

Introduction to musculoskeletal modelling

Blender part 2 Building muscles

Dr Hugo Dutel

Building muscles

Blender (<https://www.blender.org/>) is a free and open-source 3D computer graphic software application used for creating films, visual effects, etc. We will use this software during the practical, which has been already installed on the university computers.

A live introduction to Blender will be done at the beginning of the practical.

The objective of this second part is to build the three adductor muscle groups: the masseter, medial pterygoid, and temporalis. You will then **extract the 3D coordinates of the origin and insertion of each muscle**, that will have to be saved into a .csv file.

This document provides you with a step-by-step tutorial to achieve this goal.

Save (Ctrl+S) your work regularly!

Building muscles

Jaw adductor muscles will be discretised into a series of **strands**, that represent their **line of action**. Try to divide each muscle into **three strands**, as shown in the example on the right.

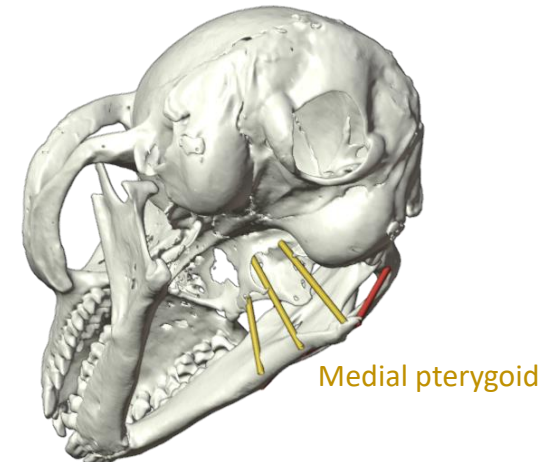
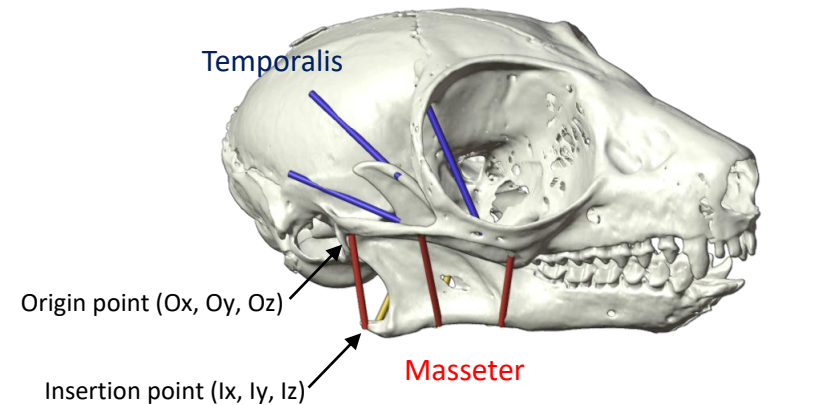
Each strand is made of a **starting** and **ending point**. The coordinates of these points correspond to the **origin (on the cranium)** and **insertion (on the mandible)** of the muscle strand. We will extract automatically these coordinates **once all the strands have been built**.

The **strand names** must follow this convention (case sensitive):

m.muscleName_strandNumber

E.g. *m.master_01* for the first strand of the masseter, *m.masseter_02* for the second strand of the masseter, etc.

Make sure to use the same naming convention as presented in the tutorial + same muscle names for the different species!

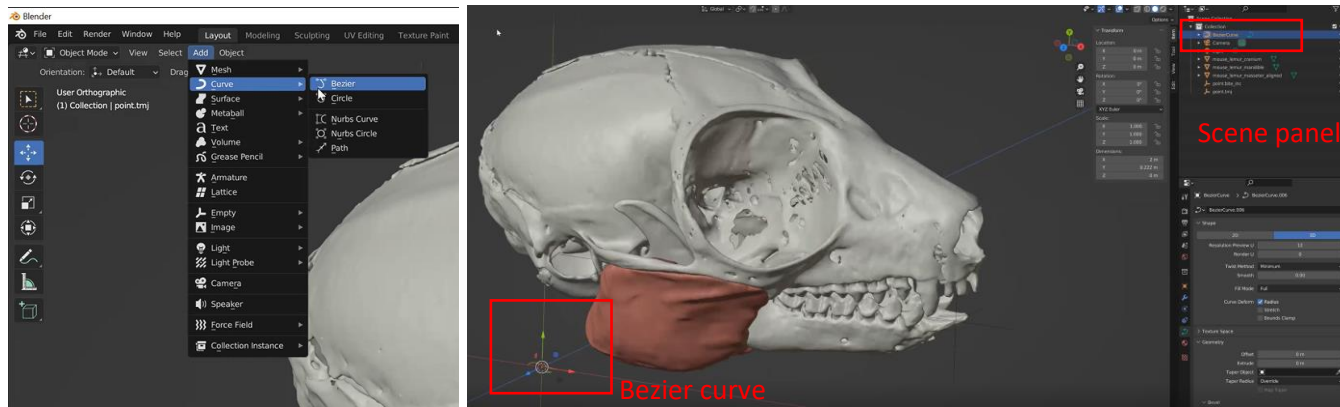


Mouse lemur (*M. murinus*)

