Let's weigh that dinosaur!

How can a plastic model reveal the mass of an actual dinosaur?

You can estimate the mass of a dinosaur from the depth of its footprints: (http://www.earthlearningidea.com/PDF/How_to_weigh_a_dinosaur.pdf). But in this alternative method, the mass is calculated from measurements on a plastic scale model of a dinosaur immersed in water. If we know the volume of an animal and can estimate its density, then we can find the mass. This can be done on a reasonably accurate scale model and can then be multiplied up to the full size of the once-living animal.

Plastic *Stegosaurus* model (*P. Kennett*)

To find the volume of the model, **either** immerse it totally in a Eureka can, and measure the volume of the displaced water in a measuring cylinder, **or** weigh the displaced water as follows. Place a shallow dish on an electronic balance and zero the reading. Stand a deep, clear container which is completely full of water in the dish. Completely immerse the dinosaur in the water, which will spill over into the dish beneath.

Model dinosaur totally immersed in water (*P. Kennett*)

Remove the dinosaur and the deep container and weigh the water that spilled into the dish beneath. Repeat several times to obtain an average value. In our trial the mass of water displaced was 187g.

This figure also gives the volume of the model: since 1g of the displaced water has a volume of 1ml, it is also the volume displaced in ml.
How does this relate to the volume of the real dinosaur itself? First look at the base of the model to find the scale. If there is no scale, you will need to look up the average length of whichever dinosaur species you happen to have. The scale of the animal is then given by:

$$\text{Scale} = \frac{\text{actual length of dinosaur (m)}}{\text{length of model (also in m)}}$$

Watch out that the same units are used throughout. Students will probably measure the model in millimetres, but if this is converted to metres straight away (i.e. divide by 1000), it will make the calculation easier later.

In our example, the textbook length for most specimens of *Stegosaurus* is about 6.5m (with some up to 9m) and the measured length of our model is 250mm (i.e. 0.25m). So the scale is:

$$\frac{6.5\text{m}}{0.25\text{m}} = 26$$

i.e. a scale of 1:26

To find the volume of the real, three-dimensional dinosaur, the length, width and height of the model all have to be multiplied by the scale given on the model, or calculated as above. So the volume of the actual dinosaur is given by multiplying the volume of the model by (scale x scale x scale), i.e. the scale cubed. In our example, the volume of the model is 187ml.

$187\text{ml} \times 26^3 = 3286712\text{ ml}$
$= 3287$ litres; or about 3.3m^3

To obtain the mass of the dinosaur when it was alive, we need to know the average density of the tissue of the dinosaur. Measurements on living reptiles suggest their tissue has a density of about 0.9 grams per cm^3. This can also be expressed as 0.9 tonnes per cubic metre. $\text{Density} = \frac{\text{mass}}{\text{volume}}$
So the mass of the living dinosaur = density x volume. For the model which we used, we obtained the following mass for the living dinosaur:

Mass = 0.9 x 3.3 = 2.97 tonnes, i.e. nearly 3 tonnes.

Basic websites give a range of estimated weights for *Stegosaurus* from 5 to 7 tonnes, but the Natural History Museum used a variety of methods to calculate the weight of an exceptionally well-preserved specimen, and arrived at a weight of 1.6 tonnes (See Useful Links below).

Note: if you don't have an electronic balance, you could find the volume of water displaced by the toy dinosaur using a set of kitchen scales to measure the mass, when the volume will be the same figure as explained above.
Or, without a balance of any sort, you could measure the volume directly by **either**;

- pouring the dish of displaced water into a measuring cylinder or jug;
- **or** marking how much water is left in the container after the dinosaur has been removed, and then using a measuring cylinder to fill the container again, and recording how much water was used.

Whichever method you use, repeat the measurements several times and calculate the average value.

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The back up

Title: Let's weigh that dinosaur!

Subtitle: How can a plastic model dinosaur reveal the mass of the actual animal?

Topic: A class activity to estimate the mass of a living dinosaur using a plastic model

Age range of pupils: 14 -18 years

Time needed to complete activity: 30 minutes

Pupil learning outcomes: Pupils can:

- carry out an accurate measurement of water displaced by an object;
- calculate a mass from an assumed density and a measured volume;
- calculate a scale from an actual measurement and a value from a textbook;
- appreciate that such calculations can only be an approximation.

Context: The activity provides one method of estimating the mass of an extinct animal as used by academics. The result can be compared with textbook values and with results obtained by alternative methods, based on measurements such as the depth of animal footprints, or the size of the thigh bone.

Following up the activity:

- Repeat the activity using other dinosaur models. (Pupils could be encouraged to bring in models which they have at home).
- Discuss the uncertainties in using a model of an animal whose shape and size are known mostly from fossil bones alone.
- Discuss probable errors in such an investigation, e.g. measuring the volume of water displaced in a vessel which is wide enough to immerse the model, but where the change in level cannot be as accurately measured as in a narrower vessel.
- Compare the mass of a familiar object, such as a car, with the mass of the dinosaur.

Underlying principles:

- A solid object displaces its own volume when totally immersed in a liquid.
- Scaling a model up in three dimensions involves using the cube of the scale (i.e. 3x) and not simply the relationship of the length of the model compared with that of the fossil remains of the real animal,

Thinking skill development: The relationship between the assumed density of the living dinosaur and its volume establishes a pattern. The debate about the reliability of the method involves cognitive conflict. Applying this learning to the once-living dinosaur is a bridging activity.

Resource list:

- one or more plastic scale models of dinosaurs;
- deep glass or plastic container, or Eureka can
- shallow dish
- measuring cylinder or jug
- **or** balance/kitchen scales
- tap water
- calculator

Useful links:
http://www.earthlearningidea.com/PDF/How_to_weigh_a_dinosaur.pdf
https://www.nhm.ac.uk/discover/news/2015/march/weight-of-the-worlds-most-complete-stegosaurus-revealed.html

Source: Adapted by Peter Kennett of the Earthlearningidea Team from "How heavy is my pet dinosaur", by Mark David Walker in School Science Review (**101**) 377, June 2020.