

September 2001: Antibodies

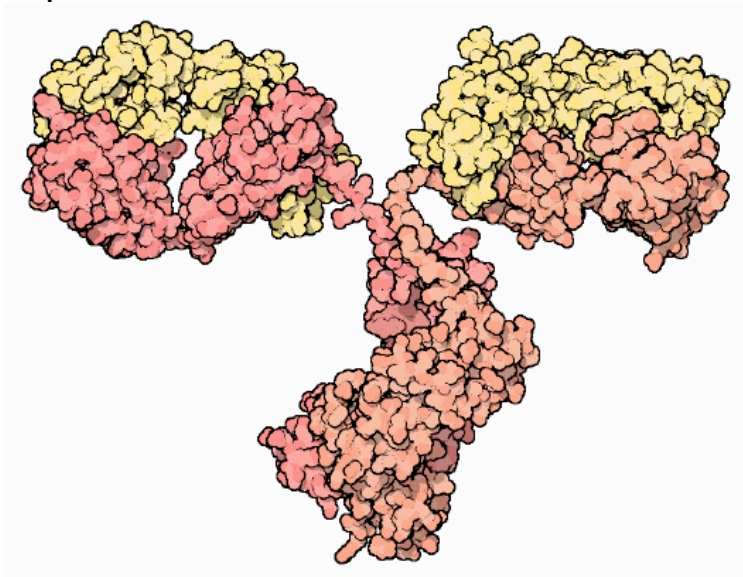
Molecular Watchdogs

Antibodies are our molecular watchdogs, waiting and watching for viruses, bacteria and other unwelcome visitors. Antibodies circulate in the blood, scrutinizing every object that they touch. When they find an unfamiliar, foreign object, they bind tightly to its surface. In the case of viruses, like rhinovirus or poliovirus presented last month in the Molecule of the Month, a coating of bound antibodies may be enough to block infection. Antibodies alone, however, are no match for bacteria. When antibodies bind to a bacterial surface, they act as markers alerting the other powerful defensive mechanisms available in the immune system.

Getting a Grip

Antibodies, and many of the other molecules used in the immune system, have a distinctive shape. Typically, they are composed of several flexible arms with binding sites at the end of each one. This makes perfect sense: since antibodies do not know in advance what attackers they might be fighting, they keep their options open. The flexible arms allow the binding sites to work together, grabbing with both arms onto targets with different overall shapes.

The antibody shown here, from PDB entry [1igt](#), has two binding sites, at the tips of the two arms extending right and left at the top. Notice the thin, flexible chains that connect these arms to the central domain at the bottom.



Some antibodies have longer flexible linkers connecting the arms together, allowing them even more latitude when finding purchase on a surface. Other antibodies have four or ten

September 2001: Antibodies

binding sites, so each contact can be weaker and still allow the whole antibody to bind firmly.

Power in Numbers

Your blood contains upwards of 100,000,000 different types of antibodies. Each type binds to a different target molecule. Remarkably, all of these antibodies are created before they ever see a virus or bacterium. You don't make a special antibody when a virus or bacterium infects your body. Instead, all of your antibodies are pre-fabricated, lying in wait until a virus or bacterium attacks. There are so many different kinds of antibodies that one or two are bound to be the right ones to fight the infection.

This amazingly huge collection of antibodies is created by recombination of genes in lymphocytes, the blood cells that make antibodies. Each lymphocyte creates a different type of antibody, based on how it has recombined its antibody genes. When an antibody encounters a virus or bacterium, the appropriate lymphocytes will multiply, flooding the blood with the particular antibodies needed to battle the invader. These lymphocytes may also make small adjustments on the antibodies they produce, tailoring their antibodies to bind more tightly and more specifically.