Building muscles

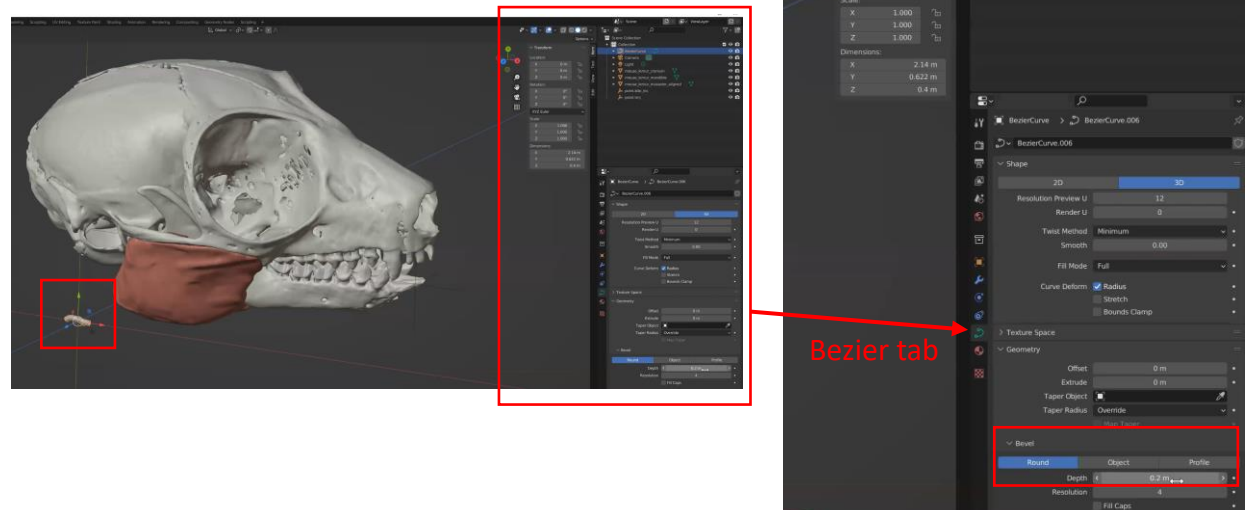
1. Each muscle strands will be built with a **Bezier curve** (0:15). Go to Add > Curve > Bezier.

The Bezier curve is created at the world origin and will appear in the list of objects in the Scene panel on the right.



2. Increase the diameter of the Bezier curve (0:20). Select the Bezier curve in the Scene panel and go to the Bezier tab > Bevel and set Depth at 0.2.

You can now see a clear cylinder.

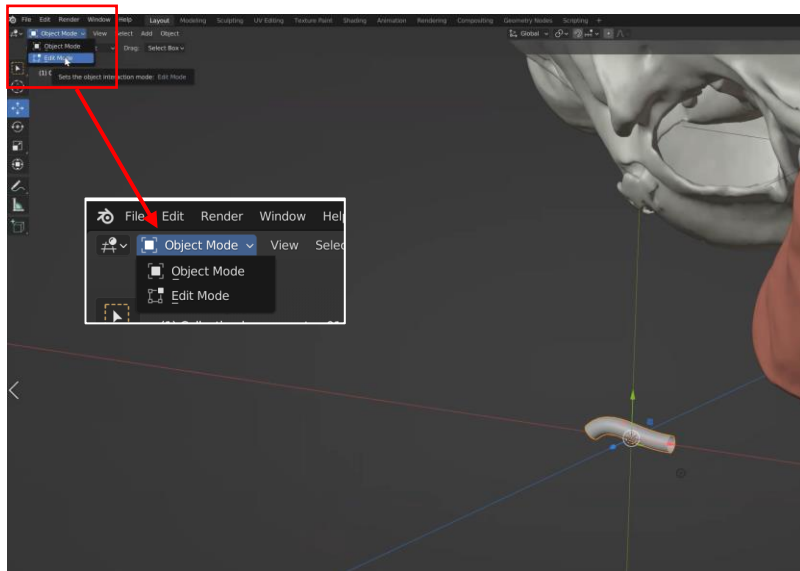


Building muscles

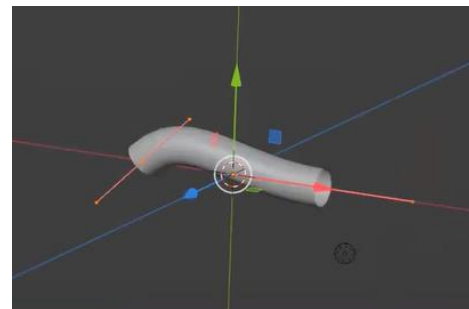
3. We want the **Bezier curve to be straight as a vector** (0:41). Make sure to select the Bezier curve (the outline of the selected object is yellow).

Go to the left top corner of the window to change Modes of editing of the object: select **Edit Mode**.

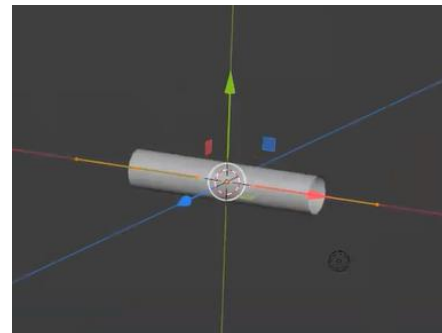
Edit Mode allows you to **change the geometry** of the object, while **Object Mode** allows you to **move/rotate** the object.



