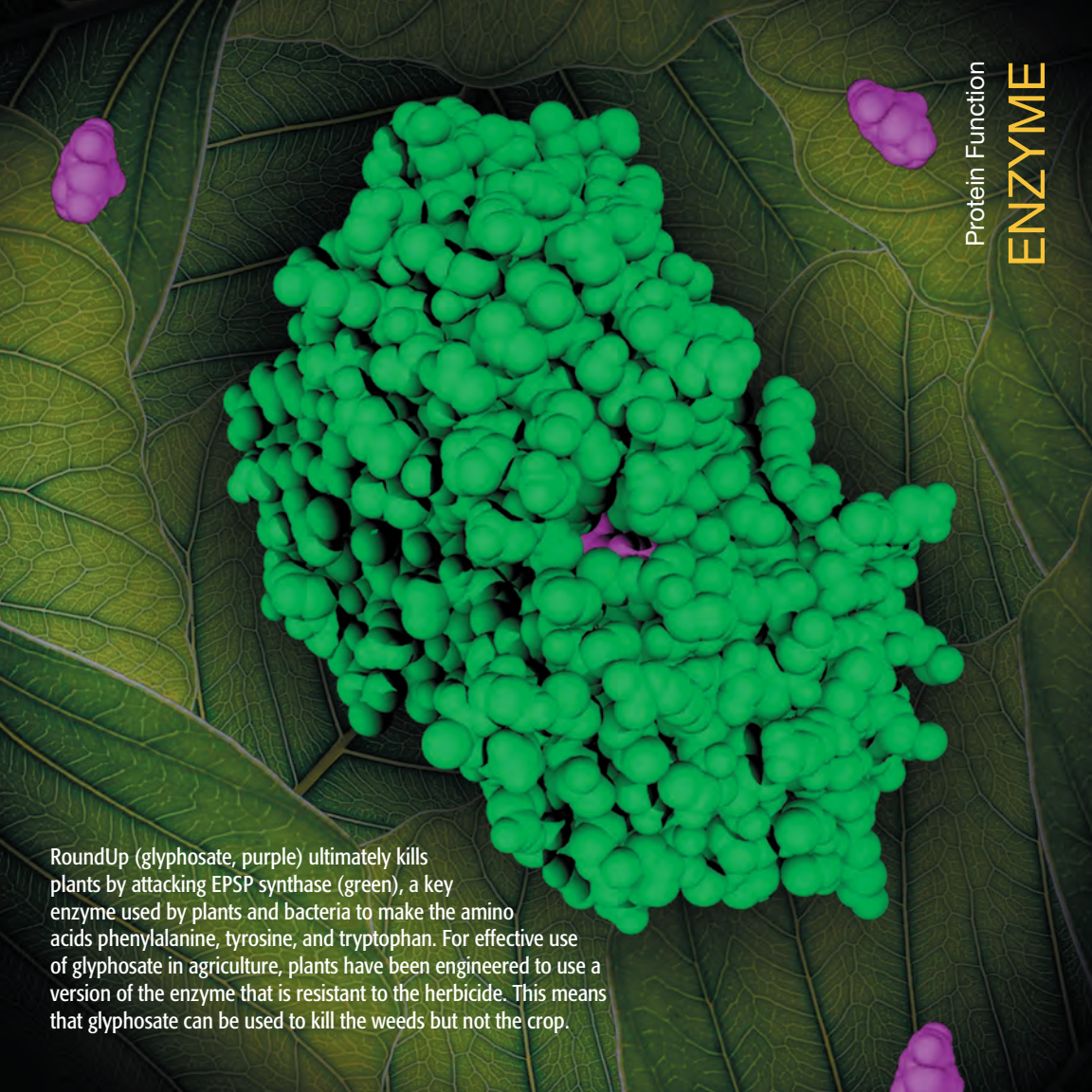

RoundUp (glyphosate, purple) ultimately kills plants by attacking EPSP synthase (green), a key enzyme used by plants and bacteria to make the amino acids phenylalanine, tyrosine, and tryptophan. For effective use of glyphosate in agriculture, plants have been engineered to use a version of the enzyme that is resistant to the herbicide. This means that glyphosate can be used to kill the weeds but not the crop.

