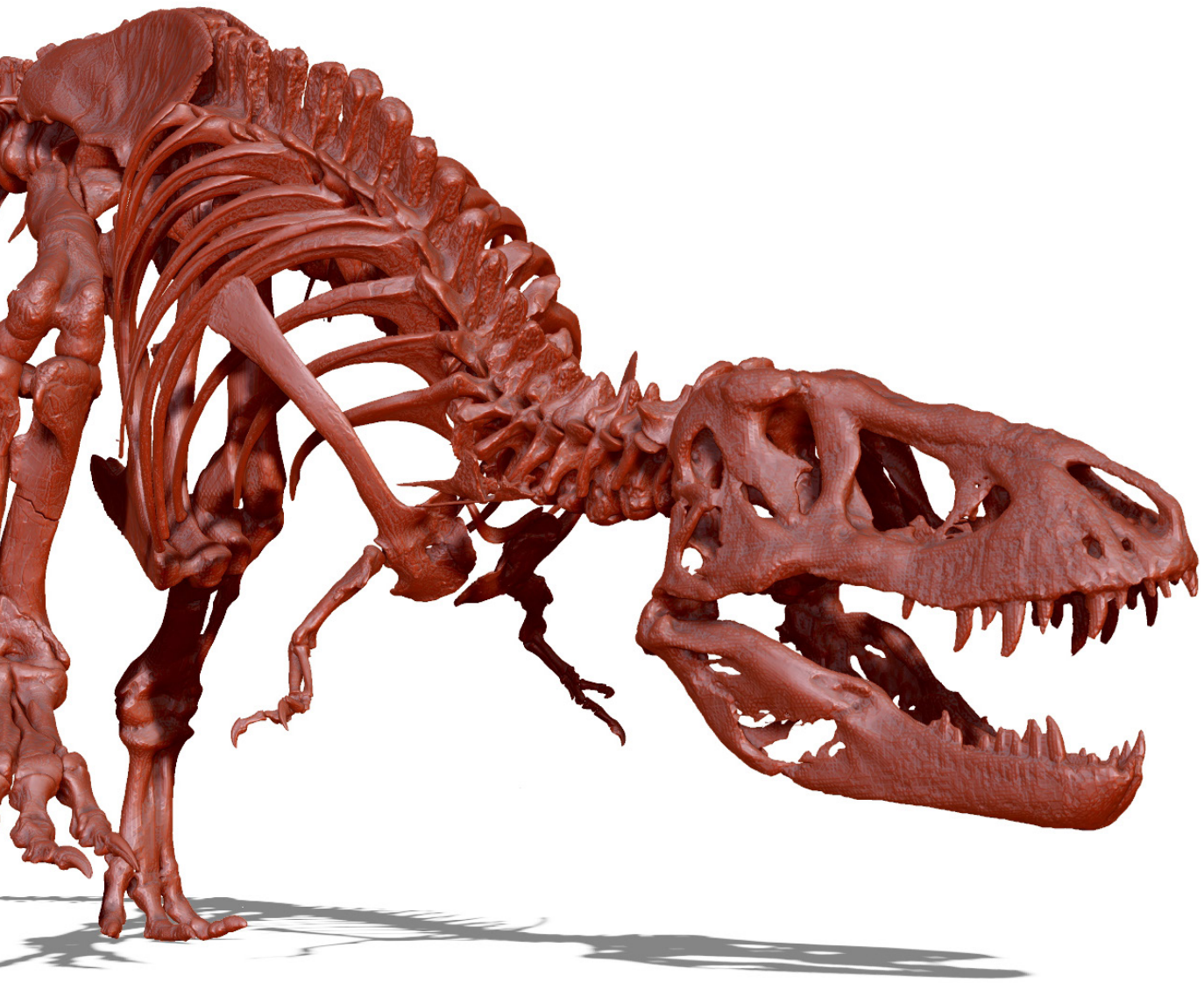


T. Rex 'Trix'

Reviving a fossil



Teacher's guide

Dear teacher,

Here's the educator's guide for the 3D printing activity "Print your own T.rex". This document contains information about:

- The structure of the activity
- The prints
- Background information on *T. rex* Trix of Naturalis
- Assembly Instructions
- References to necessary resources and helpful tips

Plan your lesson according to your own best judgment. Work on another activity, while the 3D printer is running. In total, the students will be working on this lesson effectively for about a day part.

For questions about printing, please contact your local technical support team via this link:

<https://ultimaker.com/contact>

Have fun printing and investigating!

Kind regards,

Matthijs Graner
matthijs.graner@naturalis.nl
Educational developer Naturalis

Lesson plan

Short description of the activity

During the activity, you will print different bones of Trix - one at a time. Students will wonder about what will come out of the printer. They will think about what it is, where it came from and where it belongs. They will think about the form and function and will be able to do calculations on steps and scale. Eventually, your students will put together Trix into a model (scale 1:15) for the classroom.

Target audience

Upper primary education (grade 4-7).



Objectives

- Students learn about the form and function of dinosaur bones.
- Students make connections between the bones of contemporary animals and their own skeletons.
- Students are able to describe broadly how *T. rex* lived.
- Students learn how scientists research dinosaur fossils.
- Students learn about the possibilities of 3D printing.

Link with core objectives

The lesson is consistent with core objective 41* and can be extended with geometric assignments so the lesson will also be in line with core objectives 32** and 33***.

41* Students learn about the build of plants, animals, and people and about the form and function of their parts.

32** Students learn to solve simple mathematical problems.

33*** Students learn to measure and calculate with units and measurements, such as time, money, length, perimeter, area, volume, weight, speed, and temperature.

Introduction

You can access the [3D scans](#) of the bones of Trix in a small format. You print the bones in the classroom. Choose either to print every part or only a part of the skeleton. The second option is closer to reality, as a complete *T. rex* skeleton has never been found.

Step 1 (print time: +/- 3 hours)

To spark curiosity, you start printing a part of Trix's skeleton at the beginning of the activity: the bottom of the pelvis (see photo), without giving any substantive information to the students. Students wonder what is being printed. They are curious, but only know that the print is the beginning of a fun activity, in which more will be printed.



Step 2 (length: +/-15 minutes)

Discuss the first print in class. What do you notice? What does it look like? Where does it belong? What can you do with it? There are no answers yet. Ask students if it is part of a larger whole.

Step 3 (print time: +/- 8 hours)

Then print three parts: arms/shoulder blades, hind legs, and a tail piece.

Step 4 (length: 1 hour)

Students learn more by examining the individual prints in groups and gather information on them. Everyone gets to see and examine all four components. They draw/craft how they think the animal looked according to their bones. The drawings will differ. You show them that there are many possibilities. How do we find out what the animal really looked like?

Step 5 (length: 30 minutes)

Not all parts are being printed. Why not? In reality, one also doesn't find all of the bones. Students view movie clips of i.a. paleontologist Anne Schulp about how an excavation works. These videos can be found on the island 'Opgravia' in the [Verwonderwereld](#) of the so-called Verwonderpaspoort.

Step 6 (length: depending on the number of prints)

Which parts are the students still missing? When the questions on the form/function are answered correctly, an animal is pieced/devised, and videos of Anne are viewed and discussed in class, you may decide to print more or even all of the bones. Each time a part is printed, the students adapt their drawing accordingly

Step 7 (length: 1 hour)

Put Trix together when every part has been printed. The parts can be glued together. As a final task the students build the environment of Trix with many different materials (paper, branches, wood, etc.), in which eventually the printed skeleton can be 'exhibited'. If only some parts of Trix are printed to mimic reality, the excavation site can be built instead, in which the bones can be exhibited scattered and half buried.