4. In **Edit Mode** you can see handles and points at the tip of the Bezier curve (0:49).



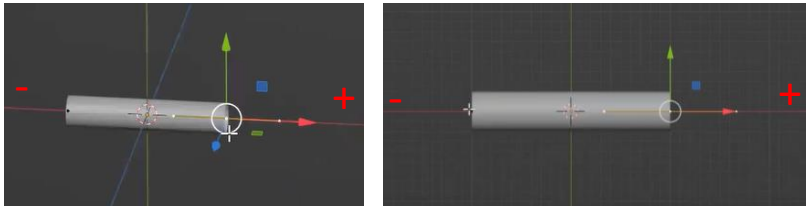
5. Press **V V** (twice V key) to **straighten** the Bezier curve. This sets the handles to *vector*.



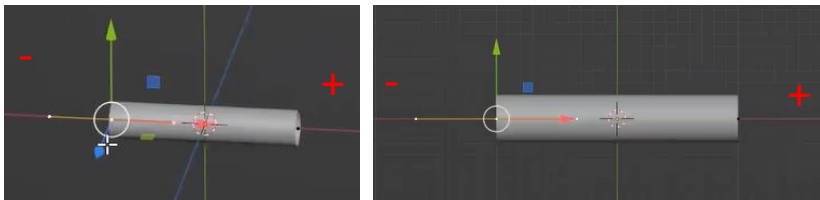
Building muscles

6. You can **select the end points** of the Bezier curve (1:00).

The end point on the **positive side** of the world X axis (red) is the **insertion point on the mandible**



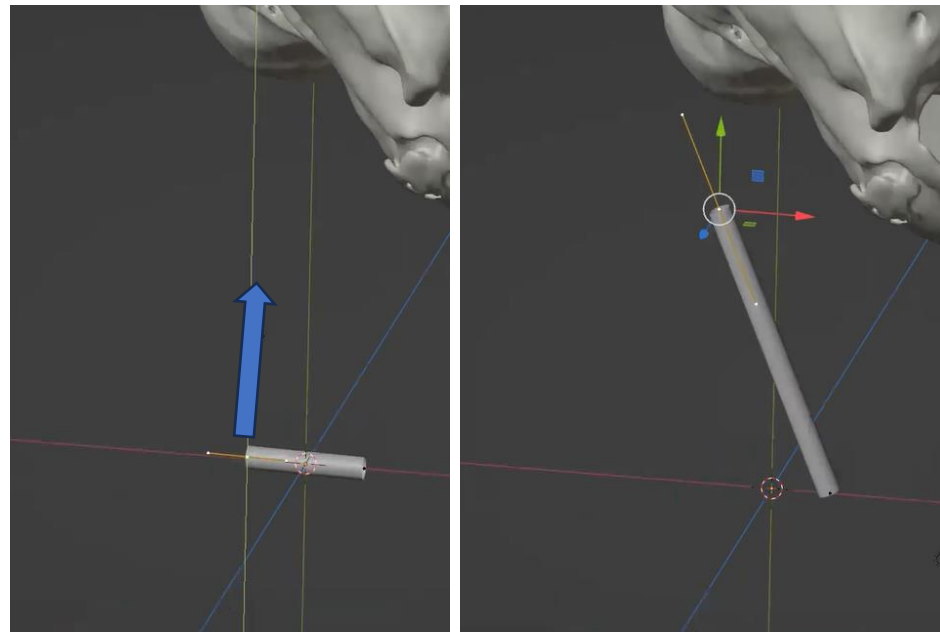
The end point on the **negative side** of the world X axis is the **origin point on the cranium**



This order matters: if you do not respect it, your origin and insertion coordinates will be swapped!

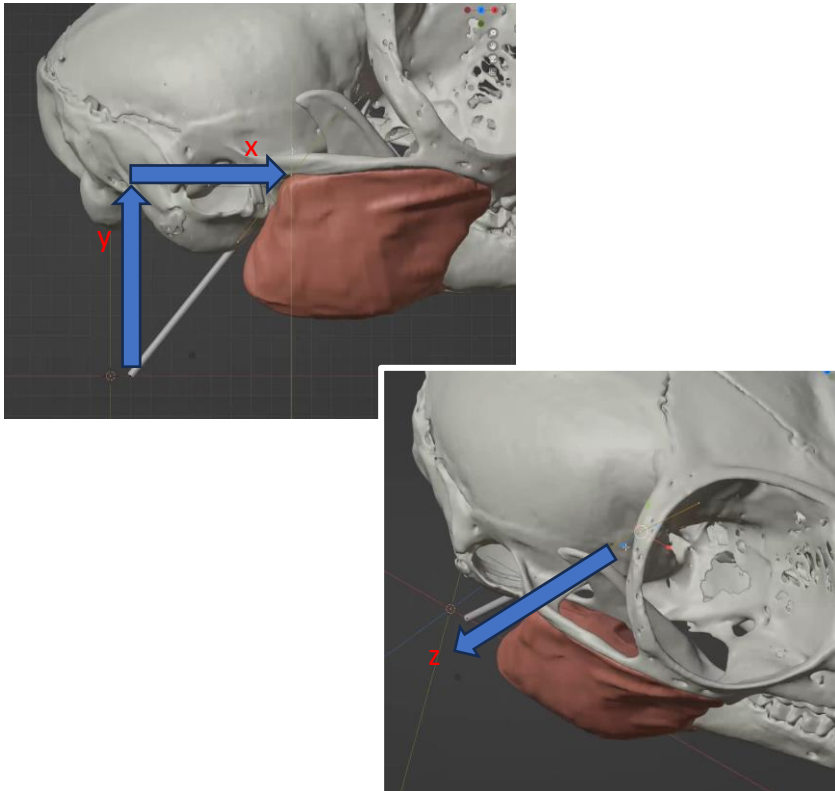
7. You can translate along the three axes the origin and insertion point of the muscle strand (1:20). Just like the points you built to model the TMJ and bite point, **hold right click** once you clicked on one of the axes and drag it in the direction of your choice.

