Musculoskeletal study of cebocephalic and cyclopic lamb heads illuminates links between normal and abnormal development, evolution and human pathologies

Authors: Rui Diogo, Daria Razmadze, Natalia Siomava, Nora Douglas, Jose S. M. Fuentes, Andre Duerinckx

Supplementary Information 1, including SI Tab.1
### Table 1: Results obtained from specimens dissected by us (R=right; L=left; anomalies in red)

| Muscle Name                              | Normal (stage 1) | Abnormal (stage 2) | Abnormal (stage 3) | Abnormal (stage 4) |
|------------------------------------------|------------------|-------------------|-------------------|-------------------|
| Platysma myoides                         | Mainly normal    | Mainly normal     | Mainly normal     | Mainly normal     |
|   - Mainly from the neck/pectoral region to skin and muscles of mouth region |                  |                   |                   |                   |
|   - Mainly normal                         |                  |                   |                   |                   |
| Platysma cervicale                       | Mainly normal    | Mainly normal     | Mainly normal     | Mainly normal     |
|   - Mainly from the temporal/muscular region to skin and muscles of mouth region |                  |                   |                   |                   |
|   - Mainly normal                         |                  |                   |                   |                   |
| Retractor anguli oculi medius profundus   | Mainly normal    | Mainly normal     | Mainly normal     | Mainly normal     |
|   - From fascia covering anterior portion of masuetor, plus orbicularis oculi, to fascia of lower eyelid |                  |                   |                   |                   |
|   - Mainly normal                         |                  |                   |                   |                   |
| Sphincter colli profundus proprius       | Mainly normal    | Mainly normal     | Mainly normal     | Mainly normal     |
|   - Mainly deep to platysma cervicale and platysma myoides, gives rise to sphincter colli profundus pars palpebralis (note: it is not continuous with sphincter colli profundus pars palpebralis) |                  |                   |                   |                   |
|   - Mainly normal                         |                  |                   |                   |                   |
| Sphincter colli profundus pars palpebralis | Mainly normal    | Mainly normal     | Mainly normal     | Mainly normal     |
|   - Mainly from buccinatorius to lacrimal bone |                  |                   |                   |                   |

**Normal (stage 1)**: configuration seen in 6 sides of normal newborn lamb and adult sheep specimens.

**Abnormal (stage 2)**: dissected by DR and 6R (dissected by RD; stage 2).

**Abnormal (stage 3)**: dissected by RD, 6R, 5L, and 16R (dissected by ND; stage 2).

**Abnormal (stage 4)**: dissected by RD; stage 3.

**Normal (stage 1)**: primarily from skin of the neck/pectoral region to skin and muscles of mouth region.

**Abnormal (stage 2)**: dissected by DR and 6R (dissected by RD; stage 2).

**Abnormal (stage 3)**: dissected by RD, 6R, 5L, and 16R (dissected by ND; stage 2).

**Abnormal (stage 4)**: dissected by RD; stage 3.

**Normal (stage 1)**: primarily from skin of the temporal/muscular region to skin and muscles of mouth region.

**Abnormal (stage 2)**: dissected by DR and 6R (dissected by RD; stage 2).

**Abnormal (stage 3)**: dissected by RD, 6R, 5L, and 16R (dissected by ND; stage 2).

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**Normal (stage 1)**: primarily from skin of the temporal/muscular region to skin and muscles of mouth region.

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**Abnormal (stage 3)**: dissected by RD, 6R, 5L, and 16R (dissected by ND; stage 2).

**Abnormal (stage 4)**: dissected by RD; stage 3.

**Normal (stage 1)**: primarily from skin of the temporal/muscular region to skin and muscles of mouth region.

**Abnormal (stage 2)**: dissected by DR and 6R (dissected by RD; stage 2).

**Abnormal (stage 3)**: dissected by RD, 6R, 5L, and 16R (dissected by ND; stage 2).

**Abnormal (stage 4)**: dissected by RD; stage 3.

**Normal (stage 1)**: primarily from skin of the temporal/muscular region to skin and muscles of mouth region.

**Abnormal (stage 2)**: dissected by DR and 6R (dissected by RD; stage 2).

**Abnormal (stage 3)**: dissected by RD, 6R, 5L, and 16R (dissected by ND; stage 2).

**Abnormal (stage 4)**: dissected by RD; stage 3.
| Muscle Name | Region | Attachments | Shape | Fibers | Insertions | Other Notes |
|-------------|--------|-------------|-------|--------|------------|-------------|
| Sphincter colli profundus pars auricularis (= "Parotido-auricularis" or "Auricularis inferior et depressor auriculae" sensu May 1964) (Note: the mandibulauricularis, often named "styloauricularis" in ruminants, is absent in goats/sheep) | Deep to platysma cervicale, inserts dorsally to region of the ear | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Deeply involved in the area directly under the orbita. The other part lies more superficial, originate from the posterior area of the cheek from the sphincter colli profundus, and inserts onto the orbicularis oculi in the area. |
| Zygomaticus | From zygomatic bone to angle of mouth/upper lip | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| Levator labii superioris alaeque nasi (= "Levator nasolabialis" sensu | From skin if frontal and nasal regions, and from orbicularis oculi. | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Seemingly absent. |

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Region of the facial tuber, which is markedly more posterior than normally, to reach the eye region, and not posterodorsally as normally; that is, basically the size and direction of the fibers changes, but the attachments are mainly normal.