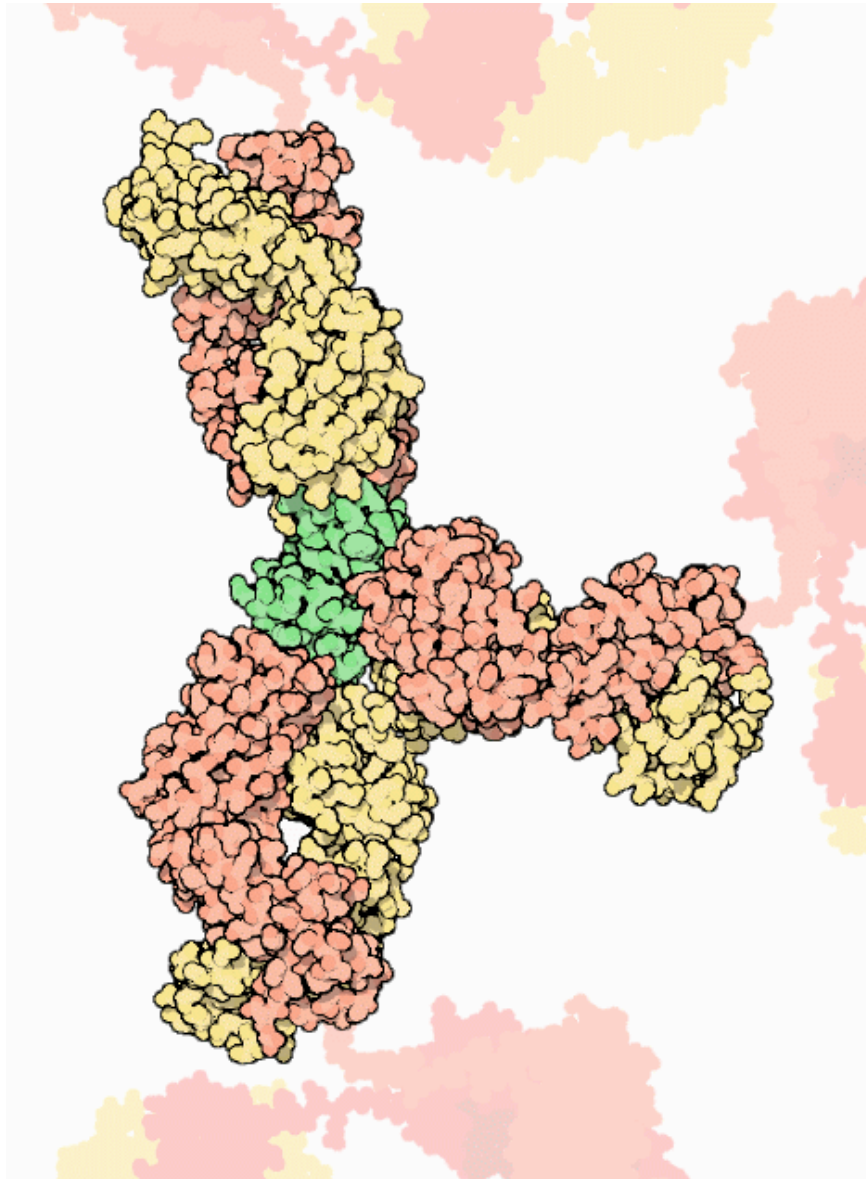
Antibody Structure

Antibodies are composed of four chains, two long heavy chains and two shorter light chains. The specific binding site is found at the tips of the two arms, in a pocket formed between the light and heavy chain. The binding site is composed of several loops in the protein chain that have very different lengths and amino acid composition. Differences in these "hypervariable loops" form the many types of pockets in different antibodies, each of which bind specifically to a different target. The rest of the antibody--the rest of the arms and the large constant domain that ties the two arms together--is relatively uniform in structure, providing a convenient handle when antibodies interact with the rest of the immune system.

September 2001: Antibodies

Attack From Many Angles

When a foreign molecule is found in the blood, many different antibodies may bind to it, attacking at different angles. Three different antibodies that bind to the protein lysozyme (in green at the center) are shown here. The crystal structures (PDB entries [1fdl](#), [3hfl](#), and [3hfm](#)) each include only one arm of the antibody (termed "Fab" for "antigen-binding fragment"), which has been separated from the antibody for ease in study. The rest of the antibody is indicated extending from the edges of the illustration. Notice that the antibodies pick entirely different binding sites on the small lysozyme molecule.