This stretches the Bezier curve.

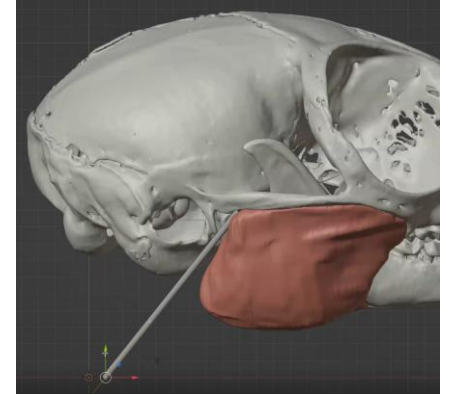


Building muscles

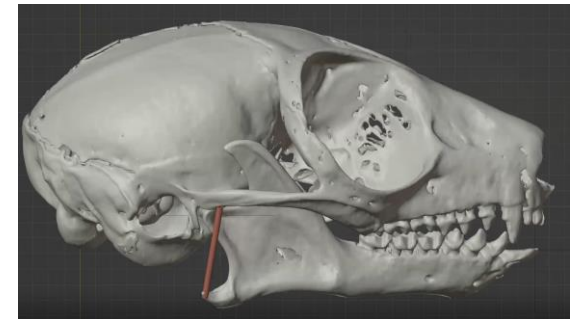
8. Move the **origin point** at the posterior edge of the attachment area of the masseter on the zygomatic arch (1:30). First move the point anteriorly and dorsally within the (x, y) plane and then laterally within the (x, z) plane.



9. Once the origin point has been placed, follow the same procedure to **move the insertion point** on the surface of the mandible.

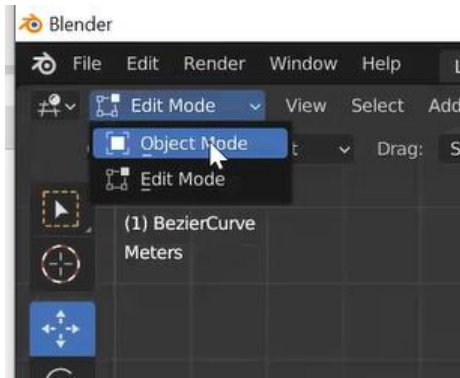


The first strand of the masseter is now built.

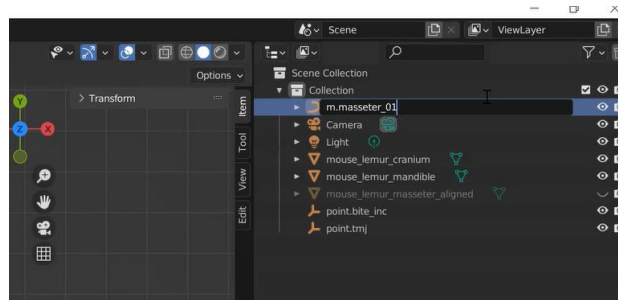


Building muscles

10. Switch back to **Object Mode**.

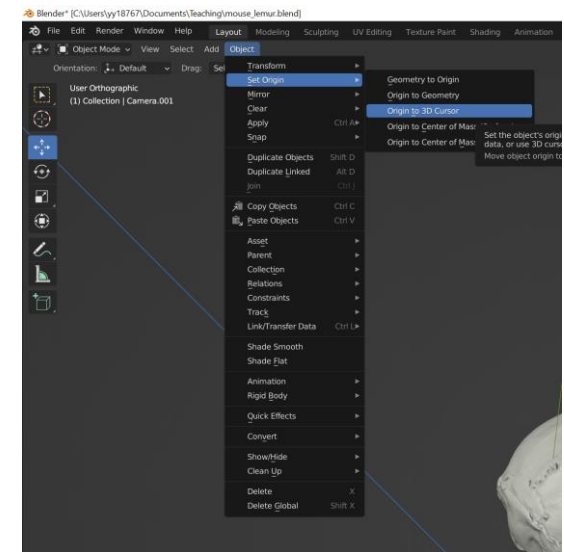


11. Rename the Bezier curve by following the naming convention (3:50):
m.muscleName_strandNumber



12. Select the Bezier curve. Go to Object > Set Origin > Origin to 3D Cursor

The **local reference frame** of the end point coordinates of the Bezier curve is now the same as the **global reference frame**.