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| Region | Description | Notes |
|--------|-------------|-------|
| Nasalis (= 'Dilatator naris apicalis' or 'Transversus nasii' sensu May 1964) | From premaxilla ('incisive bone') to nostril, meeting its counterpart at the midline, to nostril and upper lip | Not analyzed |
| Dilatator naris lateralis (= 'Caninus' sensu Getty 1975, who confused the identity of the true caninus, which he named 'depressor labii maxillaris'; see below) | From facial tuber of maxilla to nostril | Wide but short because of truncation of snout, Mainly normal, Not analyzed |
| Levator labii superioris (= 'Levator labii superciliis', Levator labii superciliis) | From facial tuber of maxilla to upper lip and nostril | Wide but short because of truncation of snout, Mainly normal, Not analyzed, On the left side it originated as usual from facial tuber, but on the right side it originated anteriorly to the facial tuber; on both sides it attached mainly to the 'proboscis'; moreover, it was deeply fused with the levator anguli oris facialis and with the levator labii superioris on the right side, only two of these three muscles being really seen on that right side | Very peculiar, running from the facial tuber
| Muscle Name | Description | Left Side | Right Side |
|-------------|-------------|-----------|------------|
| Levator anguli oris \( \text{facialis} \) \( \text{(= Depressor labii maxillaris) or Depressor labii inferioris sensu May 1964)} \) | Running from the facial tuber almost completely dorsomedially to form a "constrictor" that met its counterpart at the midline just above the nose, i.e. it did not go at all to the region of the nasal proboscis | Not analyzed | Seemingly missing |
| Levator labii superioris proprius | Skin between nostrils, meeting its counterpart at the midline | Mainly normal | Mainly normal |
| Depressor labii inferioris \( \text{(= Depressor labii mandibularis) sensu May 1964; note that the depressor anguli oris is not present as a separate, well-}} \) | From mandible to inferior lip and adjacent skin | Mainly normal | Mainly normal |
| Detailed muscle | From | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
|-----------------|------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| Orbicularis oris (note: the ‘incisivus mandibularis/superior’ and ‘incisivus maxillaris/superior’ sensu May 1964 are part of the orbicularis oris sensu the present work) | From superior and inferior lips to mandible and skin around mouth | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| Buccinatorius | From the alveolar border of maxilla and mandible to the entire length of the cheek | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| Mentalis | From body of mandible near symphysis to skin of chin region | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| Orbicularis oculi | From palpebral ligament and lacrimal tubercle to skin of eyelid region | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| Frontalis (note that the levator anguli oculi medialis, or ‘corrugator supercilii’, is not present in ruminants according to Getty 1975, and not in sheep according to May 1964) | From skin of frontal region to eye region and skin of the dorsal surface of forehead | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| Zygomaticoauricularis (Zygomatico-auricularis sensu May 1964) (Note: we are not including in this study the numerous small facial muscles related to the movements of the ear, but our | From zygomatic arch to auricular cartilage | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| Muscle Name                  | Origin                                                                 | Insertion                                                                 | Observations                                                                 |
|-----------------------------|------------------------------------------------------------------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------|
| Zygomaticoauricularis (= 'Zygomaticoauricularis' sensu May 1964)      | From zygomatic arch to auricular cartilage                             | Mainly normal                                                              | Note: we are not including in this study the numerous small facial muscles related to the movements of the ear, but our dissections indicate that their presence, and attachments, were constant and similar to the normal phenotype in all abnormal specimens we analyzed, both the more and the less defective ones |
| Levator palpebrae superioris| From pterygoid crest to palpebral fascia of superior eyelid            | Mainly normal                                                              | Mainly normal                                                               |
| Rectus superioris           | From sphenoide bone to eye                                             | Mainly normal                                                              | Not analyzed                                                               |
| Rectus inferioris           | From sphenoide bone to eye                                             | Abnormal, fused with rectus medialis, although its attachments are as normal | Mainly normal                                                              |
| Rectus lateralis            | From sphenoide bone to eye                                             | Abnormal, fused with rectus inferioris, although its attachments are       | Mainly normal                                                              |
| Rectus medialis             | From region of optic foramen to eye                                    | Abnormal, fused with rectus inferioris, although its attachments are       | Seemingly missing                                                         |

Mainly normal: The muscle was observed to be normal in most cases.
Not analyzed: The muscle was not analyzed in this study.
Seemingly missing: The muscle was not consistently observed in the analysis.
Muscles of the ear

Zygomaticoauricularis (= 'Zygomaticoauricularis' sensu May 1964) (Note: we are not including in this study the numerous small facial muscles related to the movements of the ear, but our dissections indicate that their presence, and attachments, were constant and similar to the normal phenotype in all abnormal specimens we analyzed, both the more and the less defective ones)

| Muscles of the ear | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
|-------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| Zygomaticoauricularis from zygomatic arch to auricular cartilage | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |

