

August 2002: Chaperones

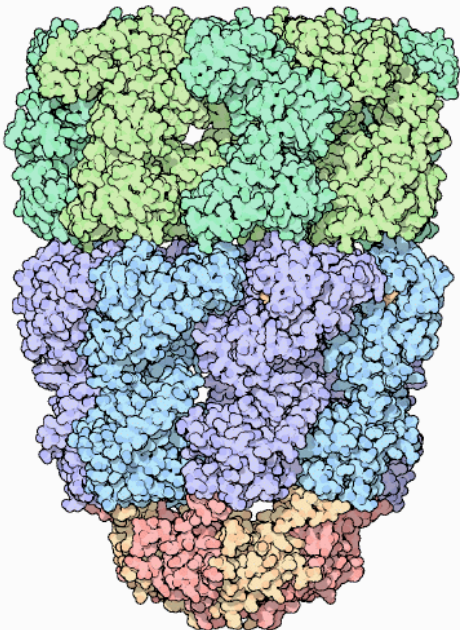
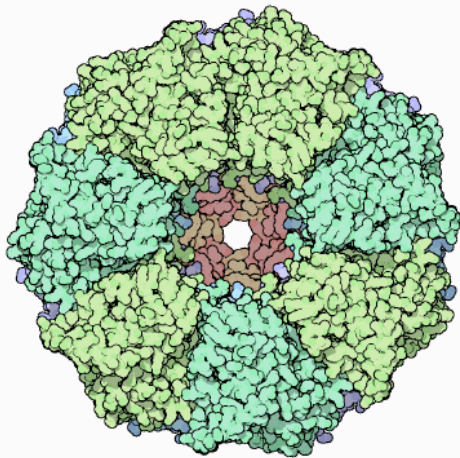
As you can see when looking through the many structures in the PDB, most active proteins have a stable, globular structure. However, proteins are built as formless chains, pieced together one amino acid at a time by ribosomes. Most protein chains then fold spontaneously into their final structure, driven by the need to shelter their carbon-rich portions from the surrounding water. But some--large proteins or proteins with several domains--need some assistance. As they fold into a compact shape, they might get stuck somewhere along the way.

The Dangers of Misfolding

This is not a trivial problem. Cells cannot merely wait for proteins to fold properly. Misfolded proteins often have carbon-rich amino acids on their surfaces, instead of tucked safely inside. These carbon-rich patches associate strongly with similar patches on other proteins, forming large aggregates. Random aggregates are death to cells: diseases such as sickle cell anemia, mad cow disease, and Alzheimer's disease are caused by unnatural aggregation of proteins into cell-clogging fibrils.

Guides Along the Folding Pathway

Chaperones are proteins that guide proteins along the proper pathways for folding. They protect proteins when they are in the process of folding, shielding them from other proteins that might bind and hinder the process. Many chaperone proteins are termed "heat shock" proteins (HSP) because they are made in large amounts when cells are exposed to heat. Heat, in general, destabilizes proteins and makes misfolding more common. So when it gets really hot, cells need some extra help with their proteins.

