Triceratops 'Dirk'
Reviving a fossil

Naturalis
Biodiversity
Center

Teacher’s guide

Dear teacher,

This is the educator’s guide for the 3D printing activity “Triceratops 'Dirk': reviving a fossil”. This document contains information about:

- The structure of the activity.
- The prints.
- Background information on *Triceratops* Dirk 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 half a day.

Have fun printing and investigating!

Kind regards,

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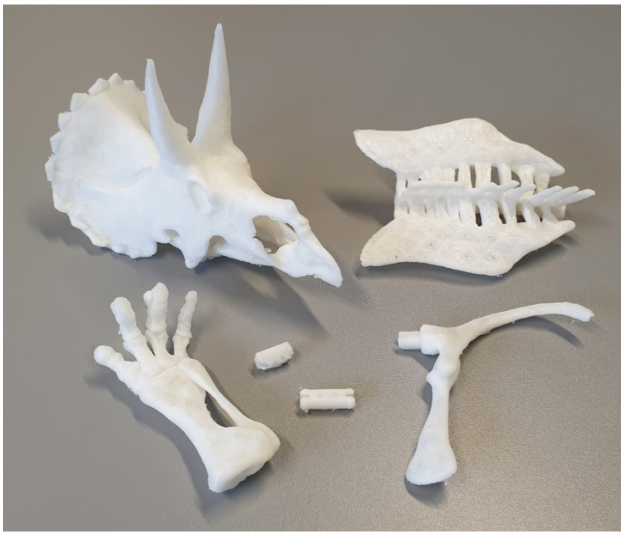
Lesson plan

Short description of the activity

During the activity you print bones from *Triceratops* one by one. Students marvel at what comes out of the printer. They wonder what it is, where it belongs and what its function is. Students practice reasoning from a form and function perspective. Eventually, the students assemble a *Triceratops* into a model (scale 1:8) for display in the classroom.



Target audience

Upper primary education (grade 4-7).

Objectives

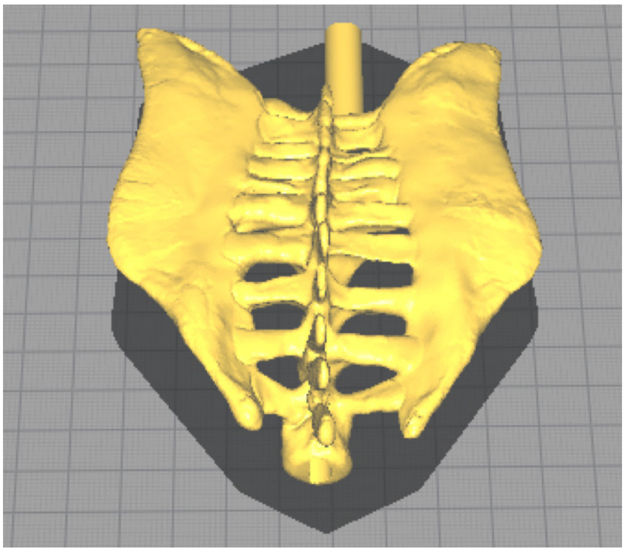
- Students learn about the form and function of dinosaur bones.
- Students make connections between the bones of contemporary animals and their own skeletons.
- Students are able to describe broadly how *Triceratops* lived.
- Students learn how scientists research dinosaur fossils.
- Students learn about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

Link with core objectives

The lesson is consistent with core objective 41: Students learn about the build of plants, animals, and people and about the form and function of their parts.

Introduction

You can find and download the 3D scans of the bones of *Triceratops* in small format here. The bones are printed in the classroom. Choose whether you print each part, or only a portion of the whole skeleton. The latter option is more realistic, since a complete skeleton of *Triceratops* has never been found.



Step 1 (print time: +/- 9 hours)

To create amazement at the beginning of the activity, print a part of the skeleton of *Triceratops*: the 'Sacrum' (see image). Tell the students that they are going to participate in a 3d print activity. Without giving further information to the students, they wonder what will be printed. They are curious, but only know that the print is the beginning of a fun activity, during which more will be printed.

Step 2 (length: +/-20 minutes)

Let the printed sacrum circulate in the classroom. Discuss this first print with the students. What stands out? What does it look like? What is its function? After a short discussion, indicate that it's a piece of bone from a dinosaur that's actually over a meter long. Let students (in small groups) discuss about what part of the skeleton it is and let them find out if we humans have this bone as well. At the end of this section, use a (picture of a) human skeleton to show that our hips are almost identical to those of *Triceratops*, but that they are in a slightly different position in the body.

Step 3 (print time: +/- 9 hours for both prints together)

Next, print two parts: 'Clavicles' and 'Tail'.

Step 4 (length: 1 hour)

Students learn more and more by examining the individual prints in groups and by gathering information about them. They do this by consulting each other and getting information from books and from the internet. Everyone gets all the printed parts in their hands to investigate. Each student draws or tinkers the animal that belongs to these bones. What do they think this dinosaur looked like? The creations will be different. It shows that there are many possibilities. Explain to the students that scientists often have to do their research using an incomplete fossil. The more information there is, the more accurate the reconstructions will be. Ask the students: how do scientists reconstruct the entire animal? Paleontologists often compare their finds with fossils that have come to light during another excavation. They also compare the fossils with skeletons of animals that are alive now*. If all goes well, the pupils have already discovered (in step 2) that we humans largely have the same bones as this dinosaur (at least in the hips). In other words, the <u>building plan</u> of vertebrates is largely comparable to that of animals from a distant past.

*Show some examples of skeletons of today's animals (e.g. those of a rhino or an elephant), so that students can compare the prints (fossils) with them.

Step 5 (length: 30 minutes)

Not all pieces will be printed. Why not? In reality, chances of finding a complete skeleton are very slim. Discuss briefly how that is possible. Bones can be rinsed away with water, or moved and eaten by carrion and meat eaters.
The students now get more background information about the *Triceratops* excavation. Watch one or more of the videos below (in Dutch) in the classroom, which explain the working method in the field. Afterwards, discuss what students noticed. What have they learned and what would they like to know? Can they jointly come up with answers to their questions?

- Life on the prairie.
- Nosebone of *Triceratops*.
- Plaster fossils for transport.
- *Triceratops* versus *T. rex.*

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

The students now know more about the construction of the skeleton and how an excavation works. But how many animals have actually been found? It turns out that not one, but perhaps about six *Triceratops* were lying together. None of the skeletons is complete and all the bones were found lying over and on top of each other. Now that all the bones have been removed from the ground, researchers are doing their best to find out how these animals lived. One of the most important questions: were they herd animals?*
Option 1: print the remaining parts of the skeleton. Also print the base on which the skeleton rests.
Option 2: print bones double and don't print all parts. This option best mimics reality.

*For more information about this research, read the story of *Triceratops* 'Dirk' further on in this guide.

Step 7 (length: 2 hours)

When chosen for option 1
Each time a part is printed, the students adapt their creation based on this new part. Have some students assemble the *Triceratops* skeleton when everything is printed. The parts can be connected to each other. As a final assignment, the students (in groups or together as a class) recreate the living environment of *Triceratops* with many different materials (paper, sand, wood, etc.) in which the printed skeleton can eventually be ‘exhibited’. Let the students look up missing information. They present the result to each other.

When chosen for option 2
When more incomplete skeletons have been printed to mimic reality, students recreate the excavation site in groups, where the bones can be interspersed and half-buried. To do this, divide the prints over the groups. Have the students add miniature tools that they can tinker themselves. They present the result to each other.

Step 8 (length: 1 hours)

Students have now learned a lot about digging up fossil dinosaur bones and reconstructing a skeleton and its habitat. Now they will discover more about the animal’s **way of life**. What did the animal look like when it was still alive? Finish the activity with a little research. The students answer a number of open questions about *Triceratops*, such as: How did he live? What did he eat? Who were his enemies? And the most important research question: ‘were they herd animals? Create a number of groups for this. Each group answers a different question by writing the answer on a large sheet of paper with arguments for it. After 5 to 10 minutes, each question is passed on to another group. This group gives its own opinion and arguments. Finally all questions are answered and a classroom discussion takes place, in which students name and discuss the arguments for the given answers. For this discussion use the information from The story of *Triceratops* ‘Dirk’ at the end of this manual.

Step 9 (Optional)

Do the students want to learn more about Naturalis and dinosaurs? Then let them surf to the open world of the ‘Wonder Passport’. This can also be done in class. Here they can watch all kinds of videos, carry out experiments and go in search of treasure. Also fun to watch is the episode of ‘Klokhuis’ about dinosaurs. In addition, there are many fun and accessible articles on Natuurwijzer about the dinosaur era (all in Dutch).

Tip!

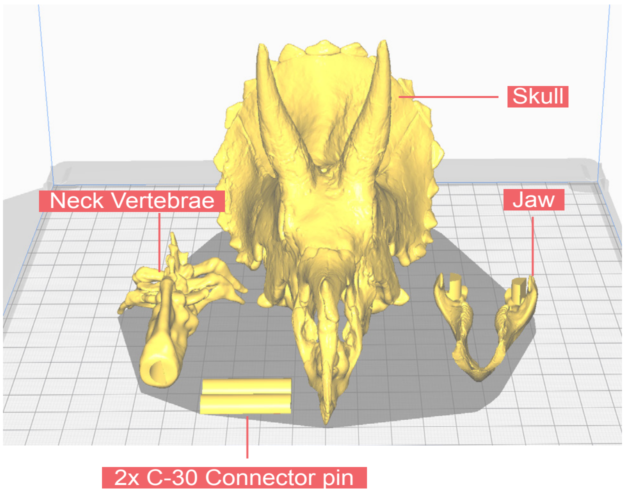
Now that the students have learned a lot about *Triceratops* and created their own exhibition revolving around the bones, it would be nice to come and see the real skeleton in the dinosaur hall of Naturalis. Take a look at the website for the possibilities.
You can also see our preparers at work in the dinolab in the LiveScience hall. Here the real fossils are processed and finally assembled into new skeletons. The students are allowed to ask their questions directly to the preparer. Is there no option to visit naturalis? Book an online dinosaur lesson!

The Prints

Below you will find an overview of the ten prints. The photos are placed in the orientation in which they are easiest to print. Some prints include small connectors. These are used to connect the skeleton parts together. The print times are based on the settings from the supplied Cura-profile.

The head of Dirk (print time: +/- 16 hours)

This is Dirk's head. In reality, the skull is one and a half metres long. On the head there are three horns, two above the eye sockets and one on the nose. This allowed *Triceratops* to defend itself well against attacks from for example a *T. rex*. At the back of the head there is a large neck shield. Although the neck shield most probably had a protective function of the neck, there are also scientists who suspect that the neck shield was used to show off and attract a partner.

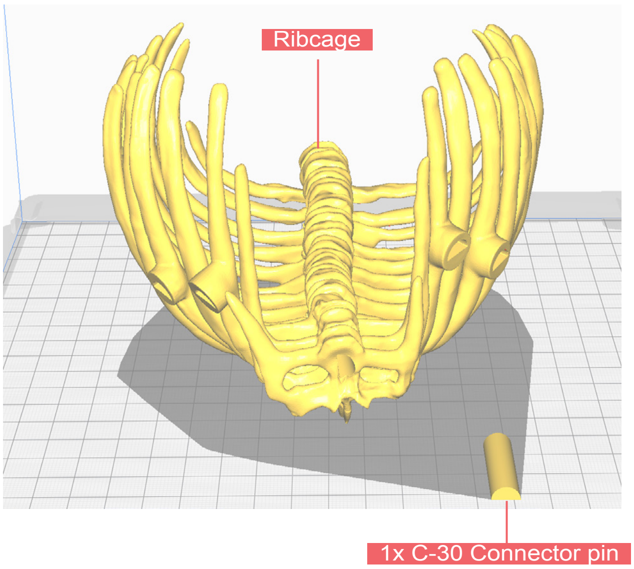


Vertebrae and ribs

(print time: +/- 33 hours)

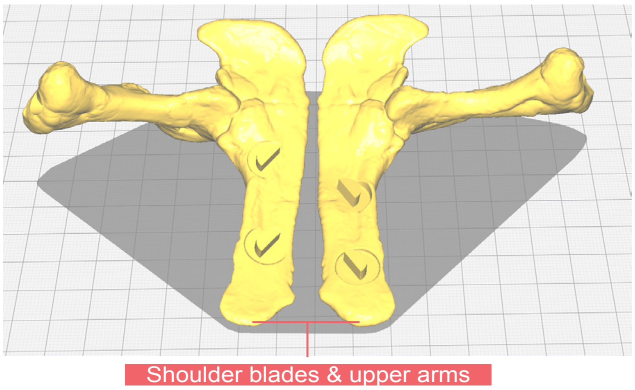
The rib cage consists of 15 pairs of ribs. Thus, *Triceratops* had a total of 30 chest ribs protecting the underlying organs

*because this is a large, complicated print, the print time is relatively long.



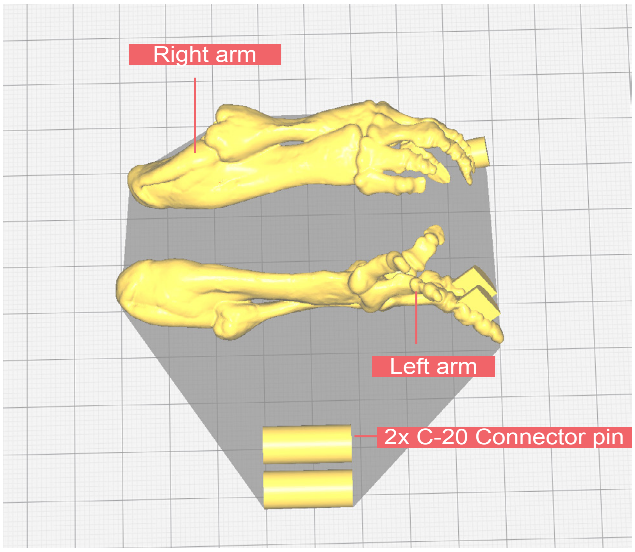
Shoulder blades & upper arms
(print time: +/- 6)

The front legs of *Triceratops* are very solidly built, as they must be able to carry the great weight of the skull, among other things. Each leg has five fingers, two lower arm bones and one upper arm bone. This makes the building plan equal to that of humans. The shoulder blades are very elongated and run along the body. At the front, the shoulder blades run into the ravenous bones that touch each other in front of the body.



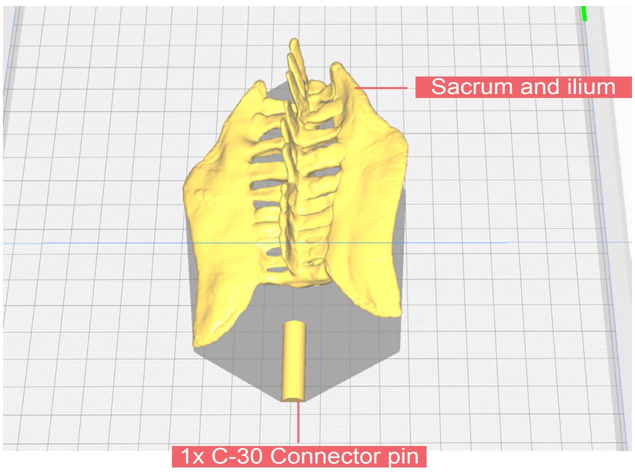
Arms (print time: +/- 4 hours)

The front legs of *Triceratops* were robustly built and consist of the same bones as in humans. The sturdy bones ensured that the weight of the heavy head with horns and neck shield could be carried well.