Masseter

Superficial layer from facial tuber, maxilla and zygomatic arch portion of zygomatic bone; middle and deep layers from zygomatic arch, malar bone, and maxilla; superficial layer to caudal and ventral parts and to angle of mandible; middle layer to caudal and ventral borders and angle of ramus of mandible; deep layer to neck of ramus and articular surface of mandible, coronoid process,
| Muscles          | Origin                                                                 | Attachments                                                                 |
|------------------|------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| **Temporalis**   | From temporal bone, frontal and temporal crests and zygomatic arch to coronoid process of mandible | Mainly normal                                                               |
| **Pterygoideus medialis** | From palatine bone, pterygoid bone and pterygoid process of basiaphenoid bone, to medial surface of mandible | Mainly normal                                                               |
| **Pterygoideus lateralis** | Only one head; from pterygopalatine fossa and pterygoid process of basiaphenoid to medial surface of mandible and base of coronoid process | Mainly normal                                                               |
| **Digastricus**  | It is crossed by the stylohyoides, and the anterior and posterior digastic bellies are connected by thin intermediate tendon, which does not perforate the stylohyoides; the anterior head of digastricus is deeply blended with mylohyoides; digastricus as a whole runs from jugular ('paramastoid' sensu May 1964) process of | Mainly normal                                                               |
| Muscle                                      | Occipital bone to mandible                                                                 |
|---------------------------------------------|------------------------------------------------------------------------------------------|
| Mylohyoideus                                | Has superficial and deep bundles in sheep according to May 1964; both bundles run from   |
|                                             | mylohyoid line of mandible to hyoid bone and to midline raphe                          |
|                                             | Mainly normal                                                                           |
|                                             | Much shorter than normal, but basically same attachments                                |
| Stylohyoideus                               | Has a long thin tendon of origin, from muscular angle of stylohyoid bone ('great cornu   |
|                                             | of hyoid bone' sensu May 1964) to basihyoid bone ('body of hyoid bone' sensu May 1964)  |
|                                             | Much shorter than normal, but basically same attachments                                |
| Jugulohyoideus (= 'Occipitohyoideus' sensu | From jugular process of occipital bone to stylohyoid bone                                |
| May 1964)                                   | Mainly normal                                                                           |
| Geminohyoideus                              | Contacts with counterpart at midline, from mandible just near to stylohyoid              |
|                                             | Mainly normal                                                                           |
| Ceratohyoideus                              | From ceratohyoid (and also stylohyoid according to May 1964) to stylohyoid              |
|                                             | Mainly normal                                                                           |
| Hyoideus transversus                        | Connects ceratohyoid cartilages                                                        |
|                                             | Mainly normal                                                                           |
| Styloglossus                                | From stylohyoid to tongue                                                                |
|                                             | Mainly normal                                                                           |
| Hyoglossus                                  | From basihyoid and lingual process of                                                   |
|                                             | Mainly normal                                                                           |
| Muscle           | Origin                                                                 | Insertion                                                                 | Status                  |
|------------------|-------------------------------------------------------------------------|---------------------------------------------------------------------------|-------------------------|
| Hyoglossus       | From basihyoid and lingual process of thyrohyoid (but from stylohyoid according to May 1964, what seems to be a mistake) to tongue | Mainly normal                                                             | Mainly normal           |
| Genioglossus     | From mandible (chin) just near to symphysis, to tongue                  | Mainly normal                                                             | Mainly normal           |
| Hyoepiglotticus  | Contacts its counterpart at midline; innervated by hypoglossal nerve, so seems to be hypobrachial muscle, not true laryngeal or pharyngeal muscle; runs from basihyoid to epiglottic cartilage | Not analyzed                                                             | Not analyzed            |
| Cricothyroideus  | From posterior border and lateral surface of arch of cricoid cartilage to lateral surface of, and lateral surface of, thyroid cartilage | Mainly normal                                                             | Mainly normal           |
| Cricothyroideus posterior (= Cricothyroideus dorsalis) | From dorsal surface and median ridge of lamina of cricoid cartilage to arytenoid cartilage | Mainly normal                                                             | Mainly normal           |
| Cricothyroideus lateralis | From nostril border and lateral surface of arch of cricoid cartilage to muscular | Mainly normal                                                             | Mainly normal           |
| Muscle                  | Origin                        | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
|------------------------|-------------------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| Arytenoideus (= Arytenoideus transversus) | Unpaired, from arytenoid cartilages to arytenoid cartilages |               |               |               |               |               |               |               |               |               |               |
| Thyroarytenoideus      | From thyroid cartilage to arytenoid cartilage | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
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Supplementary Information 1, including SITab.1
| muscle | Normal (stage 1) | Abnormal specimen 6L (dissected by DR) and 6R (dissected by ND; stage 2) | Abnormal specimen 12L and 2R, 2L, 5L, 5R, and 10R and 16R (dissected by RD; stage 2) | Abnormal specimen 65L and 65R (dissected by RD; stage 2) | Abnormal specimen 122AL and 122AR (dissected by RD; stage 2) | Abnormal specimen 4L and 4R (dissected by RD; stage 3) | Abnormal specimen 9L and 9R (dissected by ND; stage 3) | Abnormal specimen 5L (dissected by ND) and 3R (dissected by RD; stage 4) | Abnormal specimen 11L (dissected by RD; stage 4) | Abnormal specimen 199R and 199L (dissected by RD; stage 4) | Abnormal specimen 993R (dissected by RD; stage 4) |
|--------|-----------------|------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|
| Platysma myoides | Mainly from skin of the neck/pectoral region to skin and muscles of mouth region | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| Platysma cervicale | Mainly from skin of temporal/mucaul region to skin and muscles of mouth region | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| Retractor anguli oculi medius profundus (= "Posterior portion of malaris" or "depressor palpebrar inferioris" sensu May 1964) | Mainly from deep fascia covering anterior portion of masueter, plus orbicularis oculi, to fascia of lower eyelid | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Abnormal: seems to be not present as a separated muscle | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| Sphincter coli profundus proprius | Mainly deep to platysma cervicale and platysma myoides, gives rise to sphincter coli profundus pars palpebralis (note: it is not continuous with sphincter coli profundus pars palpebralis) | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Abnormal, because due to the truncation of the snout, it runs antero-dorsally (as it originates mainly from the) | Abnormal, because due to the truncation of the snout, it runs antero-dorsally (as it originates mainly from the) | Abnormal, because due to the truncation of the snout, it runs antero-dorsally (as it originates mainly from the) | Abnormal, because due to the truncation of the snout, it runs antero-dorsally (as it originates mainly from the) | Abnormal, because due to the truncation of the snout, it runs antero-dorsally (as it originates mainly from the) | Seemingly missing | Seemingly missing |
| Sphincter coli profundus pars palpebralis (= "Anterior portion of malaris" or "levator buccalis" sensu May 1964) | Mainly from buccinatorium to lacrimal bone | Mainly normal | Mainly normal | Abnormal, because due to the truncation of the snout, it runs antero-dorsally (as it originates mainly from the) | Abnormal, because due to the truncation of the snout, it runs antero-dorsally (as it originates mainly from the) | Abnormal, because due to the truncation of the snout, it runs antero-dorsally (as it originates mainly from the) | Abnormal, because due to the truncation of the snout, it runs antero-dorsally (as it originates mainly from the) | Abnormal, because due to the truncation of the snout, it runs antero-dorsally (as it originates mainly from the) | Abnormal, because due to the truncation of the snout, it runs antero-dorsally (as it originates mainly from the) | Abnormal, because due to the truncation of the snout, it runs antero-dorsally (as it originates mainly from the) | Abnormal, because due to the truncation of the snout, it runs antero-dorsally (as it originates mainly from the) | Seemingly missing | Seemingly missing |
| Muscle Name | Description | Normality | Abnormality |
|-------------|-------------|-----------|-------------|
| **Sphincter colli profundus pars auricularis** (= "Parotidoauricularis" or "Auricularis inferior et depressor auriculae" sensu May 1964) (Note: the mandibuloauricular is, often named "stylauricularis" in ruminants, is absent in goats/sheep) | Deep to platysma cervicale, inserts dorsally to region of the ear | Mainly normal | Mainly normal |
| **Zygomaticus** | From zygomatic bone to angle of mouth/upper lip | Mainly normal | Mainly normal |
| **levator labii superioris alaeque nasi** (= "levator nasolabialis" sensu) | From skin of frontal and nasal regions, and from orbicularis oculi | Mainly normal | Mainly normal |