Alternatively, the activity can be completed in class with a discussion on Trix. How did she live? In what kind of environment? What did she eat? Would you like to see Trix in real life? Then visit Naturalis (with the class or on your own).

Step 8 (optional)

Do the students want to learn more about Naturalis and dinosaurs? Let them visit the open world of the [Verwonderpaspoort](#). This can also be done in class. Here they see all kinds of movies, carry out experiments and go in search of treasure. The episode of [Klokhuis](#) (in Dutch) on dinosaurs is also fun to watch.

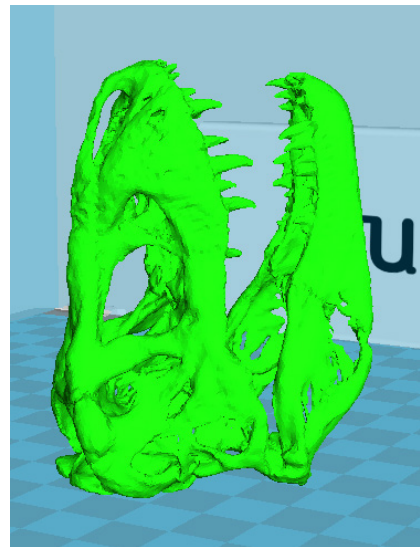
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The prints

Here is the list of the seven objects that can be printed. The pictures are placed in the orientation in which you can print them.

The head of Trix (print time: +/- 4 hours)

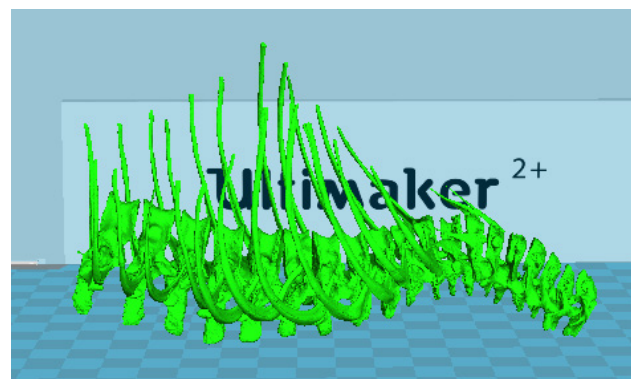
This is the head of Trix. In reality, the skull is one and a half meters long. In the lower jaw, you can see big holes. Scientists have discovered that it is highly likely it was bitten there by another *T. rex*. On the front of its snout (on the right) you can see a small hole below the nostril. Trix has probably had a nasty infection that never healed properly, but was there for a long time. Trix is most likely a female, as she is built very robustly. Males were a lot smaller. The bite force of a *T. rex* is about 6000kg. So it would feel like there were six cars on top of you! She was probably over 30 years old when she died.



Vertebrae and ribs

(print time: +/- 7 hours)

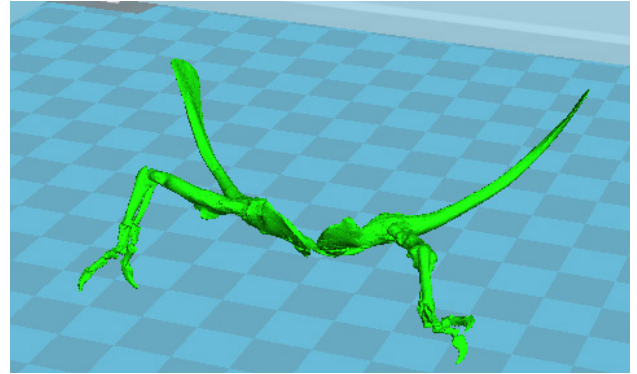
A lot of Trix's vertebrae and ribs were found. *T. rex* also had so-called belly ribs (not present in the print). These belly ribs protected the animal from e.g. the horns of *Triceratops*.



Arms and shoulder blades

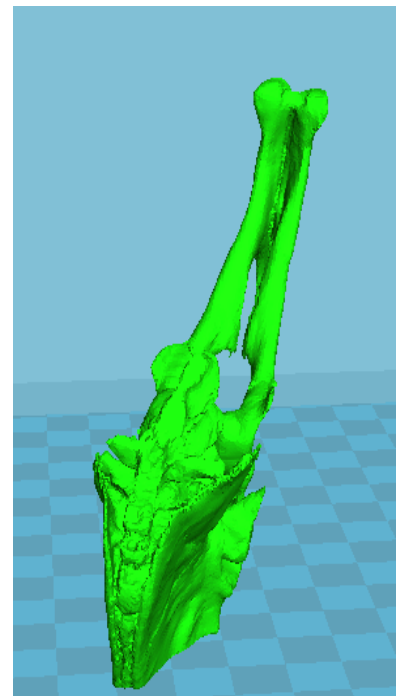
(print time: +/- 1)

The arms of *T. rex* were very small, about the size of the arms of a 7-year-old child, but it could lift up to 300 kg with them! The muscles that were needed for this were attached to the long shoulder blades. There were two sharp claws the dinosaur probably used to rip apart its prey. Researchers believe it could have also used its arms to hold its partner during reproduction.



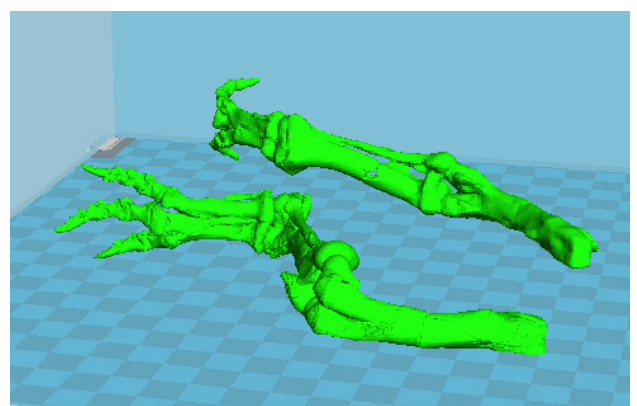
Hips (print time: +/- 6 hours)

The hips of *T. rex* were huge. It consists, as with humans, of roughly two times three parts (left and right): the ilium, pubis, and ischium. The ilium is located at the top and clasps the vertebrae. The ilium is called that way because, with humans, it holds the intestines as a sort of bowl, in a *T. rex* this is not the case. The pubis is situated at the front in humans, but in a *T. rex* it sticks almost straight down like an anchor and is very large. The ischium protrudes to the back and is located underneath the tail. It possibly offered protection of the buttocks and may have served as a kind of protection for the eggs, so they would not smash to pieces on the ground. With humans, the ischium can be felt when you sit on someone's lap. It sits at the bottom of our buttocks.



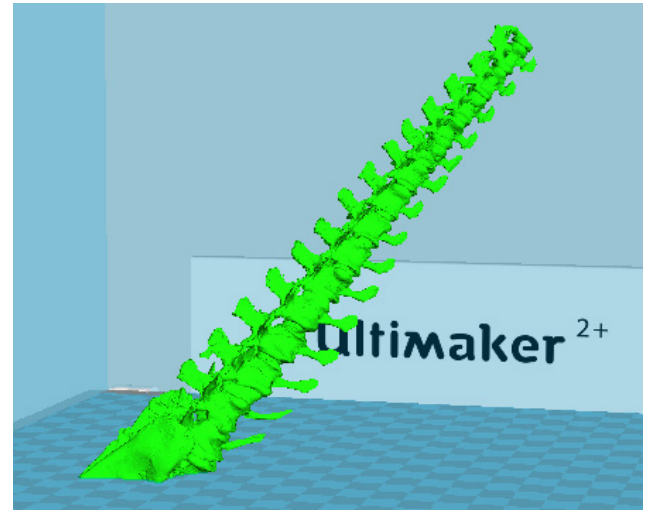
Legs (print time: +/- 4,5 hours)

The hind legs of *T. rex* were huge and roughly similar to the shape of a chicken leg. It couldn't run very fast with them, scientists believe about 20 km/h, so you could ride your bike and be faster than this dinosaur.