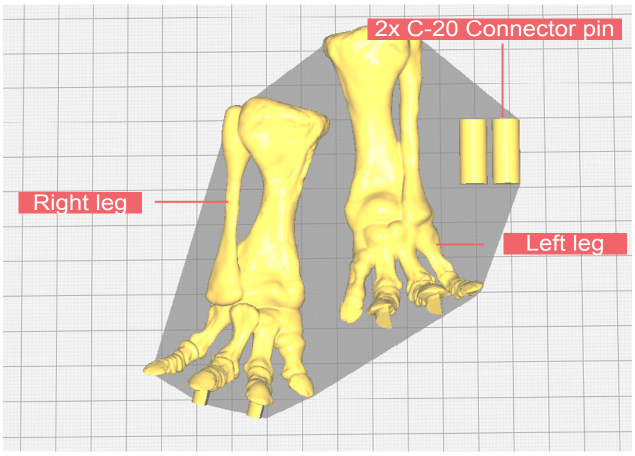
Sacrum and ilium (print time: +/- 6 hours)

The hips of *Triceratops* were huge. The construction plan is almost the same as the hips of humans, only the bones are orientated differently in the body. It consists of roughly three parts: the ilium, the pubic bone and the ischium. This print concerns the ilium. It is located left and right in the lower back and clasps the vertebrae in between (the sacrum). In this position it gives protection to the back.



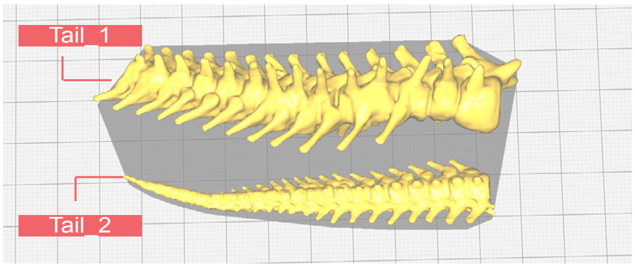
Legs (print time: +/- 7 hours)

The hind legs of *Triceratops* were robustly built and consist of the same bones as in humans. It is not known how fast the animals could walk. Most likely not very fast, because it was a heavily built animal.



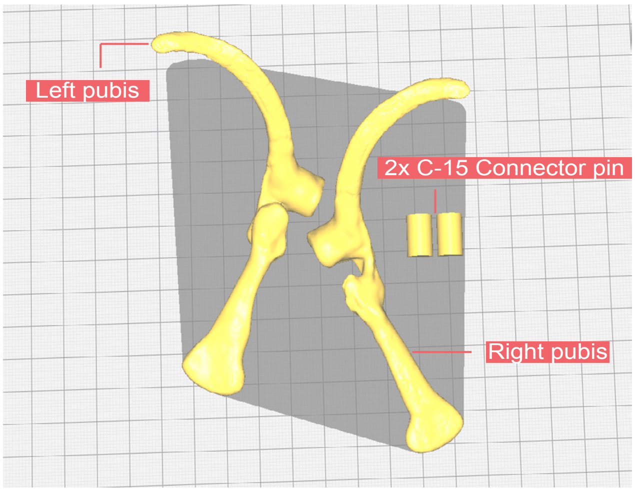
Tail (print time: +/- 3 hours)

The tail of a *Triceratops* is quite long and counterbalanced the heavy head. This kept the animal in balance. It is not known how many bones the tail consists of, since a complete tail has never been found. Not very strange, as the bones in the tail are the smallest in the whole skeleton and they easily washed away with the water or were eaten by other animals.



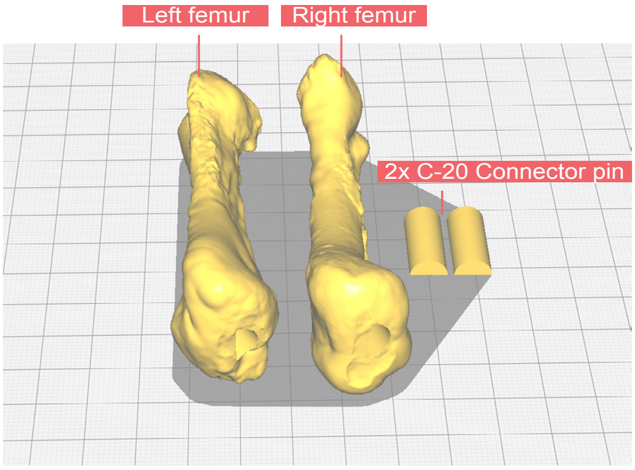
Pubic bone & ischium
(print time: +/- 4 hours)

The pubic bone and the ischium are part of the hips, just like the ilium. In humans, the pubic bone is at the front, but in *Triceratops* it protrudes diagonally downwards and forward. The ischium protrudes backwards and sits under the tail. It may have protected the buttocks and served as some kind of protection for the eggs, so they didn't fall apart on the ground. In humans, the ischium is easy to feel when sitting on someone's lap. It's located at the bottom of our buttocks.



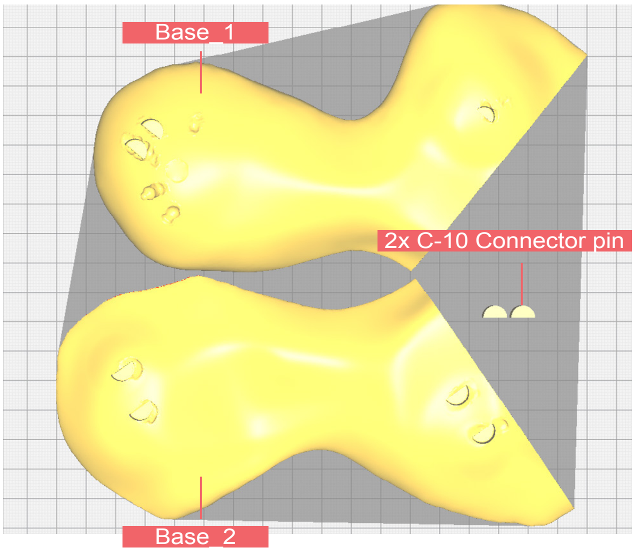
Femurs (print time: +/- 5 hours)

The thighs are relatively long and slender compared to the upper arms. The back of the animal usually protruded above the head.



Base (print time: +/- 2 hours)

This is the basis on which the skeleton can be placed.



The Story of Triceratops ‘Dirk’

Passport

Nickname: Dirk

Species: *Triceratops horridus* (Three-horned-face)

Gender: Probably male

Length: up to 9 meters

Weight: 5.900 to 12.000 kg

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

Habitat: Western North America

The fossils found come from the Upper Cretaceous (100.5-66.0 million years ago), to be exact from the Maastrichtian age (72-66 million years ago). At that time many dinosaurs like *T. rex*, hadrosaurians (*Edmontosaurus*, *Parasaurolophus* etc.) and of course *Triceratops* lived in North America.

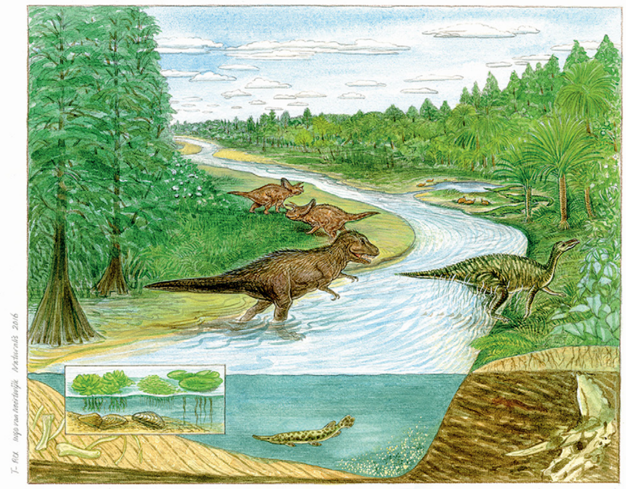
America in the Dino era

At the time, North America was split in two by a large sea from north to south: the Western Interior Seaway (photo). At the edge of this sea, which had already shrunk 66 million years ago, lived the group of *Triceratops* that Naturalis excavated. Rivers flowed into this sea. One of those rivers ran close to what is now the site of the fossils.

The Western Interior Seaway existed from about 100 to 66 million years ago. (c) Wikipedia CC-BY-4.0.

The climate

The climate was subtropical with open forests (see drawing). It was warm and it probably rained a lot (tropical storms). Researchers can see this in the plant fossils and soil layers found. Because of the storms the rivers flooded regularly. This was also the case on the spot where the *Triceratops* bones lay. Researchers know this because there is a clay layer under the bones. It was probably a swampy area that was sometimes completely flooded when the river flowed outside its bed.



Impression of the flat river landscape in Montana where *Triceratops* walked 67 million years ago, drawn by Inge van Noortwijk.

The location

The fossil site of *Triceratops* is situated in the state of Wyoming, America, near Newcastle. The site can be divided into two parts: a lower part (A) and an upper part (B). In the upper part, remains of one *Triceratops* have been found, below of at least four. The difference in height between the sites is four metres, which corresponds to roughly about 5,000 to 15,000 years of difference in time. A total of around 600 bone fragments have been found.

Both sites seen from the air.

Site A.

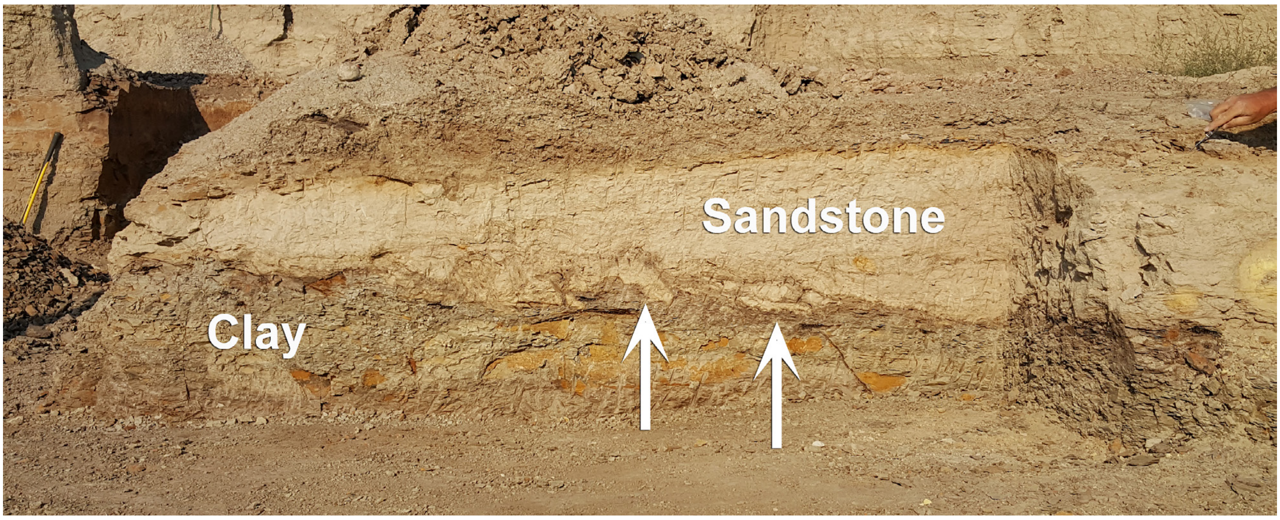
Site B.

How did the site come to the surface?

At the time, the country was pretty flat. To the west of the site, forces drove up the Rocky Mountains. Thanks to this mountain formation a lot of erosion took place and over millions of years hundreds of meters of river deposits (sand, silt, clay from river systems) were deposited over the triceratop bones and the mass grave was well preserved. From about 30 million years ago, these layers were also subject to weathering and erosion. Thus, more and more sand disappeared and the dinosaurs eventually reappeared on the surface. The sedimentary layer in which the bones were found is part of the so-called 'Lance Formation'. Although this layer is similar to the layer in Montana in which T.rex Trix was found ('Hell Creek formation'), researchers do not yet know if both layers are of the same age.

How did these Triceratops die?

The animals probably died in this place, but how? Researchers don't know for sure yet, but the latest hypothesis says that they themselves walked into the swampy riverbank and sank away. Why do the researchers think that? One can tell from the soil layers what happened in one place. The photo shows a vertical piece of land on the east side of the lower site. The bottom layer shows a clay layer. The clay layer is and was quite soft. You can see that from the depressions in that layer (arrows). These are possibly smeared paw prints. On top of the clay layer the fossils have been found. This means that there is a small chance that these depressions are paw prints of the Naturalis *Triceratops*, which sank slightly into the clay. Eventually they walked a little too far into the swamp (floodplain lake) and got stuck there and died. The layer above it is homogeneous sandstone, almost without layering. This is most likely deposited on the clay layer during a breakthrough of the river. (This is also called a 'crevasse splay'). Not much can be said about the flow velocity and direction, because this layer has different thicknesses in different places. Naturalis is looking for more vertical pieces where this layer (with depressions) can be seen, to confirm this 'swamp hypothesis'.



Arrows show depressions in the sof clay layer (lowe layer). *Triceratops* possibly walked here.

Could something else have happened?

There is still a lot unclear about how the animals came to their end. There is another possibility, though not very plausible. This hypothesis says that the *Triceratops* fled to this place from a big fire. In a swamp there is water and few trees, so the *Triceratops* might have been safer here, not knowing that they would get stuck. In the ground this could be seen by the layers of charcoal, in other words: burnt wood and plant material. Still, finding a lot of charcoal does not necessarily mean that there was a fire. So it is not very likely that the animals were killed by fire. Yet another possibility is that the animals lived in different places along the river and after their death they were flushed and deposited at this site. The remains of the animals were not immediately covered. We know that because bones were moved and the teeth were detached from the jaws and found scattered on the site. So they've been on the surface for years? No, they haven't, because most of the bones are very well preserved. Therefore, since the animals were dead for a while before they were covered by deposits and were exposed for a considerable period of time, it is extra difficult to find a cause of death.

How did *Triceratops* live?

The fossils found give clues about the lifestyle of these animals. Were they herd animals or not? Our find causes a lot of discussion about whether *Triceratops* were herd animals or not: never before have so many individuals been found together. In only two occasions remains from more than two animals were found together. However, the fact that for the first time now a larger group has been found, does not necessarily mean that they were always in herds: due to the current of the river or a natural disaster, the remains may have washed up together. Nevertheless, it is possible that the *Triceratops* of Naturalis belonged to the same herd. We are dealing with individuals of different ages. Most likely a 'pre-puber', who had not yet experienced a growth spurt, two (or three) adolescents, a young adult and an older animal. The fossils of the different individuals were buried very close together, suggesting that they died at the same time or shortly after each other. This information alone is not enough evidence that they were herd animals. However, although there is a chance that the flow of the river has flushed bones from different places in to the same place (in this case the dig site), this is not plausible. In that case we expect to find fossils of very different animals that also died along that river. This is not the case except for a single, explainable fish scale, crocodile skin plate and small mammal jaw. For the time being there is little evidence of inflow of bones, although this is still being investigated. By now we know that the fossils were all deposited at once, but the question remains whether they all died at the same time, although this now seems a lot more plausible. They were probably together, or at least close to each other. So were *Triceratops* herd animals? It's certainly possible, but further investigation will have to reveal this.

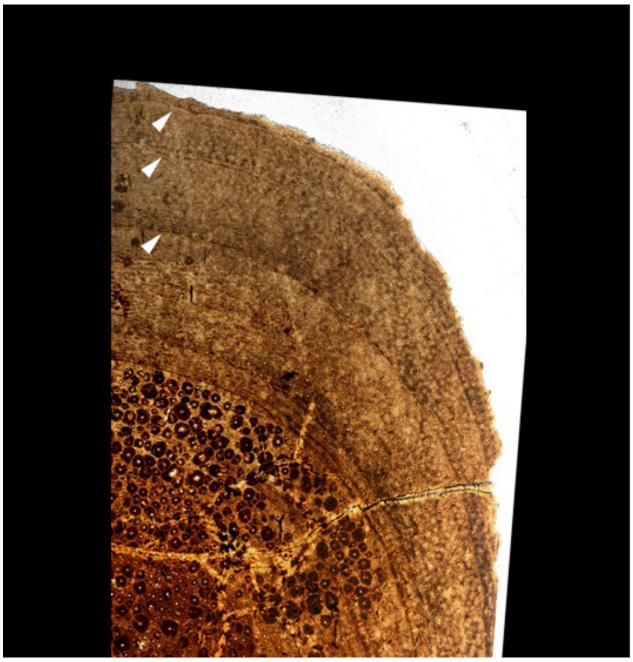
What research does Naturalis do?