PDB Structure **2gga**
T. Funke *et al.* (2006) Molecular basis for the herbicide resistance of Roundup Ready crops. *Proc.Natl.Acad.Sci.Usa* **103**: 13010-13015

Background edited from *A leaf with laminar structure and pinnate venation* photo by Jon Sullivan (Public domain)

June 2019

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

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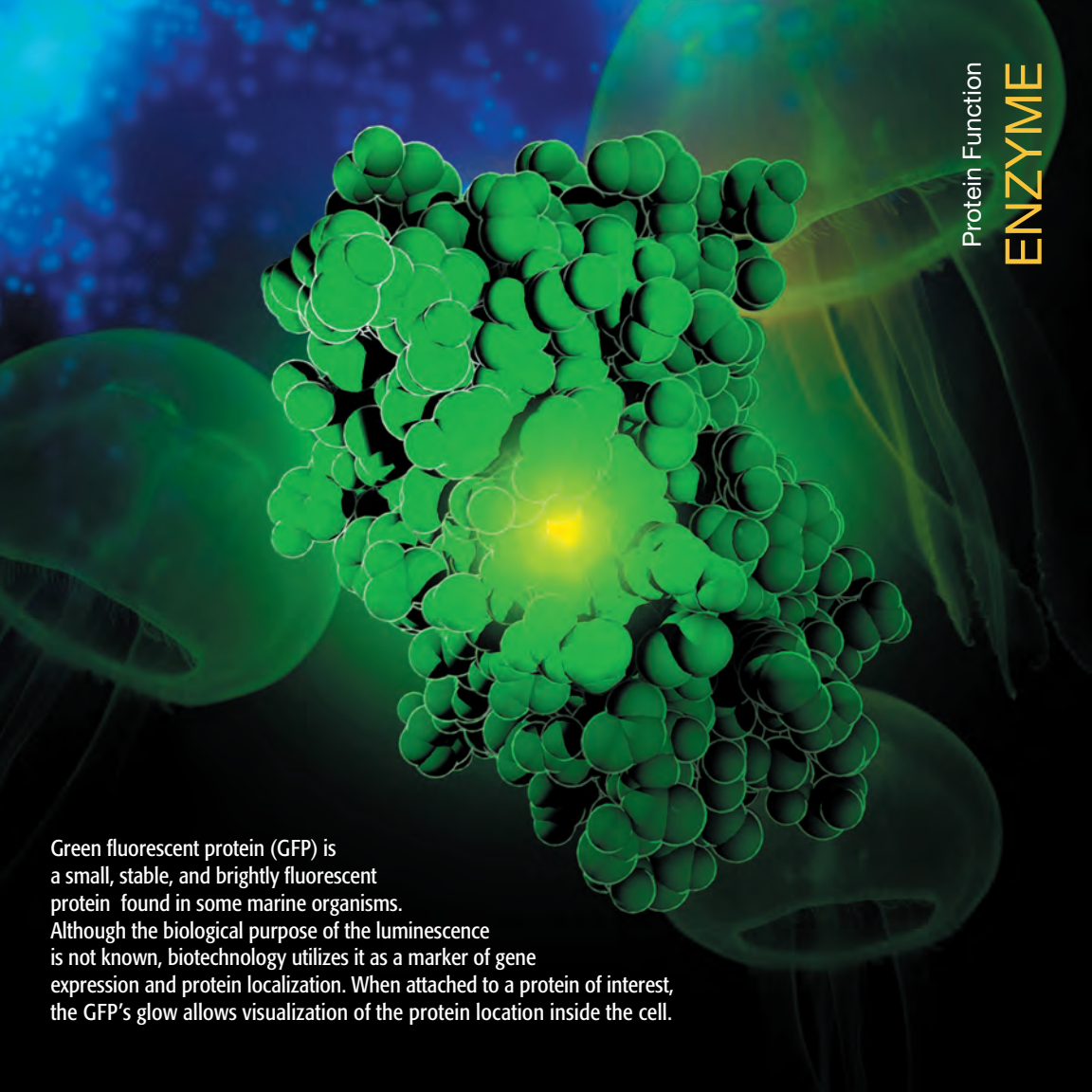