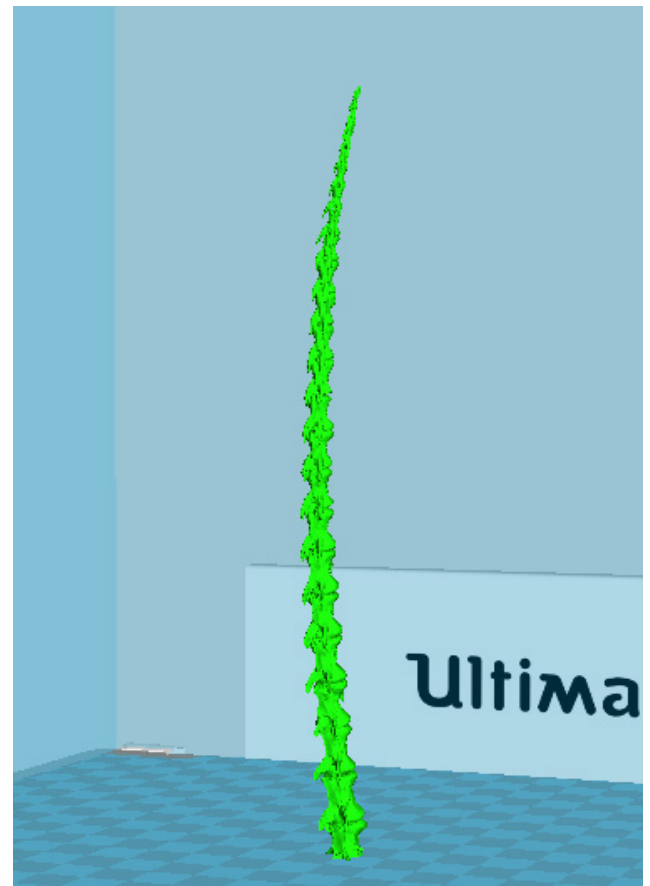
Tail origin (print time: +/- 7 hours)

The tail of a *T. rex* is very long so it could maintain its balance easily, since its head is very heavy. In this part of its tail, Trix has a slightly crooked vertebra. Because of this, its tail may have been a little skewed. Perhaps this also caused its pain and difficulty walking.



Tail end (print time: +/- 2 hours)

This is the end of Trix's tail. We're not sure how many tail vertebrae a *T. rex* had, since a complete tail has never been found. We looked at other skeletons of *T. rex*, where more of the tail was found. We think Trix had 42 tail vertebrae, but the bones at the end of the tail and some vertebrae in the middle were never found.



The Story of Trix

Passport

Nickname: Trix

Species: *Tyrannosaurus rex* (king of the tyrant lizards)

Gender: probably female

Length: up to 13 meters

Weight: up to 5.000 kg

Time period: Late Cretaceous: 67,5 to 66,0 million years ago

Habitat: Western North America

Expedition

Naturalis went on an expedition for the first time in the spring of 2013, from April 29 to May 18. In Wyoming, a few nice fossilized bones of the left foot were found. This find was promising, even the small phalanges were still neatly together. These are usually the bones that are lost first. Despite this promising discovery only parts of the left foot and leg of *Tyrannosaurus rex* were found. Why the small bones were preserved, but not the rest of the skeleton, remains a mystery. The whole hill that should have held the rest of the skeleton was excavated. "The layer of sand where the bones should have been, was getting thinner and eventually disappeared," says Anne Schulp. "Perhaps the carcass was eaten at the time, or was taken much further by the river that ran through the area. We do not know."



From August 30 to September 8, 2013 Naturalis dug up a *Tyrannosaurus rex*. This happened in Montana, USA, in collaboration with the Black Hills Institute.

Fortunately, the chances of a *T. rex* for Naturalis was not lost. Pete Larson, paleontologist at the Black Hills Institute in America, pointed Naturalis to another place in Montana, America, where a couple of amateur paleontologists had found remains of *T. rex*. The lower jaw, loose teeth and a part of the hip joint and tail bone were found by them. The expectation was that there was more material of *T. rex* buried in the ground. Naturalis had also gone there to dig. Meanwhile, a very complete skeleton has indeed been found!

Exceptional find

What paleontologist doesn't dream of someday finding a tooth or bone of this terrifying predatory dinosaur? Even better: a complete skeleton. But you can keep dreaming: complete *Tyrannosaurus rex* skeletons have never been found and are the world's most coveted fossils. So far, less than ten were found, one more complete than the next. "So far" has been quite some time, if you know that Barnum Brown had the good fortune in 1902 to dig up the first skeleton. If anyone wants to try his luck, they should search the west of North America, home of *T. rex*, just as Brown.

How did T.rex live?

When did *T. rex* live and with did he do in a day? How will you find this out? Learn all about the habitat of *T. rex*.



Skeletons of *T. rex* are among the world's rarest fossils. Our *T. rex* Trix is extra special: Trix is among the top three of most complete skeletons ever found!

Time period

Tyrannosaurus rex lived at the end of the Cretaceous. To be exact, in the Maastrichtian, named after the chalk layers of the Mount Saint Peter in Maastricht, approximately between 67.5 and 66 million years ago. He is one of the last dinosaurs. The species was around the moment a meteorite impact wiped these unique reptiles off the face of the earth. The impact took place not too far south of the habitat of *T. rex*, to be exact at the Mexican Yucatán Peninsula. The meteorite impact also meant the end for other life forms: other species of dinosaurs on land, reptiles, ammonites in the sea and pterosaurs in the sky.



Habitat

Tyrannosaurus rex was only found in North America. At least, no fossils of this species were unearthed in any other places. North America was still occasionally connected to Eurasia. This allowed *Tyrannosaurus*-like species to also conquer this continent. Even in Asia species from the tyrannosauridae family were found. These dinosaurs are similar to the 'real' *Tyrannosaurus* in many respects. For example, we know about the *Tarbosaurus* from excavations in Mongolia. This dinosaur is also a robber and is closely related to *T. rex*.

Lifestyle

Little is known about the daily life of *T. rex*. After all, behavior can only be linked to bones indirectly. For example, it is not clear whether *T. rex* lived alone (solitary) or in a group of family. So far, there are no indications of a group life, such as multiple skeletons grouped together. Tracks, for example, tell us more about this, but, unfortunately, tracks of *T. rex* have hardly been found. One find of a few tracks in Canada is indicative of herd behavior. Nevertheless, a few things can be learned from the construction of the skeleton. *T. rex* was one hundred percent meat eater, a hyper-carnivore. With such teeth, he simply ate nothing but meat. Grinding plants would not have worked with those pointy teeth.

Interestingly, the front legs were too short to bring food to the mouth, but they were heavily muscled. Possibly *T. rex* used them during mating. They would use them to hold each other. Another theory states that they used their feet to press up and get up from a lying or squatting position. Possibly they also kept struggling prey at bay, like a lion holding a wildebeest down. The comparison with the lion might continue. Would *T. rex* also have administered a lethal bite to his victims, or constricted the throat until they choked? Did he let other predatory dinosaurs do the work and feed himself with the remains?