We are now working hard in the dinolab in the (free to visit) LiveScience hall in Naturalis. This is where the fossils are prepared. The research can only partly start, because not all bones are freed of their stone encasing yet. At this point Naturalis is investigating how old the *Triceratops* have become.

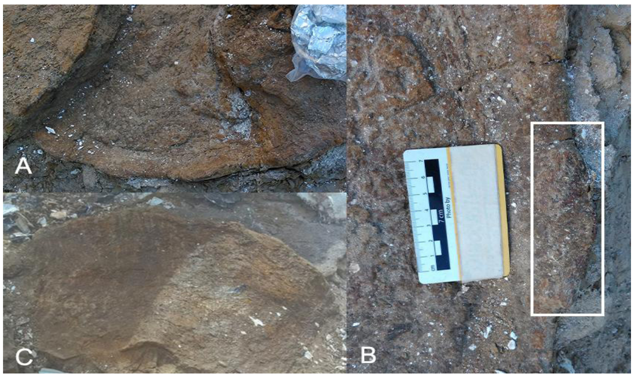
To do this, the researchers drill a piece of bone from a leg bone and examine it under the microscope. Sometimes growth lines can be seen in these bones (see photo). These mark periods in which an animal did not grow as fast. It is a bit similar to the annual rings of a tree, but with one big difference. Where a tree never breaks down layers, an animal breaks down some material on the inside of the bone and new bone grows on the outside. In addition, new cells replace old ones when growth slows down or even stops. This makes it difficult to determine the age.

Triceratops' neck shield also helps to determine the age of the individual animals. At the edge of the so-called frill, one can see in which growth phase the animal resided. Very young animals have a small frill sloping backwards with small protuberances loosely on it. These are also called 'epi-bones' (epi = 'on top of' or 'over' in latin).

When an animal reached sexual maturity, these protrusions, made of bone, were clearly visible at the edge of the frill (pictures). In older animals the protrusions disappeared. They were, as it were retracted into the bone. Possibly *Triceratops* had these protrusions to stand out to other *Triceratops*. Finally, of course, the size of the bones is also taken into account. Based on this one makes a rough estimation of age.



Arrows show depressions in the sof clay layer (lowe layer). *Triceratops* possibly walked here.



Protrusions at a *Triceratops*' frill (A). A piece of frill with enlarged protrusions (B). This is most probably concerns a young adult. At the frill of older animals (C) hardly any protrusions are visible.

To determine whether *Triceratops* were herd animals, the molars are examined. By doing this, a lot can be learned about the last phase of life. The molars are examined in different ways: on isotope level and layer thickness.

Triceratops tooth.

Part of a *Triceratops* Jaw (upper left).

<u>Enamel</u>

In a living *Triceratops*, a small layer of glaze was deposited on the outside of a new molar every day. Depending on what happened during a day of *Triceratops*' live, this concerns a thicker or thinner layer. The molar consists of about thirty layers. The 30th layer was broken off when a new layer was created, otherwise the molar would have kept growing. When the molar was fully grown, the layers slowly wore off. This allows you to 'look' back in time for up to thirty days. If a *Triceratops* had eaten well for a day, the layer of enamel would have been quite thick. If he was chased by a *T. rex* all day or there was no food available, a thin layer would have been deposited. The layers provide information about their diet in the last thirty days.
By comparing the layers in one individual's molar with those of another individual, one can find out if they have lived together during their last thirty days. If the pattern matches, it is likely that this is the case. If so, they might have been part of a herd.

<u>Isotopes</u>

The composition of the layers of tooth is also important. When a new layer is made, the tooth absorbs certain substances. These substances are called isotopes. These are different forms of certain substances. Calcium is such a substance. One calcium particle weighs more than the other. Depending on what the animal has eaten or drunk, each layer of tooth consists of a different amount of isotopes. The ratio of different isotopes in the teeth is useful for all kinds of research. Strontium, for example, is used in herd research. The ratio of different strontium isotopes differs per type of soil. If different proportions are found in the different layers of one tooth, it is very well possible that *Triceratops* migrated.

Can DNA be examined?

DNA research is not possible when it comes to dinosaurs. DNA is a very unstable molecule that breaks down relatively quickly after death. With luck, one can still find a piece of usable DNA from, for example, a mammoth that lived a few thousand years ago. However, looking further back in time than around 800,000 years ago is not yet possible. Perhaps with better techniques in the future researchers will be able to find more DNA.

The *Triceratops* skeleton in museum Naturalis.

The result

By now, the *Triceratops* found on the upper site has been completely prepared and put together into a skeleton. The result, Dirk (named after volunteer Dirk Cornelissen, who worked a lot on the upper site fossils) can be seen in the Naturalis dinosaur hall. The fossils of the lower site are still being worked on at this moment.

Volunteer Dirk using glue on a broken fossil of *Triceratops*.

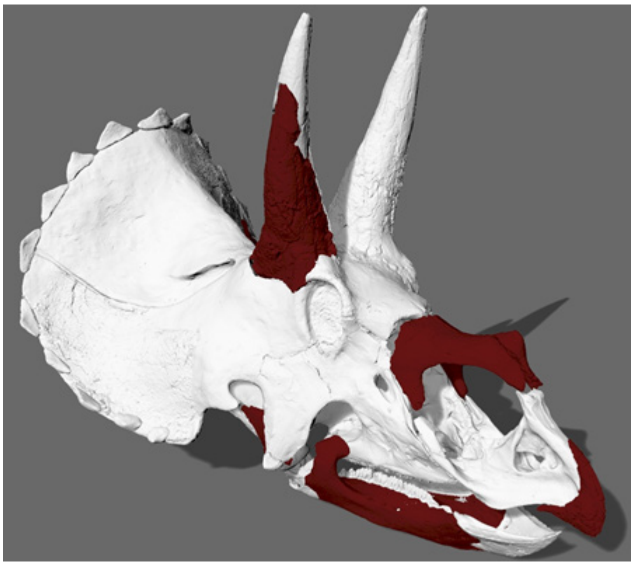
A complete skeleton?

Complete skeletons of dinosaurs have never been found. There are always bones missing that were eaten or washed away at the time, or were lost in the course of time due to shifting of the ground. This also applies to the skeletons found by Naturalis. Dirk is about 55% complete in terms of bone volume and 20% in terms of number of bones. The skeleton consists of about 300 bones. Of those, 61 have (partly) been recovered.

Schematic view of all the found bones of *Triceratops* Dirk. Drawing based on a model from Scott Hartman and modified by Olof Moleman.

3D printing

Bones that have not been found are often printed in 3d nowadays. This requires real bones, as 3d scans have to be made of them. Luckily there are many *Triceratops* fossils found in America, to make use of. The printed part of Dirk's skull consists of four different individuals. Not all the printed material comes from other *Triceratops* specimens. We try to use as many of the found fossils as possible. Take for example the right horn of *Triceratops* Dirk. Naturalis dug up part of it. This was scanned and then mirrored and 3d printed as the left horn. Although this horn is not real, it has been made as real as possible. In the end almost half of the skeleton consists of copied and 3d printed bones.



3d model of *Triceratops* Dirk with the the real parts indicat-ed in brown. Model by Pasha van Bijlert.

Updates from the field

The Naturalis excavation team likes to keep all dino fans informed. For example, during the second *Triceratops* expedition in June 2016 blog posts were regularly posted on the website and Matthijs Graner, one of the team members, kept a vlog and shared the group's findings. He took viewers to the plains of Wyoming and showed what tools they use in an excavation. The vlogs (in Dutch) can be found here. Vlogs 4 to 6 contain subtitles in English.

Part of the excavation team (2019).

Assembly Instructions

Please remember to keep the same order of the parts after removing them from the print bed

List of parts

1. Schedel + onderkaak + halswervels (skull + mandible + cervical)

Skull
Neck vertebrae
Jaw

x2 C-30 connector pin

2. Ribben (ribs)

Ribcage
x1 C-30 connector pin

3. Schouderbladen + opperarmbenen (clavicles)

Right shoulder blade & upper arm
Left shoulder blade & upper arm

4. Voorpoten (arms)

Right arm
Left arm
x2 C-20 connector pin

5. Darmbeen + heiligbeen (sacrum)

Sacrum & ilium
x1 C-30 connector pin

6. Achterpoten (legs)

Right leg
Left leg
x2 C-20 connector pin

7. Staart (tail)

Tail_1
Tail_2

8. Schaambeen + zitbeen (pubis)

Right pubic bone & ischium
Left pubic bone & ischium

x2 C-15 connector pin

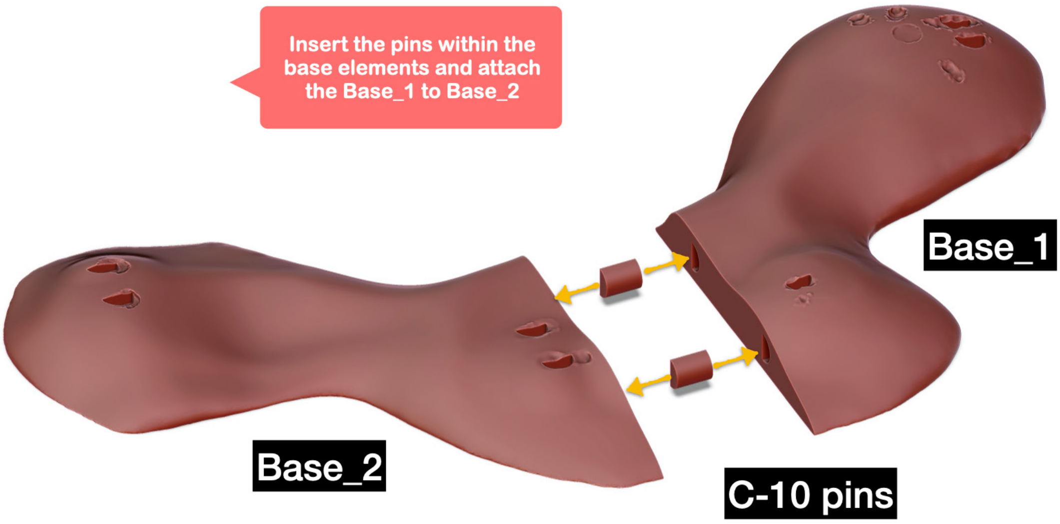
9. Dijbenen (femurs)

Right femur
Left pubic bone & ischium
x2 C-20 connector pin

10. Basis (base)

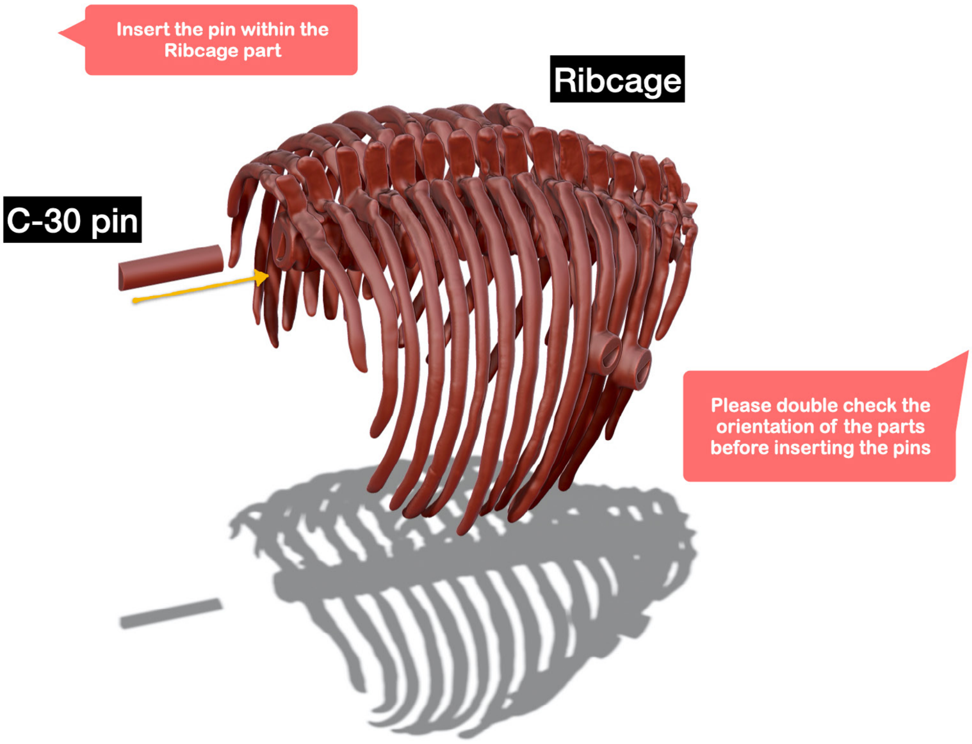
Base_1
Base_2
x2 C-10 connector pin

Base

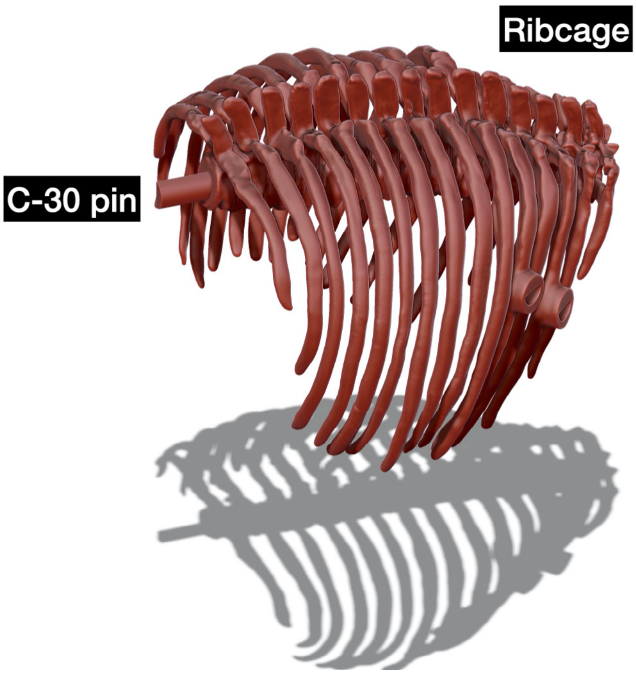

Insert the pins within the base elements and attach the Base_1 to Base_2
Base_1
Base_2
C-10 pins


