Animal diets in the Age of Dinosaurs

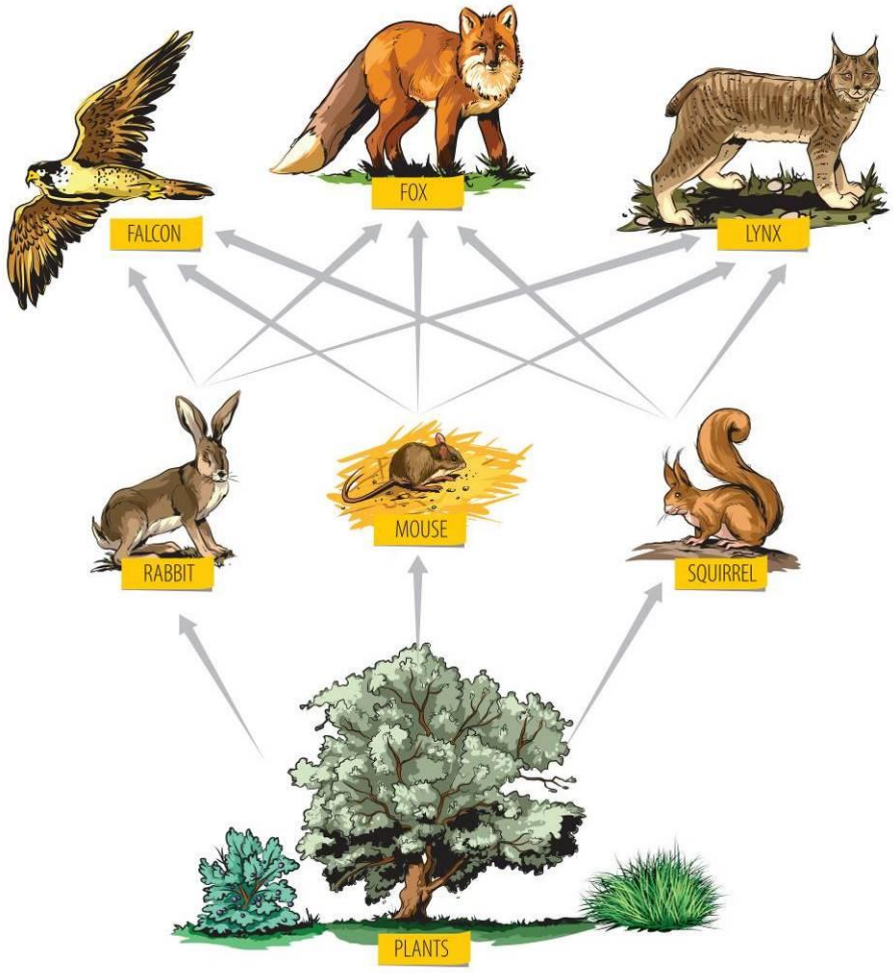
In this activity, you will learn how scientists study living and extinct animals to discover what they ate. You will become a palaeontologist by examining fossils of dinosaurs and extinct mammals from the Cretaceous period, over 65 million years ago.

A reconstruction of the meat-eating *Tyrannosaurus rex* (foreground) and the plant-eating hadrosaur *Parasaurolophus* (background, right) during the Late Cretaceous. Image credit: Warpaint/Shutterstock.com.

You are what you eat

You might be wondering why it is important to understand what extinct animals ate. Food is essential for all animal life on Earth, and always has been. Diet controls many important aspects of an animal's biology, including how fast and how large they can grow, how they reproduce, and how long they can live – to name only a few! The diet of an animal also tells us a lot about its role in an ecosystem (or its **ecological niche**).

Just by knowing what an animal eats, we can begin to understand how an ecosystem is structured. The picture below shows six animals that live in forests across Europe today. Using information about diet, we can link animals together in a **food web**: the rabbit, mouse and squirrel are all **herbivores** (plant-eaters), and these three small mammals are hunted by **carnivores** (meat-eaters) like the falcon, fox and lynx. We can make similar food webs for ancient ecosystems and extinct animals if we know what their diets were like.



