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MOLECULE OF THE MONTH: DENGUE VIRUS

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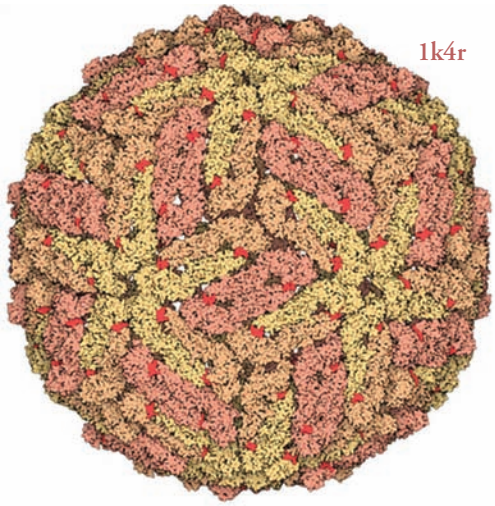
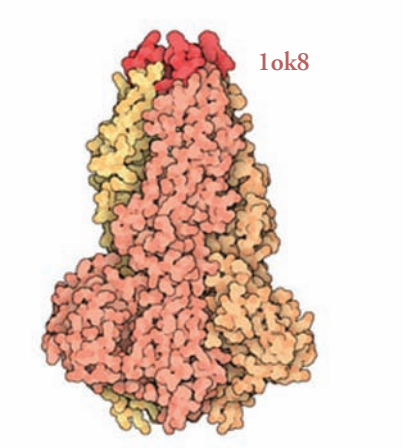
Dengue virus is a major threat to health in tropical countries around the world. It is limited primarily to the tropics because it is transmitted by a tropical mosquito, but even with this limitation, 50-100 million people are infected each year. Most infected people experience dengue fever, with terrible headaches and fever and rashes that last a week or two. In some cases, however, the virus weakens the circulatory system and can lead to deadly hemorrhaging. Researchers are now actively studying the virus to try to develop drugs to cure infection, and vaccines to block infection before it starts.





The Dengue Virus Genome

Dengue virus is a small virus that carries a single strand of RNA as its genome. The genome encodes only ten proteins. Three of these are structural proteins that form the coat of the virus and deliver the RNA to target cells, and seven of them are nonstructural proteins that orchestrate the production of new viruses once the virus gets inside the cell. The outermost structural protein, termed the envelope protein, is shown here from PDB entry 1k4r[1]. The virus is enveloped with a lipid membrane, and 180 identical copies of the envelope protein are attached to the surface of the membrane by a short transmembrane segment. The job of the envelope protein is to attach to a cell surface and begin the process of infection.

A Deadly Switch

In the infectious form of the virus, the envelope protein lays flat on the surface of the virus, forming a smooth coat with icosahedral symmetry. However, when the virus is carried into the cell and into lysozomes, the acidic environment causes the protein to snap into a different shape, assembling into trimeric spike, as shown above from PDB entry 1ok8[2]. Several hydrophobic amino acids at the tip of this spike, colored bright red here, insert into the lysozomal membrane and cause the virus membrane to fuse with lysozome. This releases the RNA into the cell and infection starts. The hemagglutinin protein on the surface of influenza virus plays a similar role, but the two proteins use entirely different mechanisms to perform a similar task.

The Hunt for a Dengue Vaccine

A dengue vaccine has proven difficult to develop, in part because there are four major subtypes of dengue virus, each with slightly different viral proteins. Many researchers currently believe that the deadly dengue hemorrhagic disease is caused when a person is infected with one subtype, and then infected later by a second subtype. The antibodies, and immunity, gained from the first infection appear to assist with the infection by the second subtype, instead of providing a general immunity to all subtypes. This means that an effective vaccine will have to stimulate protective antibodies against all four types at once, a feat that has not yet been achieved.