Base_1
Base_2

Ribcage

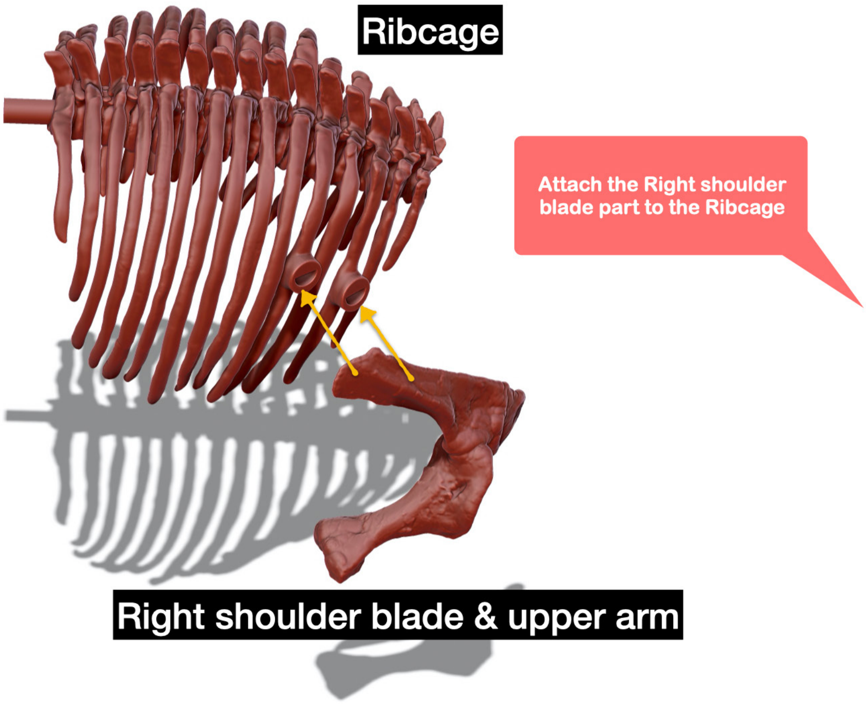


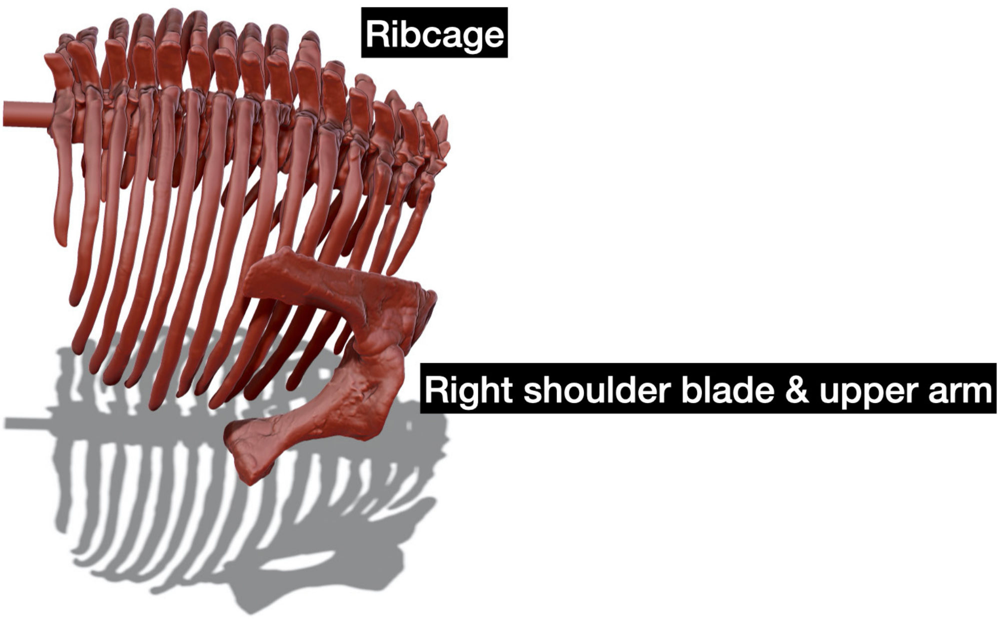
Insert the pin within the Ribcage part
Ribcage
C-30 pin
Please double check the orientation of the parts before inserting the pins



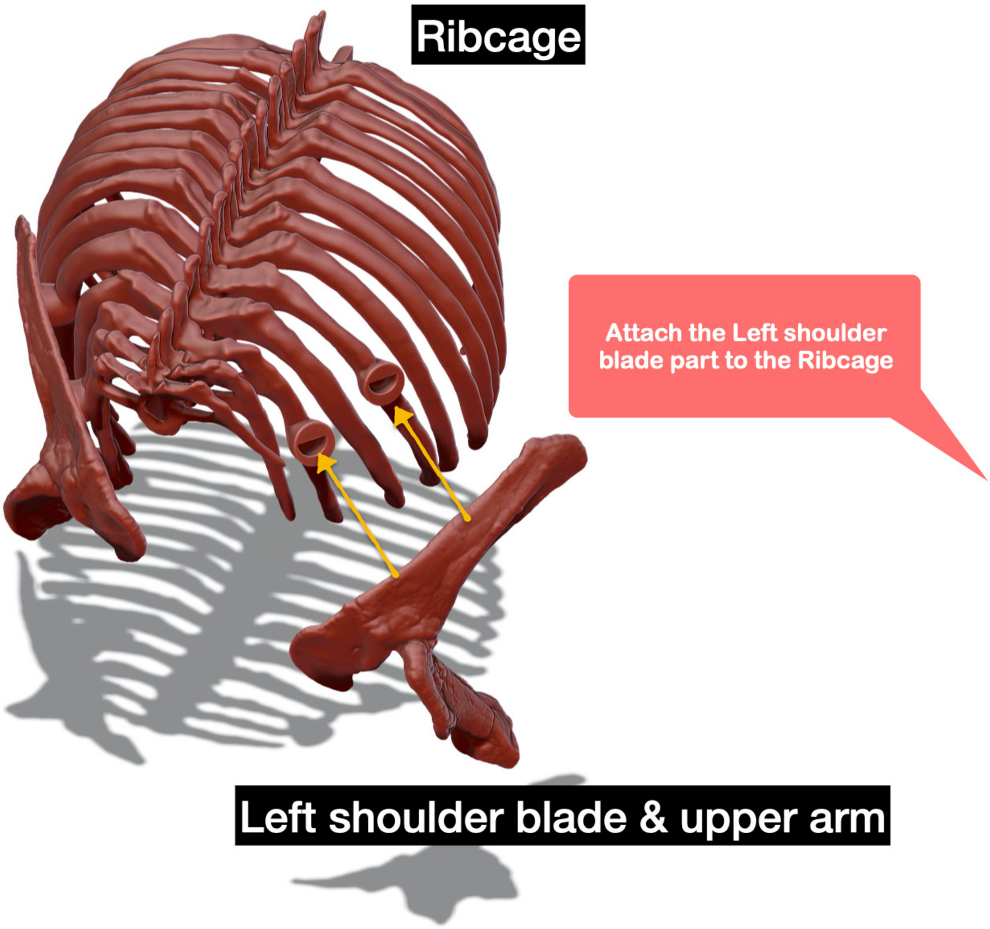
Ribcage
C-30 pin

Shoulder Blades 1

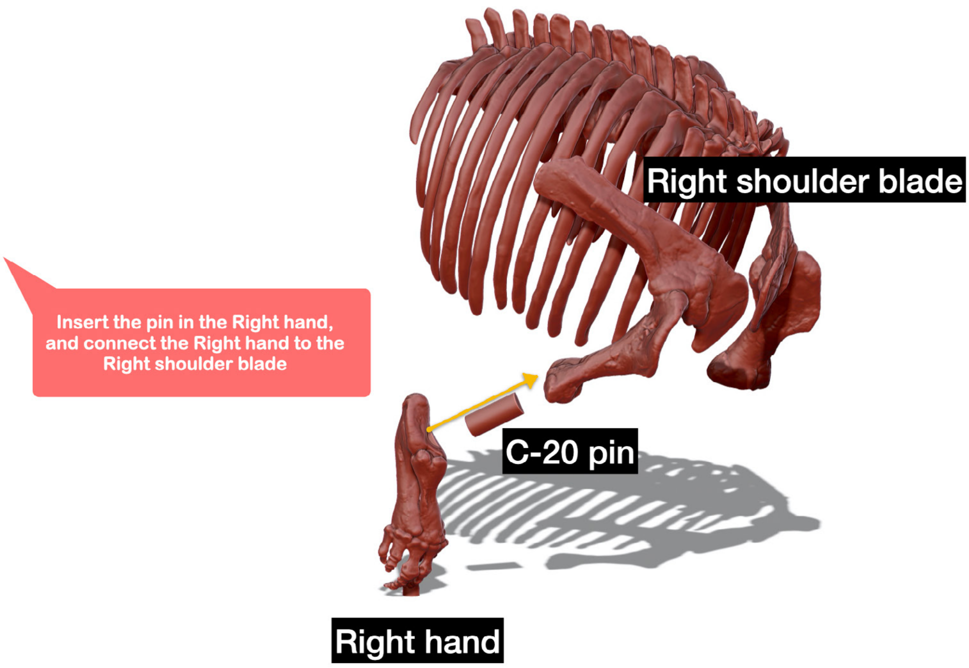




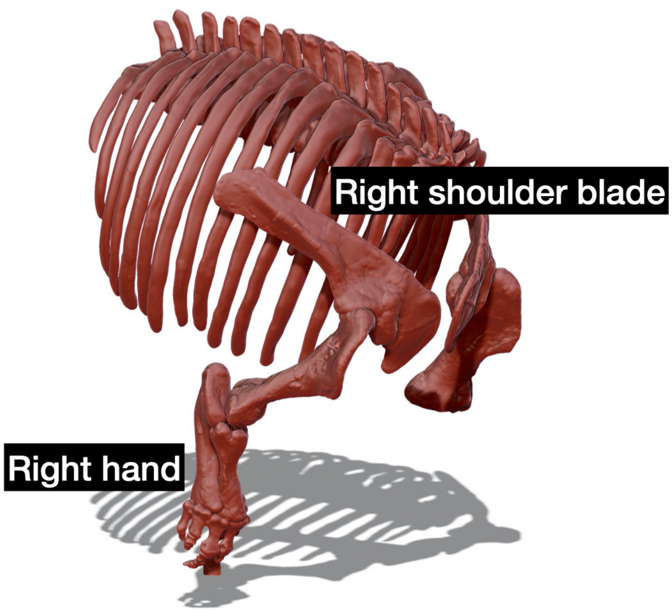
Shoulder Blades 2



Arms 1

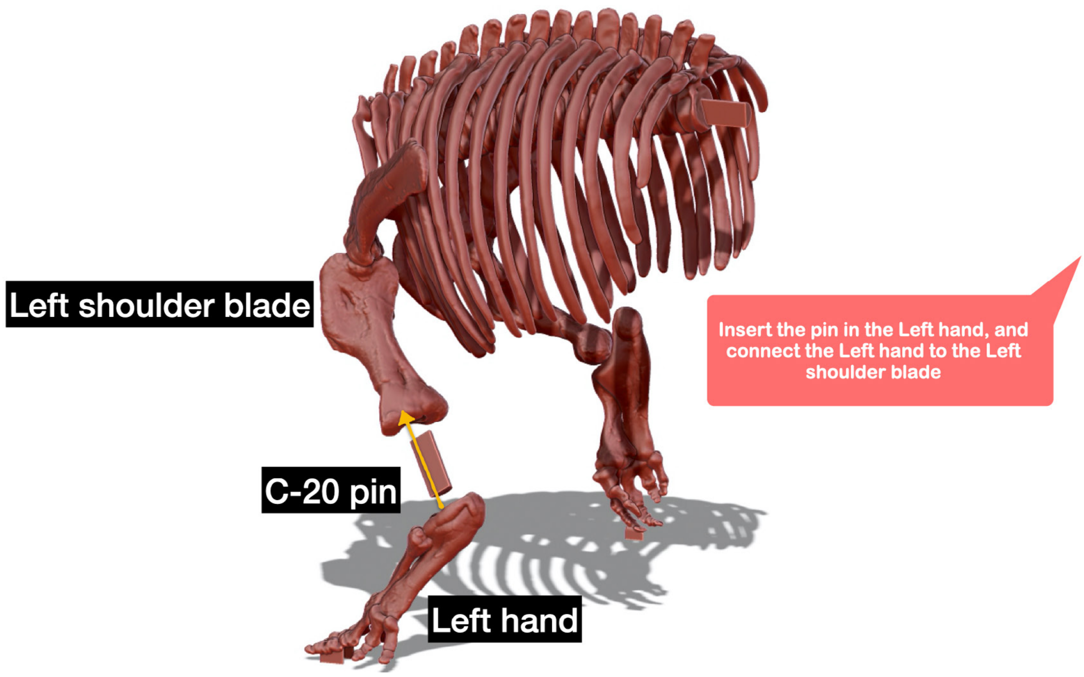


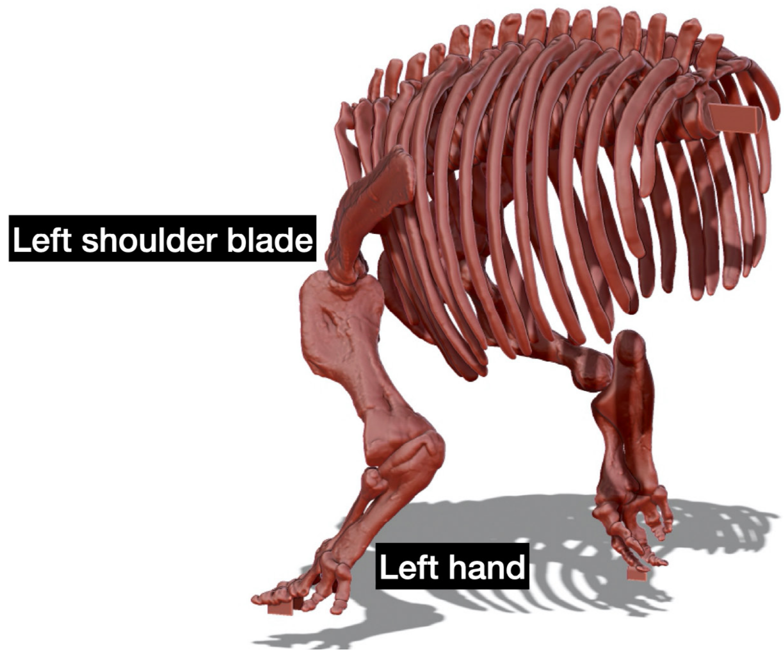
Insert the pin in the Right hand, and connect the Right hand to the Right shoulder blade
Right shoulder blade
C-20 pin
Right hand



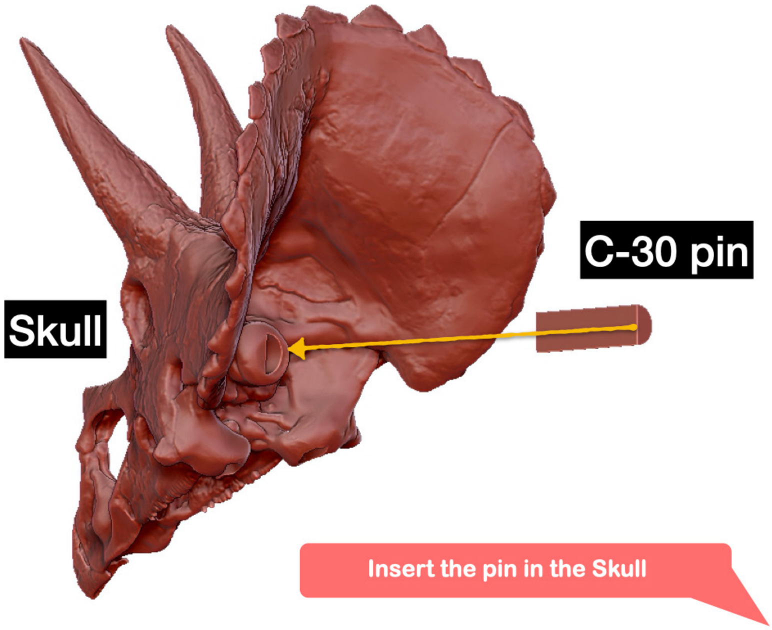
Right shoulder blade
Right hand

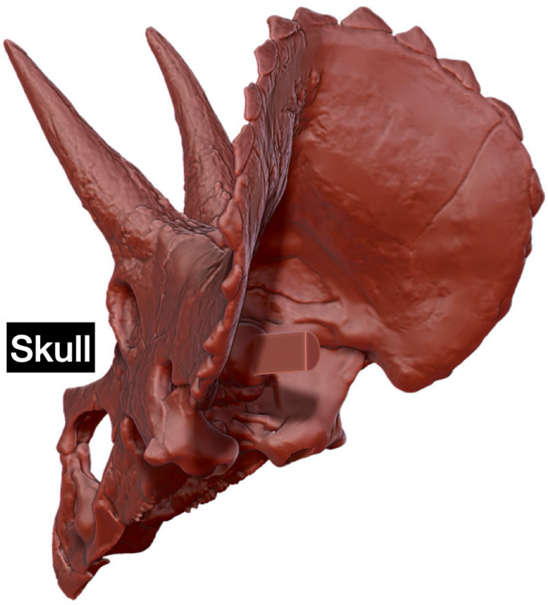
Arms 2


Left shoulder blade
Insert the pin in the Left hand, and connect the Left hand to the Left shoulder blade
C-20 pin
Left hand

