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Molecular Machinery: A Tour of the Protein Data Bank

Cells build many complex molecular machines that perform the biological jobs needed for life. Some of these machines are molecular scissors that cut food into digestible pieces. Others then use these pieces to build new molecules when cells grow or tissues need to be repaired. Some molecular machines form sturdy beams that support cells, and others are motors that use energy to crawl along these beams. Some recognize attackers and mobilize defenses against infection.

-  Adenosine Triphosphate (ATP)
-  Glucose
-  Water

Researchers around the world are studying these molecules at the atomic level. These 3D structures are freely available at the Protein Data Bank (PDB), the central storehouse of biomolecular structures. A few examples from the ~100,000 structures held in the PDB are shown here, with each atom represented as a small sphere. The enormous range of molecular sizes is illustrated here, from the water molecule (H₂O) with only three atoms (shown at the left) to the ribosomal subunits with hundreds of thousands of atoms.

Digestive Enzymes: breaking food into small nutrient molecules

1. Amylase [1smd](#)
2. Phospholipase [1poe](#)
3. Deoxyribonuclease [2dnj](#)
4. Lysozyme [1lz1](#)
5. Pepsin [5pep](#)
6. Trypsin [2ptc](#)
7. Carboxypeptidase [3cpa](#)
8. Ribonuclease [5rsa](#)

Blood Plasma Proteins: transporting nutrients and defending against injury

9. Factor X [1xka](#), [iiod](#)
10. Thrombin [1ppb](#)
11. Fibrin [1mlj](#), [2baf](#)
12. Serum Albumin [1e7i](#)

Viruses and Antibodies: engaging in constant battle in the bloodstream

13. Antibody [1igt](#)
14. Rhinovirus [4rhv](#)

Hormones: carrying molecular messages through blood

15. Glucagon [1gcn](#)
16. Insulin [2hiu](#)
17. Epidermal Growth Factor [1egf](#)

Channels, Pumps and Receptors: getting back and forth across the membrane

18. Ras Protein [5p21](#)
19. Beta2-Adrenergic Receptor/Gs Protein [3sn6](#)
20. Acetylcholine Receptor [2bg9](#)
21. Epidermal Growth Factor Receptor [1ivo](#), [2jwa](#), [2gs6](#)
22. Rhodopsin [1f88](#)
23. P-glycoprotein [4m2t](#)
24. Potassium Channel [3lut](#)
25. Calcium Pump [1su4](#)
26. Cyclooxygenase [1prh](#)

Photosynthesis: harvesting energy from the sun

27. Photosystem II [1s5l](#)
28. Light-harvesting Complex [1rwt](#)
29. Photosynthetic Reaction Center [1prc](#)

Energy Production: powering the processes of the cell

30. Cytochrome c Oxidase (Complex IV) [1oco](#)
31. Cytochrome c [3cyt](#)
32. Cytochrome bc1 (Complex III) [1bgj](#)
33. Succinate Dehydrogenase (Complex II) [1nek](#)
34. NADH-Quinone Oxidoreductase (Complex I) [3m9s](#), [3rko](#)
35. ATP Synthase [1e79](#), [1c17](#), [1l2p](#), [2a7u](#)
36. Myoglobin [1mbd](#)
37. Hemoglobin [4hbb](#)

Storage: containing nutrients for future consumption

38. Ferritin [1hrs](#)

Enzymes: cutting and joining the molecules of life

39. Fatty Acid Synthase [2ubv](#), [2uvc](#)
40. RuBisCo: Ribulose Bisphosphate Carboxylase/Oxygenase [1rcx](#)
41. Green Fluorescent Protein [1gfl](#)
42. Luciferase [2d1s](#)
43. Glutamine Synthetase [2gls](#)
44. Alcohol Dehydrogenase [2ohx](#)
45. Dihydrofolate Reductase [1dhf](#)
46. Nitrogenase [1n2c](#)
47. Leucine Aminopeptidase [1lap](#)
48. Beta-Lactamase [4blm](#)
49. Catalase [1qqw](#)
50. Thymidylate Synthase [2tsc](#)
51. Tryptophan Synthase [1wsy](#)
52. Aspartate Carbamoyltransferase [4at1](#)
53. Hexokinase [1dgc](#)
54. Phosphoglucose Isomerase [1hox](#)
55. Phosphofructokinase [4pfk](#)
56. Aldolase [4ald](#)
57. Triosephosphate Isomerase [2ypi](#)
58. Glyceraldehyde-3-phosphate Dehydrogenase [3gpd](#)
59. Phosphoglycerate Kinase [3pgk](#)
60. Phosphoglycerate Mutase [3pgm](#)
61. Enolase [5enl](#)
62. Pyruvate Kinase [1a3w](#)

Scale:
1nm 5nm 10nm
1nm (nanometer) = 10⁶ millimeters

Infrastructure:
supporting and moving cells

- 63. Actin 1m8q
- 64. Myosin 1m8g
- 65. Microtubule 1tub
- 66. Collagen 1bkv (far left, reverse)

Protein Synthesis: building new molecular machines

- 67. Transfer RNA 4tna
- 68. Valyl-tRNA Synthetase 1gax
- 69. Threonyl-tRNA Synthetase 1qf6
- 70. Glutamyl-tRNA Synthetase 1euiq
- 71. Isoleucyl-tRNA Synthetase 1ffy
- 72. Phenylalanyl-tRNA Synthetase 1eiy
- 73. Aspartyl-tRNA Synthetase 1asy
- 74. Ribosome 1j5e, 1ij2
- 75. Elongation Factor Tu/tRNA 1ttt
- 76. Elongation Factor G 1dar
- 77. Elongation Factor Ts and Tu 1efu
- 78. Prefoldin 1fxk
- 79. Chaperonin GroEL/ES 1aon
- 80. Proline cis/trans Isomerase 2cpl
- 81. Heat Shock Protein Hsp90 2cg9
- 82. Proteasome 4bt4
- 83. Ubiquitin 1ubq

DNA: storing and reading genetic information

- 84. DNA 1bna
- 85. Restriction Endonuclease EcoRI 1eri
- 86. DNA Photolyase 1tez
- 87. Topoisomerase 1a36
- 88. RNA Polymerase 2e2i
- 89. lac Repressor 1lbh 1efa
- 90. Catabolite Gene Activator Protein 1cgp
- 91. TATA-binding Protein/Transcription Factor IIB 1ais
- 92. DNA Helicase 4esv
- 93. DNA Polymerase 1tau
- 94. Nucleosome 1aoi
- 95. HU Protein 1p51
- 96. Single-stranded DNA-binding Protein 3a5u