



Pasta Polymers aka: Pasta-mers

The Facilitator Guide

Background:

Proteins are everywhere in biology. They give your cells structure and help them send messages. And proteins are able to do all of that because they each have a different shape. How are proteins so versatile? They are made of small units called amino acids that can be strung together like beads on a string in a specific order to make different shapes. At C-GEM, we want to introduce new “beads” so we can make even more types of shapes that can do different things.

This activity uses dried pasta to demonstrate how the order and type of “bead” can affect the overall structure and function of a protein.

Polymers are long, molecular chains.

Plastics, proteins, fiber, and DNA are molecules that all fall under the category of **polymer**. A polymer is a type of molecule made up of covalently bonded small molecule **monomers**. For example, **cellulose**, the fibrous material found in plants, is made of **glucose** molecules bonded together in a long chain. In this case, cellulose is a polymer with glucose as its monomer. Plastics are the same way, but scientists can make their own monomers in the lab to give plastics different properties.

Polymers can have multiple types of monomers.

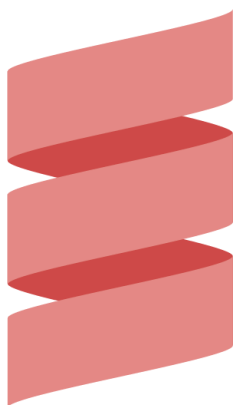
DNA, **RNA**, and **Proteins** are unique in the world of polymers in that they are made up of many different monomers to form a sequence. DNA and RNA each use 4 types of **nucleotides** as monomers. The order of these nucleic acids store the information needed to build proteins. Proteins use 22 types of **amino acids** as their monomer. The order of these amino acids changes the overall shape of the protein and what it can do.

DNA and RNA hold the code to build proteins.

DNA is the blueprint for building proteins. The order of the nucleic acids in the genetic code dictates what order to assemble the amino acids in the protein. However, it can be dangerous for our cells to directly use DNA to make protein since each cell only has one copy. If that copy gets messed up, the cell could get messed up. So, DNA is copied over to RNA in a process called **transcription**. This allows the cell to make many copies of the same gene and to preserve the original DNA code during the protein making process. The RNA code then gets **translated** into protein using a piece of cellular machinery called the **ribosome**.

**Shape informs function.**

The 20 amino acids our cells use to make proteins share an important attribute—the backbone groups. These are the elements of amino acids that bind together to make one big chain. What makes each amino acid unique are the side chains that hang off the backbone. These different side chains have different properties. For example, there are side chains with positive charges and ones with negative charges. If they are close together in a protein, those side chains will attract each other and fold the rest of the protein strand in order to be next to each other. Side chains can make amino acids **hydrophobic**, **hydrophilic**, positively and negatively charged, or they can have special compositions that give proteins other properties such as containing a sulfur atom that allows it to form specific types of bonds within a protein. When amino acids are translated in specific orders, these amino acids can twist into helixes, turn into loops, or zig zag into flat sheets. These larger structures allow proteins to do things like bind specific molecules, perform chemical reactions, and arrange into larger assemblies to provide cells with structural stability.

**C-GEM's science.**

Researchers at C-GEM are finding ways to incorporate new monomers into proteins using the ribosome. They are redesigning essential parts of the ribosome to try to accommodate new types of chemical reactions, and they are changing the structure of these modified proteins in ways that would be impossible otherwise.



Glossary

Amino acid: The building blocks of proteins. There are 22 naturally occurring amino acids that are used to make all proteins you find in organisms.

Cellulose: A naturally occurring polymer found in the cell wall of plant cells.

DNA: The double stranded molecule that codes for all life on Earth. It is passed from parent to child and contains the instructions to build an organism. It is a naturally occurring biopolymer.

Glucose: A small molecule commonly known as a type of sugar. It is the monomer, or single unit, of many kinds of naturally occurring plant polymers including cellulose.

Hydrophilic: A property of molecules where, when exposed to water, the molecules readily associate with the water molecules.

Hydrophobic: A property of molecules where, when exposed to water, the molecules only associate with themselves and not with the water.

Monomer: The single unit of a polymer. “Mono-” means one, and “-mer” means part.

Nucleotide: The building blocks of DNA and RNA. There are 8 total, 4 for DNA and 4 for RNA. The sequence of nucleotides holds the information to make proteins among other things.

Polymer: A large molecule made up of lots of small molecules chained together. “Poly-” means many, and “-mer” means part.

Protein: A type of molecule made of amino acids. They can have many different functions depending on the order of amino acids and the overall shape of the protein. It is a naturally occurring biopolymer.

Ribosome: The cell machinery made of a combination of RNA and protein that uses an RNA template to build proteins. It is in every living organism.

RNA: A single stranded molecule made of nucleotides. RNA is used by the ribosome to build proteins. It is also used by the cell for other functions like performing chemical reactions and short term information storage among other things.

Transcription: The process of copying DNA into RNA. The sequence of nucleotides is preserved while making it more accessible to the rest of the cell to turn into proteins, regulate genes, etc.

Translation: The process of turning RNA code into a protein using the ribosome. The ribosome reads the code of an RNA molecule and bonds amino acids together in a particular order to form a protein.