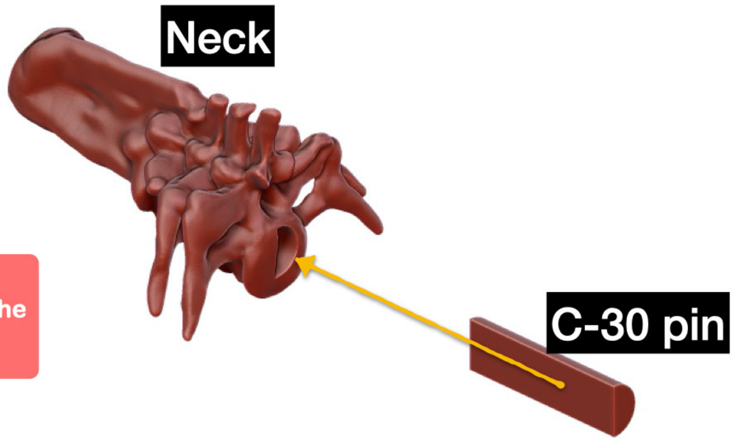

Left shoulder blade
Left hand

Head 1



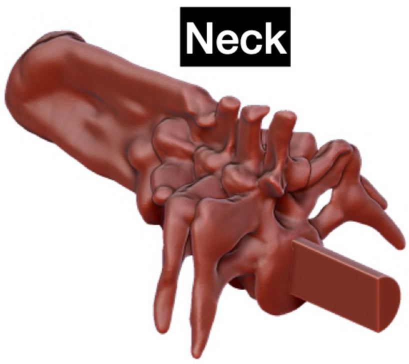


Head 2

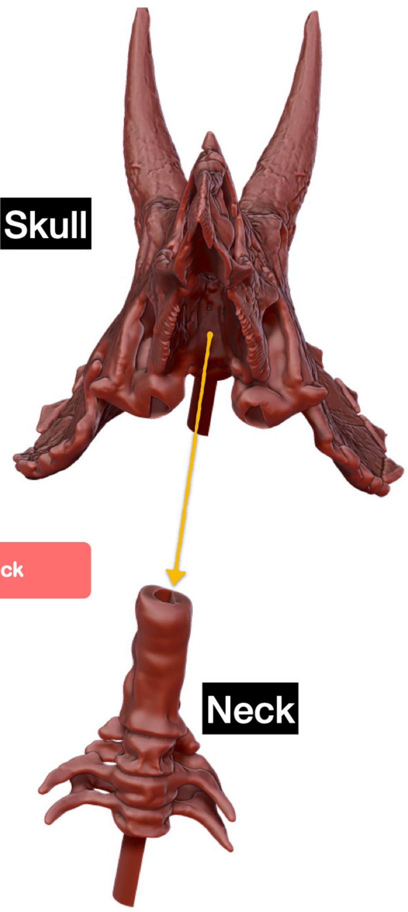


Double check the orientation of the parts

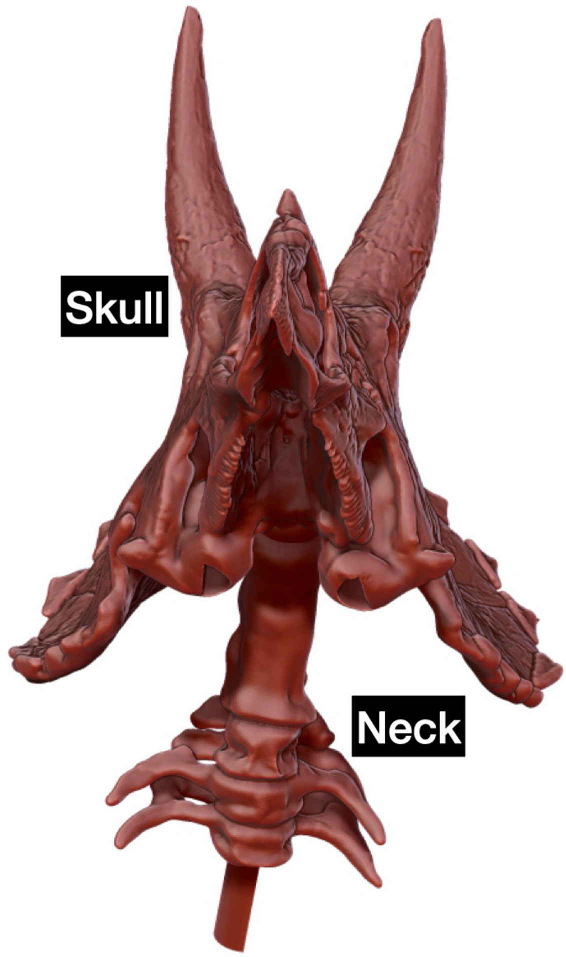
Insert the pin in the Neck



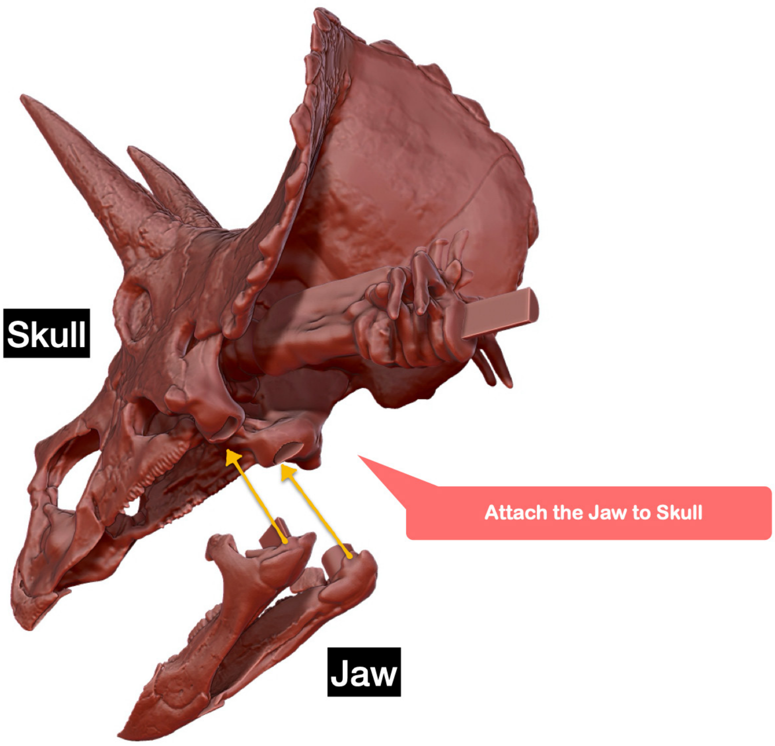
Head 3

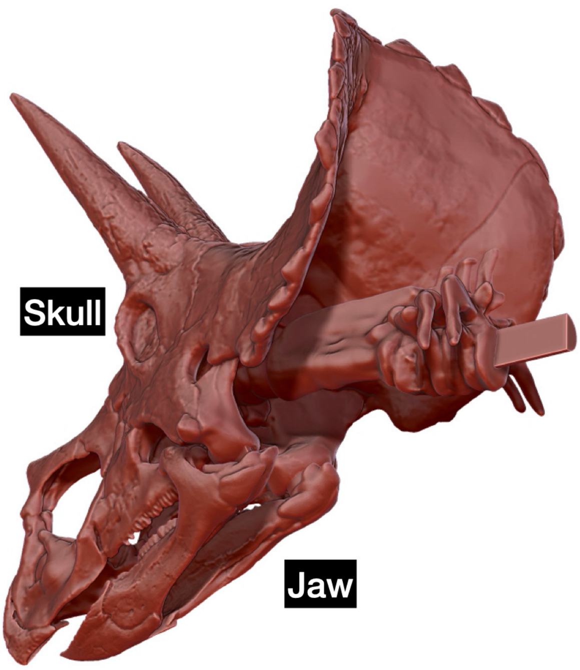


Attach the Skull to Neck



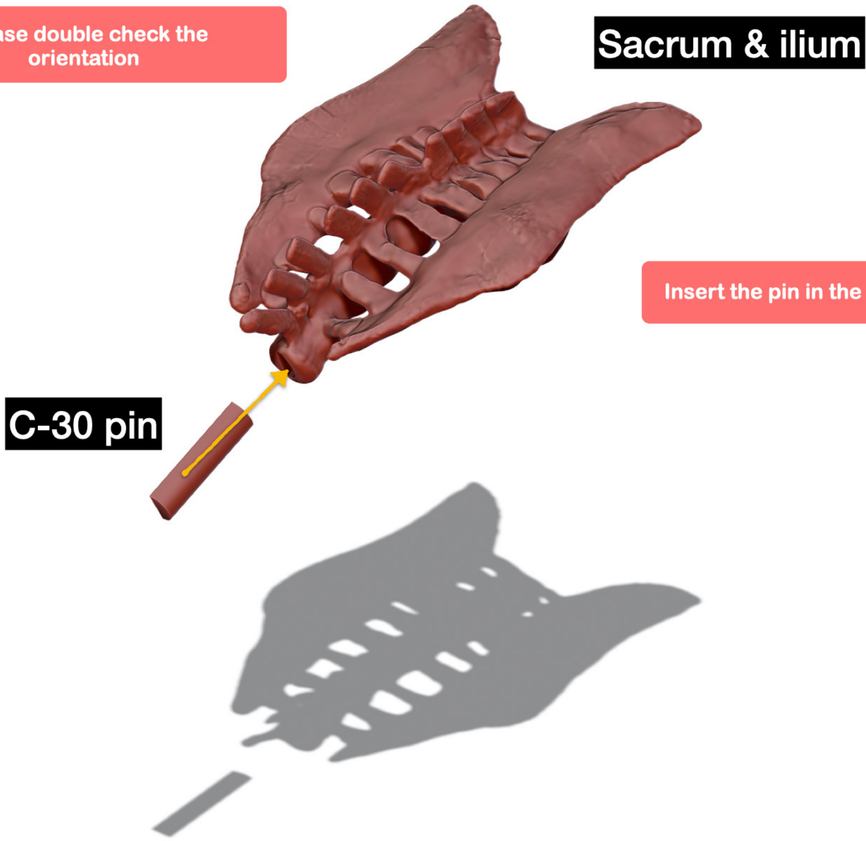
Head 4



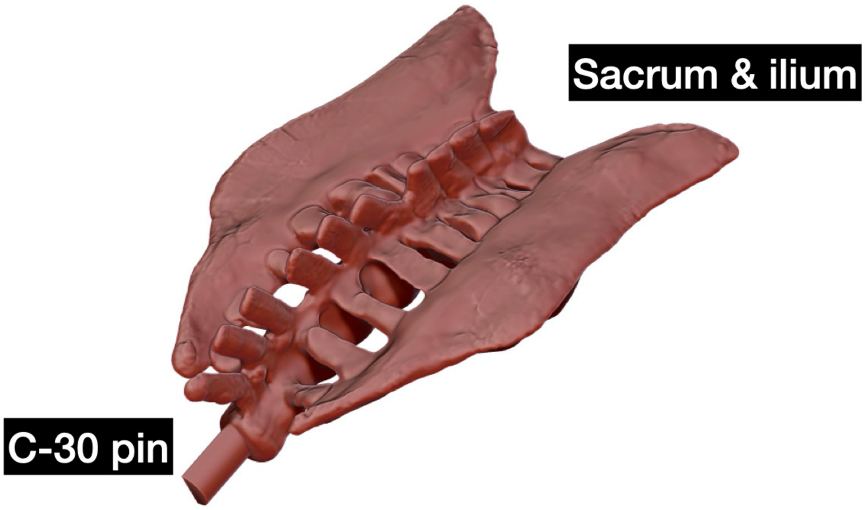


Hips

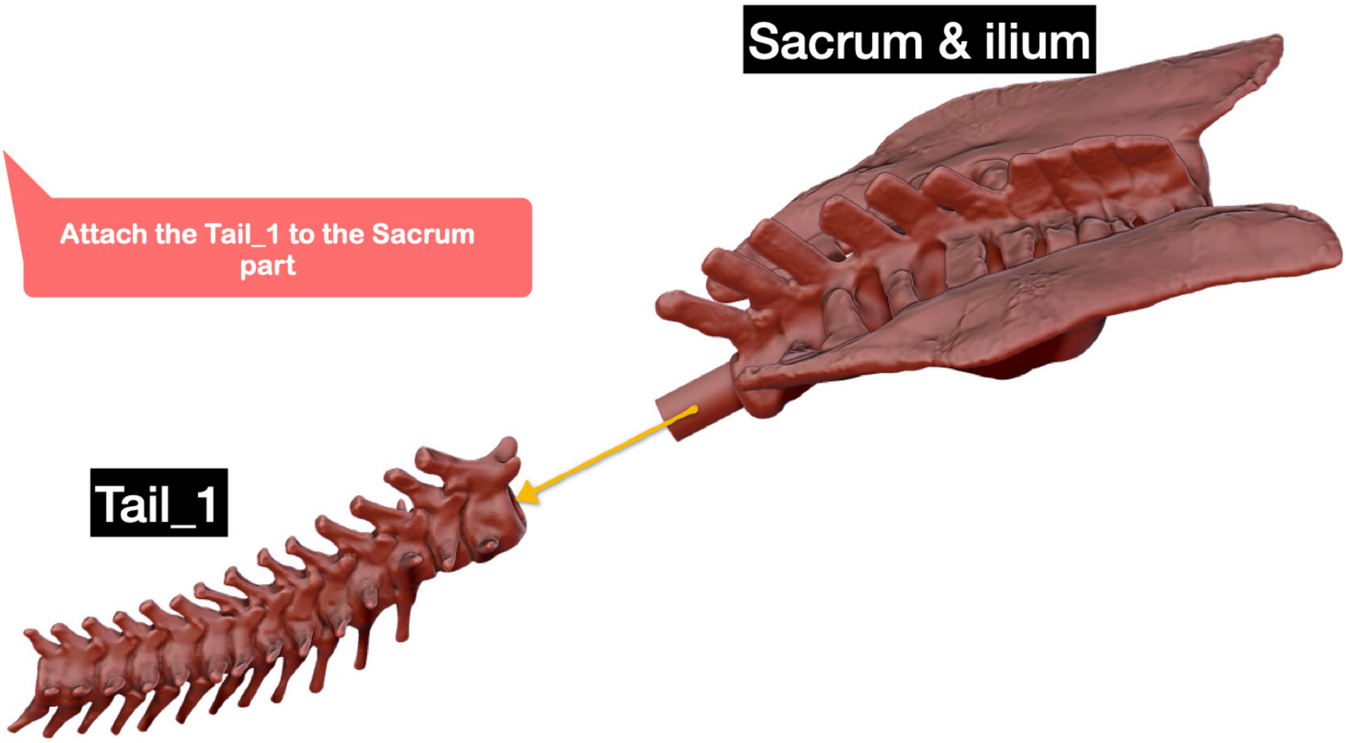
Please double check the orientation