The science behind *T. rex*

Very few fossil finds of *T. rex* are known. Each bone of a *T. rex* that is found, however small or large, can be of vital importance for science. There is much left to explore about our *T. rex*. When and where did *T. rex* live exactly? What was the age of the *T. rex* of Naturalis? How fast could *T. rex* run? We want to get insight in the medical file: which bones did *T. rex* break? Which diseases did he possibly have? What was *T. rex*'s diet like? How did *T. rex* migrate; for instance, did he reach mountainous areas or the coast? Using fossils, Naturalis researchers contribute to solving these issues or gaining new insights. "Each bone of every *T. rex* provides us with more knowledge", says our director Edwin van Huis. "We have years of scientific research left with this."



To floor 13

Paleontologists Dylan Bastiaans and Martijn Guliker, who among others performed preparation work on a *Triceratops* skull, previously visited the collection tower of Naturalis. Here they keep the *T. rex* bones that have already come from America. Upon seeing and touching the aforementioned tail bones, Dylan and Martijn are thrilled: "These bones are preserved magnificently!" Dylan, a medically trained paleontologist, immediately notices abnormal structures in one of the bones, which may indicate that the *T. rex* was suffering from an infection. Martijn: "It is interesting to compare the scan of a healthy bone with one of an anomalous bone later on."

Osteoporosis

How can you find out more about diseases that *T. rex* possibly had? You go to the hospital with the bones! Recently, three paleontologists visited the LUMC to make a CT scan of three bones from the tail of *T. rex*. They were the haemapophyses, also known as the chevron bones. These Y-shaped bones were located on the underside of the caudal vertebrae and gave the tail more firmness. Because of this we now know that the tail of *T. rex* didn't drag along the ground. Furthermore, they protected the blood vessels and formed an attachment surface for the tail muscles. Dylan is involved in the research into the medical history of *T. rex*. In studying an earlier CT scan of a tail vertebra, he found a pattern that was similar to osteoporosis in humans. To get more clarity on this, it is important to scan more bones.

Diagnosis

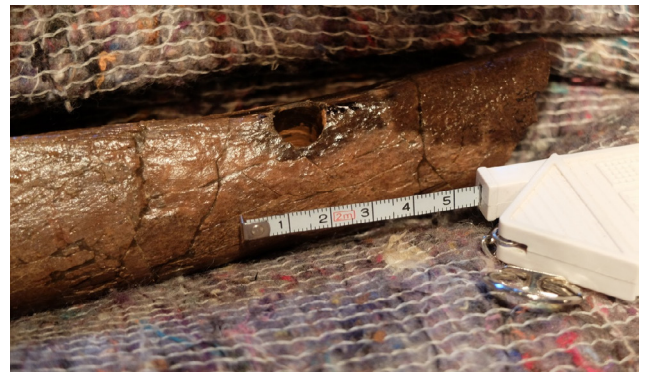
The scans, which were made at the LUMC, show the structure of the inside and outside of the fossil tail bones in detail using a computer program. Dylan can now get to work to formulate a diagnosis of the conditions of the *T. rex*. In a while a follow-up appointment with a medical specialist will be made to discuss the diagnosis. There is no rush, since the patient has long been deceased.

What age did *T. rex* reach?

Thanks to the growth lines in the bones the age of our *T. rex* can be determined. Not exactly, unfortunately: you count the minimum age. *T. rex* Sue is the oldest found *T. rex* so far, it reached an age of about 28 years old. 23 growth lines were counted in its case, which is considered to correspond to 28 years. Preliminary research seems to suggest that Trix was possibly even older than Sue, maybe even older than 30 years.

Drilling or sawing

But how are those growth lines visible in a bone? Naturalis has a unique *T. rex* that is attended to with great caution. So as to apply the least possible damage to the bone, a drill core from the fibula was obtained. A thin section is made from this. The drill core is then placed back into the bone. This thin section makes it possible to count the growth lines. When a 'slice' would be cut out of the bone, a seam would appear in the bone, which would be a shame.



Verification

During the research, a drill core will probably be taken from other bones as well, such as the thighs or ribs. By counting the growth lines in more places, something can be said about the age of our *T. rex* with more certainty.

A pleasant surprise

Let's go back to 2013, when Naturalis paleontologists traveled to Wyoming in search of *T. rex* bones - they found more! A skeleton of a *Triceratops* was also found. Two years later an expedition was organized to dig it out. The excavation surprised everyone: instead of one skeleton, paleontologists found no less than five! A part of these bones were extracted during the 2013 field season and transported to the Netherlands. Since December 2015, these are being excavated and cleaned before the eyes of visitors of Naturalis.

More bones

However, there were indications that there were more bones in the ground than the 600 that were found at first. The Naturalis team therefore travelled to Wyoming every year until the summer of 2019 to dig up the rest. In total more than 1000 bone fragments have been found.



Excavating, a tough job

Such an expedition is a challenge: it is very hot, and you have to be very careful while digging. Some bones are completely whole and easy to dig up – the ground around the bones of the *Triceratops* wasn't petrified – but others are compressed. The bones are then carefully taken out of the ground.

Updates from the field

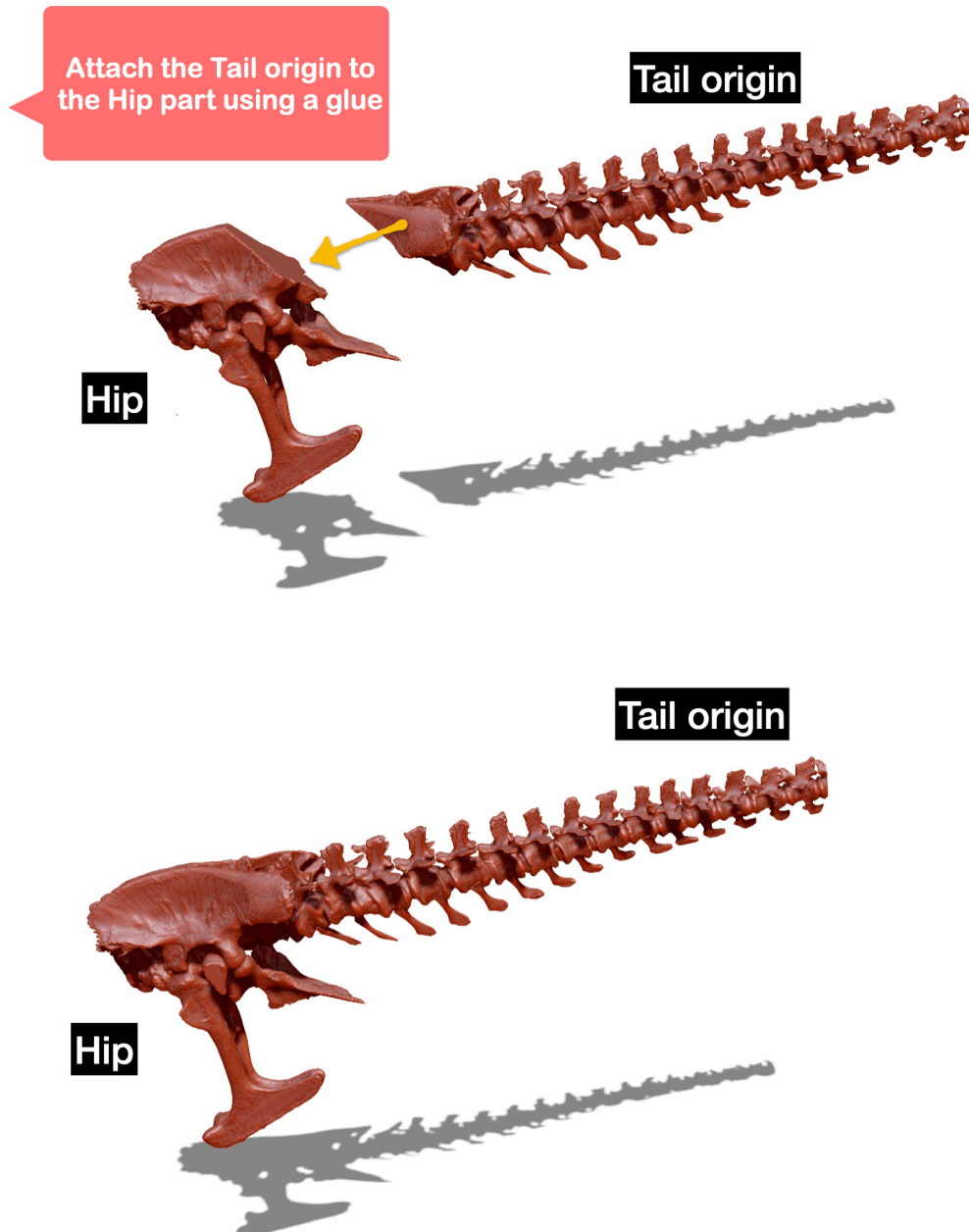
The Naturalis excavation team likes to keep all dinosaur fans informed. Thus, during the second *Triceratops* expedition in June 2016, Matthijs Graner, one of the team members, kept a vlog and shared the findings of the group. For instance, he showed what tools are used in a dig and what the plains of Wyoming look like. The vlogs can be found [here](#).