A simple forest food web. Image credit: lukaves/Shutterstock.com.

The problem with fossils

It is much easier to figure out the diet of animals that are alive today than those that are extinct.

Activity #1

How do you think scientists can figure out the diets of animals that are alive today? If you went out to a forest, how would **you** work out the diets of the animals that lived there?

See if you can list three ideas:

1) .....

2) .....

3) .....

The problem for **palaeontologists** (scientists that study extinct animals) is that usually only the hard bones and teeth are left behind as fossils. All the soft bits – skin, muscles, guts – often rot away entirely. This means that we can't use many of the techniques that we use on living animals to determine the diets of extinct animals. Palaeontologists have had to come up with new ways to work out the diet of extinct animals from only fossil bones and teeth.

***Left,* a red fox eating a mouse – this kind of feeding observation provides direct evidence of diet. *Right,* the skull of a red fox – what we might find if the fox became a fossil. This is similar to the fossils that palaeontologists often have to work with.** Image credits: schaef67/Shutterstock.com and photowind/Shutterstock.com.

Tooth shape and diet

Teeth are very valuable to palaeontologists. This is because they can study the relationship between tooth shape and diet in living animals, and use that information to predict the diets of extinct animals. Three important aspects of tooth shape are linked to diet:

(1) tooth **complexity**, (2) tooth **relief**, (3) tooth **slope**

Tooth complexity

Tooth complexity is a measure of the number of features or 'tools' on a tooth. In other words, it is the number of lumps and bumps on the surface of a tooth that are used to break down food. The more lumps and bumps a tooth has, the more 'complex' a tooth is.

Meat-eating carnivores have simple teeth of low complexity; there are not many lumps and bumps on their chewing teeth (called **molars**). This is because meat is quite soft, so doesn't need lots of 'tools' on the tooth surface to break it down. However, plant-eating herbivores have complex teeth with lots more lumps and bumps. These 'tools' help break down the hard, tough vegetation that herbivores eat.

Activity #2

Below are images showing two teeth in side view (top row), in top view (middle row), and showing the number of tools on the tooth surface coloured by orientation (bottom row).

One tooth belongs to a plant-eating giant panda and one belongs to a meat-eating red fox. Can you tell which is which based only on the tooth complexity?