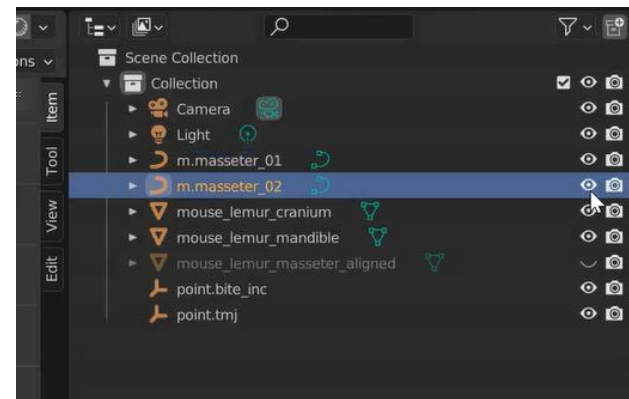
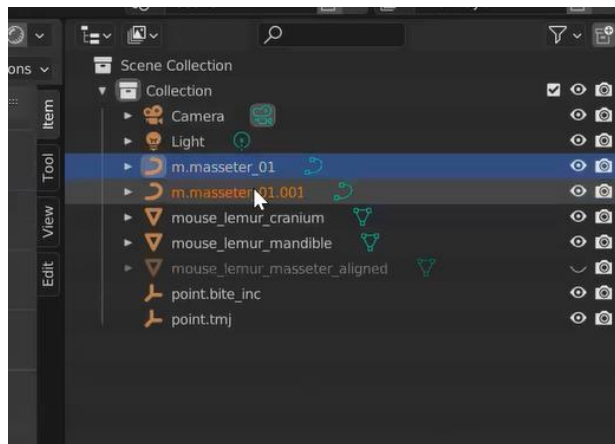
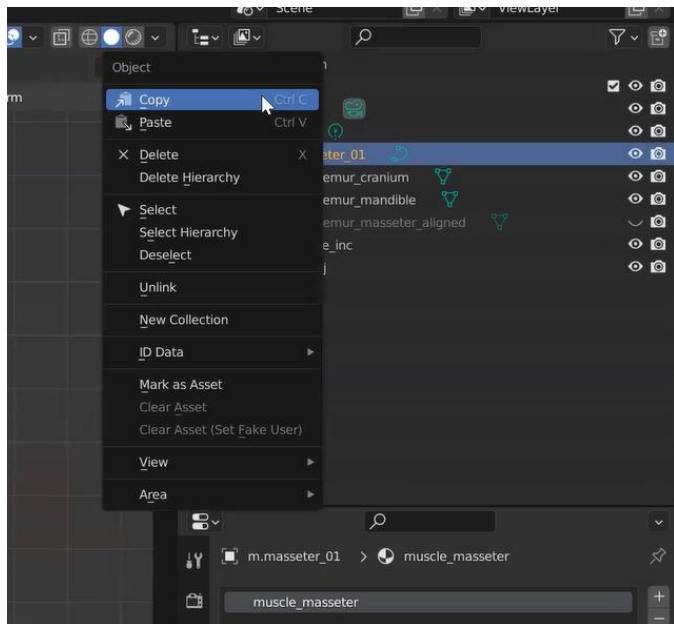
Building muscles

13. You can now build the other muscle strands by following the same procedure. To speed up the process, **you can duplicate the muscle strand that has already been built (4:00).**

Right click on the muscle strand > Copy
or Ctrl + C

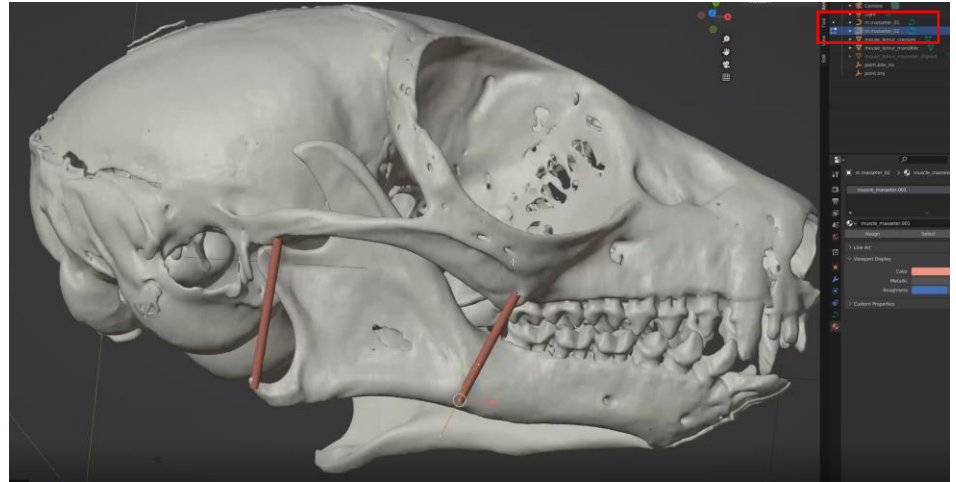
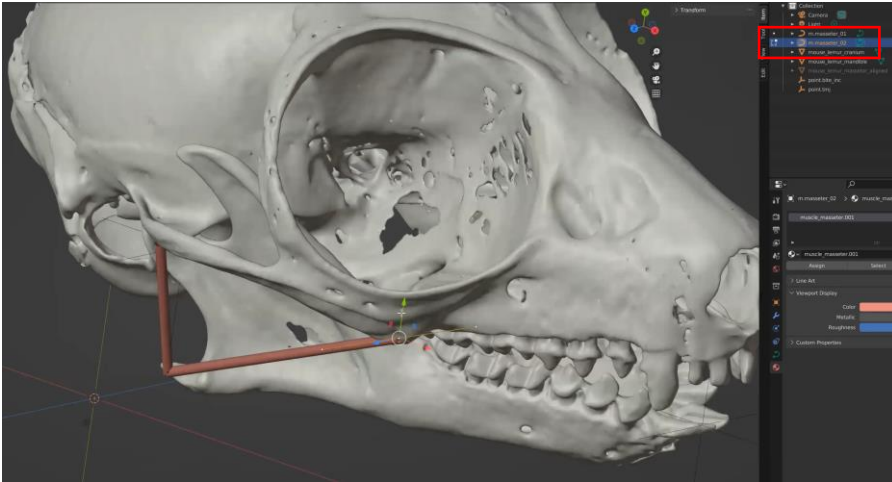
Paste Ctrl + V