Assembly Instructions

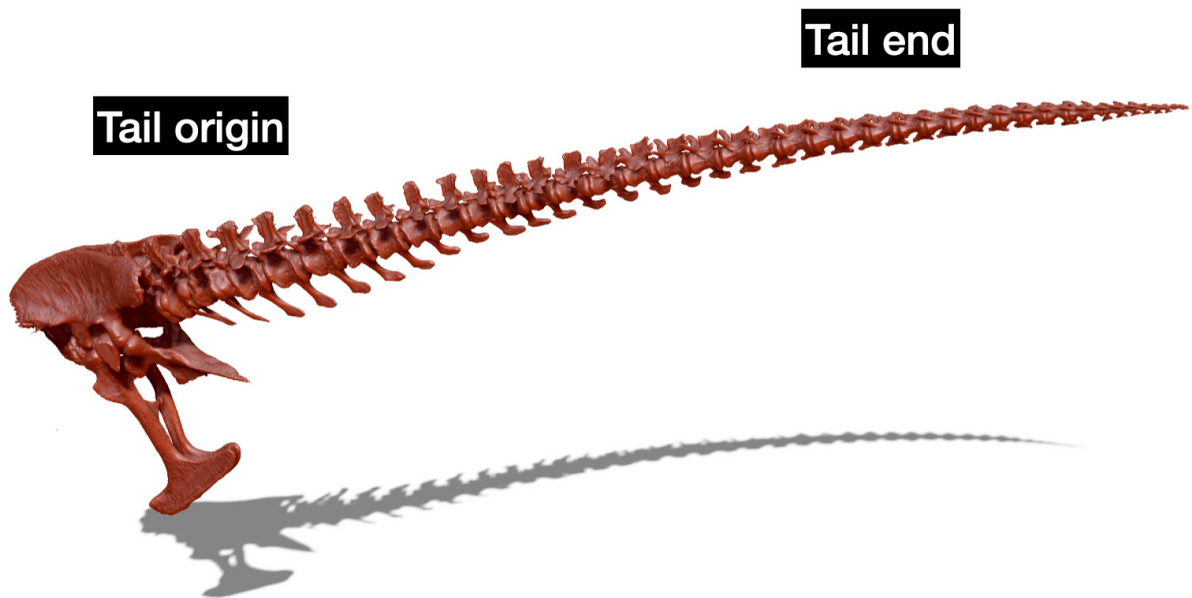
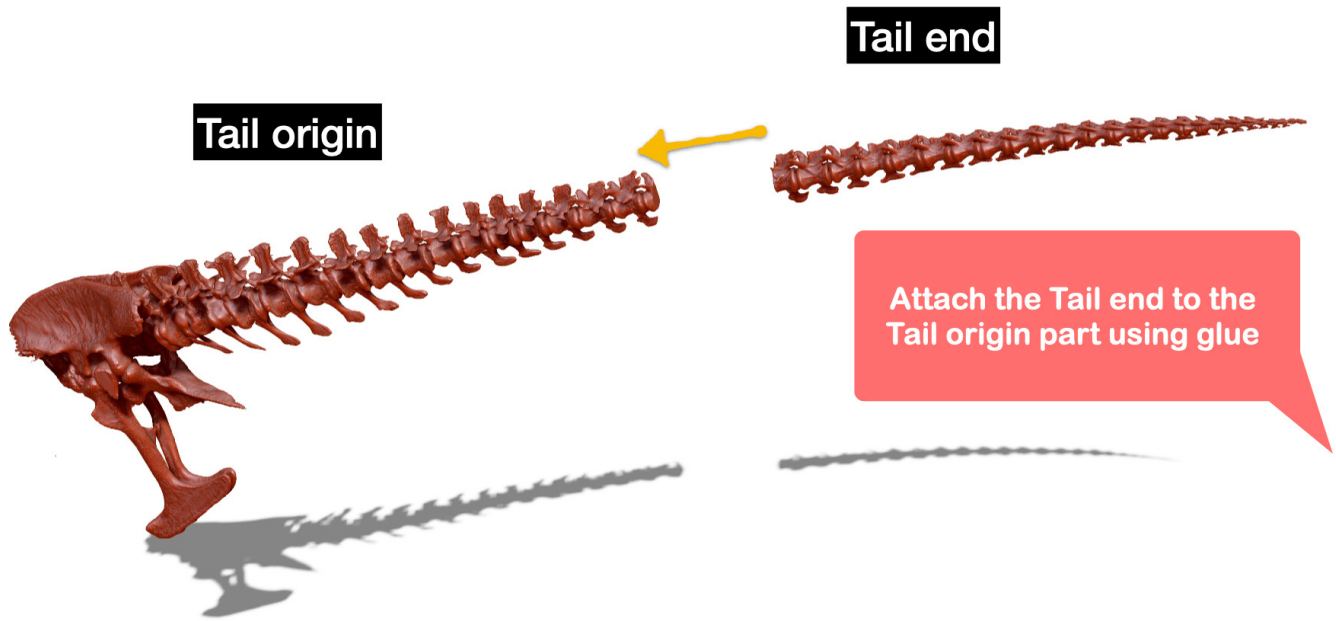
List of parts