*Note:* The table format is not correctly represented in the text. The text should be formatted as a table with the following structure:

| Muscle Name | Description | Normality | Abnormality |
|-------------|-------------|-----------|-------------|
| **Sphincter colli profundus pars auricularis** (= "Parotidoauricularis" or "Auricularis inferior et depressor auriculae" sensu May 1964) (Note: the mandibuloauricular is, often named "stylauricularis" in ruminants, is absent in goats/sheep) | Deep to platysma cervicale, inserts dorsally to region of the ear | Mainly normal | Mainly normal |
| **Zygomaticus** | From zygomatic bone to angle of mouth/upper lip | Mainly normal | Mainly normal |
| **levator labii superioris alaeque nasi** (= "levator nasolabialis" sensu) | From skin of frontal and nasal regions, and from orbicularis oculi | Mainly normal | Mainly normal |
| Muscle Name | Description | Details |
|-------------|-------------|---------|
| Nasalis \(=\) 'Dilatator naris apicalis' or 'Transversus nasi' sensu May 1964 | From premaxilla ('incisive bone') to nostril, meeting its counterpart at the midline, to nostril and upper lip | Not analyzed |
| Dilatator naris lateralis \(=\) 'Caninus' sensu Getty 1975, who confused the identity of the true caninus, which he named 'depressor labii maxillaris'; see below | From facial tuber of maxilla to nostril | Wide but short because of truncation of snout, Mainly normal |
| Levator labii superioris \(=\) 'Levator labii | From facial tuber of maxilla to upper lip and noper | Wide but short because of truncation of snout, Mainly normal |

Note: the dilatator naris alaris is seemingly poorly developed in the ox (Getty 1975) and very reduced/absent in sheep, as it was not described as a separate muscle by May 1964, nor found by us; according to Getty 1975 in ruminants it is usually fused with the levator anguli oris facialis, levator labii superioris alaeque nasi, levator labii superioris and dilatator naris lateralis, originating from the premaxilla and lateral nasal cartilages, and inserting onto the nostril.

On the left side it originated as usual from facial tuber, but on the right side it originated anteriorly to the facial tuber; on both sides it attached mainly to the 'proboscis'; moreover, it was deeply fused with the levator anguli oris facialis and with the levator labii superioris on the right side, only two of these three muscles being really seen on that right side.

On the right side only a muscle was present where the dilatator naris lateralis and levator anguli oris facialis are usually present, while on the left side both muscles were present as distinct structures.

On the left side it originated as usual from facial tuber; on the right side only a muscle was present where the dilatator naris lateralis and levator anguli oris facialis are usually present; it was difficult to analyze these muscles on the left side.

On both the left and right there was seemingly only a muscle where normally lie the levator anguli oris facialis and the dilatator naris lateralis.
| Muscle(s) | Descriptive Details |
|-----------|---------------------|
| Maxillaris (or 'Levator labii superioris proprius' sensu May 1964) | skin between nostrils, meeting its counterpart at the midline |
| Levator anguli oris facialis (='Depressor labii maxillaris' or 'Depressor labii inferioris' sensu May 1964) | From maxilla to nostril and upper lip, mainly normal, not analyzed |
| Depressor labii inferioris ('Depressor labii mandibularis' sensu May 1964; note that the depressor angularis oris is not present as a separate, well-developed muscle) | From mandible to inferior lip and adjacent skin, mainly normal, not analyzed |

Note: in the text above, 'snout' refers to the region of the animal's nose and upper lip, and 'proboscis' to the elongated nose and upper lip characteristic of some species. The 'dilatator naris lateralis' is a muscle involved in dilating the nostrils. The 'buccinatorius' is another muscle involved in the movement of the lips and cheeks. The 'facial tuber' is a prominence on the side of the face. The 'nasal proboscis' is the elongated nose region. The 'levator labii superioris proprius' is a muscle that helps elevate the upper lip. The 'levator anguli oris facialis' is a muscle that elevates the angle of the mouth. The 'depressor labii maxillaris' is a muscle that helps depress the upper lip. The 'depressor labii inferioris' is a muscle that helps depress the lower lip. The 'constrictor' is a muscle involved in constricting or narrowing a body part. The 'levator labii inferioris' is a muscle that helps elevate the lower lip.
| Muscle            | Description                                                                 | Typically | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
|-------------------|-----------------------------------------------------------------------------|-----------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| Orbicularis oris  | From superior and inferior lips to mandible and skin around mouth          | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| (note: the 'incisivus mandibularis/superior' and 'incisivus maxillaris/superior' sensu May 1964 are part of the orbicularis oris sensu the present work) | | | | | | | | | | | | | | | | | | |
| Buccinator        | From the alveolar border of maxilla and mandible to the entire length of the cheek | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| Mentalis          | From body of mandible near symphysis to skin of chin region                 | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| Orbicularis oculi | From palpebral ligament and lacrimal tubercle to skin of eyelid region      | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| Frontalis         | From skin of frontal region to eye region and skin of the dorsal surface of forehead | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| Zygomaticoauricularis arteriosus (= Zygomatico-auricularis arteriosus sensu May 1964) (Note: we are not including in this study the numerous small facial muscles related to the movements of the ear, but nor) | From zygomatic arch to auricular cartilage | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| Muscle Name                   | From                                      | Normal Observation                                                                                                                                                                                                                                                                                                                                 |
|------------------------------|-------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Zygomaticoauricularis (= 'Zygomaticoauricularis' sensu May 1964) | From zygomatic arch to auricular cartilage | (Note: we are not including in this study the numerous small facial muscles related to the movements of the ear, but our dissections indicate that their presence, and attachments, were constant and similar to the normal phenotype in all abnormal specimens we analyzed, both the more and the less defective ones) |
| Levator palpebrae superioris | From pterygoid crest to palpebral fascia of superior eyelid | Mainly normal                                                                                                                                                                                                                                                                                                                                       |
| Rectus superioris            | From sphenoid bone to eye                 | Mainly normal                                                                                                                                                                                                                                                                                                                                       |
| Rectus inferioris            | From sphenoid bone to eye                 | Abnormal, fused with rectus medialis, although its attachments are as normal Mainly normal Mainly normal Mainly normal Mainly normal Mainly normal Mainly normal Mainly normal Mainly normal Mainly normal Mainly normal Mainly normal Not analyzed Mainly normal |
| Rectus lateralis             | From sphenoid bone to eye                 | Mainly normal Mainly normal Mainly normal Mainly normal Not analyzed Mainly normal Mainly normal Mainly normal Mainly normal Mainly normal Mainly normal Mainly normal Not analyzed Mainly normal |
| Rectus medialis             | From region of optic foramen to eye       | Abnormal, fused with rectus inferioris, although its attachments are as normal Mainly normal Mainly normal Mainly normal Not analyzed Mainly normal Mainly normal Mainly normal Mainly normal Mainly normal Mainly normal Seemingly missing Seemingly missing Not analyzed Missing |
Muscles of the ear