Green fluorescent protein (GFP) is a small, stable, and brightly fluorescent protein found in some marine organisms. Although the biological purpose of the luminescence is not known, biotechnology utilizes it as a marker of gene expression and protein localization. When attached to a protein of interest, the GFP's glow allows visualization of the protein location inside the cell.

PDB Structure **1gfl**
F. Yang *et al.* (1996) The molecular structure of green fluorescent protein. *Nat.Biotechnol.* **14**: 1246-1251

July 2019

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
30	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

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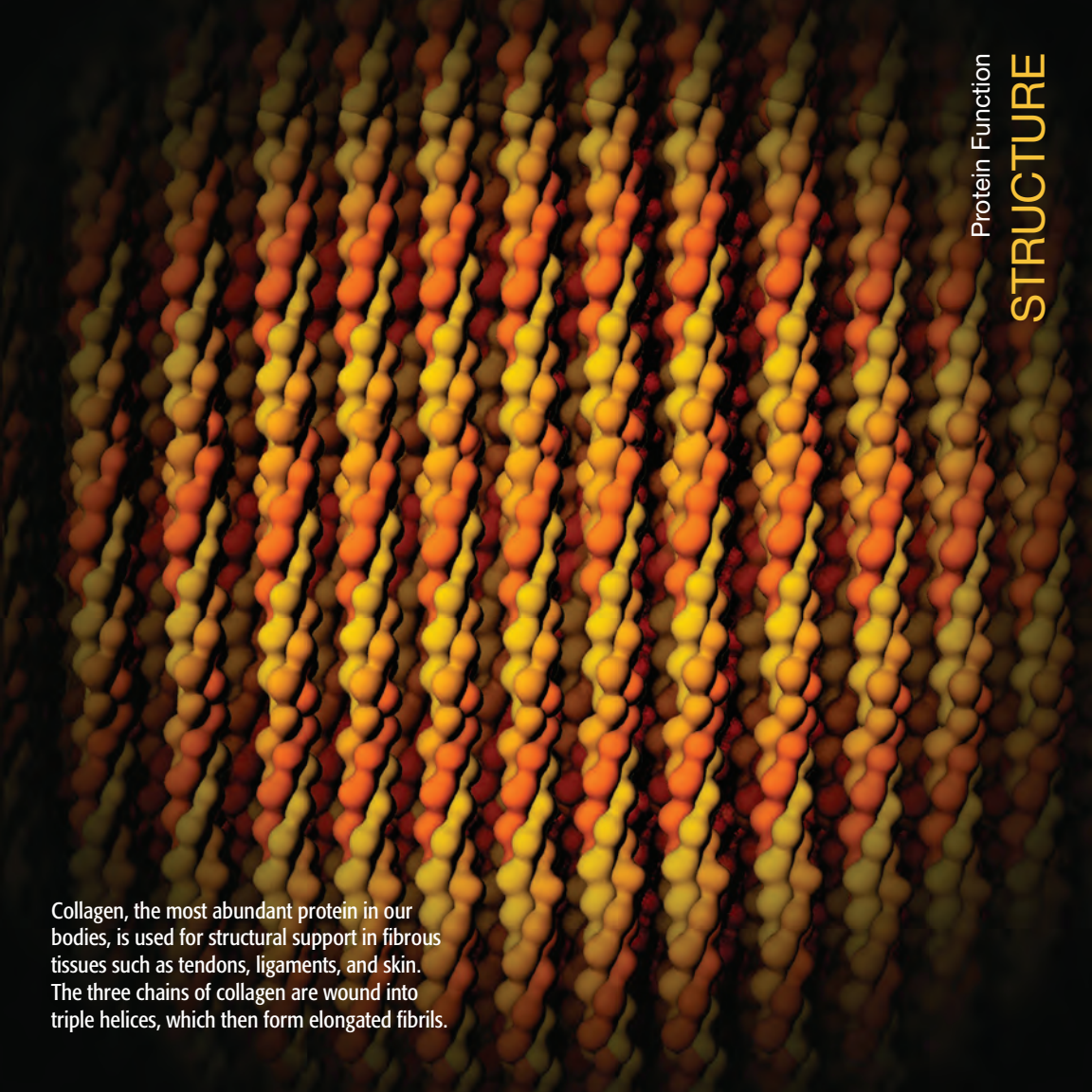