1. Skull
2. Arms
3. Ribs & spine tube
4. Hip
5. Right leg
6. Left leg
7. Tail origin
8. Tail end

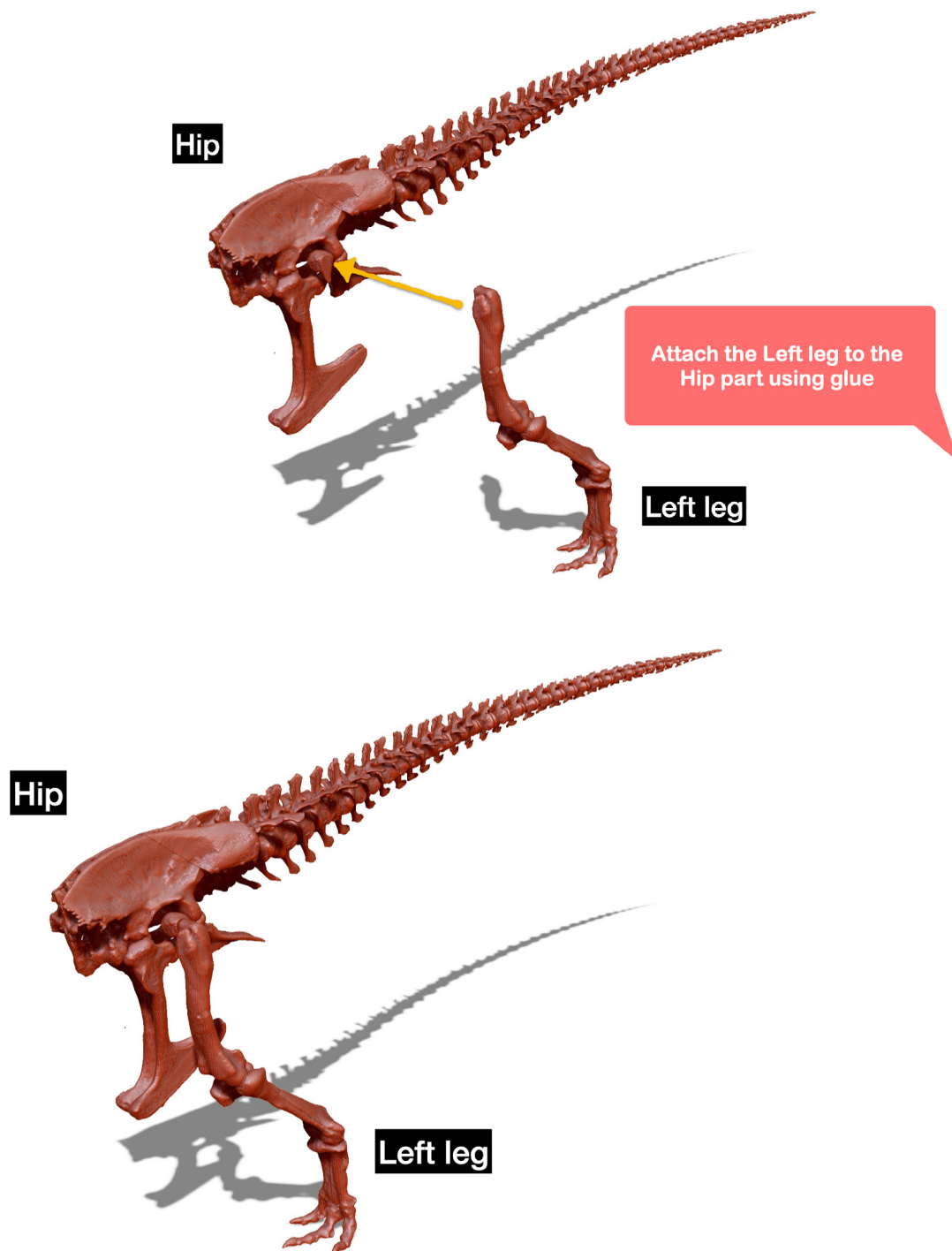
Tail 1



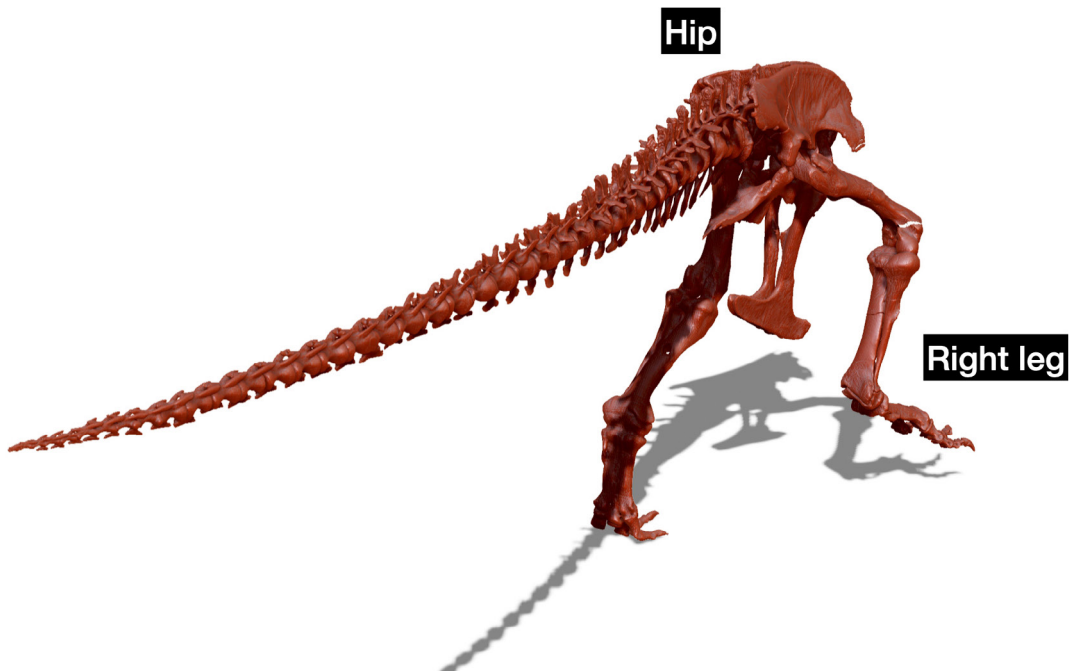
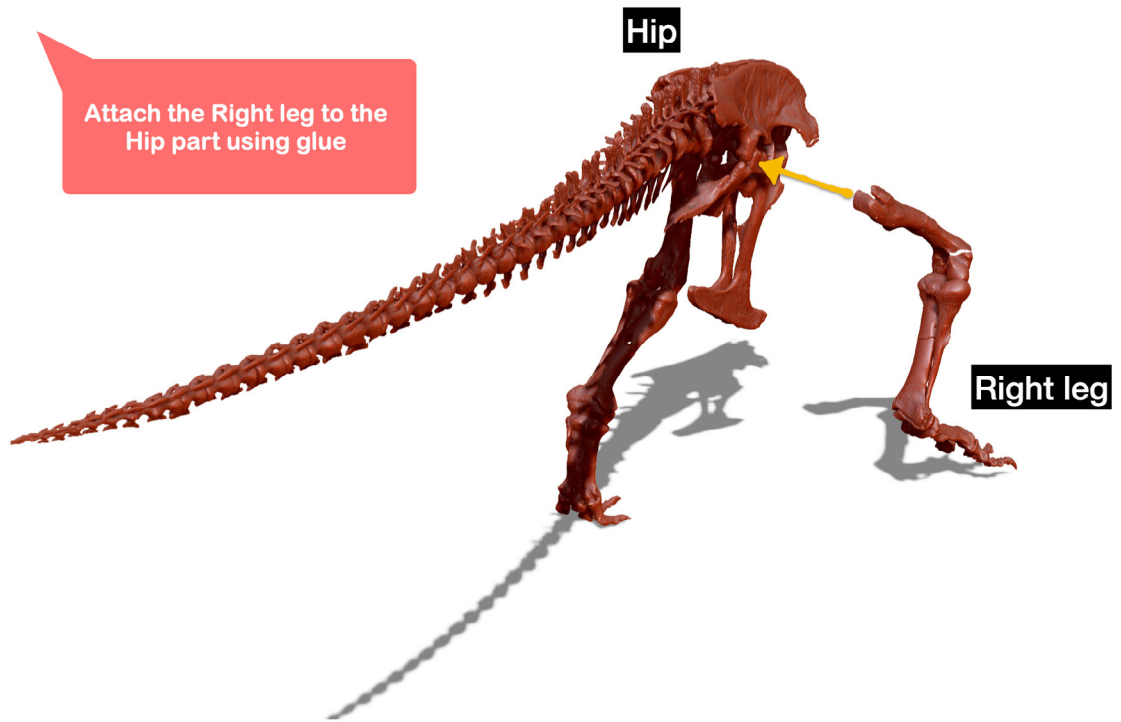
Tail 2