rename the strand



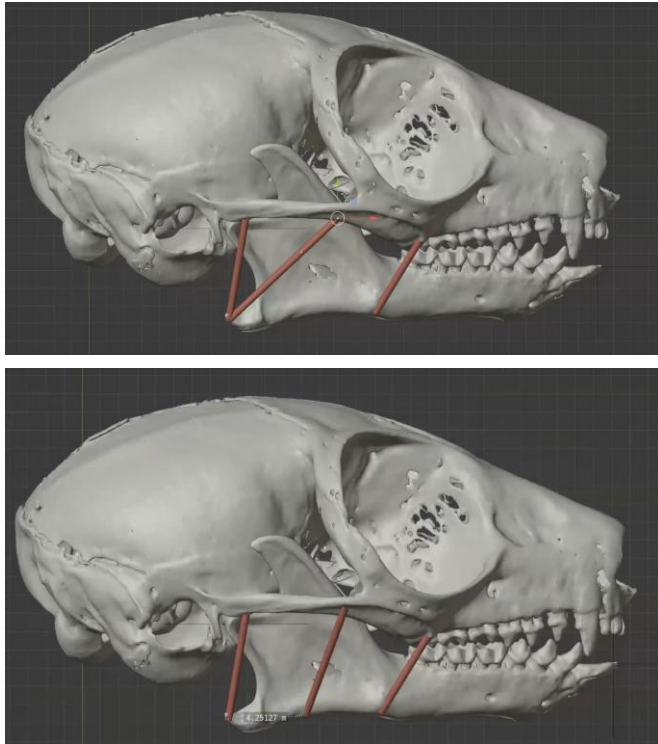
Building muscles

14. The duplicated strand is created at the **same position** as the original one (4:00). Make sure to **select the new strand** (it is easy to get confused). Switch to **Edit Mode** to move its origin and insertion. Once you have positioned the strand switch back to **Object Mode** and align its **reference frame** with the global reference frame (Object > Set Origin > Origin to 3D Cursor).

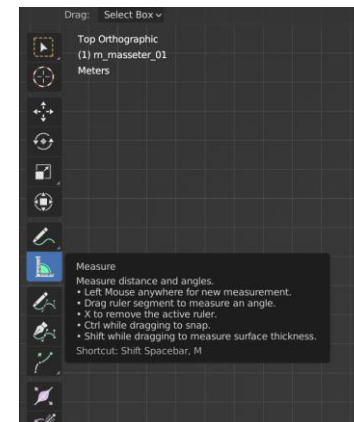
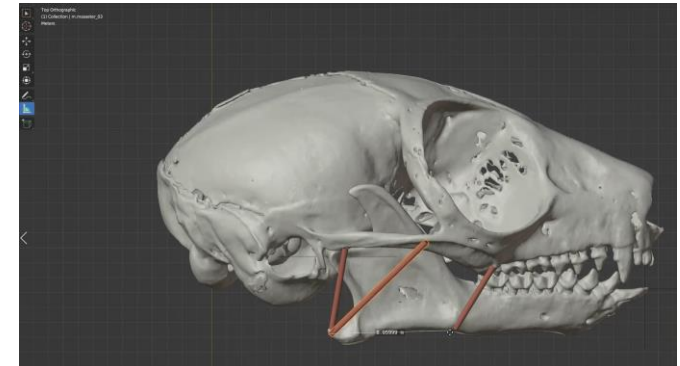


Building muscles

15. The second strand is positioned at the anterior margin of the attachment areas of the muscle. The third strand will be positioned at mid-distance (roughly) between the posterior and the anterior strand.

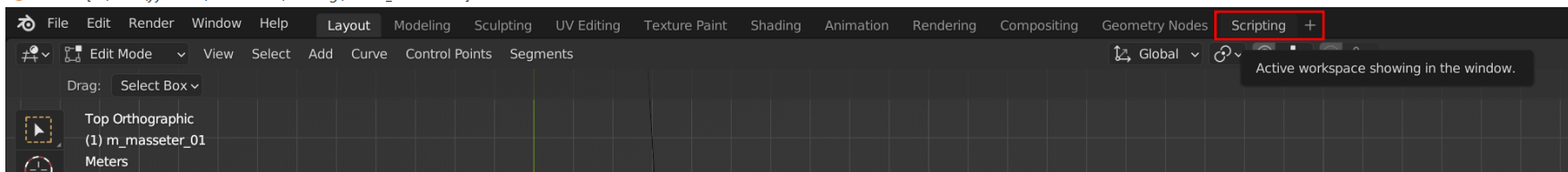


16. You can use the **Measure tool** to measure distances. To make things easier, **switch to lateral view to make your measurements.**