Building New Viruses

Dengue virus also makes several proteins that create new viruses once it is inside a cell. Two of the major ones are shown on the reverse. Both are multifunctional proteins with several enzymes strung together. The one on the left, NS5 from PDB entries 1l9k[3] and 2j7w[4], contains a methyltransferase and a polymerase, and the one on the right, NS3 from PDB entry 2vbc[5], contains a protease and a heli-

About the *RCSB PDB Molecule of the Month*

Using selected molecules from the PDB archive, each feature includes an introduction to the structure and function of the molecule, a discussion of its relevance to human health and welfare, and suggestions for viewing and accessing further details.

The *RCSB PDB Molecule of the Month* is read by students, teachers, and scientists worldwide at **www.pdb.org**.

This July 2008 edition was written and illustrated by David S. Goodsell (RCSB PDB and The Scripps Research Institute).

DENGUE VIRUS

RCSB Protein Data Bank

The Protein Data Bank (PDB) is the single worldwide repository for the processing and distribution of 3D structure data of large molecules of proteins and nucleic acids. The RCSB PDB is operated by Rutgers, The State University of New Jersey and the San Diego Supercomputer Center and the Skaggs School of Pharmacy and Pharmaceutical Sciences at the University of California, San Diego –two members of the Research Collaboratory for Structural Bioinformatics (RCSB).

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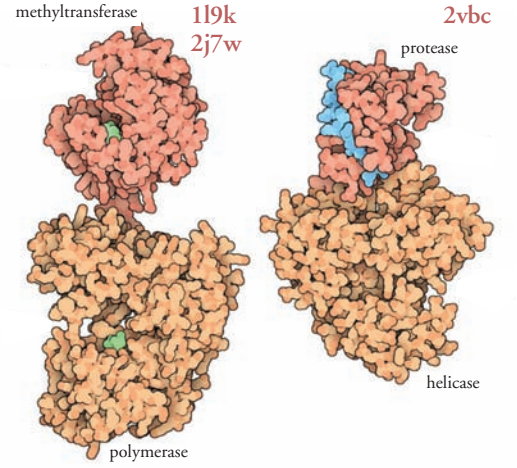
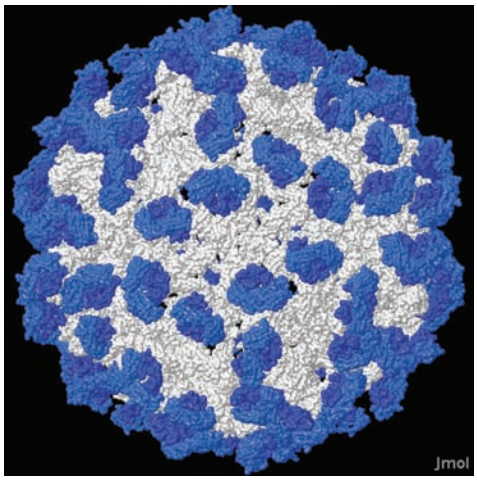
The RCSB PDB is a member of the worldwide PDB (**wwPDB; www.wwpdb.org**).

case. Each of these enzymes performs a different part of the life cycle. The polymerase builds new RNA strands based on the viral RNA, the helicase helps to separate these strands, and the methyltransferase adds methyl groups to the end of them, protecting the RNA strands and coaxing the cell's ribosomes to create viral proteins based on them. The viral proteins are created in one long polyprotein chain, which is finally clipped into the functional units by the protease. The little chain colored blue is a portion of another viral protein, NS2B, that assists with the protease activity.



Exploring the Structure



Cryoelectron microscopy has been used to study many aspects of the life cycle of the dengue virus. In these structures, a low resolution image of virus, not quite detailed enough to see atoms, is obtained by the electron microscope, and then atomic structures of the individual pieces are fit into the image to generate the final model. The one shown here, from PDB entry 2r6p[6], shows the envelope protein on the surface of the virus (in white) with many antibody Fab fragments (in blue) bound to the viral proteins. By looking carefully at this structure, researchers have discovered that the antibodies distort the arrangement of the envelope proteins, blocking their normal action in infection. Other dengue virus structures in the PDB include immature forms of the virus (for instance, in PDB entry 1n6g[7]) and structures that include the membrane-spanning portions of the viral coat (PDB entry 1p58[8]).