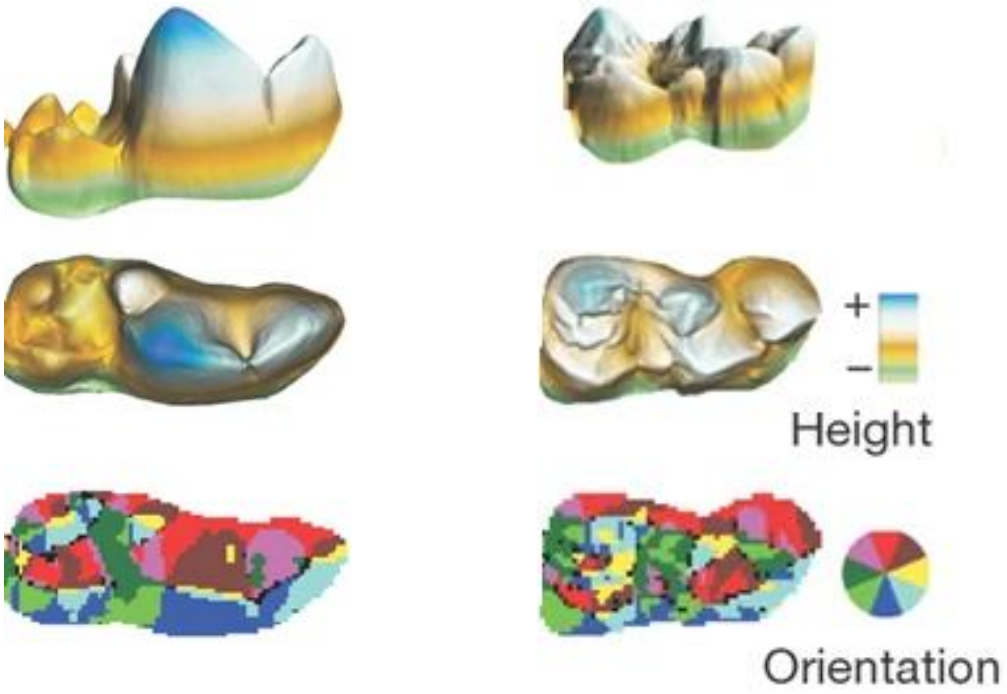


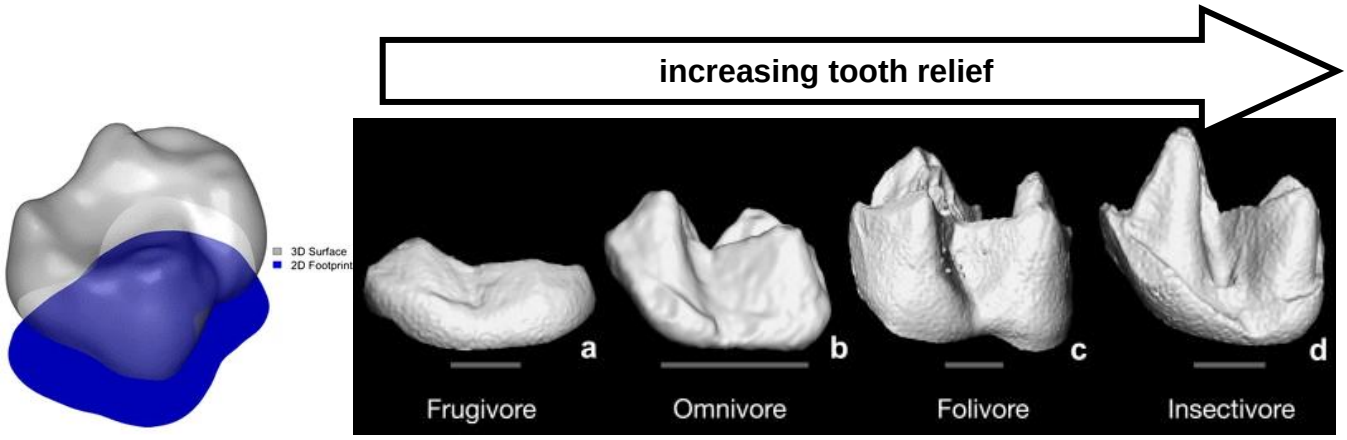
Image credit: adapted from Fig. 1 in Evans *et al*. (2007) *Nature*, 445: 78-81.

Tooth relief

Tooth relief is a tooth's 3D surface area divided by its 2D area. In other words, how tall a tooth is compared to its width and length.

To calculate tooth relief in the picture below, you would measure the 3D surface area (in grey) and divide this by the 2D area (in blue).

We know from living animals that tall teeth with high relief usually belong to meat-eating **carnivores** and animals that eat insects (**insectivores**). Animals that eat fruits are called **frugivores** and have very short teeth with low relief. Animals that eat both plants and meat are called **omnivores** and have tooth relief in between frugivores and insectivores.



How tooth relief is calculated, with examples from living primates showing how relief is different in different diets. Image credits: adapted from Fig. 3 in Pampush *et al*. (2016) *J. Mammal. Evol.* 23: 397-412 and Fig. 1 in Boyer (2008) *J. Hum. Evol.* 55: 1118-1137.

Tooth slope

Tooth slope is the average angle of the tooth surface. In other words, how steep the tooth surface is overall.

Carnivores and insectivores have steeper teeth with pointed edges for puncturing and shearing meat and insects. Herbivores are the opposite and have flatter tooth surfaces, which are better for crushing and grinding plant materials.