| Muscles of the ear | (Note: we are not including in this study the numerous small facial muscles related to the movements of the ear, but our dissections indicate that their presence, and attachments, were constant and similar to the normal phenotype in all abnormal specimens we analyzed, both the more and the less defective ones) |
|--------------------|--------------------------------------------------------------------------------------------------|
| Zygomaticoauricularis (= 'Zygomatico-auricularis' sensu May 1964) | From zygomatic arch to auricular cartilage |
| Masseter | Superficial layer from facial tuber, maxilla and zygomatic arch portion of zygomatic bone; middle and deep layers from zygomatic arch, malar bone, and maxilla; superficial layer to caudal and ventral parts and to angle of mandible; middle layer to caudal and ventral borders and angle of ramus of mandible; deep layer to neck of ramus and articular surface of mandible, coronoid process, |
| Muscles          | Description                                                                                                                                   | Status   | Status | Status | Status | Status | Status | Status | Status | Status | Status |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|----------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| **Temporalis**   | From temporal bone, frontal and temporal crests and zygomatic arch to coronoid process of mandible                                             | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
|                  |                                                                                                                                               |          |        |        |        |        |        |        |        |        |        |
| **Pterygoideus medialis** | From palatine bone, pterygoid bone and pterygoid process of basi-sphenoid bone, to medial surface of mandible                                    | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
|                  |                                                                                                                                               |          |        |        |        |        |        |        |        |        |        |
| **Pterygoideus lateralis** | Only one head; from pterygoalatine fossa and pterygoid process of basi-sphenoid to medial surface of mandible and base of coronoid process | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
|                  |                                                                                                                                               |          |        |        |        |        |        |        |        |        |        |
| **Digastricus**  | It is crossed by the stylohyoideus, and the anterior and posterior digastric bellies are connected by thin intermediate tendon, which does not perforate the stylohyoideus; the anterior head of digastricus is deeply blended with mylohyoideus; digastricus as a whole runs from jugular (‘paramastoid’ sensu May 1964) process of | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| Occipital bone to mandible | Mylohyoideus | Stylohyoideus | Jugulothyoideus | Geniothyoideus | Ceratothyoideus | Hyoideus transversus | Styloglossus | Hyoglossus |
|---------------------------|--------------|---------------|----------------|---------------|-----------------|---------------------|--------------|-----------|
| Has superficial and deep bundles in sheep according to May 1964; both bundles run from mylohyoid line of mandible to hyoid bone and to midline raphe | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| Has a long thin tendon of origin; from muscular angle of stylohyoid bone ("great cornu of hyoid bone" sensu May 1964) to basihyoid bone ("body of hyoid bone" sensu May 1964) | Much shorter than normal, but basically same attachments | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| From jugular process of occipital bone to stylohyoid bone | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| Contacts with counterpart at midline; from mandible just near to symphysis, to basihyoid | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| From ceratohyoid (and also stylohyoid according to May 1964) to stylohyoid | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| Connects ceratohyoid cartilages | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| From stylohyoid to tongue | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| From basihyoid and lingual process of | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| Muscle                  | Anatomical Origin                                                                 | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
|------------------------|-----------------------------------------------------------------------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| Hyoglossus             | From basihyoid and lingual process of thyrohyoid (but from stylohyoid according to May 1964, what seems to be a mistake) to tongue |               |               |               |               |               |               |               |               |               |               |               |               |               |               |
| Genioglossus           | From mandible (chin) just near to symphysis, to tongue                            | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| Hyoepiglotticus        | Contacts its counterpart at midline; innervated by hypoglossal nerve, so seems to be hypobrachial muscle, not true laryngeal or pharyngeal muscle; runs from basihyoid to epiglottic cartilage | Not analyzed  | Not analyzed  | Not analyzed  | Not analyzed  | Not analyzed  | Not analyzed  | Not analyzed  | Not analyzed  | Not analyzed  | Not analyzed  | Not analyzed  | Not analyzed  | Not analyzed  | Not analyzed  |
| Cricothyroideus        | From posterior border and lateral surface of arch of cricoid cartilage; lateral surface of lamina of, and lateral surface of, thyroid cartilage | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| Cricothyroideus posterior (Cricothyroideus dorsalis) | From dorsal surface and median ridge of lamina of cricoid cartilage to arytenoid cartilage | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| Cricothyroideus lateralis | From posterior border and lateral surface of arch of cricoid cartilage to muscular | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| Muscles                      | Description                                                                 | Description 1 | Description 2 | Description 3 | Description 4 | Description 5 | Description 6 | Description 7 | Description 8 | Description 9 | Description 10 | Description 11 | Description 12 | Description 13 |
|------------------------------|-----------------------------------------------------------------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|----------------|----------------|----------------|----------------|
| Arytenoideus (Arytenoideus transversus) | Unpaired, from arytenoid cartilages to arytenoid cartilages                  | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
| Thyroarytenoideus            | From thyroid cartilage to arytenoid cartilage                                | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal | Mainly normal |
Musculoskeletal study of cebocephalic and cyclopic lamb heads illuminates links between normal and abnormal development, evolution and human pathologies

Authors: Rui Diogo, Daria Razmadze, Natalia Siomava, Nora Douglas, Jose S. M. Fuentes, Andre Duerinckx

Supplementary Information 2, including summarized methods, as well as results, of morphometric analysis

