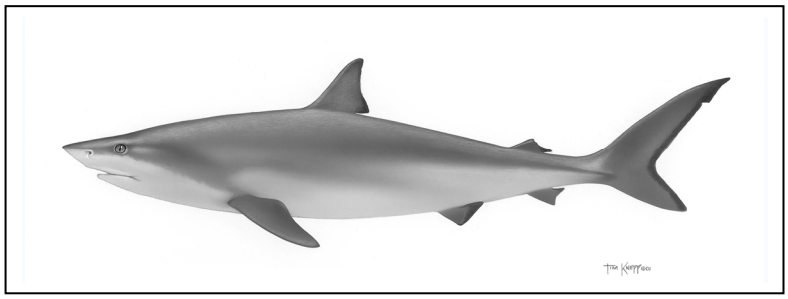
The Bone Trail: comparative anatomy
Emm Barnes, October 2006

What is comparative anatomy?

Comparative anatomy is the study of similarities and differences in the shape and structure of organisms. It is closely related to evolutionary biology because it assumes that animals are somehow related to one another, but it predates Darwin's theory of evolution by more than 50 years.

Animals from different species may have *homologous structures*, body parts similar to those in animals from another species because the two species have come from some common ancestor. Or, animals from different species may have *analogous structures*, body parts similar to those in animals from another species because the two species evolved in a similar environment. For example, sharks and whales have similar body shapes – good for swimming – but they are not closely related.





Who first developed the theory and why was it important?

Baron Georges Léopold Chrétien Frédéric Dagobert Cuvier, or Cuvier for short, was born 1769 and died in 1832. He was an important and respected man of science across Europe. His opinion about new fossil finds counted in deciding whether what fossil hunters found was taken seriously or not.

Cuvier devoted more than 30 years of his life to studying and publishing on comparative anatomy. He established a set of rules which he claimed meant he could recreate a whole animal from just one part of its skeleton – he claimed he could work out how large the animal was, how it moved, and what it ate, purely by comparing one part with the whole skeletons of other animals.

Most natural philosophers in Europe at that time – the name given to people who studied the natural world at that time, before the word 'scientist' was first dreamed up – believed that God had created all the animal types there ever would be in six days of creation, as described in the book of Genesis. Cuvier's beliefs that fossils showed that there were extinct forms of life were very controversial because they seemed to go against the teachings of the church.

The Bone Trail: fossilisation
Peter Fowler, October 2006

How are Fossils Formed?



Fossil trace of an ammonite.



Fossil sea urchin.

'Fossils' comes from the latin word 'fossus,' which means 'dug up.' The scientific definition, though, states that fossils are the mineralised or otherwise preserved remains or traces of animals, plants, and other organisms. There are many different ways in which animals and plants from earlier time periods have been preserved:

Petrification: original organic matter is replaced by substances such as calcium carbonate, silica, or iron minerals. One way this happens is that minerals soak into the spaces between the cells.

Mineral Alteration : original organic matter loses all those elements which react to other substances in the environment, leaving only the carbon.

Insects in Amber: amber is the resin from trees which has solidified. This sticky fluid can trap insects.

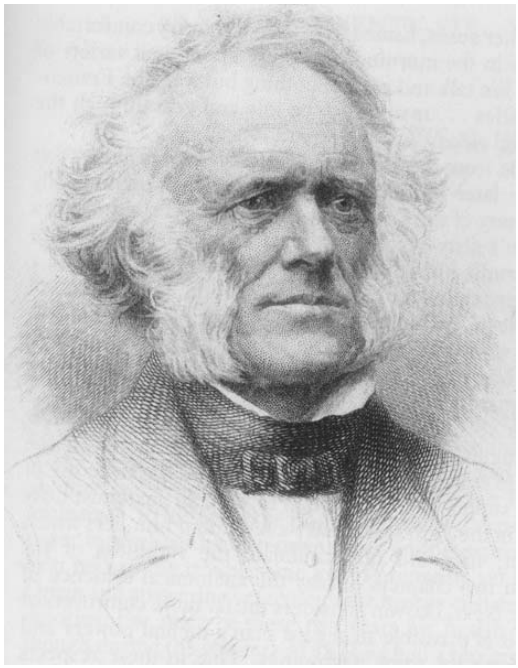
Impressions: moulds are made when the organism is surrounded by rock and then the organic matter is worn or rotted away. Casts are made when a mould is filled, and then the mould is worn away. Trace fossils (fossil 'footprints') are often formed in this way.