The grass-eating horse has much flatter teeth with lower slope (*left*) than the meat-eating lion (*right*). Image credits: vriesela/Shutterstock.com and pedrobige/Shutterstock.com.

Animal diets in the Age of Dinosaurs

Using what you've learnt so far, you will now become a palaeontologist for yourself!

Try to work out the diet of dinosaurs and extinct mammals from only their fossil teeth.

Dinosaurs from the Cretaceous

Below are some web links to 3D models of different dinosaur teeth. You'll have the opportunity to make your own digital models later in Activity #5!

Activity #3

Explore the 3D models of the dinosaur teeth online and examine the pictures below.

How complex are the teeth? What are the relief and slope of the teeth like?

What do you think these dinosaurs were eating based on their teeth? Can you see any other features (or **adaptations**) of the teeth that make them well suited to their diets?

Carcharodontosaurus (pronounced "car-car-oh-dont-oh-saw-rus"):

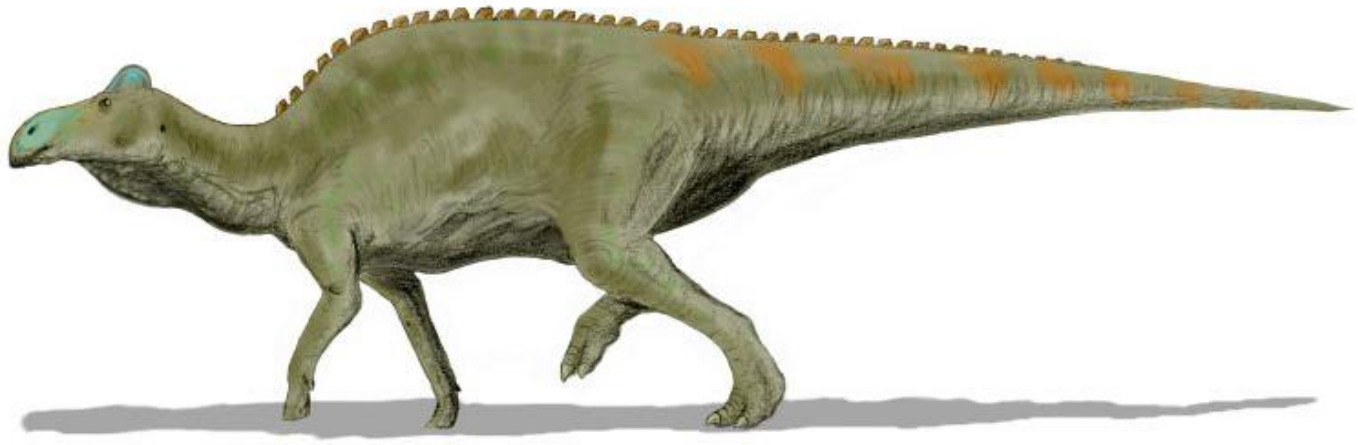
An artist's reconstruction of the theropod dinosaur *Carcharodontosaurus*. Image credit: Fred Wierum / Wikimedia Commons / CC-BY-SA-4.0.

Carcharodontosaurus lived around 100 million years ago in North Africa. It was a large dinosaur, over 12 metres in length and over 6 tons in weight. It belonged to a group of dinosaurs called the **theropods**, which includes *T. rex*.

3D model of a *Carcharodontosaurus* tooth is available here:

https://sketchfab.com/3d-models/carcharodontosaur-tooth-e298916540264ef9a3f916045af339a3

Edmontosaurus (pronounced “ed-mont-oh-saw-rus”)



An artist’s reconstruction of the duck-billed dinosaur *Edmontosaurus*. Image credit: Nobu Tamura / Wikimedia Commons / CC-BY-SA-3.0.

Edmontosaurus lived around 70 million years ago in North America. It was a large dinosaur, over 10 metres in length and over 4 tons in weight. It belonged to a group of dinosaurs called the **hadrosaurs** (also known as the **duck-billed dinosaurs**). These dinosaurs had very strange teeth! Hundreds of teeth are stacked in rows forming what is called a **dental battery**.

