Investigating a natural composite – chicken bone

This experiment takes three sessions with about 20 minutes of work in each session. It involves taking apart a natural composite, chicken bone, and looking at the consequences of the removal of each of the components. Students can do this as a practical exercise. Alternatively, they could be given prepared samples to examine.

The experiment helps to show that composites are not only manufactured materials but also exist in nature. Bone is generally about 30 % collagen and 70 % hydroxyapatite (calcium phosphate) dry mass. The water content varies.

Prior knowledge required

- This activity assumes that students know what a composite is.
- Students should be able to calculate density from mass and volume but may need reminding how to do it.
- Students should be able to calculate volume – the easiest way is for them to submerge the bone in a measuring cylinder of water and measure the volume of water displaced.

Equipment required

Per pair or group of students:

- 2 cleaned chicken bones – see note below
- Beaker – large enough to hold the chicken bone
- 1 mol dm^{-3} hydrochloric acid – sufficient to cover the bone in the beaker
- Measuring cylinder – 25 cm^3 will probably suffice; it needs to hold the chicken bone
- Crucible or other heat proof dish for heating the bone
- Eye protection.

Per class:

- Access to a balance (accurate to two decimal places)
- Oven or other way of warming the bones overnight at 60 °C
- Furnace or hot oven to remove the collagen.

An alternative to heating the bone in an oven or furnace is to roast it in a Bunsen burner flame. This should be done in a fume cupboard and eye protection worn. The bone may spit and crack so care should be taken. This step could possibly be done by students.

Note on chicken bones

The bones should be raw and clean. They are probably best cleaned by the technician prior to use. A pan scourer usually works well – as much meat and gristle as possible should be removed. Avoid using a scalpel or other sharp instrument. Alternatively, simmering (not boiling) in water with a small amount of sodium carbonate loosens the flesh and it is then easy to remove, *eg* with an old toothbrush. The bones should be rinsed after this procedure.

Health and safety

- Read our standard health and safety guidance at https://rsc.li/3G9YYMj
- Chicken bone is a potential source of salmonella and other diseases. Ensure that students are aware how to handle the bones safely. They should wash their hands after handling bone and before eating or putting anything else into their mouths. If this is a concern then the bones can be sterilised after de-fleshing, *eg* by leaving them in domestic bleach overnight. They should be rinsed prior to use.
- Wear eye protection when using 1 mol dm^{-3} hydrochloric acid.
- The bone ash produced in the final stage of this activity may contain calcium oxide.

- Avoid contact with skin and eyes.
- Eye protection should be worn and gloves made available for students with sensitive skin.

Possible homework activity

It might help students if they find out about the structure of bone between sessions 2 and 3.

Answers

1. Calcium phosphate is hard and brittle. Collagen is soft and flexible.
2. The bone is less dense than the components of the bone.
3. Students may come up with various answers. By the end of the activity they should realise that the low density of the bone is a result of its structure – it has a number of holes or cavities within it. At this stage the aim of the question is to set them thinking.
4. Calcium phosphate was removed by the acid.
5. This has made the bone far floppier and softer. It is now more flexible and bendy.
6. Bones like this would not support the body. They would not allow movement because they would bend when the muscles pulled on them rather than moving at the joints as they should.
7. Answers will vary.
8. Density = mass/volume. Answers will vary.
9. Collagen has been removed.
10. Mass of collagen = mass of bone after water removed – mass of bone after collagen removed. Answers will vary.
11. The bone is far more brittle and crumbly. It has far less strength than before.
12. The bones would break far too easily.
13. The bone contains cavities within its structure, as well as spaces for blood vessels.

Note: An image search on the internet will produce a number of interesting pictures of bone. The website **http://invsee.asu.edu/Invsee/invsee.htm** (accessed December 2005) hosts a gallery of images, including a number of electron microscopy pictures of bone (some of which are chicken bone).