Collagen, the most abundant protein in our bodies, is used for structural support in fibrous tissues such as tendons, ligaments, and skin. The three chains of collagen are wound into triple helices, which then form elongated fibrils.

PDB Structure **1cag**
J. Bella *et al.* (1994) Crystal and molecular structure of a collagen-like peptide at 1.9 Å resolution. *Science* **266**: 75-81

August 2019

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
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

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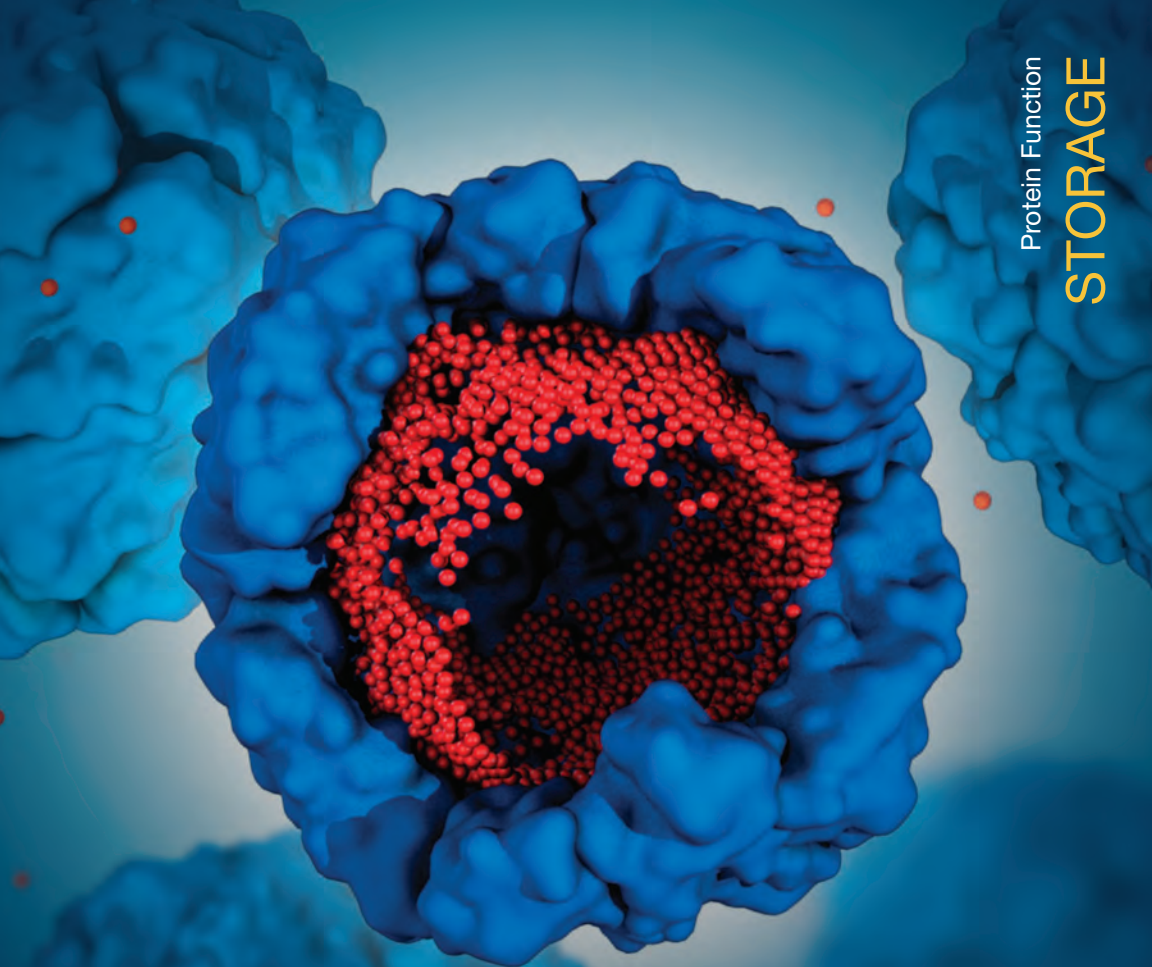