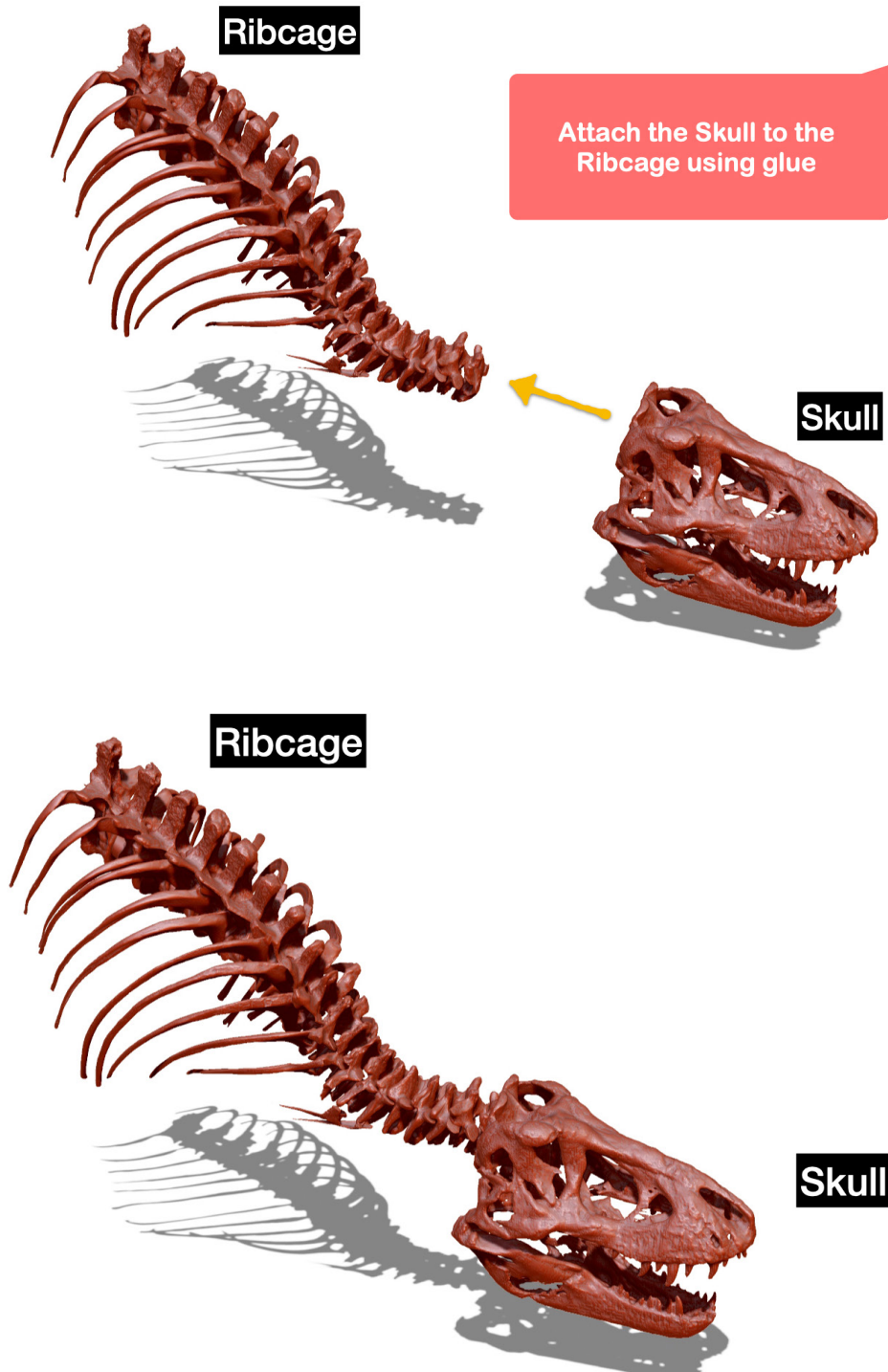
Leg 1



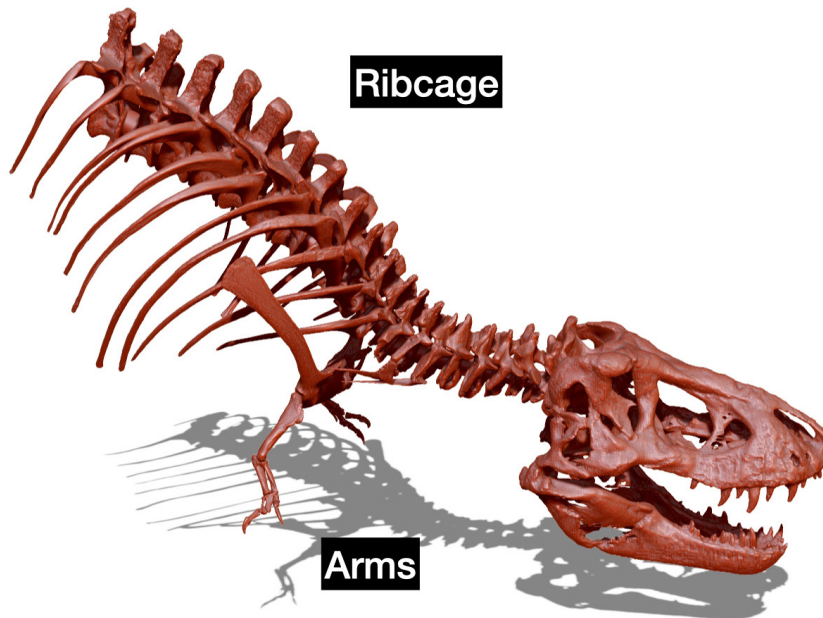
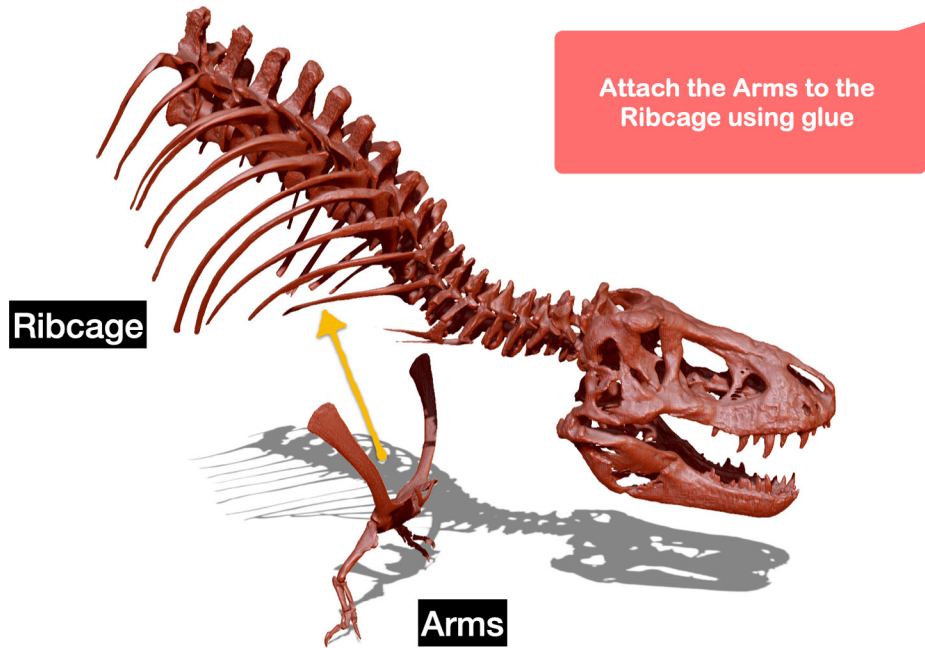
Leg 2