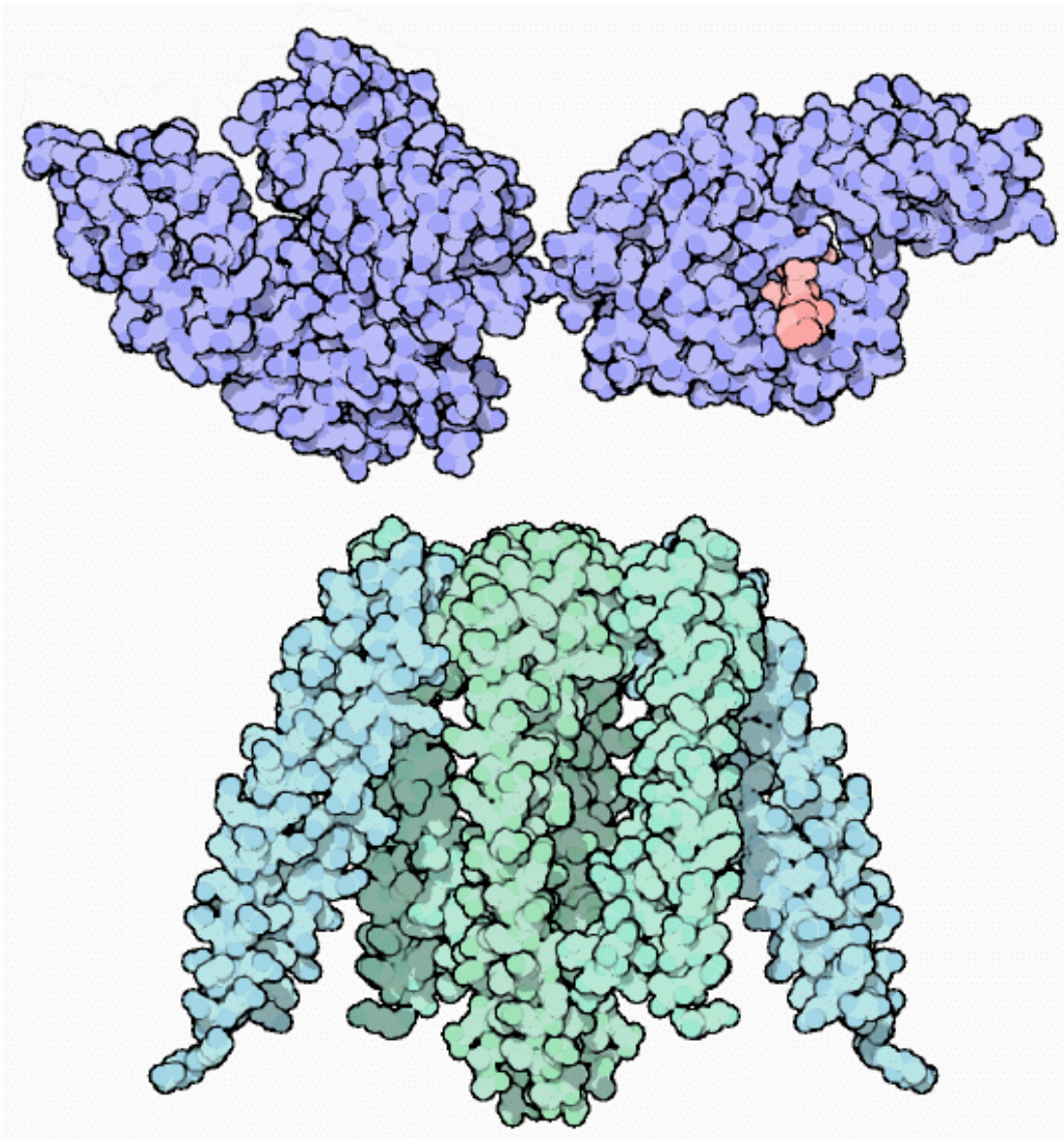


HSP-60 Chaperones

One impressive type of chaperone forms an enclosed environment for folding proteins which totally protects them as they fold. The GroEL-GroES complex of the bacterium *E. coli* is shown here, from PDB entry 1aon. It is composed of two stacked rings of GroEL proteins (blue and green), and a cap on one side composed of GroES, (red and yellow). As seen in the top view, seven GroEL proteins form a ring with a protein-sized cavity inside. Unfolded proteins enter this cavity and fold up inside.