Ferritin helps balance iron levels within the human body. It is composed of 24 identical protein subunits that form a hollow shell. Pores within this shell allow iron (red) to enter for storage and exit as needed.

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

September 2019

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	2 Labor Day	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 Rosh Hashanah begins at sundown	30	1	2	3	4	5

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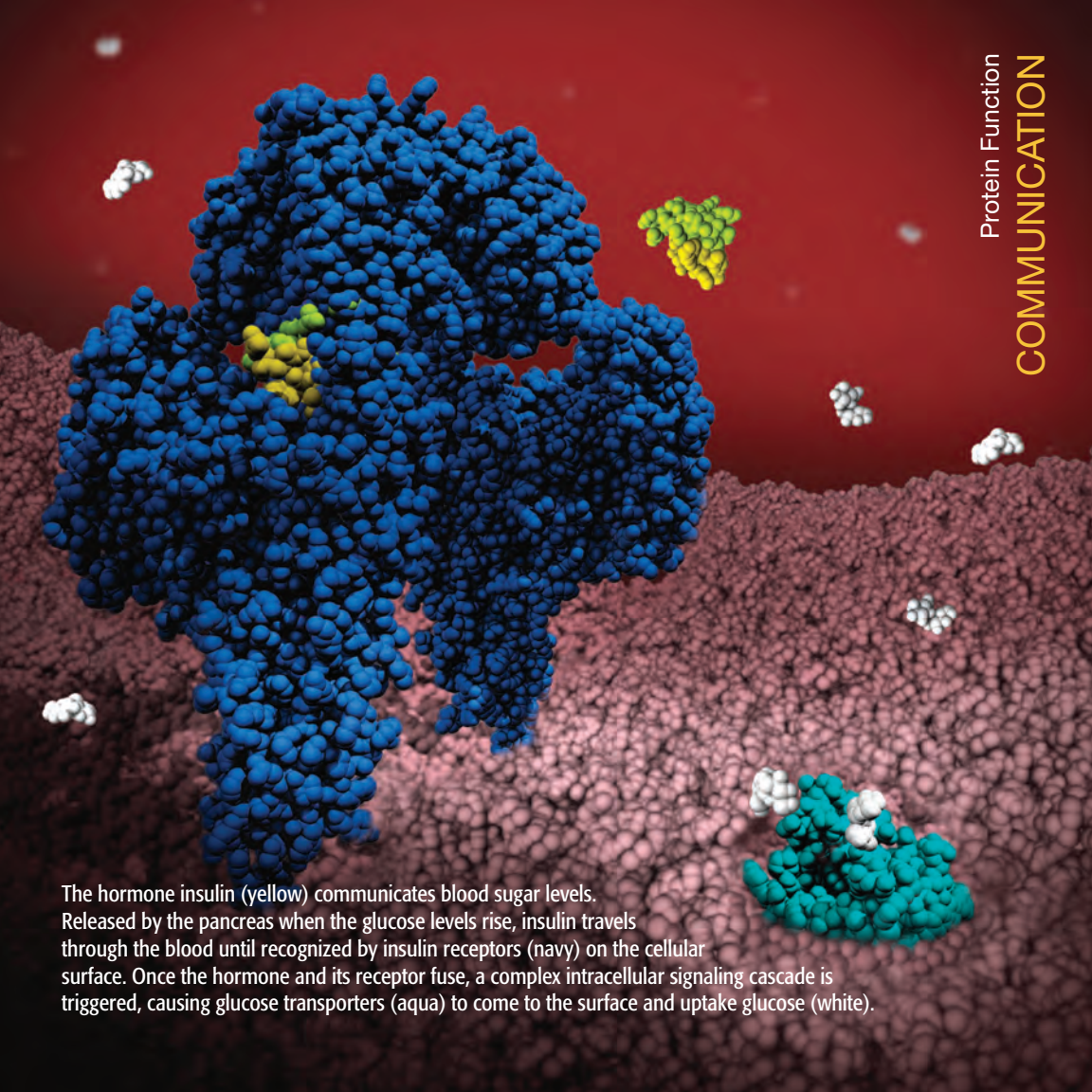