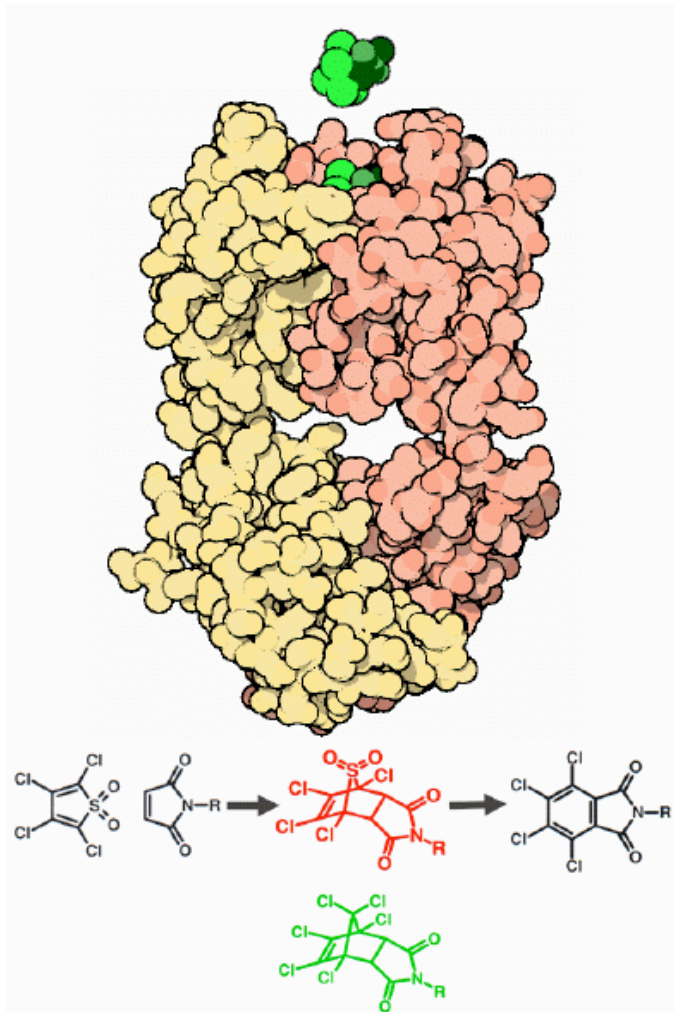


September 2001: Antibodies

Catalytic Antibodies

Researchers have used the incredible functional diversity of the immune system in a clever way: to design new enzymes. Enzymes work by easing molecules through a difficult chemical change. For instance, look at the Diels–Alder reaction shown here at the bottom of the illustration. The two molecules on the left come together, forming an unstable intermediate shown at the center in red. Then, the intermediate falls apart, releasing sulfur dioxide and forming the desired product, shown on the right. Enzymes act by stabilizing the intermediate, smoothing the path from start to finish.

To make an antibody into an enzyme, we need to find an antibody that stabilizes this intermediate transition state in a similar way. Researchers have done this by finding antibodies that bind to a molecule that mimics the transition state, like the one shown here in green. These antibody–enzymes are termed catalytic antibodies. The catalytic antibody shown here, from PDB entry [1cle](#), performs the Diels–Alder condensation reaction shown in the diagram. This is significant because this type of reaction is not performed by any natural enzymes. Antibodies that perform a number of other cleavage and



September 2001: Antibodies

condensation reactions, including reactions that are impossible any other way, may be found in the PDB.

Exploring the Structures

Antibodies are very flexible, making it difficult to study an intact antibody. Most of the hundreds of antibody structures available at the PDB are fragments of antibodies, typically of just the Fab arm with the specific binding pocket. Three examples of intact antibodies are shown here (PDB entries [1igt](#), [1igy](#), and [1hzh](#)). All are nice examples for exploration. Notice how the antibodies are able to twist into different shapes, forced by packing into the different crystal lattices. This will give you some idea of the range of motion that these molecules are capable of as they bind to their targets.

