Viruses are tricky. They use all sorts of unusual mechanisms during their attacks on cells. HIV is no exception. It is a retrovirus, which means that it has the ability to insert its genetic material into the genome of the cells that it infects. But, infectious HIV particles carry their genome in RNA strands. Somehow, during infection, the virus needs to make a DNA copy of its RNA genome.

This is very unusual, because all of the normal cellular machinery is designed to make RNA copies from DNA, but not the reverse. DNA is normally only created using other DNA strands as a template. This tricky reversal of synthesis is performed by the enzyme reverse transcriptase, shown here from PDB entry 3hvt. Inside its large, claw–shaped active site, it copies the HIV RNA and creates a double–stranded DNA version of the viral genome. This then integrates into the cell’s DNA, and later instructs the cell to make additional copies of the virus.

**Tiny Genomes**

Viruses are tiny. They only carry enough genetic material to encode a few proteins. Many viruses, such as poliovirus and rhinovirus, carry the bare minimum—just enough to specify their own structure and get synthesis started once they get inside cells. The genome of HIV, on the other hand, carries instructions for building a few enzymes that are used in the reproduction of the virus. Reverse transcriptase is one of these enzymes. But, space in the HIV genome is still at a premium, so reverse transcriptase is encoded in a tricky way. It is composed of two different subunits, but both are encoded by the same gene. After the protein is made, one of the subunits is clipped to a smaller size (shown in yellow here) so that it can form the proper mate with one full–sized subunit (shown in red).
September 2002: Reverse Transcriptase

A Sloppy Enzyme
Reverse transcriptase performs a remarkable feat, reversing the normal flow of genetic information, but it is rather sloppy in its job. The polymerases used to make DNA and RNA in cells are very accurate and make very few mistakes. This is essential because they are the caretakers of our genetic information, and mistakes may be passed on to our offspring. Reverse transcriptase, on the other hand, makes lots of mistakes, up to about one in every 2,000 bases that it copies (if this same error rate occurred in the "Molecule of the Month," there would be two typos in this month's installment). You might think that this would cause severe problems. But, in fact, this high error rate turns out to be an advantage for the virus in this era of drug treatment. The errors allow HIV to mutate rapidly, finding drug resistant strains in a matter of weeks after treatment begins. Fortunately, the recent development of treatments that combine several drugs are often effective in combating this problem. Since the virus is simultaneously attacked by several different drugs, it cannot mutate to evade all of them at the same time.

Two Enzymes in One
Reverse transcriptase performs several different functions. As indicated by the name, it can build DNA strands based on an RNA template. This reaction is performed in the polymerase active site, which is formed by two sets of arms that surround the RNA and DNA. The polymerase site is at the top in this illustration, taken from PDB entry 2hmi.

After building the DNA strand, the enzyme then removes the original RNA strand by cleaving it into pieces. This is performed by a nuclease active site, which is located at the opposite end of the enzyme. Finally, it builds a second DNA strand matched to the one that was just created to form the final DNA double helix. This reaction is also performed by the polymerase site.
Exploring the Structure
The current collection of highly-effective drugs for fighting HIV infection are a major success of modern drug design. Two types of drugs are used for blocking the action of reverse transcriptase and stopping HIV infection. One type is a modified nucleotide with a missing connector, such as the drug AZT. These are used by the enzyme like normal nucleotides and added to the growing chain. But, since they are missing a site for connecting the next nucleotide, the synthesis of the DNA chain is stopped. The other type of drug binds on the back side of the enzyme and changes the shape of the active site, blocking its action. The drug Nevirapine, shown here in white from PDB entry 1jlb, is an example of this type of drug. Notice how it is located just under the floor of the active site, below the big groove that binds to DNA and RNA.