The hormone insulin (yellow) communicates blood sugar levels. Released by the pancreas when the glucose levels rise, insulin travels through the blood until recognized by insulin receptors (navy) on the cellular surface. Once the hormone and its receptor fuse, a complex intracellular signaling cascade is triggered, causing glucose transporters (aqua) to come to the surface and uptake glucose (white).

PDB Structure **3w14**
J. G. Menting *et al.* (2013) How insulin engages its primary binding site on the insulin receptor. *Nature* **493**: 241-245

PDB Structure **4zxb**
T. T. Croll *et al.* (2016) Higher-resolution structure of the human insulin receptor ectodomain: Multi-modal inclusion of the insert domain. *Structure* **24**: 469-476

PDB Structure **4zwc**
D. Deng *et al.* (2015) Molecular basis of ligand recognition and transport by glucose transporters. *Nature* **526**: 391-396

October 2019

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

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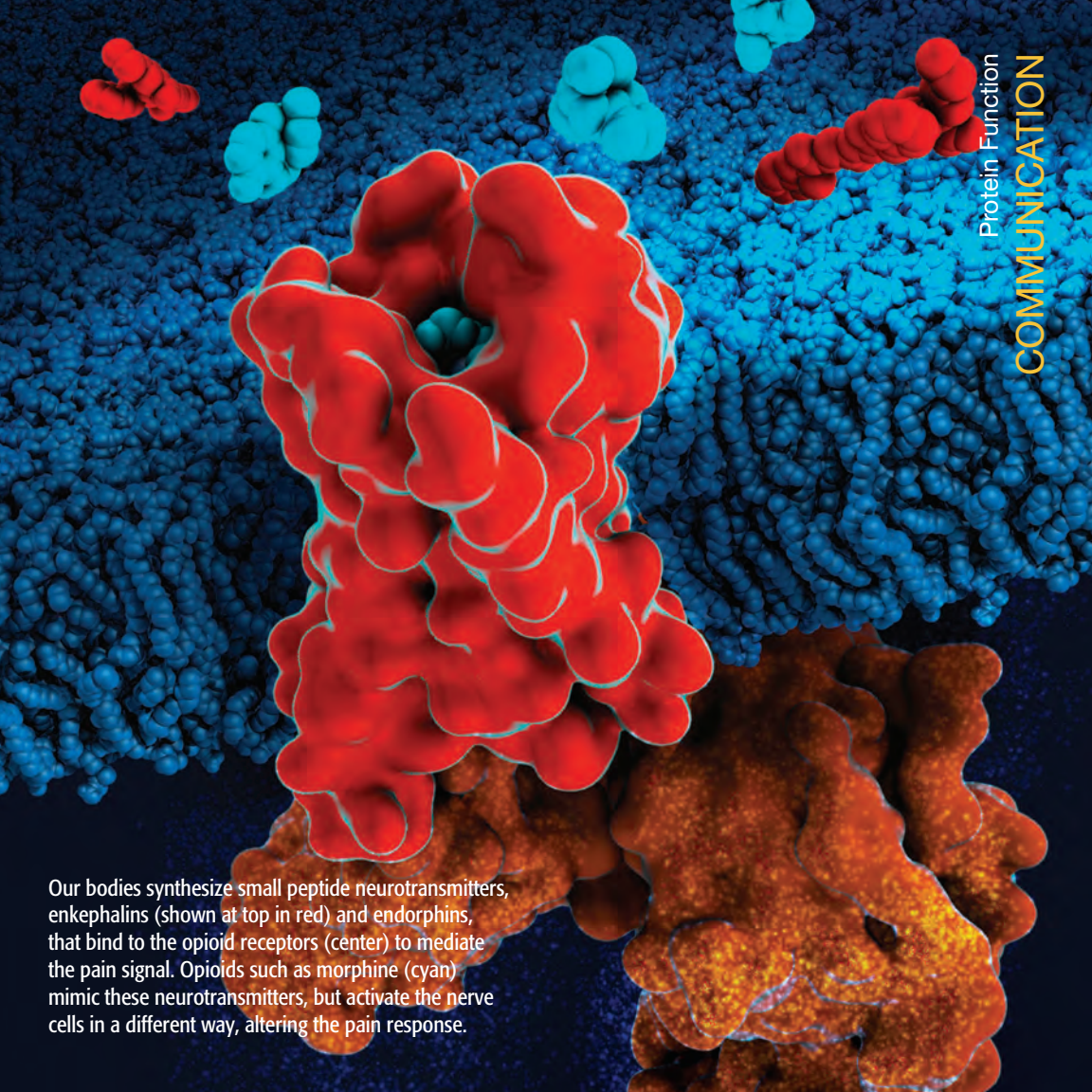

Our bodies synthesize small peptide neurotransmitters, enkephalins (shown at top in red) and endorphins, that bind to the opioid receptors (center) to mediate the pain signal. Opioids such as morphine (cyan) mimic these neurotransmitters, but activate the nerve cells in a different way, altering the pain response.

PDB Structure 6dde
A. Koehl *et al.* (2018) Structure of the μ-opioid receptor–G_i protein complex. *Nature* **558**: 547-552