Mummification: some animals have been mummified in extremely cold environments.

Tar Pits: animals have become stuck in pits of tar which bubbled up from the ground. The bones of sabre-toothed tigers and their prey have been found in this way.

The Bone Trail: Lyell
Emm Barnes, March 2006

The geological revolution



Charles Lyell (1797 to 1875) was not the only important man in the history of geology, which was perhaps the most exciting and controversial science in the early nineteenth century. But Lyell's books on geology caused the biggest stir.

He published the many volumes of his masterwork "Principles of Geology" between 1830 and 1833. The book's subtitle was "An Attempt to Explain the Former Changes of the Earth's Surface by Reference to Causes Now in Operation," and this points towards why Lyell had such a big impact on the field of what was coming to be called "science." He was the leading advocate of the theory of *uniformitarianism*. This theory stated that the Earth was shaped entirely by slow-moving forces acting over a very long period of time. It was in contrast to *catastrophism*, a theory which said that the Earth changed through a series of sudden events. While catastrophism fitted with the Earth being as young as the Bible suggested, uniformitarianism painted a very different picture of the Earth and its creation.

The most famous and influential holder of the catastrophe theory at the time was William Buckland. Buckland argued that fossils of extinct animals were the remains of animals drowned in the great flood of Noah.

The Bone Trail: edible geology
Emm Barnes, March 2006

William Smith used bread and butter to explain how rock strata were built up in layers on top of one another, always in the same sequence. In 1859, *Punch* carried a short funny article about teaching people about geology through making special cakes: “Let cakes be made to illustrate the science of geology - composed of strata resembling those of the earth except in their relation to the sense of taste. Children might thus be crammed at once with cake and geological science, and acquire a knowledge of the crust of the earth in eating the model of it.”



Stratified chocolate refrigerator cake

The geology of England and Wales was mapped in the early nineteenth century because for economic reasons: land owners wanted to know how to make their wet farm land drier, and their dry land wetter, for better results in farming, and industrialists wanted to know where to dig canals and later also cuttings for railroads in order to transport goods around the country. The country was heavily dependent on coal, and it was obviously very useful to know where to dig to locate rich seams of this “black gold.”

In this first recipe, we will be sandwiching a cherry-studded layer in between two other strata of chocolate “rock.” After it has set, we will create a fault line to reveal the cherry seam. We will then mine this layer for the wealth it contains.

Stratified chocolate refrigerator cake

Ingredients

100g white chocolate
100g milk chocolate
100g dark chocolate
3 pieces of butter each weighing 20g
25g rice crispies
120g glace cherries, cut into halves (if not available, use sultanas or raisins)
75g digestive biscuits, turned into crumbs
You also need a round cake tin 15-17 cm in diameter, and some toothpicks.

Method

1. Prepare the cake tin by lining it with baking parchment.

2. Melt the white chocolate with one of 20g pieces of butter, in a microwave over on medium power (set it for 30 seconds and then stir, and repeat until it is melted; it will take about 2 minutes in total), or in a heatproof bowl placed over a saucepan of simmering water.
Add the rice crispies.
Pour the mixture into the cake tin, level it off and press down. (Here you are compressing "sediments" to help them become densely packed rock.) Place somewhere cold to help it set a little while you prepare the next layer.