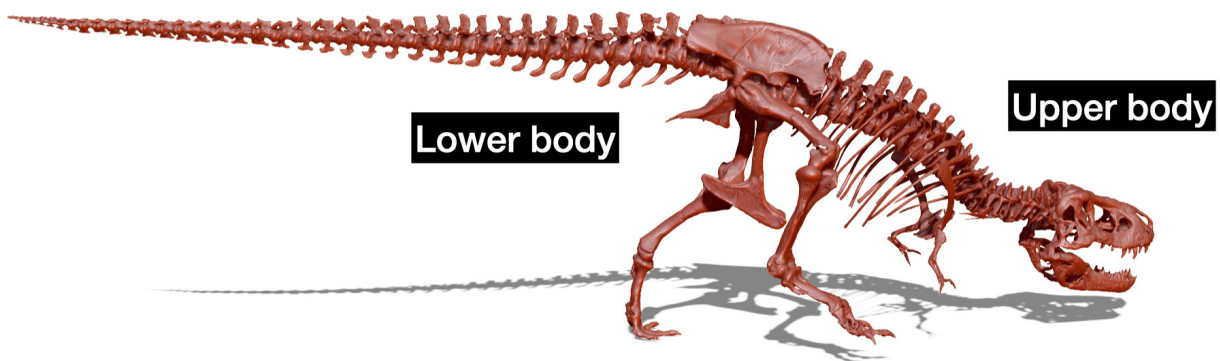
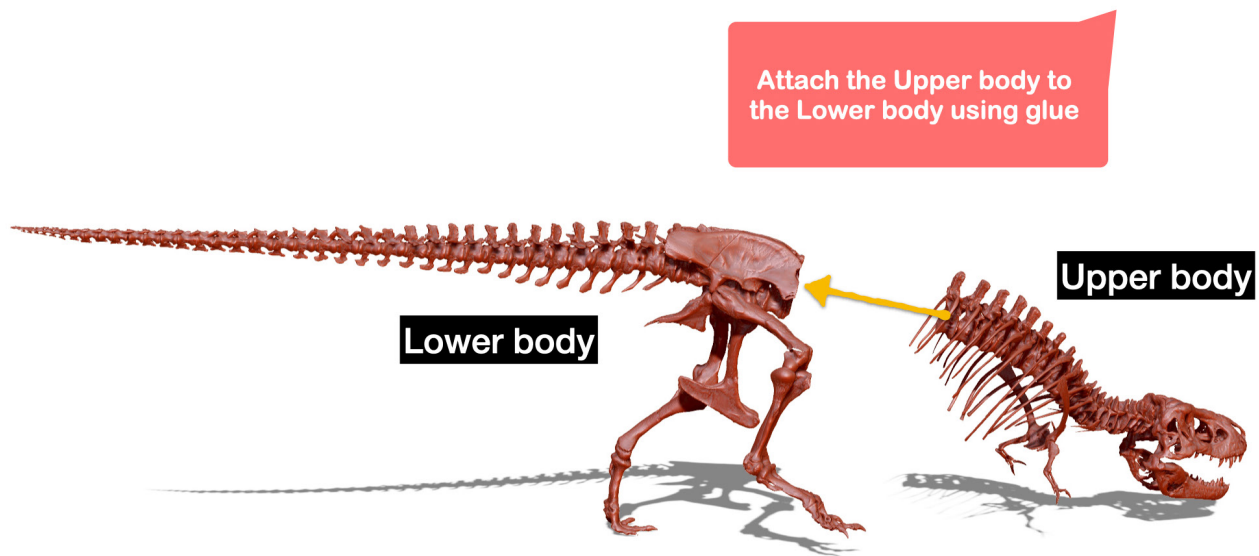
Upper Body 1



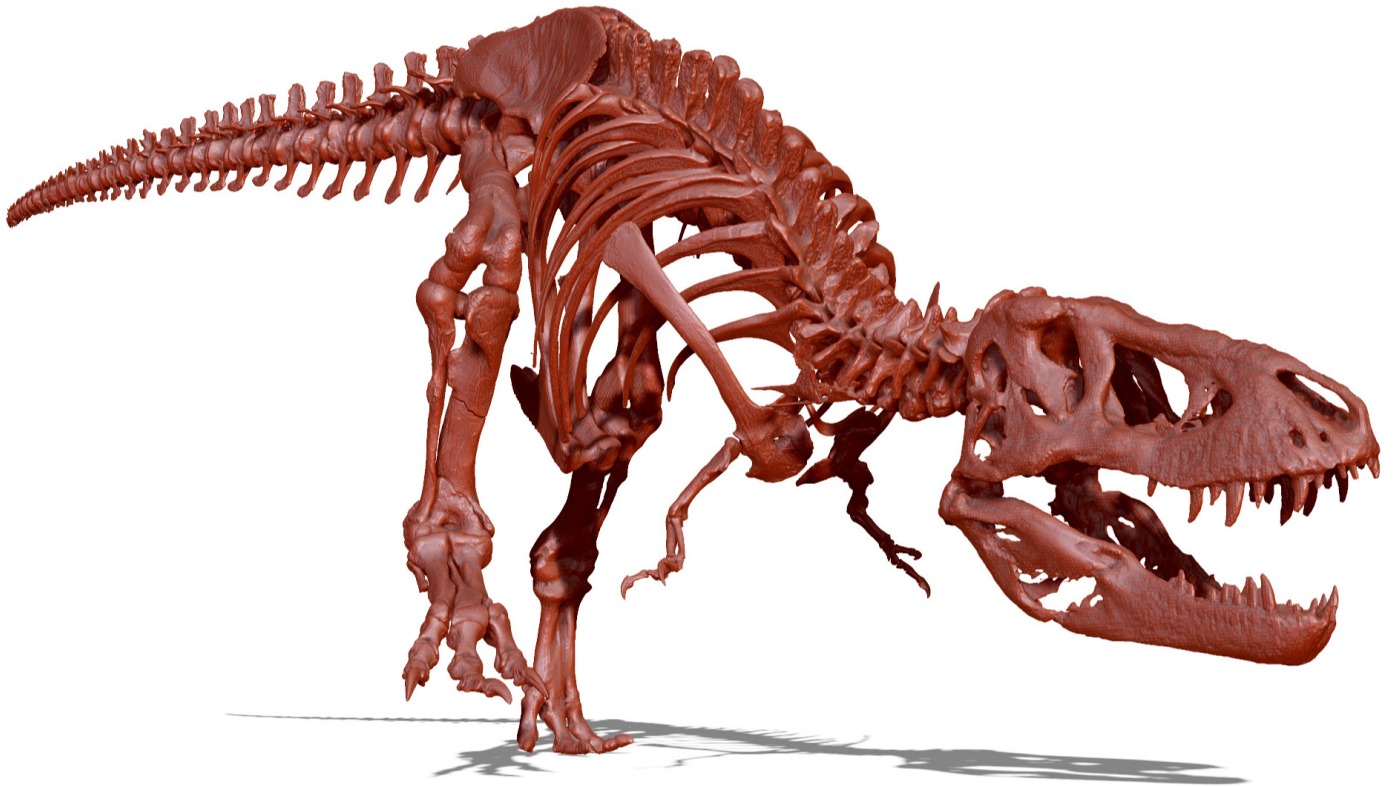
Upper Body 2



Upper to Lower Body Connection



Trix Skeleton



Complete skeleton of Trix

References

Needed for lesson:

Verwonderpaspoort dino world:

<https://www.verwonderpaspoort.nl/verwonderwereld/dinos>

Extra:

Vlogs *Triceratops* excavation:

<http://bit.ly/2go3gof>

Why Trix was preserved this well:

<http://bit.ly/2hlrb8Y>

Time-lapse building Trix:

<https://www.youtube.com/watch?v=R0koWLUCDPw>