Lipid bilayer model: Tieleman's Biocomputing Group, University of Calgary

November 2019

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

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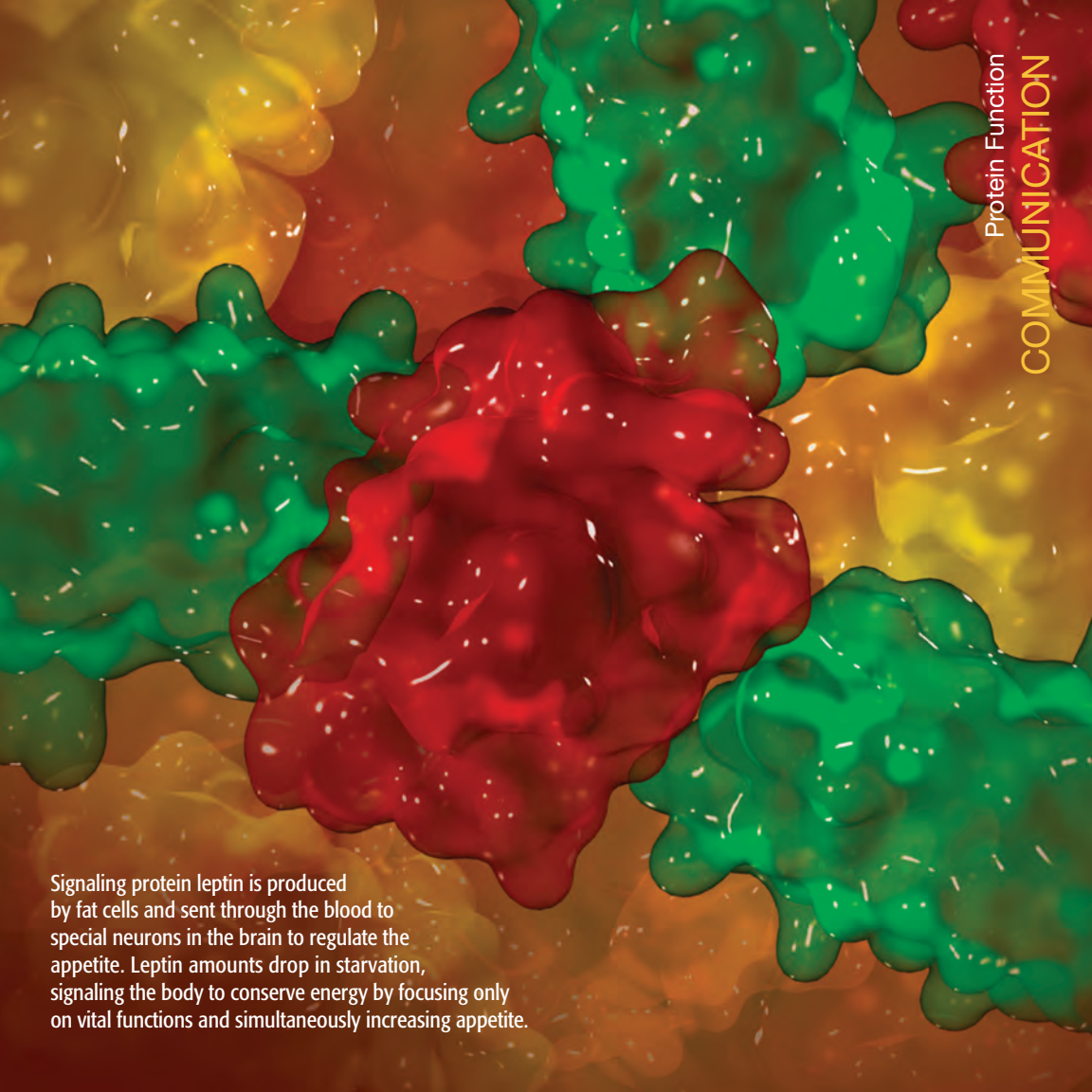

Signaling protein leptin is produced by fat cells and sent through the blood to special neurons in the brain to regulate the appetite. Leptin amounts drop in starvation, signaling the body to conserve energy by focusing only on vital functions and simultaneously increasing appetite.

PDB Structure **1ax8**
F. Zhang *et al.* (1997) Crystal structure of the obese protein leptin-E100. *Nature* **387**: 206-209

December 2019

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22 Hanukkah begins at sundown	23	24	25 Christmas	26 Kwanzaa	27	28
29	30	31 New Year's Eve	1	2	3	4

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PDB-101 is the educational portal of the RCSB PDB developed for teachers, students, and the general public to promote exploration in the 3D world of proteins and nucleic acids.

Learning about the diverse shapes and functions of these biological macromolecules helps us understand all aspects of biomedicine and agriculture, from protein synthesis to human health and disease to biological energy.

All resources are freely available, including curricular materials, paper molecular models, videos/animations, and more.

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