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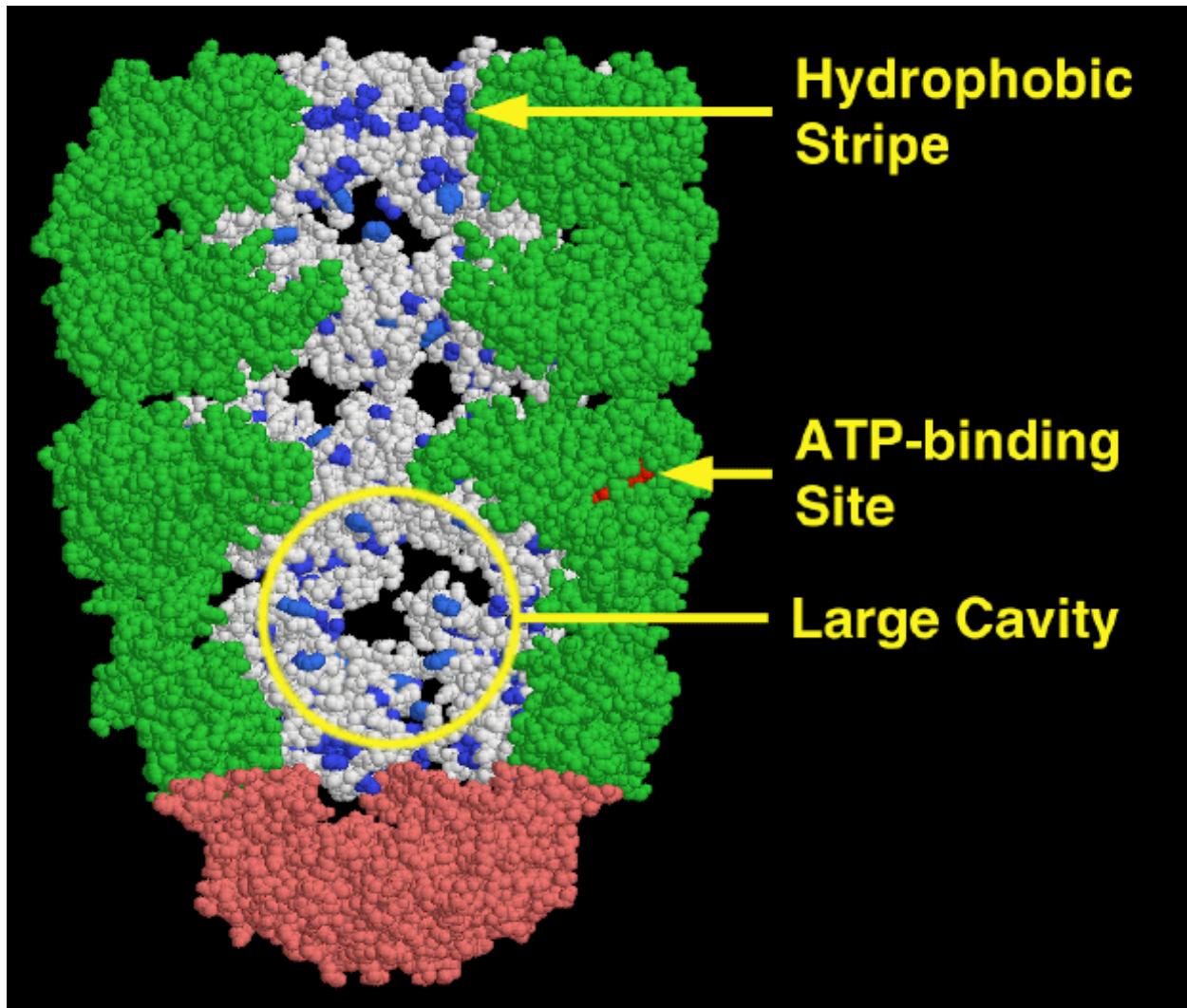
HSP-70 and Prefoldin



Smaller chaperones protect proteins just after they leave the ribosome. At this stage, they may have very little folded structure, so stretches of the chain with lots of exposed carbon atoms are particularly susceptible to aggregation. HSP-70 (shown at the top) finds these stretches and binds to them, shielding them from neighbors. Then, powered by ATP, the chaperone releases the chain when it is ready to fold. HSP-70 is composed of two domains: one that binds ATP and controls the process, shown on the left side of the molecule from PDB entry 1dkg, and one that binds to carbon-rich peptides, shown here on the right side using coordinates from PDB entry 1dkz. A little peptide, colored pink, is bound in the deep protein-binding cleft. The odd jelly-fish shaped prefoldin, shown at the bottom from PDB entry 1fxk, performs a similar job, engulfing protein chains when they are in the process of folding.

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Exploring the Structure



The large GroEL-GroES complex is available in PDB entry 1aon. In this picture, three of the subunits in each GroEL ring have been removed to show the interior, leaving four subunits in each ring. On the two in back, the carbon-rich amino acids, LEU, ILE, VAL, MET, PHE, TYR and TRP, are colored blue. Notice the stripe of carbon-rich "hydrophobic" amino acids around the entry at the top. This will interact strongly with unfolded proteins by coaxing them into the cavity. Now look at the bottom cavity, capped by the pink GroES at the bottom. Powered by ATP (ADP is found in this structure, colored bright red here), the ring of GroEL undergoes a major change in shape. The cavity is much larger, and the stripe of carbon-rich amino acids is hidden from the cavity. This forces a protein chain trapped inside (not shown in the picture) to fold on its own, giving it plenty of room for the process.