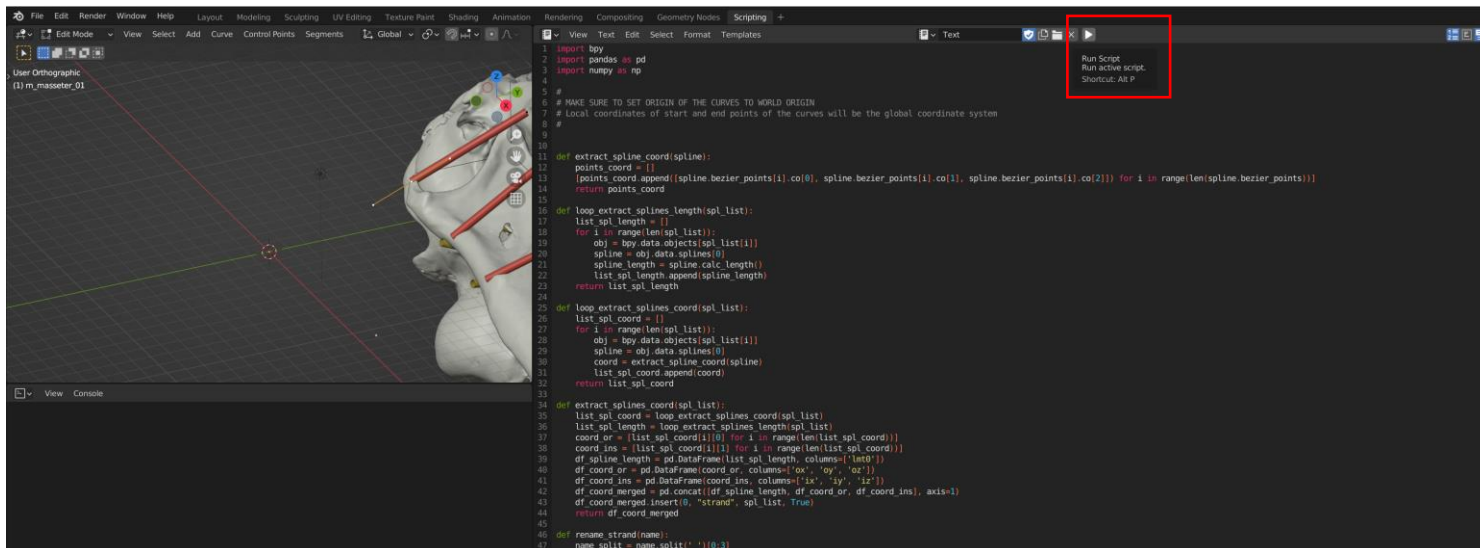


Building muscles

17. Once all the muscle strands have been built, and you have made sure that their reference frame is centred on the global reference frame go to the **Scripting** tab on top of the window.

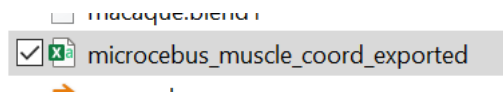





































In the Scripting tab, click on **Run Script**



Building muscles

18. Et voilà! A **.csv file** containing the coordinates of origin and insertion of the muscle strand has been created in the directory.



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Muscle
name

Muscle
strand
name

Muscle
strand
length

Muscle strand origin
point coordinates
(cranium)

Muscle strand
insertion point
coordinates
(mandible)

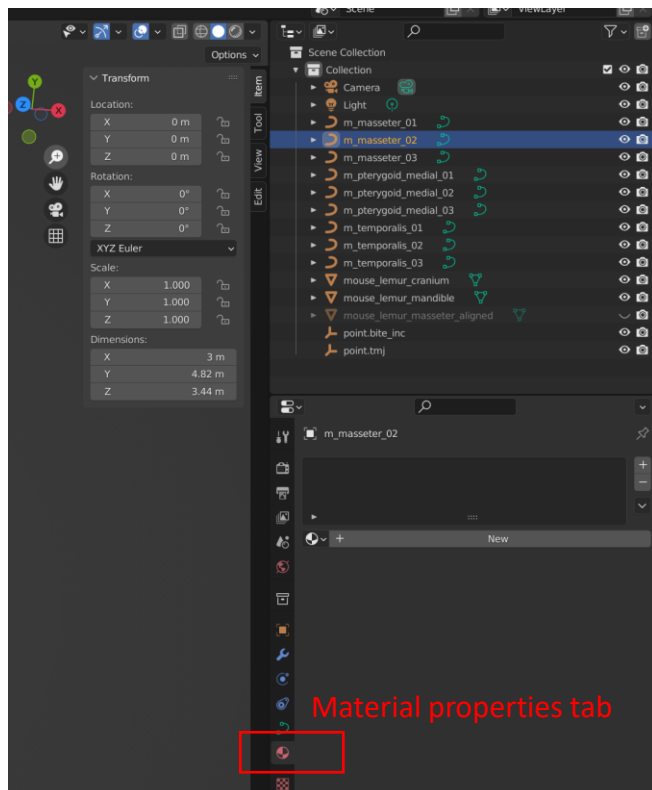
19. Once you have the .csv for the different species, **combine them into a single .csv file**. Insert a **first column** containing the **specie names**. Make sure that the specie names are strictly identical to those in the .csv containing the TMJ and bite point **coordinates!** These files are the **input variables** of the musculoskeletal model.