For the morphometric analysis of all the left and right sides of the skull of each abnormal specimen dissected by us, we first removed all the soft tissues of those specimens, and then used landmarks that are consistently used for morphometric analysis of mammalian skulls (junction of the front tooth and maxilar bone; connection between the zygomatic and temporal bones in the zygomatic arch; faci tuber; around the eye; see e.g. Bookstein 1991), in order to run our analyses, which included Procrustes ANOVA. Skull halves were photographed on a flat horizontal surface with a camera Nikon D5000 fixed in a strict vertical position. Shape of skulls was analyzed using landmark-based geometric morphometric methods (Bookstein, 1991; Rohlf, 1990). Images were digitized using tpsUtil (Rohlf, 2004) and tpsDig2 (Rohlf, 2010). Series of landmarks along the mandible and eye hole were placed equidistant along the curvature. We applied the generalized Procrustes analysis (GPA) (Dryden and Mardia, 2002; Slice, 2005) in MorphoJ 1.05f (Klingenberg, 2008, 2011) to align the landmarks. Right and left halves were analyzed separately. Shape variation was studied by performing (1) Principal Component Analysis (PCA) of the data with the allometric component included (total shape variation) and (2) PCA after the regression of the centroid size on shape (pure shape) and visualizing the shape with a scatter plot and morphological differences with thin-plate spline (TPS) deformation grids (Bookstein, 1991; James Rohlf and Marcus, 1993; Slice, 2005; Thompson, 1917). To visualize the association between size and shape, we plotted shape scores against WCS. The amount of shape variation was given as a percentage of the total variation around the sample mean. The percentage numbers were computed to shows the relative importance of allometry for shape variation in each part of the skull. A permutation test with 10,000 runs (Good, 1994; Pitman, 1937) was applied to test independence between size and shape changes. A discriminant function analysis (DFA) and canonical variate analysis (CVA) were used to distinguish between groups. Procrustes ANOVA was used to estimate the fluctuating asymmetry (FA, asymmetric variation within one individual) and directional asymmetry (DA, one side is systemically different from the other one) in both centroid size and shape.

Because the lower jaw is movable, it is difficult to always keep it exactly within the same position in the skulls: because this factor may affect the overall result we analyzed the jaw separately. The results for the lower jaw are shown in Fig. 6 of the main paper, and are also shown in the figure just below. Other parts of the skull were also have to split into regions. For example, when we analyze the snout, we cannot use true cyclops (stage 4) because they basically don't have a ossified snout. On the other hand, we can analyze the brain case in all specimens. Thus, we obtained different groupings depending on what regions were included in the various morphometric analyses. The main results are summarized below:
Lower jaw:

**Fig. PCA Lower jaw. Variation of shape of mandible in animals with different degree of defects.** PCA of shape scatter plot (PC1 and PC2) and associated shape changes of non-allometric shape component of eye curvature and snout. The TPS deformation grids illustrate shape changes indicating the relative shifts of landmarks along the PC1 axes with PC scale factor +/-0.1 and along the PC2 axes with PC scale factor +/-0.05. Shape of lower jaw is significantly different between degrees 2, 3 and 4. The difference between groups is clear along PC1, which is mainly a change in curvature of lower surface of mandible and position of coronoid and condylar processes relative to body of the mandible.

• Contrarily to what we found concerning soft tissue pattern (i.e. usual asymmetry between left and right sides), there is no directional asymmetry (DA, i.e. in which one side would be systemically different from the other one) in the skull in size (Centroid Size, p= 0.7863) or shape (p= 0.7141) revealed by Proctustes ANOVA (see Table Proctustes ANOVA below):

| Effect          | SS     | MS     | df | F     | P (param.) |
|-----------------|--------|--------|----|-------|------------|
| Individual      | 1069415.665813 | 1069415.665813 | 10 | 0.32  | 0.012      |
| Side            | 14600.301372  | 14600.301372  | 1  | 6.00  | 0.003      |
| Ind * Side      | 1513595.718121 | 1513595.718121 | 16 | 1602.80 | <0.001     |
| Error I         | 2458.154705  | 113.144763   | 22 |       |            |

| Effect          | SS     | MS     | df | F     | P (param.) |
|-----------------|--------|--------|----|-------|------------|
| Individual      | 0.25472646  | 0.0002054239 | 1240 | 16.78 | <0.001     |
| Side            | 0.00217679  | 0.0000217679  | 124 | 0.92  | 0.7141     |
| Ind * Side      | 0.02662667  | 0.00002054239 | 1240 | 0.56  | <0.001     |
| Error I         | 0.00010697  | 0.00000099901 | 2128 |       |            |

• However, there is a strong fluctuating asymmetry (FA, asymmetric variation within one individual) in both size (Centroid Size, p<0.005) and shape (p<0.0001) (Table Proctustes ANOVA; AL PCA, specimen 199). FA
and right sides. The left and right sides develop as more or less separate copies of each other within the same genome and in *nearly* the same environment. There are a variety of random processes at the molecular and cellular levels that can affect development and therefore may produce small differences between body parts even if genetic and environmental differences are absent. The differences between left and right sides are an opportunity to measure this variation and FA can therefore be used as a measure of the ‘imprecision’ of developmental processes, or *developmental instability*.

- All analysis were performed with true landmarks (LM), no semilandmark (semiLM) as the curvature of the lower jaw is very different between individuals. Relaxation of semiLM leads to their rearrangement and does not depict the trend. Repeated measurements show that the error of LM analysis is relatively low (Table Proctustes ANOVA) and suggest that the results obtained are reliable.
- R and L sides were not averages as each of them includes important information information.
- When the allometric component were included, the Principal Component 1 (PC1) explains 84.5% of the shape variation. Other PCs explain <5% (PC2 4.2%). Transformation grids located in corners of the graph illustrate shape changes along PC1 and PC2. For the PC1, it’s mainly changing of the jaw curvature. In more defective specimens, the lower jaw is wider and bent upward; in less defective specimens, the jaw is straighter. Another shape alteration is the widening of the condylar process in cyclop specimens (stage 4).
- The allometric component is very strong and can explain 49.1% of the variation (p<0.0001). In general, most defective specimens are smaller than others. However, stages 3 and 4 significantly overlap in size, as can see in this figure showing Regression:
**Fig. Regressions. Regression of centroid size on shape.** A distribution of different shapes of mandible (top panel), brain case (middle panel), and face (bottom panel) across specimens with different skull sizes. There is a clear distribution of mandible shape along size of skull and degree of defect. Specimens with stage 4 have the largest and the smallest brain cases. Animals with the stage 2 tend to have larger frontal parts of the skull than animals with stage 3, but they still substantially overlap.
• Correction for size removes the difference between stages 2 and 3 (Discriminant Function Analysis, DFA and Canonical Variate Analysis, CVA) but shape changes along PC1 and PC2 remain similar (not shown). Stage 4 is always statistically different (p<0.05) from the other two (Table CVA, top: allometric component included, bottom: excluded).