3. Melt the milk chocolate with 20g of the butter as above.
Add the cherries.
Pour on top of the white chocolate layer, and level it then press down.

4. Melt the dark chocolate with the remaining 20g of butter.
Add the biscuit crumbs.
Pour onto the top of the other two layers, level it and then press firmly.

4. Place the cake tin in a refrigerator and leave to set for about 8 hours.
Once the cake has set, remove it from the tin by lifting it out on the baking parchment. Carefully remove the paper. Leave to warm for 15 minutes or so before attempting to "fault" the "rock."

5. Take a sharp knife and make a cut through the middle of the cake, preferably at a slight angle rather than straight down. This is your fault line.

6. Now move one of the pieces so that the top of the dark chocolate layer on one half is level with the middle of top of the milk chocolate layer on the other, exposing the cherry seam. Using toothpicks, carefully mine out the cherries. Try not to disturb the other layers of rock – try to avoid causing a rock fall.

Once you've removed all the cherries you can reach, what will be the most efficient way to reach more? You will have to break away surrounding rock to access more of the cherry layer. Will it be easier to dig deeper away from the cliff face through the cherry seam? Or will you get a higher yield for efforts if you remove the dark chocolate layer from the top? The second option, which is like open cast mining, is more environmentally destructive.

Multi-decker rock sandwiches

Ingredients

For this activity you will need an 800g loaf of white bread and an 800g loaf of wholemeal. Choose unsliced loaves if possible, as then larger slices can be cut, horizontally rather than vertically.

You will also need a variety of sandwich fillings such as cream cheese, hard cheese, butter, red jam, and perhaps mayonnaise.

Finally you will need glass worktop protectors on which to place your models.

Method

1. Look at the map of the Manchester region. It has three components:
   - i) The map at the top of the sheet gives you a birds-eye-view of the *surface* rock across the whole region.
   - ii) The key underneath, on the left hand side of the sheet, shows the vertical sequence of rocks, in other words the order in which we always find those layers. Each layer corresponds to a part of the Earth's long history, when that type of rock was laid down.
   - iii) On the right hand side there are two cross-sections. There are map numbers on both ends of each cross-section which explains where these sectional lines start and stop on the map above.

2. Find where these two sectional lines are located on the surface geology map. The sections show the rocks which lie underneath the surface along those lines.

3. Pick one of the two cross-sections. You will be creating a 3D model of the rocks along this line, using the three parts of the map sheet – the surface map, the key, and the cross-section – from bread and sandwich fillings.

4. Be sure to wash your hands before you start and work on clean surfaces if you wish to eat the result.

5. In teams, discuss which ingredient should represent each type of rock in the sequence. Make sure you assemble a key, to show explain how your multi-decker sandwich corresponds to the solid geology along the section.

6. Assemble the layers, sculpting the bread if you like to create the variations in thickness as per the map. Press down as you make the sandwich to make the layers bond to one another.

7. Once you have the whole sequence, use a sharp knife cut fault lines so that you have separate pieces to arrange as per the cross-section. Remember that you may need to cut diagonally through the sandwich.

8. Place the pieces of sandwich on the glass, offsetting the layers according to the cross-section on the map.

9. Write up the key on a piece of card, and place next to your model.

10. Marvel, then enjoy.

The Bone Trail: geological timeline
Peter Fowler, March 2006

It can be hard to understand how old the universe really is.
The aim of these two activities is to make a picture which shows us just how slowly our planet and all the living things on it have developed.

First practical – small groups

1) Neatly stick about 20 A4 sheets of graph paper together lengthways (landscape). Make sure you have at least 25cm of each sheet showing.

2) Draw on the glued sheets a line of exactly 5m long, preferably at the bottom of one side of the sheets.

3) Mark a scale of 30cm for every billion years from 0 to 15 billion years. You can do this in two ways: either from 0 to 15 in steps of 1, or from -15 to 0 in steps of 1.