3D model of an *Edmontosaurus* jaw available here:

https://sketchfab.com/3d-models/edmontosaurus-juvenile-jaw-0ea3705cb3ed46a3b1e5ab2eddee9cbe

In images of the jaw below, the stacked rows of teeth (called **dental batteries**) are labelled with arrows.

Right side view:

Left side view:

Top view:

3D model of an *Edmontosaurus* tooth battery available here:

https://sketchfab.com/3d-models/leiug-121413-f55bb699a5194cea9a9bcb44453d1e0f

Side view:

Top view:

Mammals in the Age of the Dinosaurs

Although the Cretaceous is famous for dinosaurs, there were many other animals around at the same time. Running around at the feet of the dinosaurs were some of our early relatives – the mammals! Although none of them looked like humans back then.

Activity #4

As you did for the dinosaurs, take a look at some images of fossil mammal teeth and see if you can work out what they ate! Remember to think about the complexity, relief, and slope of the teeth to help you.

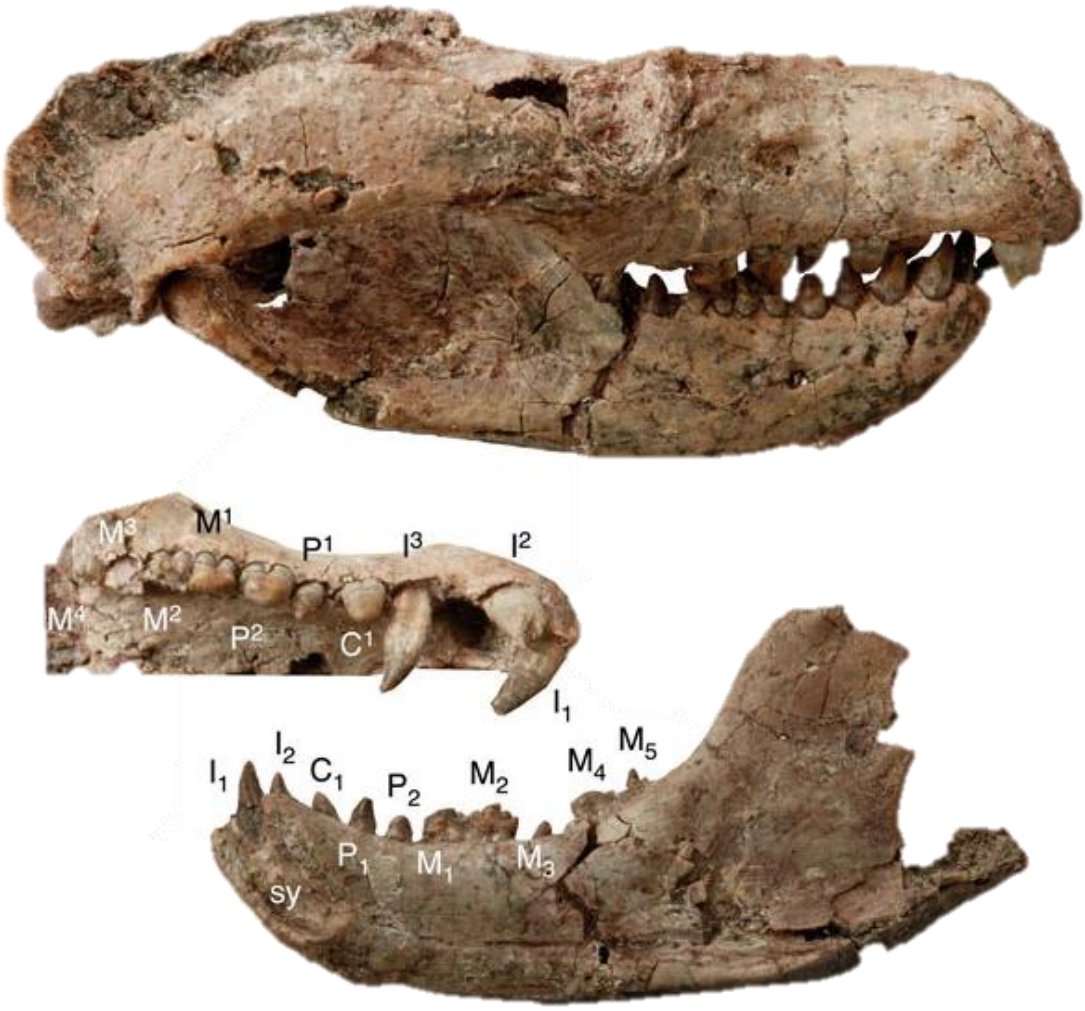
Repenomamus (pronounced “reh-pay-no-mam-us”)