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The Activity

Materials:

- Pipe cleaners
- String/yarn (optional)
- Many types of pasta with varying shapes/sizes. They must be able to be strung on yarn or pipe cleaner.
 - Our favorite pasta shapes:
 - Ditalini
 - Ziti
 - Mini Rigatoni
 - Mini wheels
 - Penne

Instructions:



1. String different pasta shapes onto string/yarn or a pipe cleaner.
 - Make note of the order. What do you want your pasta-mer to do?
 - Pro-tip: If you're a beginner, start with pipe cleaner first to make bending and making 3D shapes a little easier to start.
2. Tie off the ends so your pasta doesn't fall off, and cut away any extra string or pipe cleaner. This is your "pasta-mer."
 - Pro-tip: If you're using string, tie a piece of ditalini to start and end your pasta-mer in order to prevent your pasta from falling off!
3. Twist and fold your pasta-mer into different shapes. Try out the challenges below!



Challenges:

Beginner

1. **Turn a look.** Make a necklace, a bracelet, and a ring each using the same number of pasta pieces.
 - Which pasta shapes work best for each piece of pasta jewelry? Why?
2. **You're on a roll!** Make a pasta-mer that can roll.
 - What overall shape rolls the best? Which pasta shapes work best to make this overall shape?

Medium

3. **The leaning tower of pastina.** Make a free standing pasta-mer taller than 5 inches.
 - What overall shape is the sturdiest? What order should you string the pasta to make that shape?
 - Can you make it taller than 7 inches? 10 inches? What's the tallest free standing pastamer you can make?
4. **Strength in numbers.** Make a pasta-mer that can withstand the weight of a textbook without breaking.
 - How long does your pasta-mer have to be before folding? Which pasta shape works best for being strong and sturdy?

Challenging

5. **The C-GEM pasta-mer challenge.** With just penne, make a pasta-mer that can both fold into a sturdy cube AND coil up around a pencil.
 - How easy is it?
 - Now try the same challenge with penne AND ditalini. Are you able to do anything different with the new pasta shape?
6. **Change up the backbone.** Make two pasta-mers with the exact same sequence of pasta shapes, one using string/yarn and one using pipe cleaners. Perform the following tests on each of your pasta-mers:
 - i. Fold your pasta-mer into a spring.
 - ii. Tie your pasta-mer into a bow.
 - iii. Thread your pasta-mer through the handle of a gallon of milk and try to lift it.
 - iv. Weave your pasta-mer back and forth through your or a friend's fingers.
 - v. Cut your pasta-mer with scissors.
 - For each test, consider whether string/yarn or pipe cleaners makes the test easier to do or harder. What do you notice is happening with the different materials? Is one material better than the other?
7. **Pasta-mer al dente.** Make two identical pasta-mers using penne and pipe cleaners. Soak one in water overnight. Perform the following tests on each of your pasta-mers:

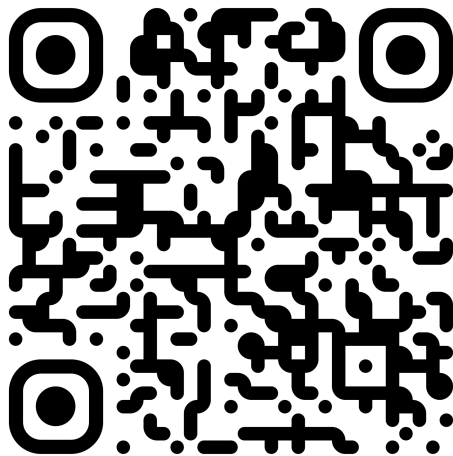


- i. Fold your pasta-mer into a sturdy cube.
 - ii. Wrap your pasta-mer around your wrist like a bracelet
 - iii. Fold your pasta-mer so it stands up on its own.
 - iv. Cut your pasta-mer in the middle of a noodle.
- For each test, consider whether the soaked pasta makes the test easier to do or harder. What do you notice is different between the two pasta-mers? Which is more durable? Which is more flexible?
- For an extra challenge, soak some penne on its own and make a pasta-mer using both soaked AND dry pasta. What new attributes does this pasta-mer have that it wouldn't have otherwise? Can you change the shape of the soaked penne and let it dry to change the shape and function of your pasta-mer?
8. **Pasta synthesis.** Using clay or [pasta dough](#), make your own pasta shapes. Make sure these shapes have at least one hole to thread string or pipe cleaner through. Dry or bake your clay/dough to harden it before using it in your pasta-mer.
 - i. If you are using pasta dough, dry your pasta by keeping it in a cool, dry place for at least 24 hours, and turning it every so often.
- What kind of shape is most versatile?
- Show us what you made! [Submit photos here.](#)

We Want Your Feedback!

Did you enjoy pasta-mers? Did you learn anything new? Do you have challenges you think other people would find fun?

We want to know! Tell us [here](#)!



Feedback

Send us photos of your creations [here](#)!

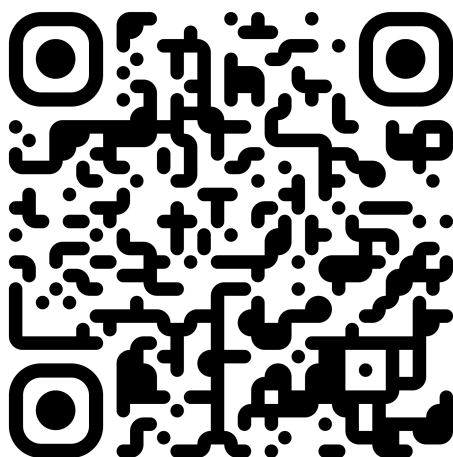


Photo submission

Reach out to us directly by emailing outreach@gem-net.net