NCSE National Center for Science Education

# In Case of Cellulose

## Overview

*In Case of Cellulose* dives into the digestive tracts of 4 species - human, panda, horse and cow; and explores how cellulose is digested differently. From mechanical digestion in the mouth to chemical digestion in the intestines, *In Case of Cellulose* provides a fun, interactive take on one of the largest systems in the body.

## Learning Goals

1. A misconception in evolution is that evolution is perfect. Through playing through this activity, participants should be able to realize that every strategy for digesting cellulose has tradeoffs. In particular, they should see the difference between foregut and hindgut digestion and realize that the risky evolutionary strategy of the panda can still lead to some amount of reproductive success
2. Participants should understand that plants and animals often have different evolutionary strategies. While these can often be conflicting or cooperative (e.g., defense against predators or attracting pollinators), cellulose is a strategy that represents neither.
3. Digestion and nutrition are complex topics of interest to personal health. Participants should be able to gain basic biological information that will help them understand digestion and take a sharper critical eye towards the wealth of nutritional misinformation that exists.

## Materials

- What's Provided
    - (40) Boli Capsules
    - (40) Cellulose Capsules
    - Beads, representing nutrients
    - (3) PVC Intestine models - panda/human, horse, and cow
    - (3) Labeled glass viles containing pigment to create digestive enzymes
    - (1) Labeled glass vile containing green food coloring
    - Graphics - activity title card, species list, species descriptions, nutrition information, digestive tract graphic
    - Table Layout Sign
- What To Purchase (For Food Base)
    - Canola oil
    - Citric acid
    - Corn starch
    - Baking soda

## Set-up

1. (Before the event) Make the food base for the expected number of participants, and fill boli. Recipe makes about 5 bath bombs; increase measurements for 40 bath bombs.
2. To make the food base - In a large container, place 2 teaspoons of canola oil, ½ cup citric acid, ½ cup corn starch, 1 cup baking soda, and food coloring. Mix together until smooth. (N.B. We suggest 2-3 participants per bolus, as stomach digestion takes a while).
3. Put 10 nutrients inside each cellulose capsules (4 blue, 2 purple, 1 yellow, and 3 pink)
4. Add **hot** water to each digestive enzyme vile. Shake vile gently to release color.
5. Fill each bolus half way, add the cellulose capsule and three silver protein pellets, then fill to the top.
6. Lay table sign and graphics onto table, and place intestines in correct spots.

## Procedure

### Short Form

1. Greet participants at the mouth. Ask participants which species they would like to be and hand them the corresponding lid color. Let them know that they are going to be digesting leaves/grass/bamboo today. Lean in hard to the gross aspect of the activity.
2. Guide them through the esophagus and into the stomach. Greet them there with some digestive enzymes and a gardening tool. Use the words chemical and mechanical digestion but don't over-explain the mechanisms.
3. Give them ample time to perform the digestion (having very liquidy digestion helps with the absorption). Help them understand that a similar chemical reaction takes place in their stomachs.
4. Once they have found the three pellets (representing protein) and the capsule, ask them what might be going on. Give them the word cellulose, but don't go into too much detail. If they are playing as a cow, talk to them about a cow's four stomachs and chewing their cud, then break open the capsule. Other species don't digest cellulose in the stomach.
5. Encourage them to put all of the chyme back into the capsule (N.B. Do not put the lid back on. If the chemical reaction has not completed, it will cause the cap to shoot off violently).
6. Help participants make observations of the differences between their intestines and other intestines.
7. Using their tools, have them spoon one spoonful of the chyme into the small intestines (purple). Count the number of seconds it takes for food to travel to the end of the large intestines for each species (panda/human should be shortest, then cow, then horse). Clarify that nutrition must be absorbed in order for it to go to the body (Otherwise it is poop - hopefully the hilarity of making poop jokes will hold their attention long enough for them to understand this point).

8. Have them spoon the rest of their food, including cellulose capsule and protein into the intestines that match their species. Every nutrient that is absorbed will **NOT** come out the other end.
9. Have them count the nutrients that were not absorbed and subtract them from the total number of nutrients. Each boli started with 10 nutrients on the inside of the cellulose capsule, and 3 pellets on the outside.
10. Have a discussion about the digestion strategy of their species. Bring in other species for comparison as needed. You might want to talk about foregut/hindgut fermentation, the number of plants an animal needs to eat to survive, or the trade-off between absorption amount and time.

*Definition of Success Participants will be able to witness the process of digestion first hand and make some age-appropriate observations about evolutionary strategies for digesting cellulose.*

## Long Form

1. **Engage**
   Review carnivore/omnivore/herbivore at age-appropriate level. Ask students why carnivores cannot eat plants and herbivores cannot eat meat. Validate the basic answer (they will get sick), then ask them why they will get sick. Make a list of specific things that might differ between herbivores and carnivores.

2. **Explore**
   Divide the group into 3 and have them self-direct through the process of digestion for horse, cow and human. Before starting, have them predict how many nutrients they may be able to absorb and document the total time of digestion and the relative lengths of the guts. At the end of the activity, have them share out to the group about what happened.

3. **Explain**
   Help make comparisons between animal strategies. What were the costs and benefits of each approach? Broaden this conversation back to why animals might eat grass or other dispersed, abundant resources, as opposed to meat, fruit or insects. Discuss basic socioecological theory and surface area to volume comparisons of guts if appropriate.

4. **Elaborate**
   Show a phylogeny of carnivores [https://www.researchgate.net/figure/AGT-distribution-in-Carnivora-is-related-to-diet-A-Phylogenetic-tree-Bininda-Emonds_fig1_8906914] with pure carnivores and omnivores labelled. Ask the group to predict what an animal nested within that phylogeny would eat, nudging them towards thinking about macronutrients, rather than broad categories. Show them where a panda is on a phylogeny and ask what they eat. Go through the process of digesting bamboo with the entire group. Pandas will only absorb protein, which is similar macronutritionally to a carnivore diet.

5. **Evaluate**
   Ask participants to research the diet of one of four animals they are familiar with (sheep, cat, mouse, pig). Ask them to predict what their gut morphology looks like and what tradeoffs they may have made, based on this diet.

*Definition of Success*: *Participants will be able to understand how diet impacts gut morphology and the evolutionary trade-offs surrounding different strategies to digest cellulose.*

## Modifications and Guiding Questions

**Modification:** If you don't want to make the boli, you can encourage participants to pack a bolus for the next group. This works better for drop-in activities, especially if you may have underestimated the total participant number

## Further Resources

- Pandas are really cool
- Overview of digestive system
- The impact of cellulose on evolution

## NGSS Standards

**5-LS2-1 Ecosystems: Interactions, Energy, and Dynamics**

Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.

**3-LS4-2 Biological Evolution: Unity and Diversity**

Use evidence to construct an explanation for how the variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing.

**MS-LS1-7 From Molecules to Organisms: Structures and Processes**

Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.

**HS-LS1-7 From Molecules to Organisms: Structures and Processes**

Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed, resulting in a net transfer of energy.

**4-LS1-1 From Molecules to Organisms: Structures and Processes**

Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.

**5-PS3-1 Energy**

Use models to describe that energy in animals' food (used for body repair, growth, motion, and to maintain body warmth) was once energy from the sun.

**5-LS1-1 From Molecules to Organisms: Structures and Processes**

Support an argument that plants get the materials they need for growth chiefly from air and water.

**MS-LS2-5 Ecosystems: Interactions, Energy, and Dynamics**

Evaluate competing design solutions for maintaining biodiversity and ecosystem services.*

**HS-LS1-6 From Molecules to Organisms: Structures and Processes**

Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.