An artist’s reconstruction of the fossil mammal *Repenomamus*. Image credit: Dorling Kindersley Limited © 2020.

Repenomamus is an extinct mammal that lived 125 million years ago during the Cretaceous, and its fossils have been found in northeast China. It was about the size of a badger and was one of the largest mammals around during the Age of Dinosaurs! It was about a meter long and weighed around 14 kilograms. It belongs to a group of extinct mammals that have no living descendants today.

No 3D models have yet been made of *Repenomamus* fossils, but use the images below to work out its diet:

Photo of a lower jaw of *Repenomamus*. Image credit: adapted from Fig. 1 in Wang *et al*. (2001) *Science*, 294: 357-361.



Photos of a skull, part of the upper jaw, and the lower jaw of *Repenomamus*. Image credit: adapted from Fig. 1 in Hu *et al*. (2005) *Nature*, 433: 149-152.

Vintana (pronounced “vin-tarn-ah”)

An artist’s reconstruction of the fossil mammal *Vintana*. Image credit: Emily M. Eng / National Geographic © 2014.

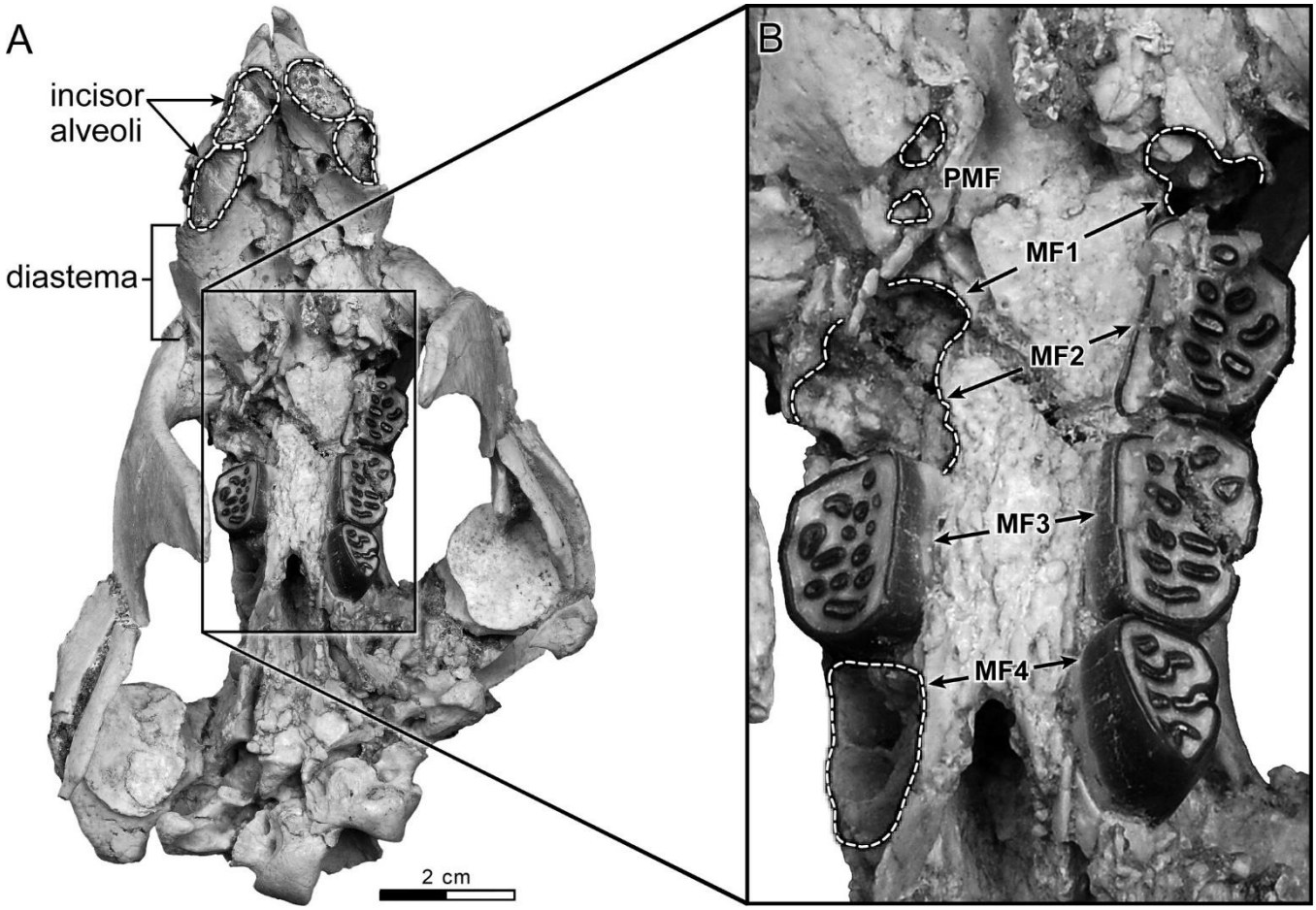
Vintana is an extinct mammal that lived 70 million years ago during the Cretaceous on the island of Madagascar. It looked a bit like a large chipmunk or a ground squirrel, but is completely unrelated to them.

