Protein Denaturing Activity

Ask A Biologist activity for classroom and home

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Break Proteins in

Learn more

This is a companion PDF for these online articles and activities:

https://askabiologist.asu.edu/activities/breaking-proteins

https://askabiologist.asu.edu/venom

https://askabiologist.asu.edu/explore/gene-expression

Overview

Proteins are essential for all living things to function. They are large molecules made up of long chains of amino acids. Depending on the types of amino acids they have, proteins fold in very specific ways. The way they fold controls what the proteins are able to do. Proteins help move other molecules, respond to signals, make reactions happen more quickly, and replicate DNA, among other things. However, if proteins lose their specific folded shape, they are not able to work properly.

Proteins require specific conditions to keep their shape. For example, most proteins in our bodies rely on us to keep a warm (but not hot) body temperature, stay hydrated, and take in enough of specific nutrients like salt. If our bodies aren't able to maintain these conditions, some of our proteins may not function as well, or at all. Most organisms actually produce special proteins called "molecular chaperones" that help other proteins and molecules continue to work even if conditions are becoming difficult to tolerate.

However, when a protein is exposed to conditions too far outside of a range it can tolerate, that protein's shape will come undone. This is called "denaturing" (basically, breaking) a protein. We denature proteins all the time when we cook food (think: eggs). In this activity, we will use common household products or processes to denature egg proteins in two main ways—by cooking them, and by exposing them to concentrated alcohol (ethanol). Do you think egg will look the same or different depending on how the proteins it holds are denatured?

Materials

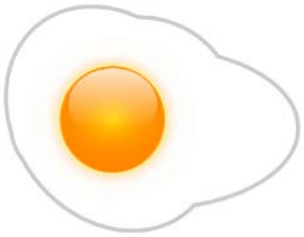
- Stove or microwave
- Pot or microwave-safe container
- 1 fork
- 1 bowl
- 1 pair scissors
- 4 small glass containers of the same size
- 1 egg (split egg white into four parts); additional can be used
- 2/3 cup water (150 ml)
- 1/3 cup of rubbing alcohol (75 ml)

Companion step-by-step video of the entire activity - **askabiologist.asu.edu/activities/breaking-proteins**

Denaturing Proteins in 8 Easy Steps

1. Pour 1/3 cup rubbing alcohol into one glass container, room temperature water (1/3 cup) into another, and the rest of the water (1/3 cup) into a microwave-safe container (or into a pot).
2. Crack egg into the bowl, removing the yolks.
3. Cut the egg white into pieces so you can add ¼ into each glass container.
4. Heat up the water for your hot water treatment and pour into one of the empty glass containers.
5. Quickly put ¼ of the egg yolk into the boiling water. Then put ¼ into the alcohol, ¼ into the room temperature water, and the remainder into the final, empty glass container.
6. Observe any immediate changes that occur in terms of egg white color and consistency. If you try stirring the different treatments, rinse your fork between stirs.
7. Wait for 30 minutes.
8. Use the fork to inspect the state of the egg whites in each treatment and note how they may have changed over time.

What Happened?



Why does denatured egg white turn from clear to white? If more than one treatment denatured egg whites, do you think the treatments denatured the egg whites in the same way?

Let's look at each of the treatments we used:

1. **Control**. Egg whites start out clear. They are almost 90% water, but the other 10% is packed with proteins. Egg whites contain more than 50% of the proteins found in the egg. The main protein in egg white is called albumin. The small, folded proteins in the egg white don't take up much space, and the gel-like egg white looks clear. The control egg showed us that, when left at room temperature, the egg whites stay clear, meaning the proteins maintain their original shape. These proteins were not denatured.
2. **Cooking (hot water)**. Whenever eggs are cooked with heat, the egg whites turn from clear to white, and the gel becomes more rubbery. As heat denatured the proteins in the egg white, it broke apart some of the bonds (mostly hydrogen bonds) that were holding the proteins in their original shape. The proteins unfolded, taking up more space (turning the gel white) and hardening them in place next to one another.
3. **Alcohol**. Alcohol also denatures proteins. It does this the same way as heat, by breaking bonds that hold parts of the protein in a folded shape. Sometimes the alcohol molecules bond directly to some of the parts of the protein, disrupting the normal way the protein would bond to itself. (So alcohol is called a "bond disruptor.") The proteins again unfolded, taking up more space and hardening in place next to one another. This process took much longer with alcohol than it did with heat, however. The longer time for denaturation with alcohol is simply because it spreads more slowly than heat. The alcohol had to diffuse (or move through the fluid) into the egg in order to affect the proteins it touched.
4. **Room temperature water**. Sometimes in this experiment, room temperature water has a small denaturing effect on some of the egg white. It acts in the same way, by breaking bonds, but its effect isn't nearly as strong as alcohol or hot water.