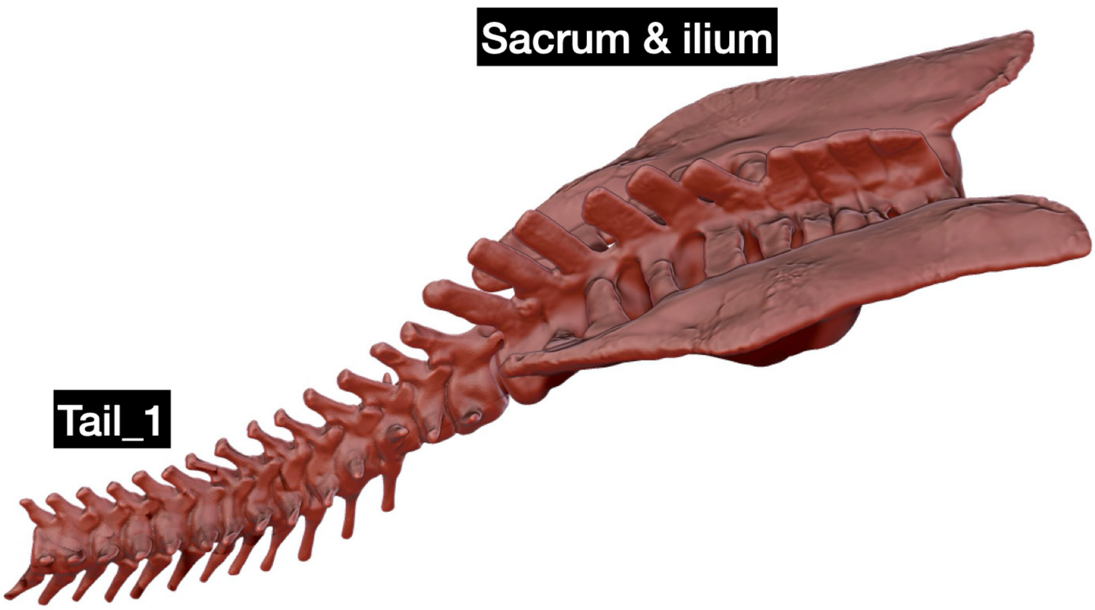


Insert the pin in the Sacrum part

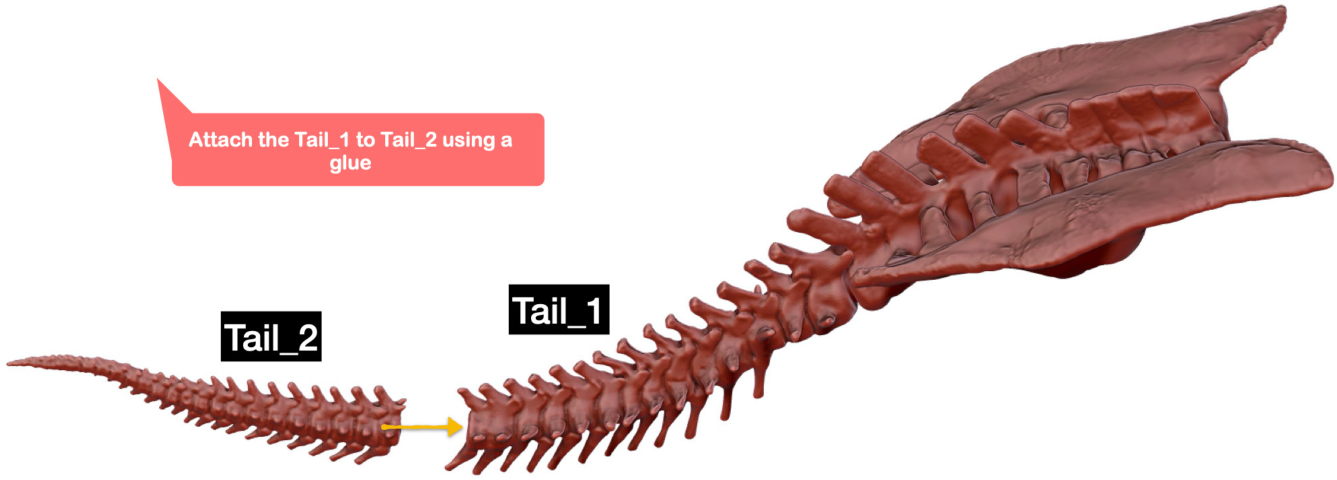


Tail 1


Sacrum & ilium
Attach the Tail_1 to the Sacrum part
Tail_1

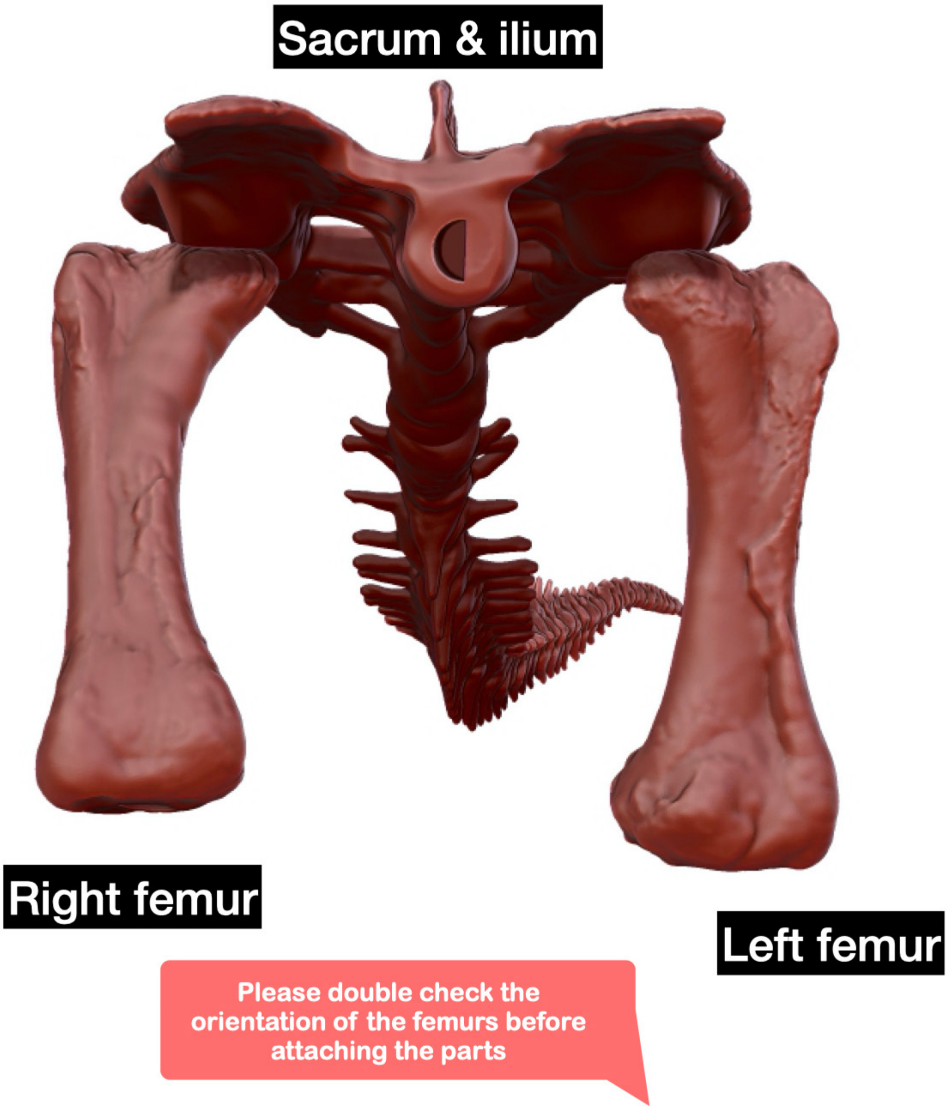

Sacrum & ilium
Tail_1

Tail 2

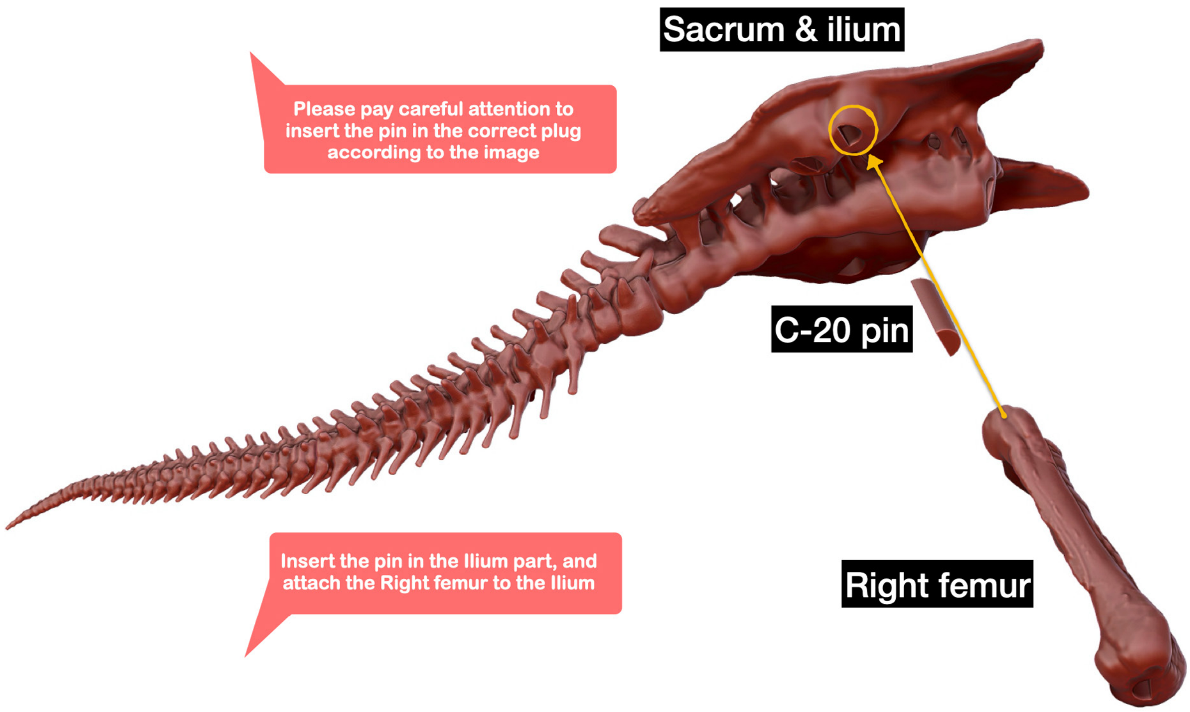

Attach the Tail_1 to Tail_2 using a glue
Tail_2
Tail_1

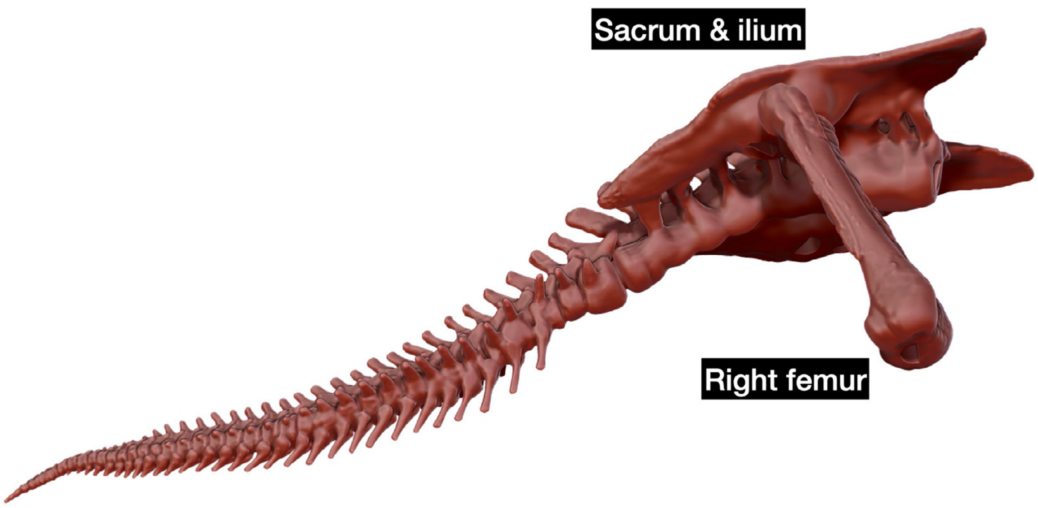

Tail_2
Tail_1

Femurs 1

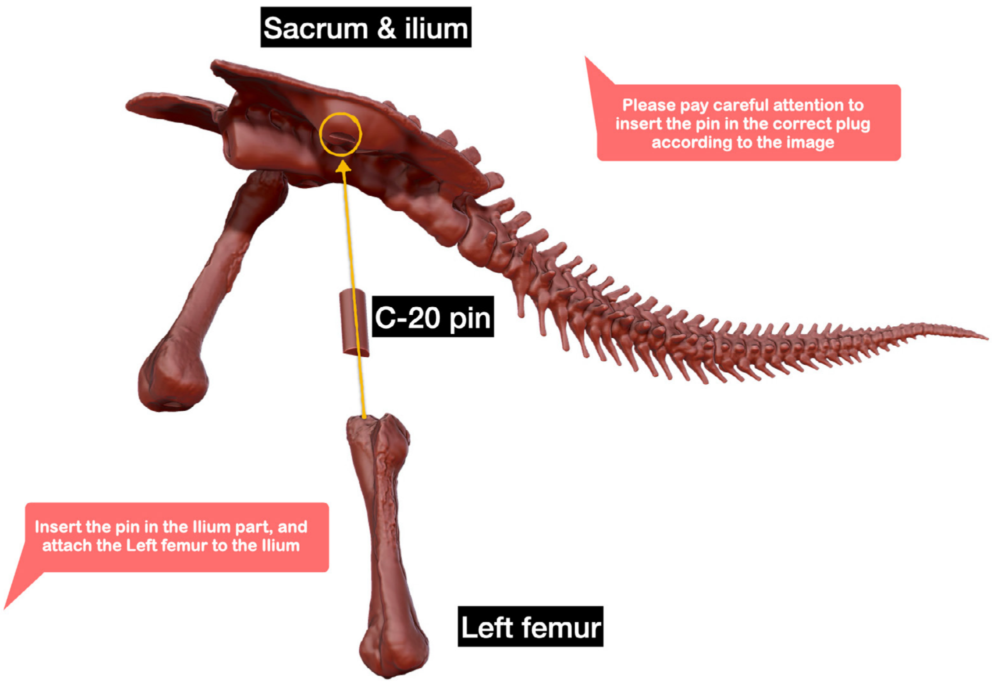

Sacrum & ilium
Right femur
Left femur
Please double check the orientation of the femurs before attaching the parts