[illegible]

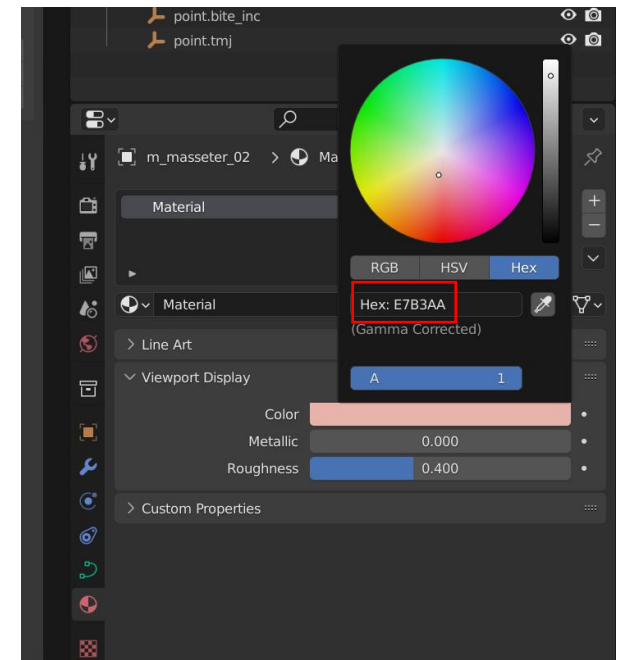
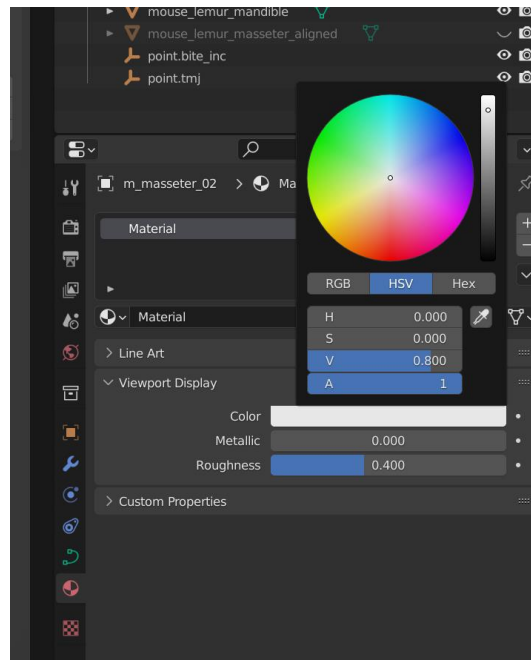
Building muscles - rendering

You can change the colour of the muscle strands. Using a different colour for each muscle group is nice and helpful not to get confused.

1. Select the strand of your choice and go to the **Material properties tab > New**

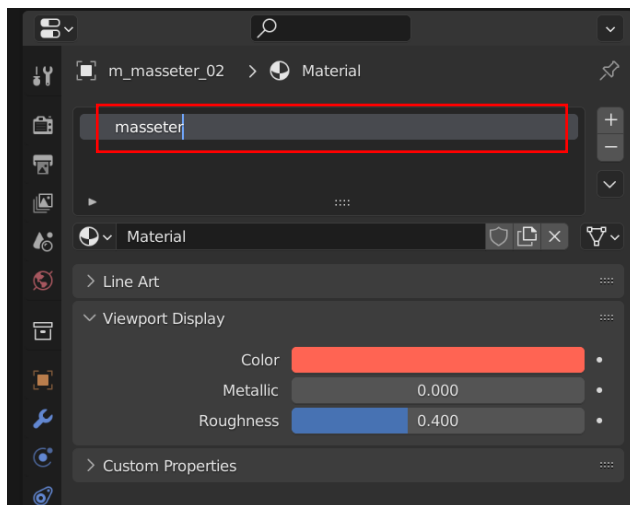


2. Double click on the **white rectangle** next to **Color** to display the colour wheel and select a colour. You can also copy-paste the HEX colour codes from the next slide.

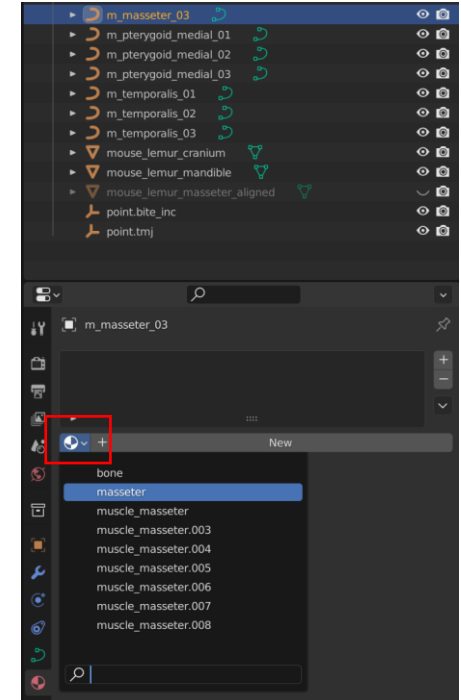


Building muscles - rendering

3. Rename your material by double clicking on it



4. Select another strand of the same muscle. Go to the **Material properties** tab and **click on the ball** to apply the material you have just created. You can **remove** the material by clicking on the – button on the right side of the panel.



HEX codes for muscle colours

Masseter = FF6453

Medial pterygoid = E3CD4B

Temporalis = 5A4BE3