Questions to think about after denaturing egg white proteins (write your answers below).

Think about the effects of the two different water treatments. In your trials, did both types of water have an effect? Was one more effective than the other? If so, what factor (water, heat, time, etc.) was denaturing most of the proteins in the water treatments?

Are there any other processes you know of that turn egg whites from clear to white? What is it and do you think the same processes are happening?

Name another condition besides heat and exposure to a bond disruptor (like alcohol) that could affect the ability of a protein to maintain its shape.

What other things change color when their proteins are denatured?

Why might a living organism want to keep their proteins from denaturing?

In this activity, why was it important to have egg whites that we did not cook or add alcohol to?

For Teachers

This short activity helps students visualize how external influences can affect protein structure, and the ability of proteins to function. The activity can be done with simple materials found in most homes. The activity is written for students at a middle school or higher level, but with more intense guidance, this activity is useful for students of any age.

Tips for Classroom Implementation

Time Required: 1 hour

- If you have more time available, you can use one egg for each treatment. More alcohol and water would be required, and wait time would likely be an hour.

Classroom set-up

- Students can test egg whites in small groups to create replicates in class. If materials are limited, one set of eggs and containers should allow the whole class to observe changes.
- Due to the dangers of boiling water and rubbing alcohol, we encourage teachers to only consider small group work if students are older (high school level). Otherwise, it may be best for the teacher to lead the class through the experiment as a group.

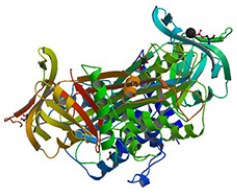
Tips

- Make sure water is boiling before adding it in, to ensure the effect of heat is clear.

Extensions

- Mechanical bond breaking can also be explored by beating egg whites.
- Effects of pH can also be explored by adding lemon juice to the egg whites.
- When combined with additional reading from Ask A Biologist, or additional short assignments, this protein denaturation activity can meet some learning standards.

Proteins

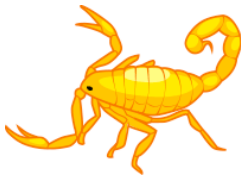


- "What are Proteins?" will provide some background on the basics of proteins. https://askabiologist.asu.edu/venom/what-are-proteins
- "Protein Parts" will help students understand how proteins are built. https://askabiologist.asu.edu/venom/building-blocks-protein
- "Controlling Genes" teaches how proteins are made and used in cells. https://askabiologist.asu.edu/explore/gene-expression
- "Protein Folding" is about how proteins are shaped. https://askabiologist.asu.edu/venom/protein-folding
- "Turning DNA into Proteins" helps students learn just that: how DNA is used to create proteins. https://askabiologist.asu.edu/making-cells-dna-protein

Protein Channels

- "Protein Channels" discusses how some proteins are gatekeepers that allow only certain materials in or out of our cells. https://askabiologist.asu.edu/venom/protein-channels

Proteins and Health



- "Scorpion Venom" explores how venom affects protein channels. https://askabiologist.asu.edu/venom/scorpion_venom
- "Diabetes Protein Puzzle" looks at how one special protein is important to avoid developing diabetes. https://askabiologist.asu.edu/plosable/diabetes-protein-puzzle

Objectives

1. Students will grasp that molecules can be denatured and stop working.
2. Students will follow directions and understand that basic treatments (heat or alcohol) can be used to break proteins and to make them unfold.
3. EXTENSION: Students will understand more ways proteins are vulnerable.
4. EXTENSION: Students will understand the basics of protein biology and how DNA is used to make proteins.

Standards

Next Generation Science Standards

High School Life Sciences
HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.

Common Core standards

Grades 6 - 8:

CCSS.ELA-LITERACY.RST.6-8.3. Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

CCSS.ELA-Literacy.RST.6-8.10. By the end of grade 8, read and comprehend science/technical texts in the grades 6-8 text complexity band independently and proficiently.

Protein Parts: 8th grade
Protein Channels: 8th grade
Scorpion Venom: 8th grade

Grades 9 - 10:

CCSS.ELA-LITERACY.RST.9-10.3
Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

CCSS.ELA-LITERACY.RST.9-10.10
By the end of grade 10, read and comprehend science/technical texts in the grades 9-10 text complexity band independently and proficiently.

What are Proteins?: 9th grade
Controlling Genes: 9th grade
Protein Folding: 9th grade
Turning DNA into Proteins: 10th grade
Diabetes Protein Puzzle: 10th grade