Topics for Further Exploration

1) The dengue virus is surrounded by 180 copies of the envelope protein. Many other viruses are surrounded by capsids composed of many identical proteins, and these often appear in multiples of 60, such as 180, 240 or 420 copies. What is significant about these numbers? Can you find examples of each in the PDB?

2) Dengue virus is a member of a family of flaviviruses that are spread by ticks and mosquitoes. Other examples include yellow fever virus and West Nile virus. Looking at the structures in the PDB, can you see similarities in the proteins made by these viruses?

3) Dengue virus replicates in the cytoplasm of infected cells, without entering the nucleus. Can you think of any problems this might cause, and how the dengue virus solves them with its ten viral proteins?

Additional Reading:

1. Mukhopadhyay, S., Kuhn R.J., Rossmann M.G. (2005) A structural perspective of the Flavivirus life cycle. *Nature Reviews Microbiology* **3**: 13-22.

2. Whitehead, S.S., Blaney, J.E., Durbin, A.P., and Murphy, B.R. (2007) Prospects for a dengue virus vaccine. *Nature Reviews Microbiology* **5**: 518-528.

3. Halstead, S.B. (2007) Dengue. *Lancet* **370**: 1644-1652.

4. Qi, R.-F., Zhang, L. and Chi, C.-W. (2008) Biological characteristics of dengue virus and potential targets for drug design. *Acta Biochimica et Biophysica Sinica* **40**: 91-101.

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1. 1k4r: Kuhn, R.J., Zhang, W., Rossmann, M.G., Pletnev, S.V., Corver, J., Lenches, E., Jones, C.T., Mukhopadhyay, S., Chipman, P.R., Strauss, E.G., Baker, T.S., Strauss, J.H. (2002) Structure of dengue virus: implications for flavivirus organization, maturation, and fusion. *Cell* **108**: 717-725

2. 1ok8: Modis, Y., Ogata, S., Clements, D., Harrison, S.C. (2004) Structure of the dengue virus envelope protein after membrane fusion. *Nature* **427**: 313-319

3. 1l9k: Egloff, M.P., Benarroch, D., Selisko, B., Romette, J.L., Canard, B. (2002) An RNA cap (nucleoside-2'-O-) methyltransferase in the flavivirus RNA polymerase NS5: crystal structure and functional characterization *Embo J.* **21**: 2757-2768

4. 1j7w: Yap, T.L., Xu, T., Chen, Y.L., Malet, H., Egloff, M.P., Canard, B., Vasudevan, S.G., Lescar, J. (2007) Crystal Structure of the Dengue Virus RNA-Dependent RNA Polymerase Catalytic Domain at 1.85 Angstrom Resolution. *J.Virol.* **81**: 4753

5. 2vbc: Luo, D.H., Xu, T., Hunke, C., Gruber, G., Vasudevan, S.G., Lescar, J. (2008) Crystal Structure of the Ns3 Protease-Helicase from Dengue Virus. *J.Virol.* **82**: 173

6. 2r6p: Lok, S.M., Kostyuchenko, V., Nybakken, G.E., Holdaway, H.A., Battisti, A.J., Sukupolvi-Petty, S., Sedlak, D., Fremont, D.H., Chipman, P.R., Roehrig, J.T., Diamond, M.S., Kuhn, R.J., Rossmann, R.G. Binding of a neutralizing antibody to dengue virus resulted in an altered arrangement of the surface glycoproteins *To Be Published*

7. 1n6g: Zhang, Y., Corver, J., Chipman, P.R., Zhang, W., Pletnev, S.V., Sedlak, D., Baker, T.S., Strauss, J.H., Kuhn, R.J., Rossmann, M.G. (2003) Structures of Immature flavivirus particles *EMBO J.* **22**: 2604-2613

8. 1p58: Zhang, W., Chipman, P.R., Corver, J., Johnson, P.R., Zhang, Y., Mukhopadhyay, S., Baker, T.S., Strauss, J.H., Rossmann, M.G., Kuhn, R.J. (2003) Visualization of membrane protein domains by cryo-electron microscopy of dengue virus *Nat.Struct.Biol.* **10**: 907-912