Vintana is slightly smaller than *Repenomamus*, weighing around 10 kg and was just over half a meter long. But it was still very large compared to the other mammals that lived during the Cretaceous. Its skull and teeth are completely different to *Repenomamus*, suggesting it had a very different diet.

You can see some rotating 3D models of the skull and upper teeth of *Vintana* on YouTube:

Skull: https://www.youtube.com/watch?v=WVaUrV_NBOE

Teeth: https://www.youtube.com/watch?v=MBoiUU0xi_4



Bottom view of the skull of *Vintana*, with a zoomed-in panel on the teeth. The skull and some of the teeth have been damaged during fossilisation, but it is still possible to look at the tooth shape to think about diet. Image credit: adapted from Fig. 1 in Krause (2014) *J. Vert. Paleontol.* 34 (suppl. 1): 137-165.

So, what do you think the diets of the Cretaceous dinosaurs and mammals were like? Can you see any similarities between any of the dinosaur and mammal teeth?

You can write down some ideas here:

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Making digital 3D models

Scientists often need to make 3D digital models of teeth so that they can be analysed and measured by computer programs. There are many ways to make these 3D models, but one common method is **photogrammetry**, where lots of photos are taken of an object from all different directions and stitched together to produce a 3D image.

Activity #5 (optional)

You can have a go at producing your own 3D digital models using photogrammetry at home!