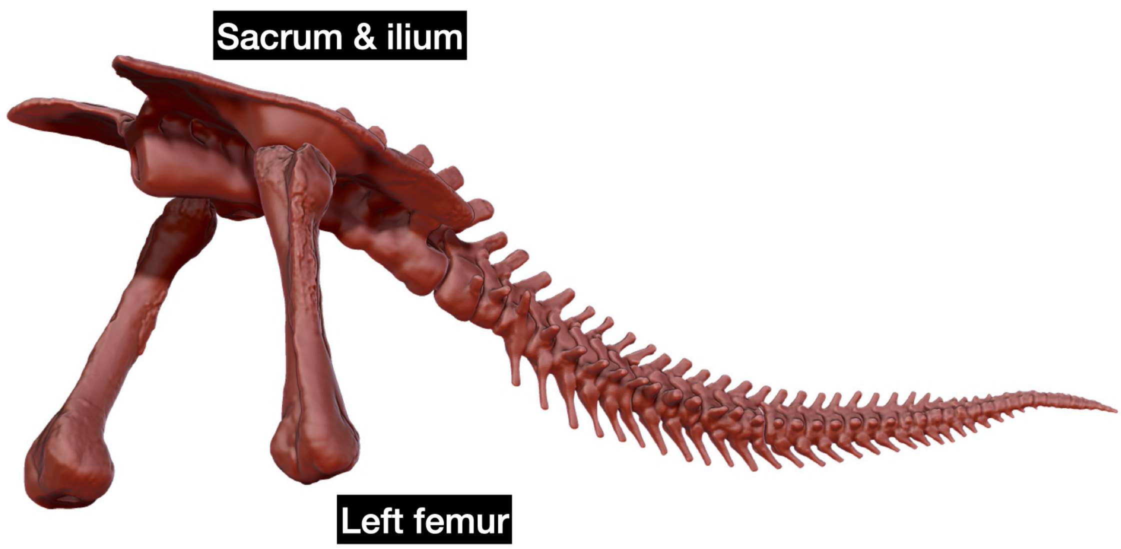
Femurs 2


Sacrum & ilium
Please pay careful attention to insert the pin in the correct plug according to the image
C-20 pin
Right femur
Insert the pin in the Ilium part, and attach the Right femur to the Ilium

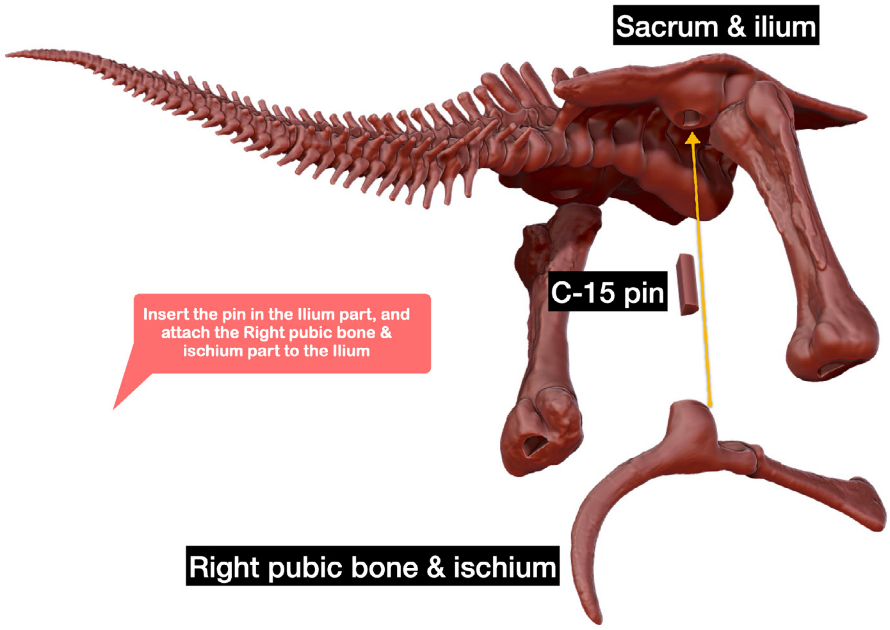

Sacrum & ilium
Right femur

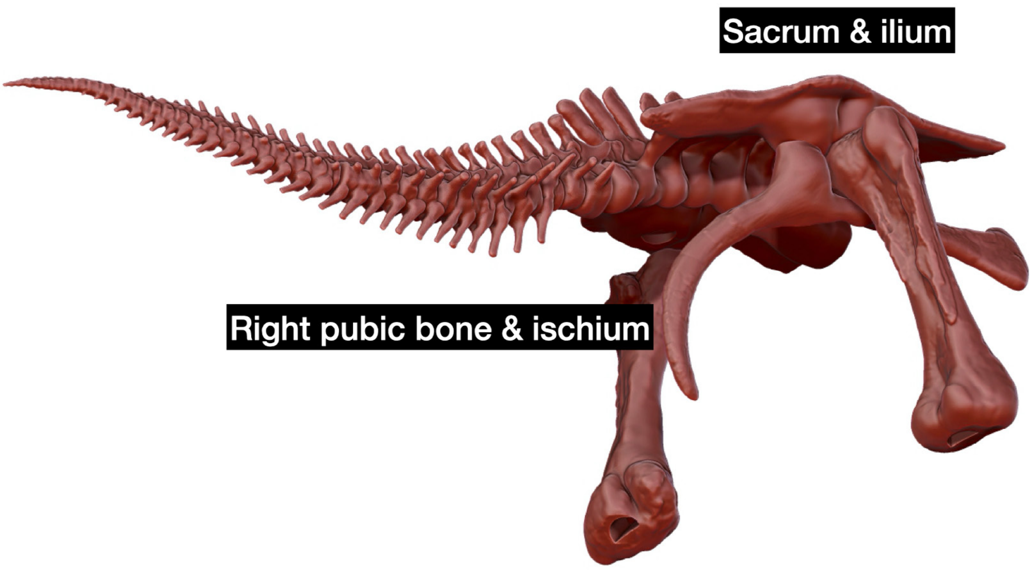
Femurs 3


Sacrum & ilium
Please pay careful attention to insert the pin in the correct plug according to the image
C-20 pin
Insert the pin in the Ilium part, and attach the Left femur to the Ilium
Left femur

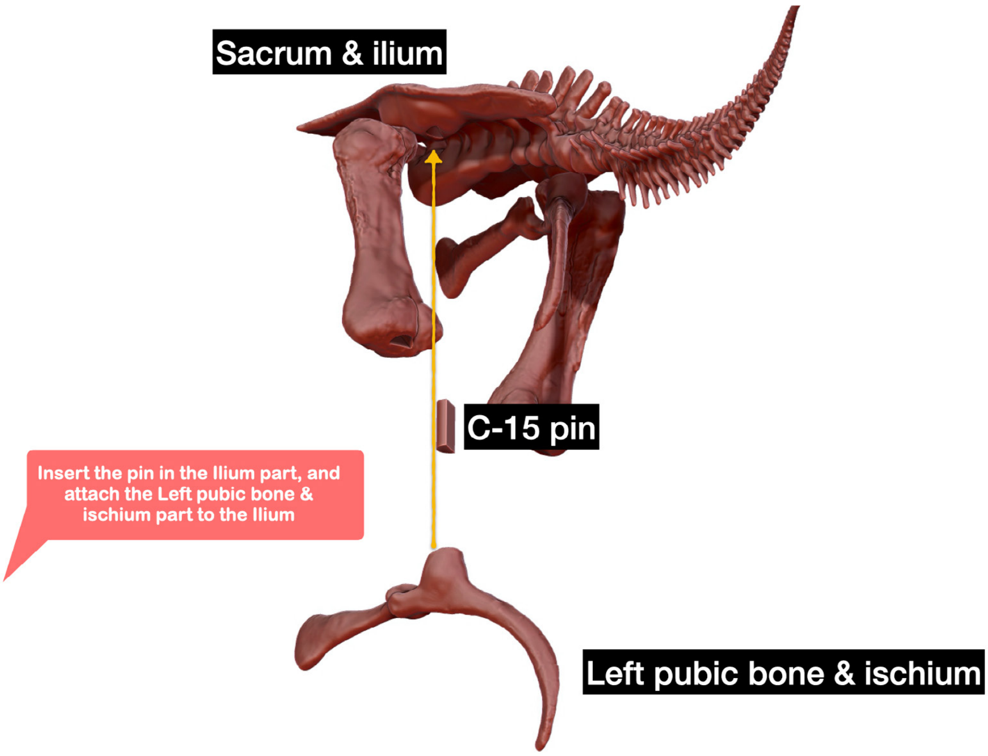

Sacrum & ilium
Left femur

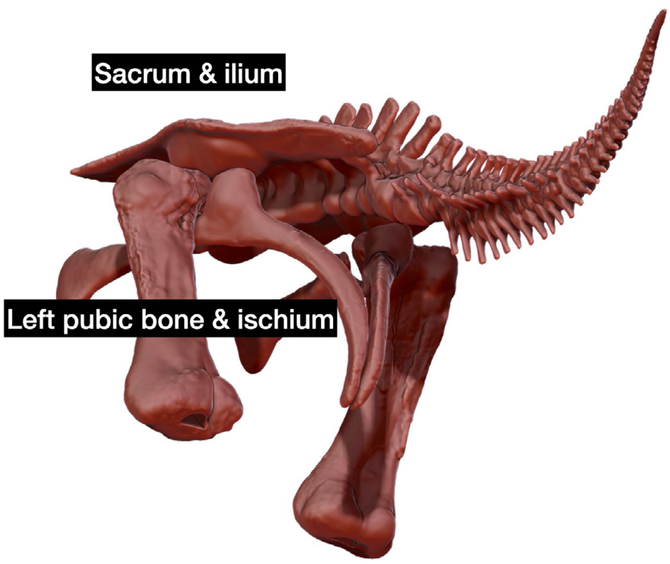
Pubic Bone 1


Sacrum & ilium
C-15 pin
Insert the pin in the Ilium part, and attach the Right pubic bone & ischium part to the Ilium
Right pubic bone & ischium

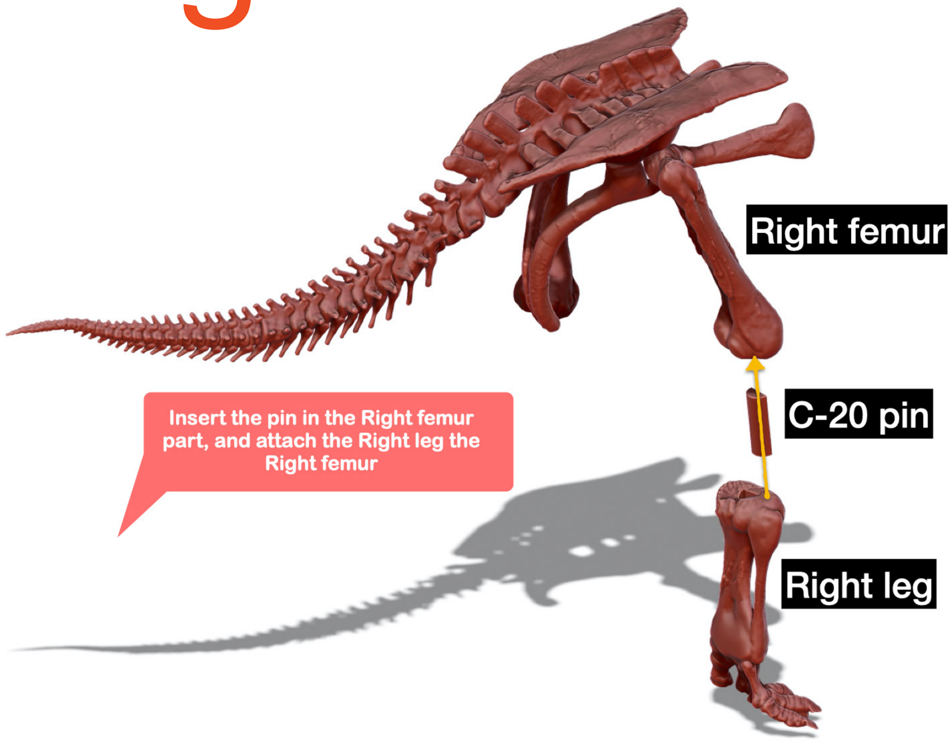

Sacrum & ilium
Right pubic bone & ischium

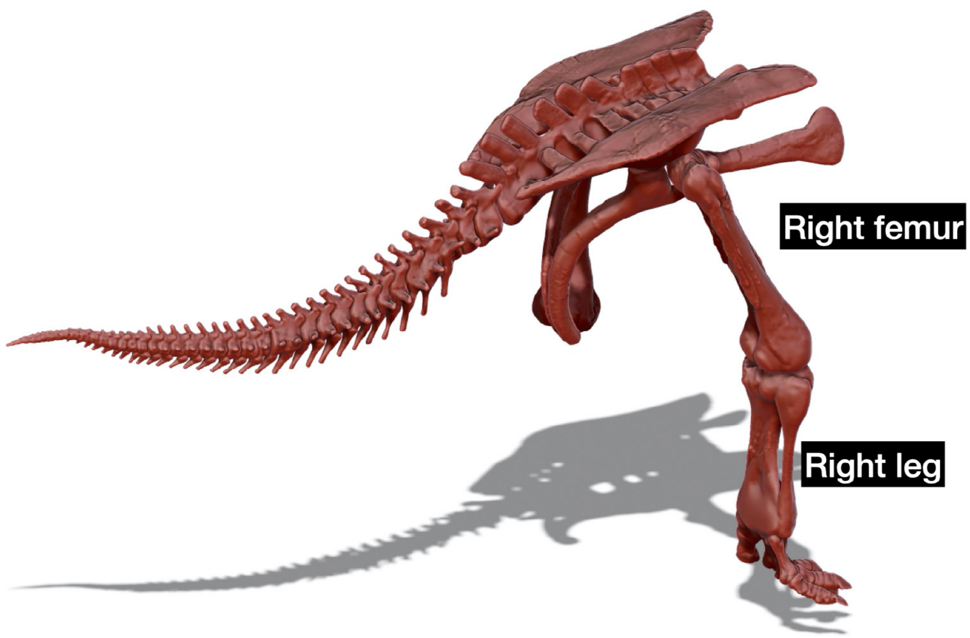
Pubic Bone 2


Sacrum & ilium
C-15 pin
Insert the pin in the Ilium part, and attach the Left pubic bone & ischium part to the Ilium
Left pubic bone & ischium