| Correction for size removes the difference between stages 2 and 3 (Discriminant Function Analysis, DFA and Canonical Variate Analysis, CVA) but shape changes along PC1 and PC2 remain similar (not shown). Stage 4 is always statistically different (p<0.05) from the other two (Table CVA, top: allometric component included, bottom: excluded). |

Specimens 199 and 993 (the most defective, stage 4, specimens) are often outliers in the morphometric analyses. Specimen 993 has the jaw most bent upward. Specimen 199 has almost no brain, but the analysis shows that not only the brain case is defective but also the facial bones and the lower jaw, in particular.

| Table Procrustes ANOVA            | PC1 (AI) | PC2 (AI) | PC3 (AI) | Predicted Allometry | PC1 (Shape) | PC2 (Shape) | PC3 (Shape) |
|-----------------------------------|----------|----------|----------|---------------------|------------|------------|------------|
| Lower Jaw (All)                   | 84.462   | 4.225    | 12.109   | 49.0954% (p<0.0001) | 72.120     | 8.241      |
| Back Skull (All)                  | 46.178   | 16.432   | 12.109   | 11.7204% (p=0.0202) | 48.077     | 16.915     | 10.050     |
| St. 4: Front Skull                | 80.475   | 12.125   | 4.032    | 36.3108% (p=0.1078) | 55.253     | 16.189     | 9.650      |
| St. 2-3: Front Skull              | 66.318   | 11.203   | 7.166    | 30.8352% (p=0.0016) | 55.253     | 16.189     | 9.650      |
PCA Brain case:

**Fig. PCA Brain case. Variation of shape of brain case in animals with different degree of defects.** PCA of shape scatter plot (PC1 and PC2) and associated shape change of non-allometric shape component of skulls. The TPS deformation grids illustrate shape changes indicating relative shifts of landmarks along axes with the PC scale factor +/-0.1. Specimens 993 and 199 are outliers. Other specimens do not show essential overlap in the shape of the brain case.
PCA Face Stages 2 and 3:

**Fig. PCA Face (Stages 2 and 3). Variation of shape of frontal part of skull in animals with different degree of defects.** PCA of shape scatter plot (PC1 and PC2) and associated shape changes of non-allometric shape component of eye and snout. The TPS deformation grids illustrate shape changes indicating the relative shifts of landmarks along the axes with PC scale factor +/-0.15. Shape of frontal part of skull is significantly different between stages 2 and 3. The difference between groups is present along PC1, which mainly concerns the length of the snout.
PCA Face Stage 4:

Fig. PCA Face (Stage 4). Variation of shape of frontal part of skull in animals with stage 4. PCA of shape scatter plot (PC1 and PC2) and associated shape changes of non-allometric shape component of the eye curvature and snout. The TPS deformation grids illustrate shape changes indicating relative shifts of landmarks along axes with PC scale factor ±0.1. Specimens 3 and 11 have similar shapes of the face; specimen 993 is rather unique as it is distant from other specimens along both PC1 and PC2.
CVA: Lower Jaw

Procrustes distances among groups:

|   | 2   | 3   | 4   |
|---|-----|-----|-----|
| 3 | 0.1113 |     |     |
| 4 | 0.2366 | 0.1289 |     |

F-values from permutation tests (10000 permutation rounds) for Procrustes distances among groups:

|   | 2   | 3   | 4   |
|---|-----|-----|-----|
| 3 | 0.6001 |     |     |
| 4 | 0.0026 | <.0001 |     |

Procrustes distances among groups:

|   | 2   | 3   | 4   |
|---|-----|-----|-----|
| 3 | 0.6346 |     |     |
| 4 | 0.0094 | 0.0020 |     |

F-values from permutation tests (10000 permutation rounds) for Procrustes distances among groups:

|   | 2   | 3   | 4   |
|---|-----|-----|-----|
| 3 | 0.2526 |     |     |
| 4 | 0.0026 |     |     |

CVA: Back Skull

Procrustes distances among groups:

|   | 2   | 3   | 4   |
|---|-----|-----|-----|
| 3 | 0.0926 |     |     |
| 4 | 0.1084 | 0.1064 |     |

F-values from permutation tests (10000 permutation rounds) for Procrustes distances among groups:

|   | 2   | 3   | 4   |
|---|-----|-----|-----|
| 3 | 0.0698 |     |     |
| 4 | 0.0490 | 0.0432 |     |

Procrustes distances among groups:

|   | 2   | 3   | 4   |
|---|-----|-----|-----|
| 3 | 0.0912 |     |     |
| 4 | 0.1842 | 0.1158 |     |

F-values from permutation tests (10000 permutation rounds) for Procrustes distances among groups:

|   | 2   | 3   | 4   |
|---|-----|-----|-----|
| 3 | 0.0692 |     |     |
| 4 | 0.0172 | 0.0123 |     |
DFA: Non-Cyclops: Front Skull

**Discriminant Function Analysis 'Discriminant function Non-Cyclops: Front Skull'**

*Comparison: 2 -- 3*

| Discriminant Function Analysis 'Discriminant function Non-Cyclops: Front Skull' |
|---|
| **Comparison: 2 -- 3** |
| **Difference between means:** |
| Procrustes distance: 0.1412444 |
| Mahalanobis distance: 1.6484 |
| T-square: 134.3768, P-value (parametric): 0.7406 |
| P-values for permutation tests (1000 permutation runs): |
| Procrustes distance: <.0001 |
| T-square: 6.0170 |
| (Note: The permutation test using the T-square statistic is equivalent to a test using Mahalanobis distance.) |

**Classification/misclassification tables**

| Group | Group 1 | Group 2 | Total |
|---|---|---|---|
| Group 1 | 4 | 0 | 4 |
| Group 2 | 0 | 15 | 15 |

**From cross-validation:**

| True Allocated to |
|---|
| Group | Group 1 | Group 2 | Total |
|---|---|---|---|
| Group 1 | 3 | 1 | 4 |
| Group 2 | 2 | 13 | 15 |