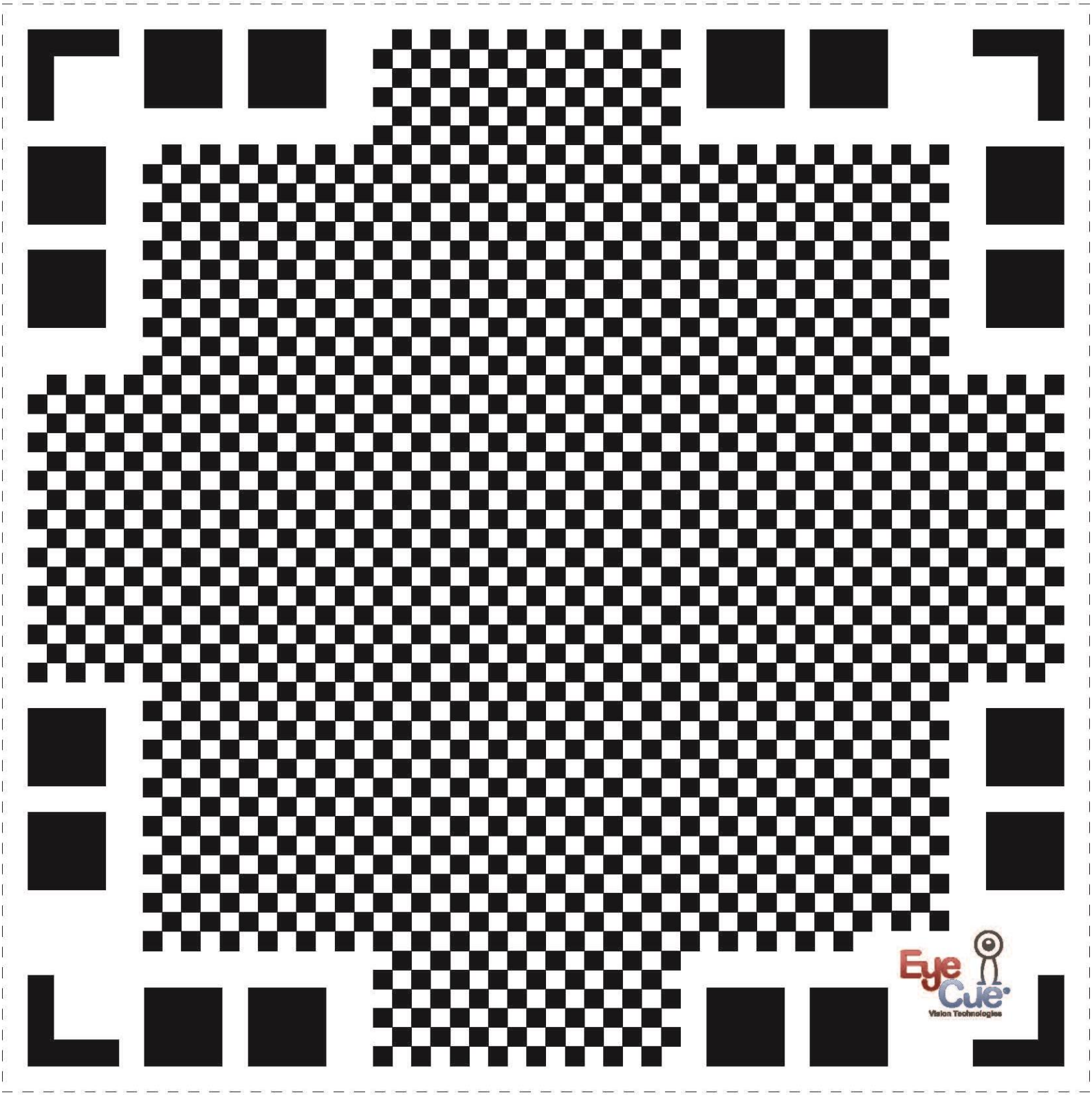
All you need is a smartphone or tablet with a camera, a print out of the checkerboard mat included on the next page, and an object that fits on the mat.

Instructions

- Download the free QLONE app to a smartphone or tablet (see: www.qlone.pro).
- Print out the QLONE checkerboard mat on the next page (also download at this link).
- Find a household object that you would like to turn into a 3D digital model. The object you choose needs to be the right size to fit on the mat you print.
- Follow the instructions in the app to create your model!

- You can see a helpful, instructional video here: https://www.youtube.com/watch?v=XkTaCOQ_OjI

- You can see an example of a horse tooth from the University of Leicester Geology Department collections scanned using the app here: https://sketchfab.com/3d-models/leiug-120809-f42f64b6aeda4aef8079ecc0d87862be.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