Designer Proteins
As we learn more and more about proteins and how they work, we naturally have the desire to use this knowledge and do some tinkering of our own. Since the early 1980's, scientists have been using the ever-expanding understanding of protein structure and function to redesign existing proteins, and more recently, to design entirely new proteins.

Designing Proteins
As scientists began this quest, they quickly found that proteins are more complicated than they might seem. The different types of amino acids, each with their own chemical features, work together to coax a protein chain to fold into a compact stable structure. A collection of carbon-rich amino acids, like leucine and phenylalanine, are usually placed inside the protein, all chosen to lock perfectly together. On the other hand, charged amino acids, such as lysine and aspartic acid, are typically spread across the surface to make the protein soluble in water. Hydrogen-bonding amino acids, such as serine and asparagine, are dotted in strategic places to tie different portions of the chain together. Finally, the odd glycine or proline is added to redirect the chain in the proper direction.

Negative Design
This combination of favorable forces locks the protein chain into a stable, compact structure. But this is only the first step in protein design. In order to design a protein that will successfully fold, you also need to make sure that the protein only has one stable structure. If there are any other ways to fold the protein, they will compete with your desired structure and spoil the construction. So, it is not enough design a stable protein structure...you also need to design a protein that is unstable in every other conformation.

Proteins from Scratch
Building on decades of protein structure research, scientists at the Fred Hutchinson Cancer Research Center and the University of Washington in Seattle have successfully weighed these positive and negative design elements to create an entirely novel protein. They started with a fold that had never been seen in nature, shown here on the left. Then, they used a computational method to design a sequence of amino acids that would adopt this fold. When they built this protein, which they call Top7, they found that it folded up and adopted exactly the structure they designed, as seen in PDB entry 1qys.
Amazing Alpha Helices

A popular approach to protein design is to start with a natural protein and make changes from there. Many groups have focused on a particularly stable structure composed of alpha helices. The GCN4 protein, a transcriptional activator from yeast, contains two chains that are linked together with a leucine zipper, a special sequence that forms an alpha helix with lots of leucines on one side. The leucines are spaced perfectly so they can zip together, gluing the two alpha helices together, as shown on the left from PDB entry 2zta. Taking this as the start, many groups have designed new proteins based on this principle. Coil-Ser (PDB entry 1cos) is composed of three short protein chains that form alpha helices and then associate into a tight bundle. Alpha3D (PDB entry 2a3d) is composed of a single chain that folds into a bundle of three alpha helices connected by short loops. RH4 (PDB entry 1rh4) was designed, by careful choice of the amino acids on the inside, to remove the characteristic twist of alpha helical bundles—notice that the alpha helices are tipped differently than in the other structures. Finally, researchers are now designing new functions in these artificial proteins, such as adding binding sites for metals in the protein DF2 (PDB entry 1jmb).
Exploring the Structure

One goal of protein design is to create mini-proteins for use in biotechnology and medicine. Several groups have created mini-proteins by taking small, stable domains out of natural proteins and then redesigning the amino acids to stabilize the desired fold. Two examples are shown here. The basic fold of TC5b (PDB entry 1l2y) was taken from a protein found in Gila monsters, and then truncated and redesigned for better stability. It has a tryptophan at the very center (shown with a star) surrounded by prolines that together stabilize the structure. Pda8d (PDB entry 1psv) and FSD-1 (PDB entry 1fsd, not shown) take their folds from a zinc finger, and were redesigned so that zinc was no longer needed for folding. Notice that it has a cluster of carbon-rich amino acids at the center (shown with a star), and lots of charged amino acids decorating the surface.