---

**Discriminant Function Analysis 'Discriminant function ...'**

*Comparison: 2 -- 3*

| Discriminant Function Analysis 'Discriminant function ...' |
|---|
| **Comparison: 2 -- 3** |
| **Difference between means:** |
| Procrustes distance: 0.1103708 |
| Mahalanobis distance: 5.2782 |
| T-square: 97.5701, P-value (parametric): 0.9125 |
| P-values for permutation tests (1000 permutation runs): |
| Procrustes distance: <.0001 |
| T-square: 9.9240 |
| (Note: The permutation test using the T-square statistic is equivalent to a test using Mahalanobis distance.) |

**Classification/misclassification tables**

| Group | Group 1 | Group 2 | Total |
|---|---|---|---|
| Group 1 | 4 | 0 | 4 |
| Group 2 | 0 | 15 | 15 |

**From cross-validation:**

| True Allocated to |
|---|
| Group | Group 1 | Group 2 | Total |
|---|---|---|---|
| Group 1 | 2 | 2 | 4 |
| Group 2 | 2 | 13 | 15 |
### Procrustes ANOVA: Lower Jaw

Asymmetries are computed and displayed as 'R' minus 'L'.

Classifiers used for the Procrustes ANOVA:
- Individuals: Specimen
- Sides: Side
- Error 1: Repeat

**Centroid size:**

| Effect    | SS    | MS    | df | F   | F (param.) |
|------------|-------|-------|----|-----|------------|
| Individual | 15094156.659813 | 1509416.65981 | 10 | 24.97 | <.0001     |
| Side       | 1460.301372 | 1460.301372 | 1  | 6.23  | 0.0480     |
| Ind * Side | 604831.954404 | 604831.954404 | 10 | 354.30 | <.0001     |
| Error 1    | 2659.1041755 | 113.447643 | 22 |       |            |

**Shape, Procrustes ANOVA:**

| Effect    | SS    | MS    | df | F   | F (param.) |
|------------|-------|-------|----|-----|------------|
| Individual | 0.25472856 | 0.0002054827 | 124 | 10.78 | <.0001     |
| Side       | 0.00217879 | 0.0000175769 | 124 | 0.92  | 0.3341     |
| Ind * Side | 0.00206287 | 0.0000158934 | 124 | 48.85 | <.0001     |
| Error 1    | 0.00146665 | 0.0000003591 | 271 |       |            |

### Procrustes ANOVA: Back Skull

Asymmetries are computed and displayed as 'R' minus 'L'.

Classifiers used for the Procrustes ANOVA:
- Individuals: Specie
- Sides: Side
- Error 1: Repeat

**Centroid size:**

| Effect    | SS    | MS    | df | F   | F (param.) |
|------------|-------|-------|----|-----|------------|
| Individual | 974126.720478 | 974126.720478 | 10 | 5.81  | 0.0581     |
| Side       | 48.722141 | 48.722141 | 1  | 0.30  | 0.9961     |
| Ind * Side | 16754.449755 | 16754.449755 | 10 | 884.50 | <.0001     |
| Error 1    | 416.706218 | 16.942560 | 22 |       |            |

**Shape, Procrustes ANOVA:**

| Effect    | SS    | MS    | df | F   | F (param.) |
|------------|-------|-------|----|-----|------------|
| Individual | 0.65928558 | 0.002278783 | 300 | 4.02  | <.0001     |
| Side       | 0.00244470 | 0.0001014699 | 30 | 1.91  | 0.0338     |
| Ind * Side | 0.17007834 | 0.0005672835 | 300 | 20.57 | <.0001     |
| Error 1    | 0.01823820 | 0.0002390316 | 440 |       |            |

### Procrustes ANOVA: Cyclop: Front Skull

Asymmetries are computed and displayed as 'R' minus 'L'.

Classifiers used for the Procrustes ANOVA:
- Individuals: Species
- Sides: Side
- Error 1: Repeat

**Centroid size:**

| Effect    | SS    | MS    | df | F   | F (param.) |
|------------|-------|-------|----|-----|------------|
| Individual | 832959.546507 | 146478.78338 | 2  | 0.77  | 0.6865     |
| Side       | 3554.464306 | 3554.464306 | 1  | 0.02  | 0.9096     |
| Ind * Side | 431504.555046 | 219752.275523 | 2  | 344.69 | <.0001     |
| Error 1    | 975.691112 | 62.615185 | 6  |       |            |

**Shape, Procrustes ANOVA:**

| Effect    | SS    | MS    | df | F   | F (param.) |
|------------|-------|-------|----|-----|------------|
| Individual | 0.58672346 | 0.0003446910 | 128 | 12.02 | <.0001     |
| Side       | 0.00152207 | 0.0006900752 | 60 | 0.55  | 0.9704     |
| Ind * Side | 0.00354944 | 0.0002531987 | 128 | 5.00  | <.0001     |
| Error 1    | 0.00343196 | 0.0000884297 | 388 |       |            |
### Procrustes ANOVA: Non-Cyclop: Front Skull

**Dataset:** Non-Cyclops: Front Skull

**Asymmetries are computed and displayed as 'R' minus 'L'.**

Classifiers used for the Procrustes ANOVA:
- Individuals: Species
- Sides: Side
- Error 1: Repeat

#### Centroid size:

| Effect   | SS  | MS   | df | F   | P (param.) |
|----------|-----|------|----|-----|------------|
| Individual | 1113975.122071 | 161396.446010 | 7 | 4.58 | 0.0312     |
| Side     | 775.704994    | 775.704994   | 1 | 0.02 | 0.8862     |
| Ind x Side | 246552.995264 | 35221.356466 | 7 | 569.73 | <.0001    |
| Error 1 | 1065.027915 | 62.014210 | 16 |     |            |

#### Shape, Procrustes ANOVA:

| Effect   | SS  | MS   | df | F   | P (param.) | Pillai tr. | F (param.) |
|----------|-----|------|----|-----|------------|------------|------------|
| Individual | 0.20305425 | 0.0003537530 | 574 | 3.64 | <.0001     |            |            |
| Side     | 0.00440171 | 0.0000538794 | 82  | 0.55 | 0.9594    |            |            |
| Ind x Side | 0.05578871 | 0.0000971029 | 574 | 42.89 | <.0001    |            |            |
| Error 1 | 0.00297283 | 0.0000522659 | 1312 |      |            |            |            |
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