4) Mark on the timeline the following universal events:

Universe started 14.6 billion (14.6×10^9) years ago
Our sun was formed about 5 billion years ago
The planets of our solar system were formed 4.6×10^9 years ago
Life began 3.8×10^9 years ago
First recognisable organisms which have left fossils appeared 600 (0.6×10^9) million years ago
Dinosaurs appeared 230 (0.23×10^9) million years ago
Dinosaurs died out 65 (0.065×10^9) million years ago
Early humans appeared 1.64 (0.002×10^9) million years ago
Human civilisation started 10,000 (0.00001×10^9) years ago

Is there a problem drawing the last line? Why?

The Bone Trail: geological timeline
Peter Fowler, March 2006

Second practical – whole group

A timeline which ran from the start of the universe to the present day and could just about show human civilisation on it would be *extremely* long.

Lets try a scale where 1mm (0.001m) represents 10,000 years.
How many 10,000 years are in 14.6 billion years?
Multiply this number by 0.001m to find out how long the graph needs to be.

How long would the graph need to be?

You probably do not have a space big enough in your school or museum to try to make a timeline like this, so lets just work with the the history of our solar system, in other words to represent the last 5 billion years.

How long would this timeline be?

Take some sugar paper rolls. Cut long strips of the paper, about 50mm high – you should be able to get about 10 strips from each roll.

Glue the strips end to end to make one long strip. The rolls are 10m long.
Each roll should give you a strip 50mm high which is almost 100m long.

How many rolls do you need?

Make up the strip. Mark on the same events as you did on your first timeline.

Discussion ideas

Consider the scale of universal time, and some very long gaps between the events that you have marked. What does this mean for humans, including yourself?

The Bone Trail: sedimentary rock
Emm Barnes, March 2006

Sedimentary rock is formed when pieces of old rocks, shells, bones, plant matter, and other bits of material, are pressed together until they harden. Sedimentary rocks include chalk, limestone, sandstone, and shale.

Many sedimentary rocks look stripy. They have been built up from layers of different kinds of sediments. Rocks that form on the bed of a lake, for example, have different coloured stripes according to how richly populated the lake was at the time: the rock formed in seasons or years when there were many creatures dying and falling to the bottom looks different from the rock formed in seasons or years when the lake supported less life.

The layers break apart when sedimentary rock is exposed to the weather. Fossils of small hard parts of animals are frequently found in sedimentary rock. Limestone in buildings is a good place to look for tiny fossil shells.

Here is an example where layers of sedimentary rock have been exposed to the surface. Lots of fossils of sea creatures were found in this cliff face.



Photograph of Wren's Nest Nature Reserve near Dudbury,
taken in 1995 for a CD-ROM for schools.

Rock making

You can make your own model of sedimentary rock, to help you learn about how this kind of rock is formed in nature and to help you understand why so many fossils are found in it.

You will need:

A clear glass jar with a lid A handful of small pebbles or gravel A handful of sand 2 handfuls of small pieces of twigs and leaves One or two small shells if you have them Some tap water A packet of Epsom salts (about 50ml)

[Epsom salts are crystals of hydrated magnesium sulfate, and can be bought at any large chemists, though you may need to order them a day in advance. The Epsom salts glue the various sediments together in this recipe.]

1. Put the stones, sand, twigs, leaves, and shells (if you have them) in the jar.

2. Add 50ml (just over 3 tablespoons) of Epsom salts.

3. Add tap water to the jar until there is a 5cm gap at the top.

4. Put on the lid, tightly, and shake to mix all the sediments.

5. Leave the jar to one side. If possible, check on it every hour or two.

6. After a day, pour the water out of the jar and leave it with the lid off in a safe place to dry out completely.

What dropped to the bottom first? Could you see layers forming?

The sediments settled at different rates and this is what gave your “rock” its stripy appearance.

Adapted from “Geology Rocks” by Cindy Blobaum.