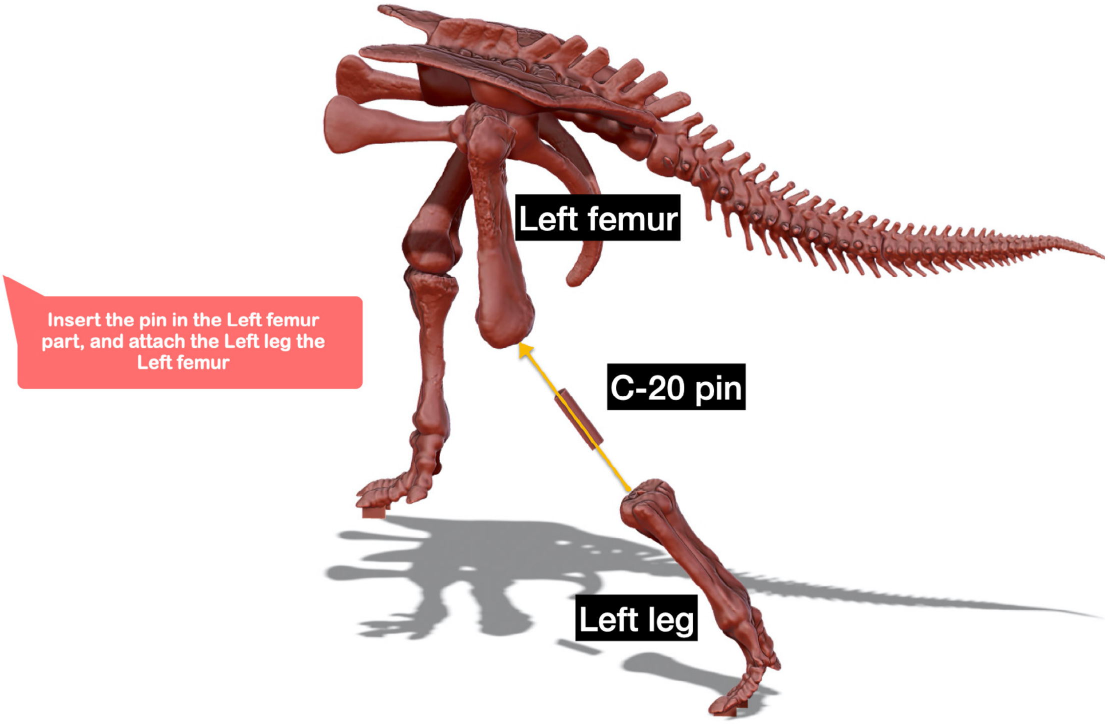

Sacrum & ilium
Left pubic bone & ischium

Legs 1

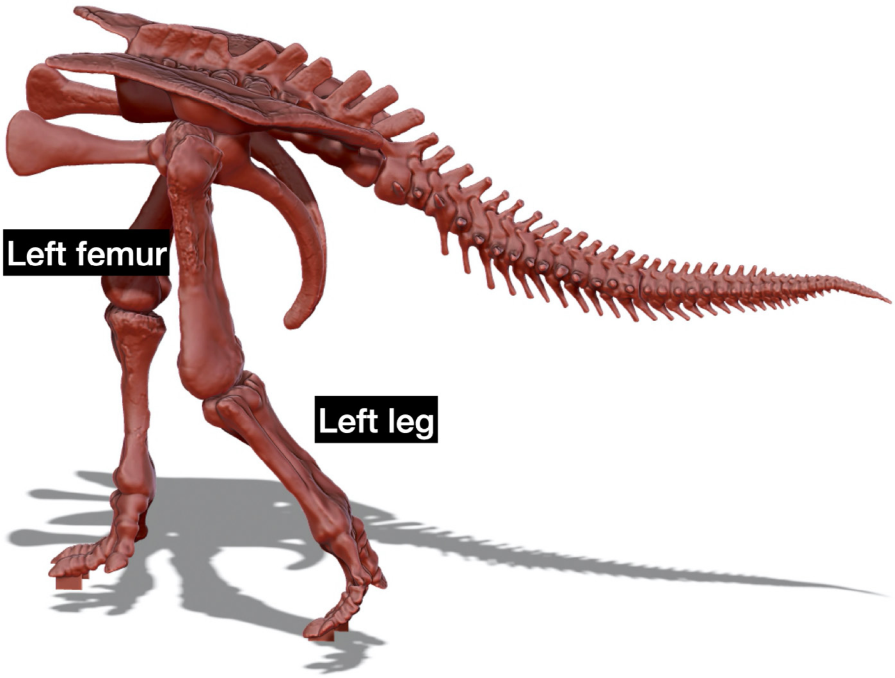

Right femur
C-20 pin
Right leg
Insert the pin in the Right femur part, and attach the Right leg the Right femur


Right femur
Right leg

Legs 2

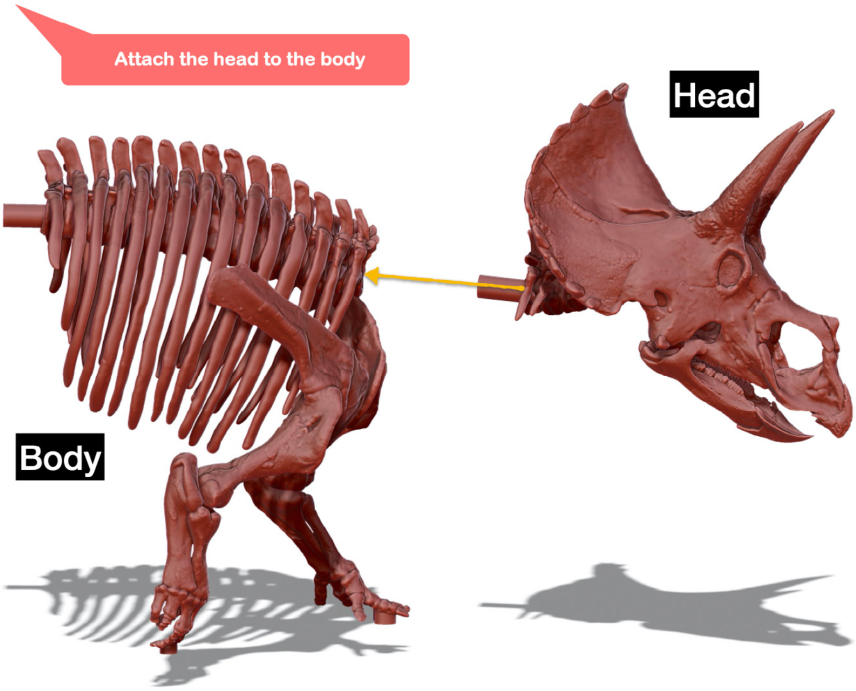


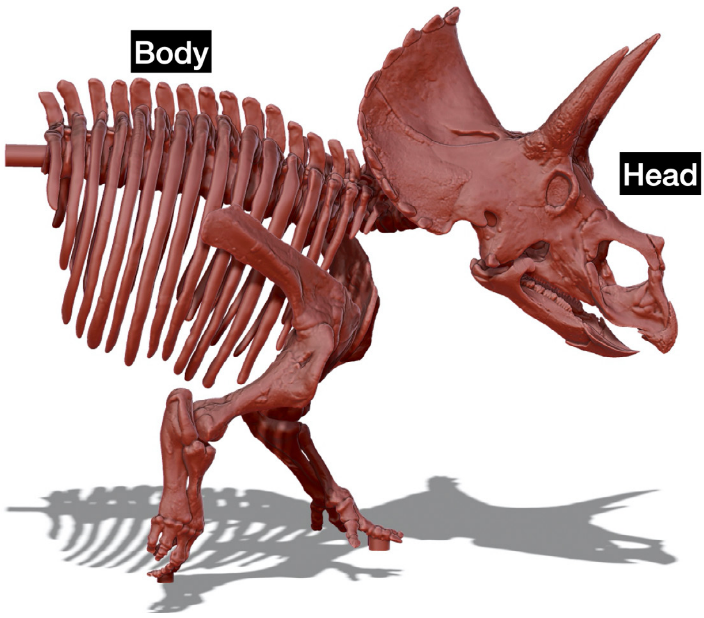
Left femur
Insert the pin in the Left femur part, and attach the Left leg the Left femur
C-20 pin
Left leg



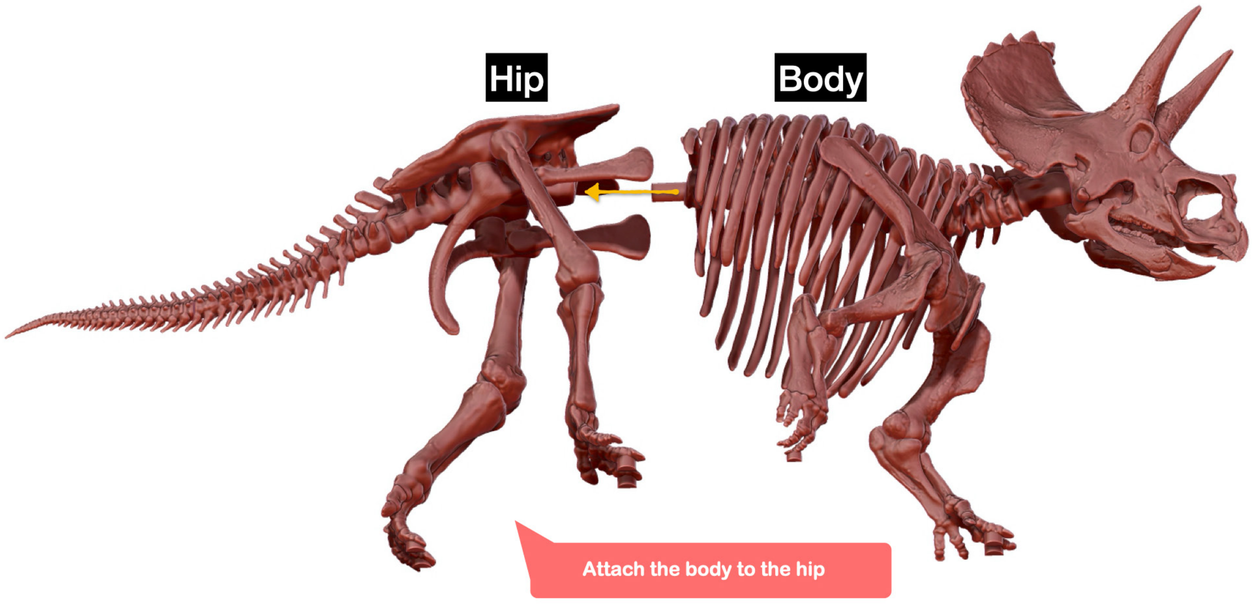
Left femur
Left leg

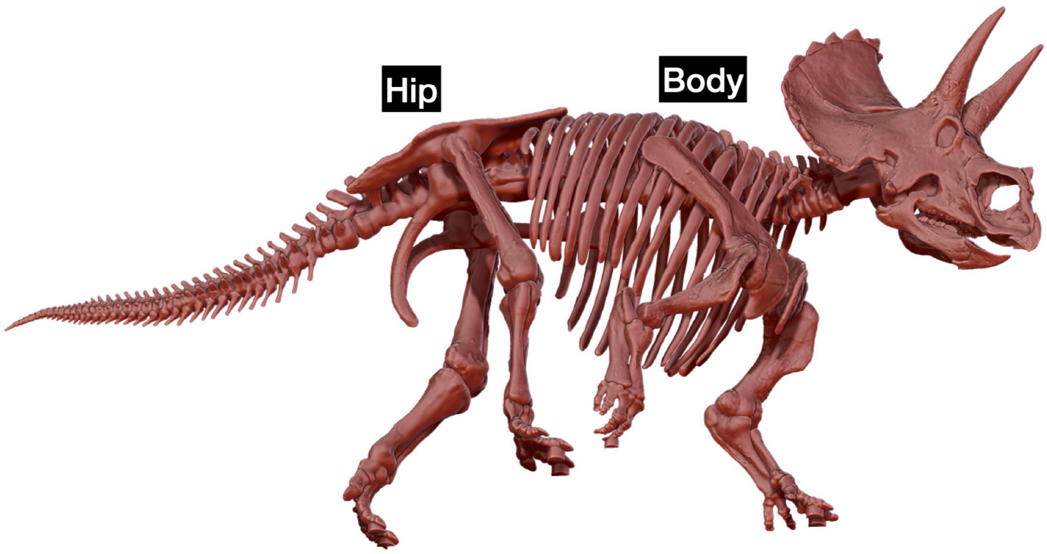
Upper Body



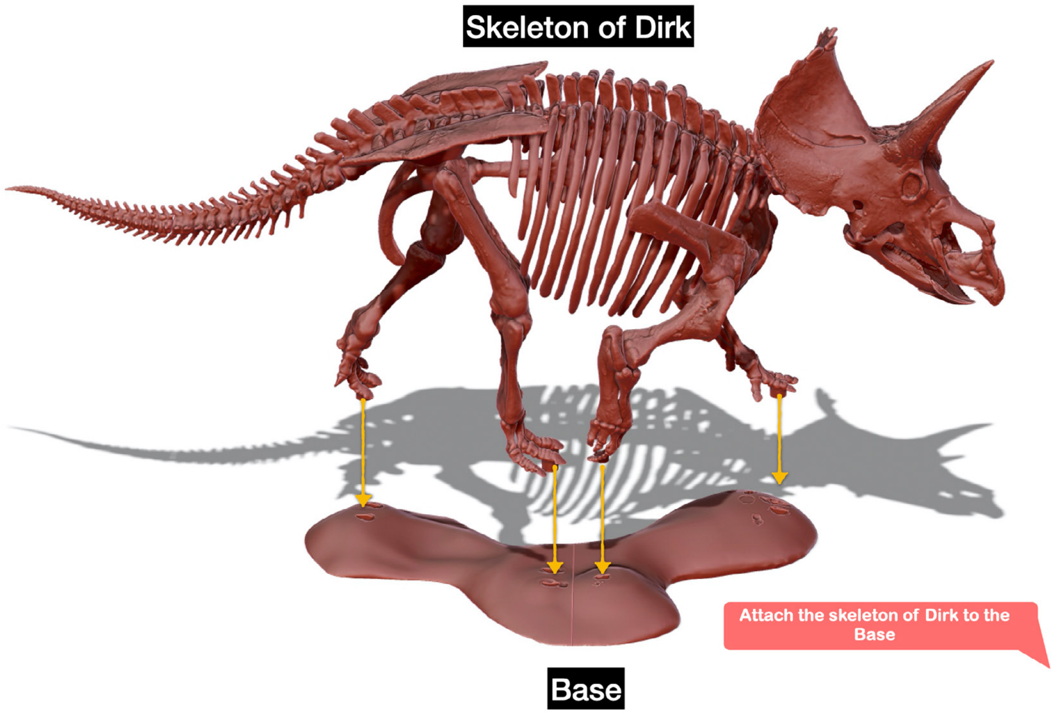


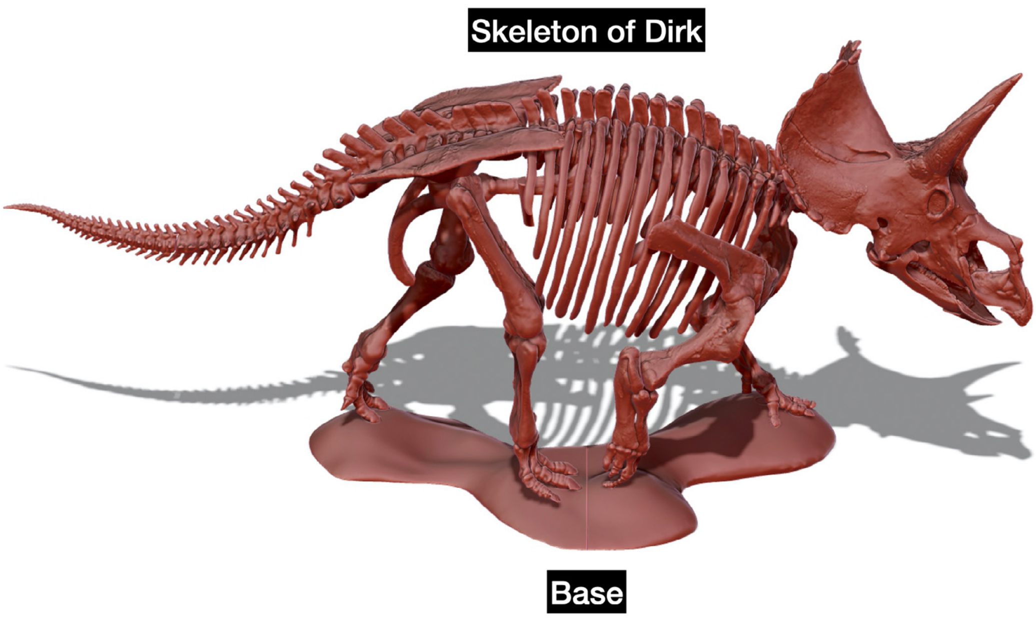
Upper Body & Hips Connection





Base Attachment





Dirk Skeleton

Links

Needed for lesson:

Print material + profile to use in Cura software*:
https://www.naturalis.nl/uploads/manual/Printbestanden_en_Cura-profiel.zip

Wonder passport dino world:
https://www.verwonderpaspoort.nl/verwonderwereld/dinos

Extra:

Vlogs *Triceratops* excavation:
http://bit.ly/2go3gof

Natuurwijzer articles about the dinosaur age:
https://natuurwijzer.naturalis.nl/themas/dinotijd

*These profiles can only be used in Cura, Ultimaker's free downloadable software and can be used when you want to configure stl's yourself. Please note: this software does not need to be used when the enclosed gcodes are used directly for printing.

Naturalis
Biodiversity
Center

Design by **Javid Jooshesh**