14. Bones containing cavities are lighter than solid bones. Therefore less energy is needed to move the animal about. The cavities also allow vital nutrients and oxygen to be delivered to the living cells within the bone.
15.

a. Bones from different parts of the skeleton are likely to have different densities. Long tubular bones have a central shaft filled with bone marrow; short bones do not. Flat bones (*eg* in the skull) consist of two layers of compact bone and vertebrae are different again.
b. Bones from different animals are likely to have different densities. For example, birds have lighter bones with more hollows in them than many other animals. This allows them to take off.

Investigating a natural composite – chicken bone

Bone is a natural composite material. It contains:

- An inorganic, giant ionic part made of a type of calcium phosphate called hydroxyapatite
- An organic, covalent molecular part made of a protein called collagen (which is also found in hair and finger nails)
- Water.

Bone is made by living cells in the body.

1. Given what you know about giant ionic substances and covalent substances, which of the following properties do you think will apply to calcium phosphate and which to collagen? Tick the correct boxes.

	Calcium phosphate	Collagen
Flexible		
Brittle		
Hard		
Soft		

You are going to carry out an experiment to remove each of the three components of bone listed above from a sample of chicken bone. You should observe what happens to the structure and properties of the bone as each part is removed.

Each part of the experiment takes some time so you will carry it out over a number of lessons.

Make sure you keep notes of what you have done and your observations.

You will need

- 2 cleaned chicken bones
- Beaker
- 1 mol/dm^3 hydrochloric acid
- Access to a balance
- Measuring cylinder
- Crucible or other heat proof dish for heating the bone
- Eye protection.

Health and safety

- Read our standard health and safety guidance at
- Chicken bones can be contaminated with salmonella and other diseases. Ensure that you wash your hands thoroughly after handling the bones and before you eat. Do not put your fingers in your mouth during the experiment.
- Wear eye protection when handling 1 mol/dm^3 hydrochloric acid.

What to do

Session 1

- Put one of the chicken bones into a beaker and cover it with hydrochloric acid. You are trying to remove the calcium phosphate from the bone. Leave it for 1–2 days. If you leave it for much longer, you will also remove the collagen. This is chicken bone 1.
- Measure the mass and the volume of the second bone. Calculate its density. This is chicken bone 2.
- Then heat the bone in an oven at 60 °C overnight to remove the water.

Densities

Part of bone	Density (g/cm^3)
Calcium phosphate	3.2
Collagen	1.0
Water	1.0

2. How does the density of the whole bone compare to the densities of the components of the bone?

_____

_____

_____

3. Try to explain the difference between the density of the bone and the densities of its components.

_____

_____

Session 2

Use forceps or tongs to remove chicken bone 1 from the acid, wash and dry it gently.

4. What was removed by the acid?

_____

_____

_____

5. What difference has this made to the properties of the bone?

_____

_____

_____

6. What problems would you have if the bones in your body were like this?

_____

_____

_____

- Take chicken bone 2 and weigh it. Mass of chicken bone 2 = _____ g

7. Work out the mass of water that has been lost from the bone. Use the following formula: mass of bone at start – mass of bone now = mass of water in bone

8. Calculate the new density of the bone. Assume that the volume of the bone is the same as it was before heating.

- Have chicken bone 2 heated more strongly in a furnace or very hot oven. This will remove the collagen and leave just the calcium phosphate.

Session 3

Health and safety

Chicken bone 2 has now become bone ash. This bone ash can contain calcium oxide which is an alkali and can cause damage if it gets in your eyes. Wear eye protection and gloves. Avoid inhaling any dust or powder from the bone.

- Weigh what is left of chicken bone 2. Mass = _____ g

9. What has been removed by this final stage of heating?

10. Calculate the mass of collagen that was present in the bone.

11. What difference has removing the collagen made to the properties of the bone?

12. What problems would you have if the bones in your body were like this?

Bone is less dense than might be expected for a simple combination of collagen and calcium phosphate.

13. Try to explain this in terms of the structure of the bone.

_____

_____

_____

14. Why might it be an advantage to have bones made this way?

_____

_____

_____

15. Would you expect bones to have the same density if they are from

a. different parts of the skeleton?

_____

b. different animals?

_____

Give reasons for your answers.